Edited by

Jane Bates

Practical Gynaecological Ultrasound

Fallopian tube

Mesovarium

Ovary

Ovarian ligament

Practical Gynaecological Ultrasound

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GMM

British Library Cataloguing in Publication Data

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Preface

The variety of ultrasound applications in gynaecology has increased with alarming speed over the last 5 years. Vaginal and abdominal techniques incorporating high resolution images, often with colour Doppler and contrast media, have catapulted the role of ultrasound in gynaecology into a front-line position.

Our understanding of physiology and pathological processes and the increasingly successful and minimally invasive treatment options have carved an important niche for the gynaecological ultrasound practitioner.

Gynaecological ultrasound now merits a dedicated text which will serve as both a reference for more experienced ultrasound practitioners and as a guide and teaching aid for students of ultrasound.

Experts from various fields of gynaecology have contributed to this project, so that the result would be comprehensive, well-informed and up-to-date.

The book incorporates both the normal and abnormal pelvis, illustrated with diagrams and high quality images. The time-honoured format of the initial `physics' chapter has been abandoned in favour of addressing the practical issues of image optimisation and equipment selection which underpin good ultrasound practice.

It incorporates the latest thinking and practice in various fields, including the acute pelvis, infertility diagnosis and treatment, and screening. The special considerations of the paediatric pelvis merit a separate chapter. Today's ultrasound practitioner is expected to be aware of the issues surrounding both the diagnosis and management of his or her patient and the book endeavours to present an accordingly holistic view, with current treatment options included in the final chapter.

It has often been said that the greatest hazard of ultrasound is that of the untrained operator. No mere text can be a substitute for practical experience and good training, but this book aims to assist the student in understanding ultrasound and the gynaecological patient. I hope it will also provide the more experienced ultrasound practitioner with an easily accessible and comprehensive reference.

The nature of medical ultrasound is such that developments rapidly outstrip publications. I hope this book will form a basic and enduring foundation which will foster best practice and encourage practitioners to develop their knowledge and skills.

JANE BATES

1—

Principles of Equipment Selection

Tony Evans

Introduction
Spatial resolution
Temporal resolution
Penetration
Contrast resolution
Probe shape and size
Scanning ergonomics
Operating modes
Safety

Introduction

The selection of equipment for gynaecological ultrasound, as in other clinical areas, amounts to:

• Selecting the scanner.

• Selecting the transducer.

• Selecting how best to use them.

Although the operator may have little or no choice about the scanner to be used, it is important to recognise that it is the combination of all three of the above which is critical. A proficient operator getting the best out of poor equipment is invariably more effective than a poor operator using potentially good equipment in an uninformed, unthinking or poorly thought-out manner. It follows that, whoever is using the equipment needs a good understanding of the ultrasonic imaging process, its limitations and characteristics. In particular, there is a need to understand the many compromises which exist, how they come about and how the operator can control the choices being made in order to optimise the quality of the scan. To get the best out of the equipment being used, the sonographer must first understand the principles behind image optimisation. The list below summarises the main considerations to be taken into account before the scan begins:

• Spatial resolution

• Temporal resolution

• Penetration

• Contrast resolution

• Probe shape and size

• Scanning ergonomics

• Operating modes, e.g., pulsed and colour Doppler

• Safety (acoustic, mechanical, electrical, biological, chemical)

Note that the transducer frequency is omitted from the above list. This is partly because manufacturer's probe labelling may be inaccurate but more importantly, because the probe frequency is not a good predictor of image quality and certainly does not describe it. The operator may well find that a low frequency probe on one scanner may give a better image than a higher frequency probe on another.

We will consider each of the features on the list in turn.

Spatial Resolution

It is important that small details within a structure or small objects are adequately imaged. This ability may be referred to as the overall `sharpness' or `definition' of the image and is described as its spatial resolution. It may be defined more strictly as the ability of the system to correctly identify two targets lying close together. Thus the targets are sets of pairs of wires lying in a tissue equivalent phantom and seen in cross-section (Figure 1). In Figure 1a the wires in the lowest row are resolved, the pair in the middle row are on the threshold of resolution but the top pair are smudged together and unresolved. In
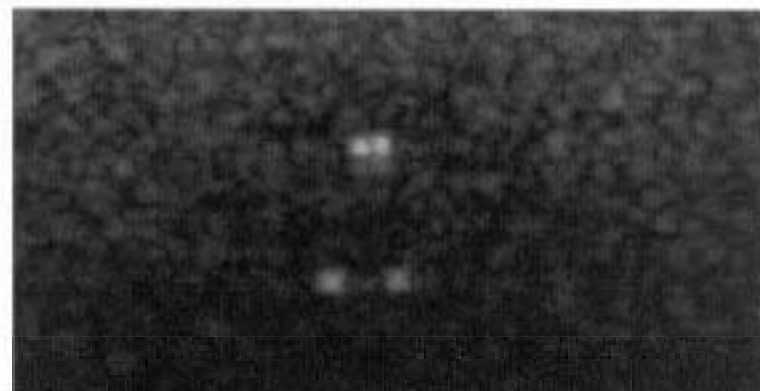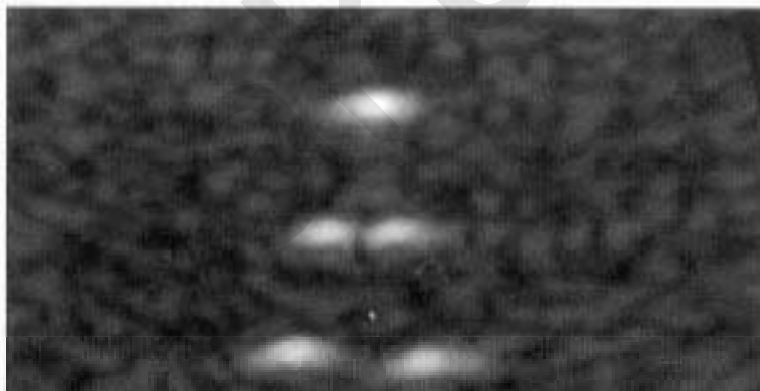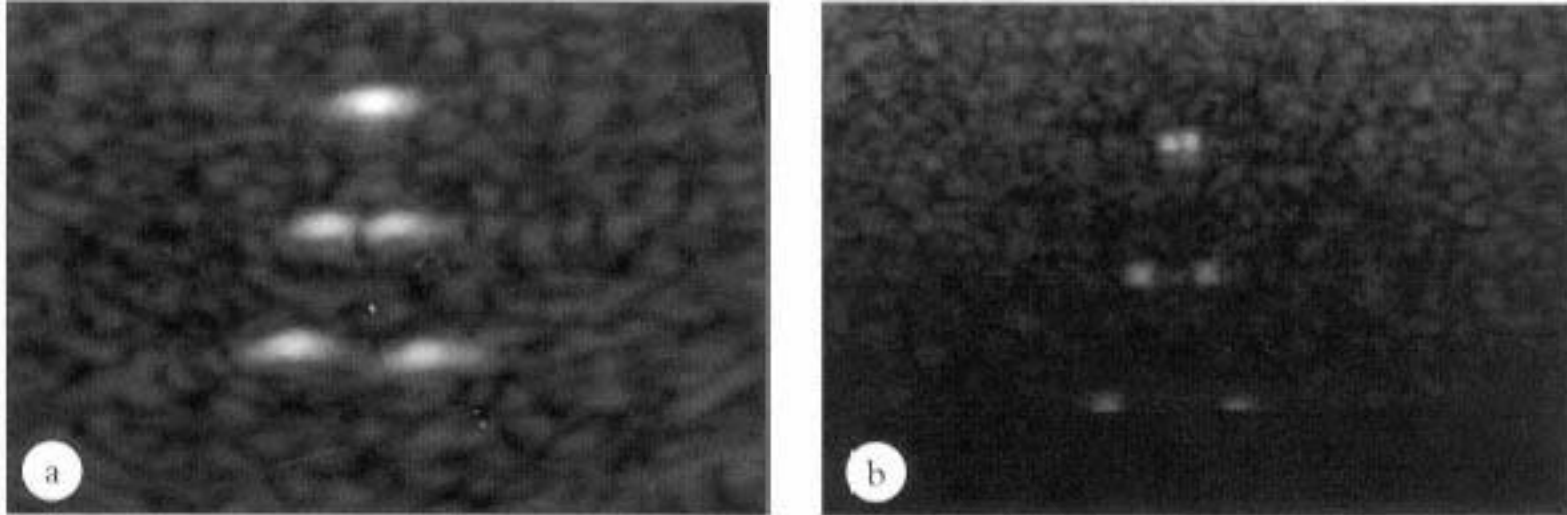
Figure 1—
Images obtained by scanning wires in a tissue equivalent phantom. *(a,* 3.5 MHz probe is able to resolve the lowest pair (5 mm separation) satisfactorily, the middle pair (2.5 mm) is only just resolvable and the top pair is unresolvable. *(b,* using a 7.5 MHz probe, all the pairs are adequately demonstrated.
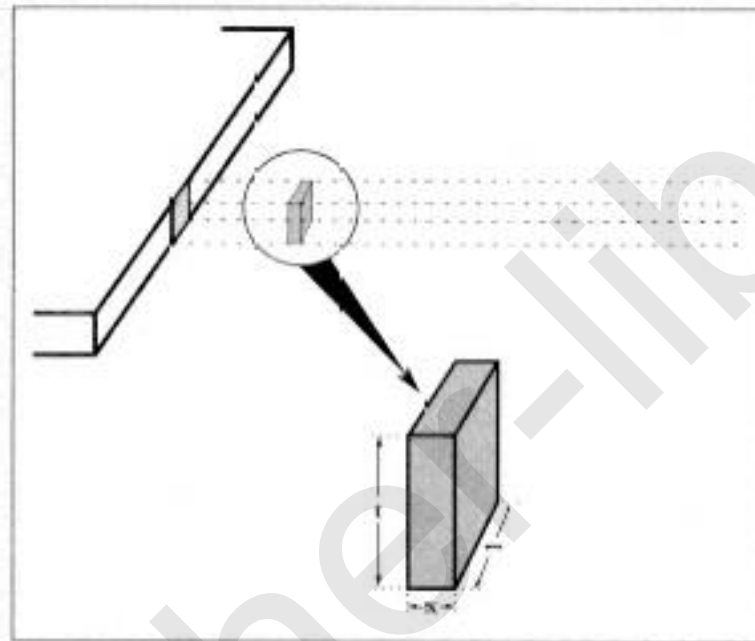
Figure 2—
The shaded area represents a single resolution cell
for the scanning system. Note that the dimensions x, 1
and t are the resolution values in each direction at the
position of the specific cell. Elsewhere, the values may
be different.

Figure 1b the same wire pairs are all adequately seen using a higher frequency.

One peculiarity of ultrasound is that the spatial resolution depends not only upon the position of the targets in the imaged section but also upon the orientation of the targets in that section. One way of describing this is to use the concept of a *resolution cell.* We can imagine the section being imaged as divided into small volumes or cells. If two targets are so small that they fit within the same cell, then they will not be resolved. In other words, details
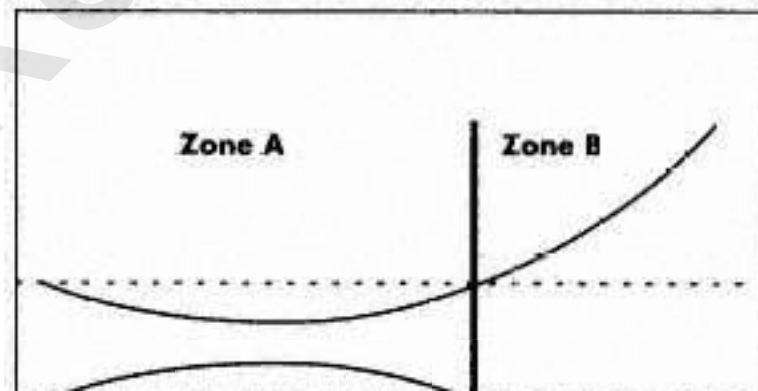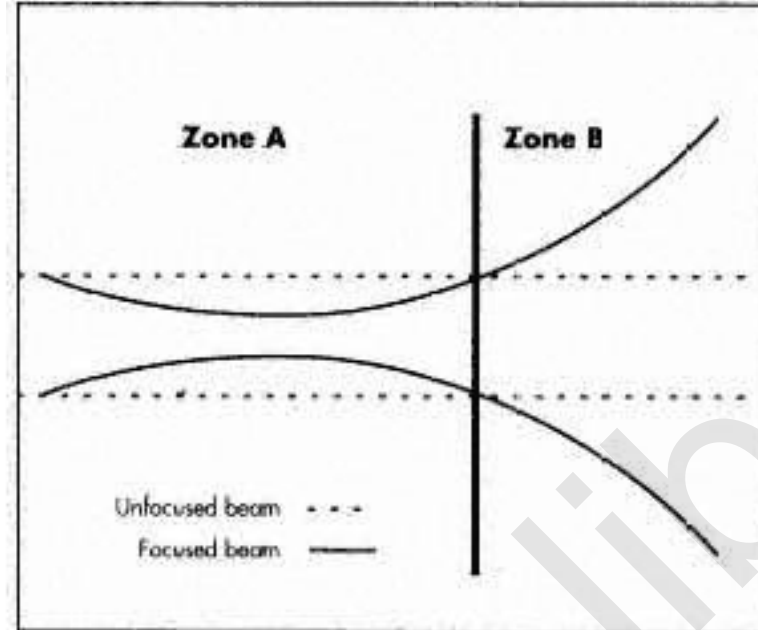
Figure 3—
The effect of focusing is normally to reduce the
lateral beamwidth in the region close to the focal
zone (Zone A). However, away from the focus in
Zone B, the effect is to degrade the beamwidth
and hence also the lateral resolution.

which are small enough to fit entirely within a resolution cell will not be visualised by the scanner. The exact shape of a resolution cell may be complex but it can be described as having three dimensions; an axial length, x, a lateral width, 1, and a slice thickness, t, (Figure 2). This leads to the need to describe the resolution of an ultrasound scanner in at least three planes and the complication that the three values obtained may not only be very different from each other but may also vary throughout the image. The three values x, 1 and t are often described as three ultrasound resolutions *axial, lateral* and *slice thickness.*

It seems obvious that smaller values of resolution are unambiguously `better' and this is so, but the means by which smaller values are achieved may involve unacceptable compromise in other features. We first need to consider more carefully what governs each of these resolutions.

Axial Resolution

The axial resolution which is the x value of the resolution cell (Figure 2), depends primarily upon the pulse length. This is normally a fixed number of cycles (typically 2-3), and so it follows that higher frequencies which bring shorter wavelengths will give better axial resolution. For frequencies between 5 and 7 MHz this will normally
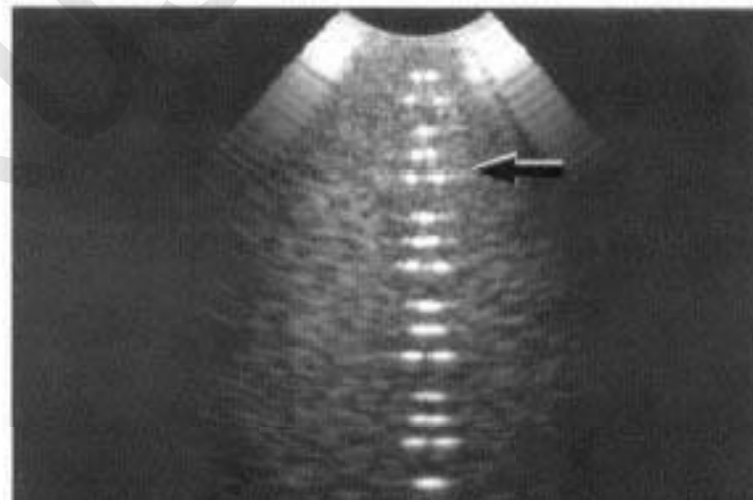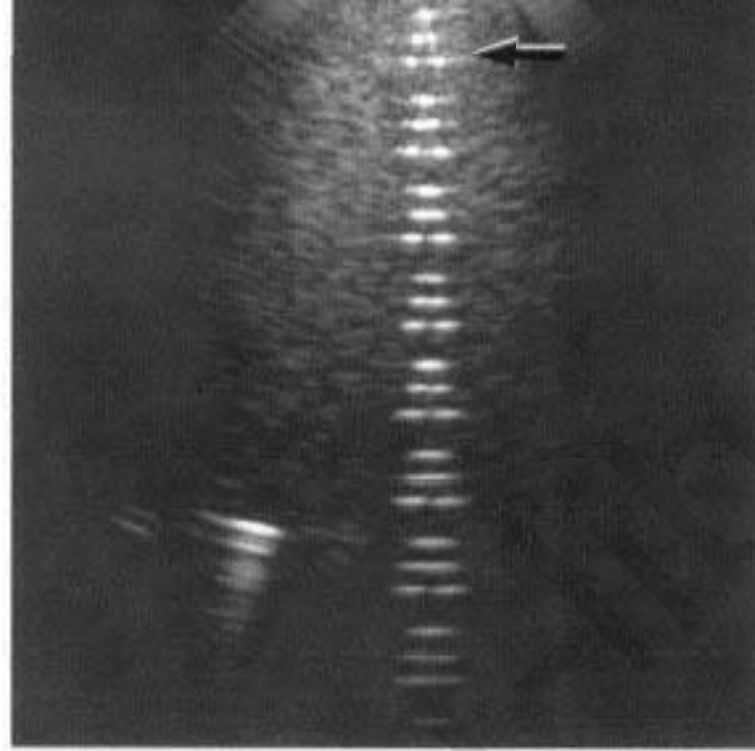
Figure 4—
Lateral resolution is normally depth dependent.
The region nearest the probe (arrow) has
significantly better resolution than at greater depths.
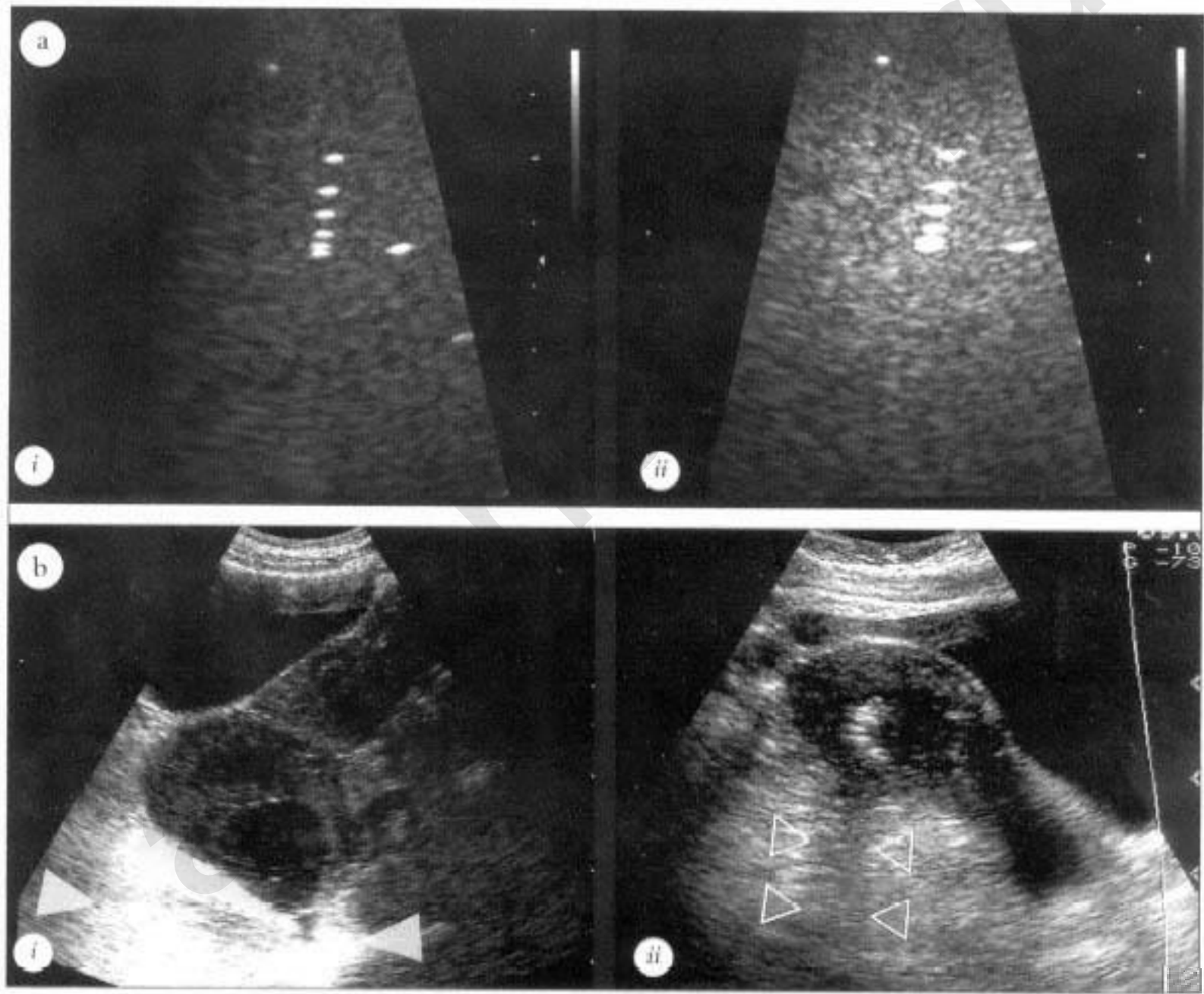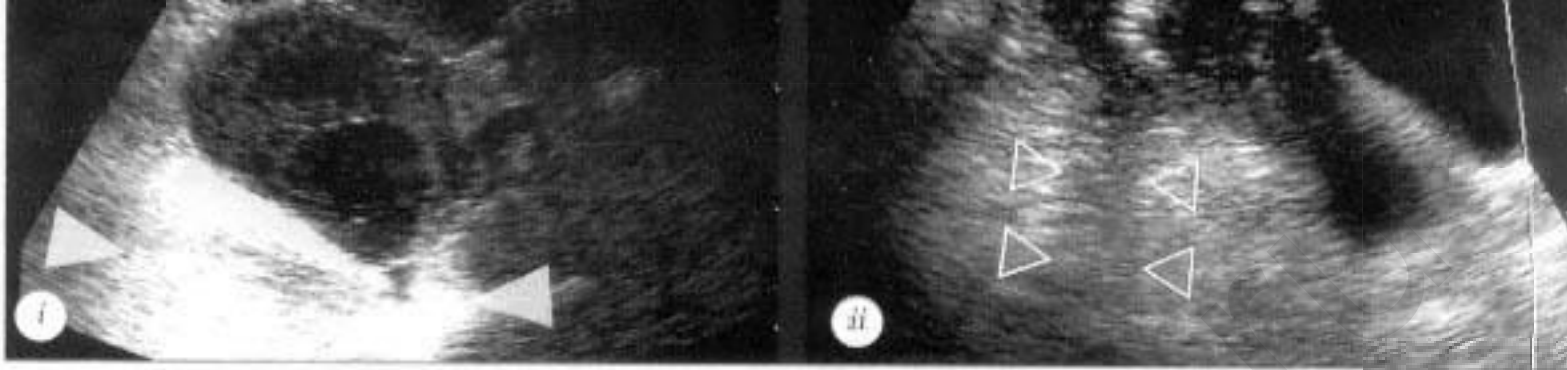
Figure 5—
a) Inappropriate TGC settings can cause misleading impressions; *i,* correct TGC with good resolution of
all the wires. *ii,* Inappropriately increased overall gain causes deterioration of both lateral and axial resolution.
b, Acoustic characteristics aid diagnosis. *i,* a band of enhancement (arrows) behind this ovarian mass is
due to reduced attenuation within the mass, and is indicative of its fluid component (despite the rather
solid-looking echoes within it). *ii,* the opposite effect of increased attenuation through a calcified
fibroid causes posterior `shadowing'.

be between 0.5 and 1 mm. In almost all cases, it is the smallest and therefore the best of the resolutions and, consequently, operators are encouraged to make measurements in an axial direction wherever possible.

Lateral Resolution

This is the 1 value in Figure 2 and is often referred to as the *beamwidth.* Manufacturers use a wide variety of ingenious methods to minimise beamwidth since it manifestly has a profound effect on image quality. In many cases this involves electronic focusing of arrays which allows the beam to be narrowed only in the plane of the scanning slice and is the reason why the beam cross-section is not circular. Furthermore, the focusing techniques used will often improve the resolution at some depths only at the expense of degrading the resolution at others, and hence the resolution depends additionally on the depth of the target, (Figures 3, 4 and 7a). In Figure 3, zone A will have improved resolution if focussing is used, but zone B will suffer degraded resolution. Figure 4 shows resolution close to the probe as significantly better than at greater depths.

Manufacturers will often include a figure for lateral resolution in their specification for a probe and with modern equipment working between 5 and 7 MHz it is commonly between 2 and 8 mm. However, this will

be a best case and may be quite misleading, and the operator is very influential here. Since the focusing depth is normally selected from the scanner's control panel, care should be taken to match the depth selected to that of greatest clinical significance. Many machines now offer the facility for additional focusing on transmission which reduces the beamwidth still further. However, this normally incurs a frame rate penalty and it is the operator who must decide whether the additional resolution gain is worth the price.

Slice Thickness

The third dimension of the resolution cell is known as slice thickness and is the t value in Figure 2. In this case, electronic focusing will have no effect and so it is likely that this resolution will be relatively poor. Some focusing can be achieved by including lenses in the front face of probe, but this will be at a fixed depth. For electronic probes, this will result in slice thickness resolution in the range 5-10 mm although for mechanical scanners, the figure will be the same as for lateral resolution since the beam cross-section will be circular. The impact of this clinically is to produce slice thickness artefacts which, for example, will result in transonic areas, such as cysts, becoming partially filled with echoes which are generated within surrounding tissue. Thus it is important that the operator is aware of the resolution characteristics of the probe in use, in order to avoid being misled by such appearances.

Temporal Resolution

We now need to consider the ability of the scanner to correctly display events which are closely spaced in time. Can a target move quickly and return to its original position before its movement has been detected? Clearly, this is associated strongly with the time between samples at a given site, in other words, the frame rate. Here we have another compromise involving the operator but based upon a fundamental limitation.

The frame rate can be increased either by accepting a reduced number of lines in the image or a reduced imaged depth, or both. There are two additional points to note. The first is that if lateral resolution is improved by selecting transmit focusing, this requires more pulses to acquire each scan line. In effect, this is increasing the time per line. Thus the improved resolution must be `bought' by a reduced frame rate, a reduced depth, a reduced number of lines in the image or some combination of these options. It is the operator who makes these decisions and selects the best compromise, although the control panel of the machine might obscure these stark choices in some cases. For a machine using

SPATIAL RESOLUTION - KEY POINTS

• The shorter the pulse, the better the **axial** resolution, i.e., higher frequencies are better.

   • The narrower the beam, the better the **lateral** resolution, i.e., in the focal zone of the beam.   (Focusing is usually worse at greater depths, with consequent inferior lateral resolution.)

   • The narrower the **slice thickness,** the better the resolution, i.e., lenses or curved elements in a   plane at right angles to the image.
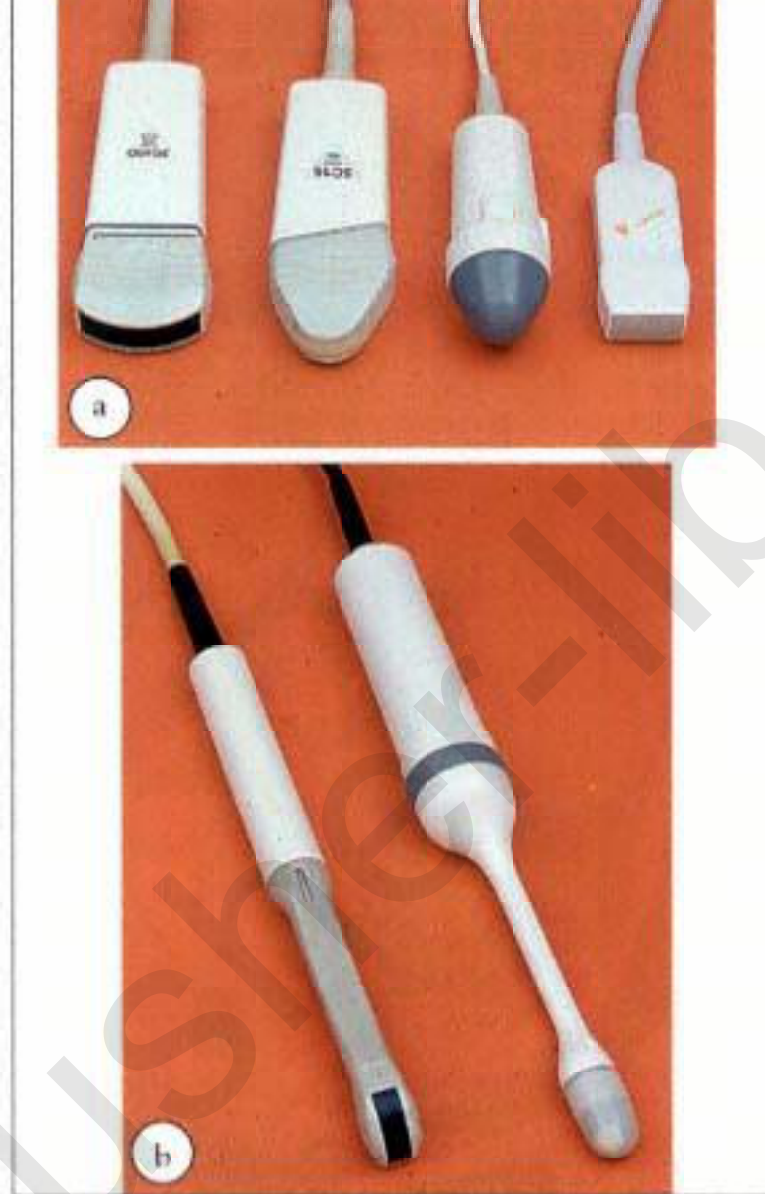
Figure 6—
Examples of transducers suitable for
gynaecological scans: a) transabdominal
probes (from left): electronic curved array,
small radius curved array, mechanical,
vector or phased array. b) transvaginal
electronic array and mechanical sector with
steerable beam.

Figure 6—
Examples of transducers suitable for gynaecological scans: *a)* transabdominal probes (from left): electronic curved array, small radius curved array, mechanical, vector or phased array. *b)* transvaginal electronic array and mechanical sector with steerable beam.

a sector shaped field of view, such as a curvilinear array, the compromise might appear as a reduced sector angle which is a means of reducing the total number of scan lines without sacrificing line density, (Figure 7b). In practice, gynaecological ultrasound, unlike cardiac or obstetric scanning, does not demand a high frame rate and there is a strong case for using all available means to maximise resolution even if the frame rate drops to around three or four frames per second or less. Once again, it is the informed operator who must make this decision. (See page 17)

The second point of interest is that the number of lines on the television display will not be the same as the number of scan lines as discussed above. The standard TV display demands 625 lines in order that conventional techniques and accessories `such as VCRs' can be used. A simple calculation shows that the real ultrasound image will be unlikely to consist of more than say 200 lines. The `missing' 400 or so lines have to be `invented' and the image processor in the machine makes an educated guess in order to fill in the inevitable gaps. Thus the operator may be lured into a false sense of security about the resolution capability of the machine. Modern equipment is extremely effective at making the image look better than the raw information justifies.

Penetration

The operator will want to be reassured that the equipment selected is capable of producing images down to a clinically acceptable depth. The maximum depth at which useful information can be obtained is determined

TEMPORAL RESOLUTION - KEY POINTS

• Depends on the frame rate.

  • Frame rate is faster when less time is taken to `construct' the image, ie. when the image has a smaller field (in terms of depth and/or width), or is constructed of fewer lines of information, which reduces image quality.
  • Frame rate is usually of less importance in gynaecological scanning than spatial or contrast resolution and is therefore often sacrificed to improve these latter considerations.
  • The frequency `label' on the transducer may not necessarily be a reliable indicator of either the penetration or the resolution capabilities.

by many factors, the dominant one of which is tissue attenuation although it can be increased by one or more of the following:

• Reducing the frequency

• Using bigger output pulses

• Reducing the system noise

The attenuation suffered by the pulse tissue in travelling through the tissue depends only upon the frequency of that pulse for a given tissue type. In normal gynaecological practice, this limits 5 MHz ultrasound to a depth range of about 7 cm and 7 MHz ultrasound to about 5 cm. Modern transducer technology does now allow probes to be used well away from their basic resonant frequency (multi-frequency probes) and this allows the operator to trade off frequency and penetration more explicitly in some cases.

Using larger pulses does provide some additional penetration but, because the attenuation is logarithmic, the effect is less than might be expected. Thus a doubling of output power will typically result in an increased penetration at 7 MHz of roughly 5 mm. As we shall see later, there is insufficient evidence to establish firm safety limits at present, and so doubling the power is not immediately vetoed on safety grounds. However, there are real limits to the power that can be efficiently transferred to a small hand held transducer in a short time and we seem to be close to those electronic limits at present. We therefore conclude that, for the most part, if the probe selected will not provide the penetration required, then the operator can only change to a probe at a lower frequency or else find a closer approach to the target of interest.

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The most obvious consequence of the high attenuation of overlying tissue has been the introduction of transvaginal (TV) probes. Instead of the conventional transabdominal (TA) approach, which involves the beam in traversing up to 7 cm of tissue, the transvaginal approach will allow many of the key structures to be positioned within 2-3 cm of the probe. This allows 7 MHz scanning with its consequent resolution improvement and also allows the operator to avoid other anatomical barriers. (See Chapter 2, Figure 8).

Options for reducing the system noise seem unlikely to provide dramatic improvements in penetration for the foreseeable future. However, the operator has many opportunities to make it worse! Significant image degradation can be caused by misuse of the controls, (Figure 5a). If the TGC and other controls are inappropriately set then regions which are generating echoes of an adequate size may not be displayed because the operator has inter-

PENETRATION - KEY POINTS

• Depends primarily on the attenuation of the pulse, which is less with lower frequencies.

• Greater penetration is achieved either by using a lower frequency transducer or by electronicly manipulating the existing resonant frequency.

• It also depends on the power setting . . .

• . . . and upon the level of system noise or artifact, which can be reduced by using the correct TGC, and is highly operator dependent.

vened to prevent it. Similarly, the opportunities for creating misleading appearances of either echogenic or transonic regions are many. The operator is able to exploit the attenuation properties of different tissues as an aid to diagnosis (Figure 5b), and may also have the opportunity to achieve some noise reduction using frame averaging at the expense of frame rate, although at present the effects are marginal.

Manufacturers may be tempted to declare that their probes are working at a higher frequency than they really are in order to impress a customer with what appears to be extremely high penetration with the tacit assumption that the corresponding resolution gains are available. The user needs to set more store by the actual performance of the probe than by the frequency label.

Contrast Resolution

Whereas spatial resolution can be defined as the ability of the system to distinguish two closely spaced targets, the contrast resolution is its ability to distinguish two targets of almost the same nature. In other words, the ability to

CONTRAST RESOLUTION - KEY POINTS

• Depends on the perceived number of grey levels.

• By using different processing or `set-up' options, contrast resolution may be improved over certain, relevant regions. However, this will differ according to the tissues under observation.

identify one point or region as being qualitatively different from another solely from the grey levels of the echo displayed from the two. If the echoes generated are in fact different, but are assigned the same grey levels by the machine, then the operator will have no way of knowing they are different. In practice, this will always be true to some extent, since the range of incoming echo sizes is many times greater than the number of available grey levels in the machine and, even when the number of grey levels within the machine is increased, the fundamental limit is set by the number which can be meaningfully displayed by a TV monitor and distinguished by the eye. Manufacturers have responded to this by providing a wide range of options for determining which echo heights are translated into which grey levels and most equipment has controls labelled pre- or post-processing, which allows the operator to choose, although there remains considerable uncertainty about how this can be optimised. The clinical significance of this is illustrated in, (Figure 7d) where the same region is scanned at two different grey-scale settings and the diagnostic consequences are clear. Operators should be aware that the `best' setting will differ between clinical areas and most scanners are set up according to some general compromise. The more sophisticated machines allow the operator to pre-programme set-ups which are dedicated to a relevant clinical area (such as gynaecology). How this is determined and validated is problematical and open to individual

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Probe Shape and Size

Transabdominal Imaging

The modern ultrasound machine consists of a main viewing and control console to which one or more probes can be attached. The operator on a day-to-day basis may have to choose between three or four probes, but at the time of purchase or upgrade a wider choice will be available. Not all types will be available on all consoles.

Linear Array

This is the most traditional of electronic array formats. It is characterised by being relatively long and narrow giving a large anterior field of view but requiring good acoustic contact over its whole length. This is not ideal for gynaecological use because of its large contact area, often referred to as its *footprint.*

Curved Array

The curved array was developed as a sector version of the
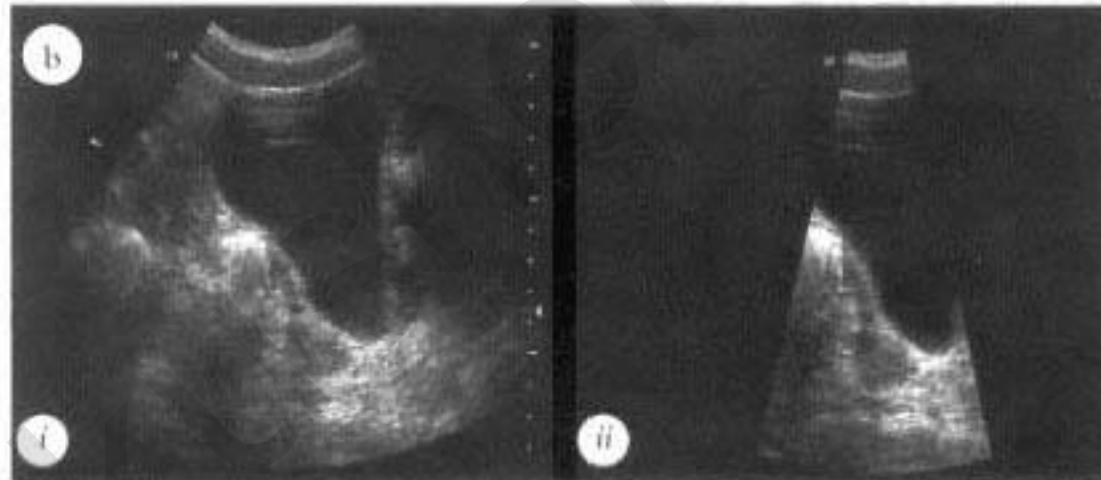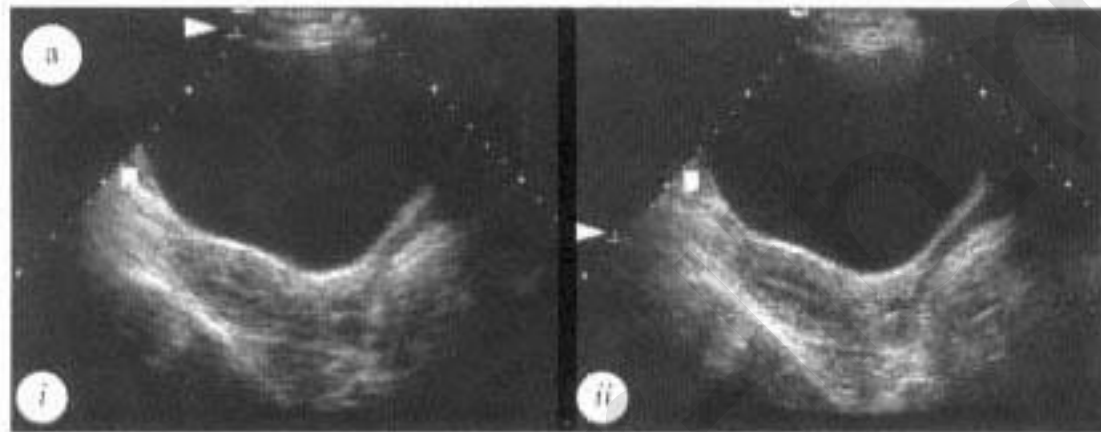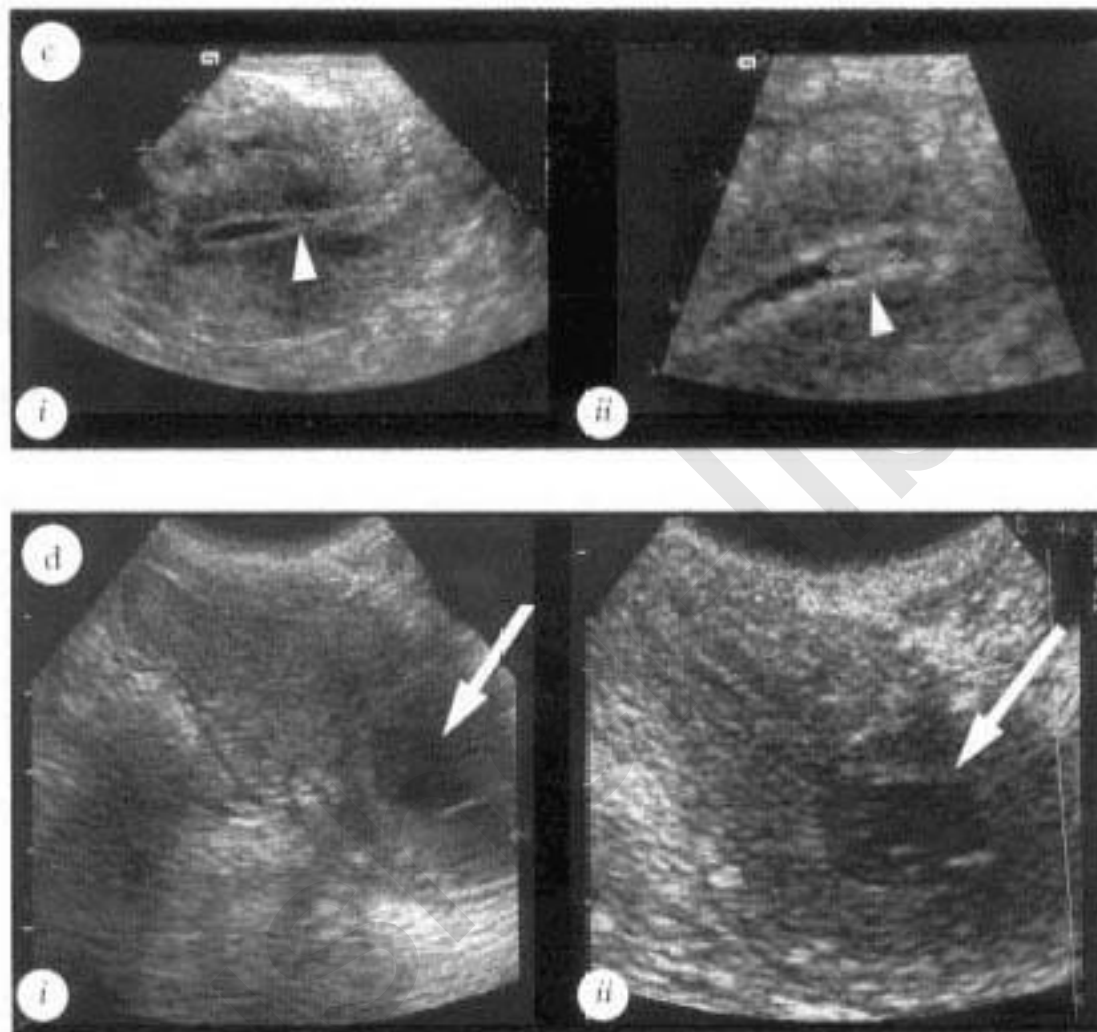
Figure 7—
Practical image optimisation
a) i - The focal zone has been incorrectly placed in the near field. i. - correct
focal zone placement at the depth of the uterus narrows the beam at this point
and results in improved resoltion.
b) The longitudinal image of the ovary i - is improved by narrowing the sector
angle i. - and thus increasing the line density.
c) This small endometrial polyp in a patient with postmenopausal bleeding
is unclear, even on the TV scan (arrowhead). i. - By reducing both the sector
angle and depth and increasing the line density, it now becomes apparent.
d) i - Fluid (arrow) is an abnormal finding in this postmenopausal endometrial

a) i - The focal zone has been incorrectly placed in the near field. ii - correct focal zone placement at the depth of the uterus narrows the beam at this point and results in improved resoltion.

b) The longitudinal image of the ovary i - is improved by narrowing the sector angle ii - and thus increasing the line density.

c) This small endometrial polyp in a patient with postmenopausal bleeding is unclear, even on the TV scan (arrowhead). ii - By reducing both the sector angle and depth and increasing the line density, it now becomes apparent.

d) i - Fluid (arrow) is an abnormal finding in this postmenopausal endometrial cavity. ii - It isbetter emphasised by adjusting the post processing options to improve the contrast resolution

linear array and now is the workhorse of many general scanning departments. It has a smaller footprint than the corresponding linear array but is subject to some loss of resolution at the edges of sector towards the larger depths.

Phased Array

This type of probe has a particularly small footprint because it uses all of the elements in its length all of the time rather than having the active section stepping along the array in sequence. It was originally most frequently found in cardiology departments where the narrow acoustic window prevents other probe types from being effective. Its main drawback in imaging the pelvis is that it is particularly prone to sidelobe artefacts because of its scanning action. Its small footprint limits the anterior field, which is not a disadvantage in TA scanning as the bladder lies anteriorly. However, in TV scanning, when the pelvic viscera lie in the near field, this may represent a limitation.

Annular Array

This is the only electronically focused probe capable of being focused in the slice thickness plane and so should theoretically produce better images than its competitors. Its scanning action, unlike its focusing, is mechanical. However, its mode of action demands that it is circular and relatively large and hence it has a very large footprint. This makes it rather heavy and cumbersome and that, coupled with some noise and vibration, has lead to its not being widely accepted.

Mechanical Probe

The simplest way to achieve a scanning action is to move the transducer and this was the earliest type of probe used for real-time scanning. Its disadvantages are that it can only be focused at one fixed depth, determined by the transducer, and that there is inevitably some vibration and noise. Thus it is probable that some form of electronic array will be the normal probe of choice for gynaecological imaging. The majority of patients will be satisfactorily imaged using 3.5 - 5 MHz probes, although a small number of difficult or obese cases will only be imaged properly at a lower frequency. In some cases, e.g., paediatrics, a higher frequency such as 7.5 MHz will give even better results.

Transvaginal Imaging

It is now widely accepted that the optimal images from many gynaecological patients will be obtained using a transvaginal rather than transabdominal technique. The probes developed for this purpose can almost always be fitted directly on to the console of a standard machine. Indeed, a number of small portable scanners are now available with transvaginal (TV) probes as an option. The range of probe types, shapes and sizes is surprisingly large and there is a marked lack of standardisation, (Figure 6 and Chapter 2, Figure 14).

It should also be noted that those probes which give the widest viewing angle are those which are mechanical, which is unsurprising since there are a number of well known problems associated with making an electronic array deflect by more than 90°. Several manufacturers offer both electronic and mechanical probes emphasising the difficulty involved in the compromise. The trade-off between viewing angle and resolution is a very difficult one. However, whether mechanical or electronic, the use of multi-frequency probes is now commonplace.

Scanning Ergonomics

The choice of probes and consoles is not entirely objective and operator preferences continue to be important. Having all the controls within easy reach is critical but there are those who prefer more adjustments and those who wish to minimise the number of knobs. There are variations in the weight of probes, the use of foot pedals, the arrangements for caliper measurements and hard copy, the choice of slider controls or others for TGC and the difficulty or ease with which probes can be interchanged. In addition, consideration must be given to whether portability is important. Even the largest machines should be moveable with good wheel design but there are many small, lightweight, inexpensive scanners available now which can easily be picked up and carried around. The compromise in this case is between portability and image quality and facilities.

Operating Modes

The normal operational mode of a conventional diagnostic ultrasound scanner is real-time B-mode and this shows no signs of changing. However, there is increasing interest in the use of the various forms of Doppler in all clinical areas and gynaecology is no exception. They can be categorised as follows:

The normal operational mode of a conventional diagnostic ultrasound scanner is real-time B-mode and this shows no signs of changing. However, there is increasing interest in the use of the various forms of Doppler in all clinical areas and gynaecology is no exception. They can be categorised as follows:

• Continuous wave Doppler (CW)

• Pulsed Doppler

• Colour flow Doppler (CF)

• Power Doppler

CW Doppler

In CW Doppler it is necessary to have separate transducers for transmission and reception although both can be incorporated into a single housing. No real-time image is possible with this type of probe.

The main problems with CW Doppler are:

• There is uncertainty about the anatomical position of the origin of the signals i.e., the operator does not know from which vessel the signal is coming and so interpretation of the Doppler information is limited, if not impossible.

• It is difficult to use, since unless the probe is positioned correctly there may be no signal at all and the operator may not know where to look.

• The angle dependence implies that if the vessel is approached at or close to 90°, no Doppler shift will result.

• Other nearby moving structures, such as vessel walls may generate much larger Doppler signals, obscuring those of interest.

As a result of the above, the use of CW Doppler in gynaecology is virtually non-existent and will not be discussed further.

Pulsed Doppler

The main advantage of pulsed Doppler is that the operator can select the vessel from which the Doppler information is to be obtained because the use of pulses allows the timing to be used as a marker. The commonest approach is to arrange for a line to be generated on the image parallel to the beam along which Doppler signals will be received and then for a small bright mark or box to be moved down the line by the operator to indicate the precise depth at which the information is required (Chapter 2, Figure 11). The display then shows the Doppler spectrum at that depth and hence the technique is also known as *spectral Doppler.*

Electronic arrays can be used for this purpose since individual elements or groups of elements can be made to generate the extended pulses or act as receivers for the Doppler shifted signals. When the appropriate command is given, the display switches to the Doppler spectrum which looks much the same as one from a CW system. It is possible using many electronic systems to continue to obtain a live image while the pulsed Doppler information is shown but this inevitably compromises the quality of both.

The spectral trace obtained from a pulsed Doppler system shows an overall pulsatility which is heavily influenced by the downstream impedance. Users wishing to exploit this will want to characterise the shape of this spectral outline and most machines have extensive computerised facilities to allow this. (See page 24)

The main problems with pulsed Doppler are:

• There is a limit to the velocity which can be correctly measured. If the blood velocity exceeds this limit, (known as the Nyquist limit) *aliasing* occurs which results in the spectrum showing the movement as being in the opposite direction.

• Greater depths and higher frequencies both lead to reduced velocities before aliasing. Furthermore, if some time is spent in updating the displayed image, then this reduces the maximum still further and hence it is more common for operators to work with recently frozen images of the section of interest

• The operator must select the region to be interrogated by the Doppler beam and only one sample volume can be used at any one time. If there is doubt as to whether blood flow is present anywhere in a given region, then this makes searching for it very difficult if not totally impractical.

Colour Flow Doppler

Colour Flow (CF) Doppler systems superimpose flow information encoded as colours on a real-time grey scale ultrasound image. With CF, Doppler information is obtained simultaneously from a large region, possibly even the whole image, allowing the operator to form an immediate impression of the blood flow in the displayed section as a whole, (Chapter 2, Figure 10). The convention is to use shades of RED when the net flow is towards the probe and BLUE when it is away from it. The compromise in this case is with the quality and nature of the Doppler information obtained. In order to sample and process signals from the whole section in real-time, the complete spectral analysis of the Doppler shifts has to be abandoned. Each scan line is sampled several times, typically 8, in quick succession and the sampled lines are analysed in pairs. A calculation reveals the mean velocities and the uncertainties, or

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OPERATING MODES - KEY POINTS

- Predominantly real-time B mode.

- CW Doppler not practical in gynaecological scanning because the position of the vessel generating the signal is unknown.

- PW Doppler uses long pulses of Doppler from individual elements or small groups within an array. It allows the operator to select a vessel visible on the real-time image and obtain a spectrum.

  The spectrum gives quantitative & qualitative information about the direction, velocity, variance and downstream resistance of the blood flow.

- CF Doppler superimposes Doppler information on the real-time image, giving the operator the immediate impression of an organ's vascular `map'.

  It needs more time per line of information to do this and therefore there are penalties of poorer image quality.

  It gives information on presence or absence of flow and its direction, and an impression of the velocity and variance, but no quantitative information. It is usually, therefore, used in conjunction with a PW spectrum.

- Power Doppler superimposes Doppler information on the real-time image as with CF Doppler, but displays only the amount of energy, without any of the directional or variance information. This results in a stronger signal which may potentially identify smaller vessels with slower velocities than CF.

Thus CF systems are very useful for giving a quick indication of the extent of blood flow in a given region, but it is important to recognise their limitations.

• The extra time per line carries a penalty in terms of image quality. This may be manifest as a reduced frame rate, or resolution degradation, or both.

• Doppler spectral flow information is lost and hence the facility for evaluating downstream impedance and characterising the waveform is unavailable. It is often necessary to use the CF as a crude indicator of where to look in more detail using pulsed Doppler.

• There is virtually no quantitative information available from CF systems. Manufacturers use very different methods for determining the colour mapping and most allow the operator to modify it still further. Thus information reported on any one machine is very difficult to interpret and diagnostic markers may well vary between systems.

• The angle dependence which limits CW and pulsed systems still applies and may lead to confusing artefacts when flow exists but is parallel to the probe face.

• The machine has to use some algorithm or rule to determine when the colour information will be allowed to overwrite and hide the grey scale information. This can lead to missing colour when close to strong stationary targets.

Power Doppler

More recently, some manufacturers have decided to display the Doppler information in a different way often described as Power Doppler, (Chapter 2, Figure 13). In such systems, all of the power from all of the Doppler shifted signals within a given region is added together to produce a single value. In this case, no

More recently, some manufacturers have decided to display the Doppler information in a different way often described as Power Doppler, (Chapter 2, Figure 13). In such systems, all of the power from all of the Doppler shifted signals within a given region is added together to produce a single value. In this case, no angle correction is needed since no attempt is being made to compute velocities and only one colour is required, since there can be no negative power values. The benefit is that a much stronger total signal emerges which does not have angle dependence and allows the identification and display of very small vessels which may be too small to detect with CF systems. Power spectral Doppler has many trade names which adds to the confusion and has mistakenly been described as producing a perfusion map which is not strictly true. It is closer to being a description of the total energy associated with moving blood in some region and seems to be skewed towards venous flow. Its clinical value, if any, remains to be proven but it is undoubtedly attracting much attention at the present time.

Safety

The safety issues which arise in gynaecological ultrasound can be categorised as follows:

• Ultrasonic

• Electrical

• Microbiological

• Mechanical

Ultrasonic Safety

The question of whether diagnostic ultrasound can have harmful effects has been the subject of many papers and discussions since it was first introduced. The reader is referred to the references for a fuller account but it is clear that there is a need for ongoing vigilance in this area. Traditionally, the view has been that ultrasound hazards can arise through three mechanisms: cavitation, heating and microstreaming. Currently, most emphasis is being place on the thermal effects of ultrasound and the possibility of ultrasound induced thermal damage. Unfortunately, it is extremely difficult to predict the temperature rise which a given ultrasound beam will produce in a given volume of tissue and the knowledge that vasodilation will generally occur in most heated living systems confounds the calculation still further. It is likely that the temperature rise will be related not to the total output power from the transducer but rather to the way in which the output is distributed in time and space. Thus the Spatial Peak Temporal Average Intensity (I_{SPTA}) is often used as a general indicator of the heating potential of a given beam.

An important statement from the American Institute for Ultrasound in Medicine and Biology [1] suggests that if the ISPTA does not exceed 100m W cm^{-2} then this should be considered unequivocally safe. This condition is satisfied by almost all machines when operating in normal imaging mode. However, when pulsed Doppler or CF Doppler is used, it is common to find I_{SPTA} well in excess of this. An additional consideration arises from the possibility of heating directly from the probe itself. In pulsed Doppler mode the transducer, which has been optimised to produce the short imaging pulses, is required to generate and receive longer pulses. Its efficiency for this purpose is relatively low. The loss of energy due to inefficiency manifests itself as heat in the probe itself and there is evidence that left unattended in worst case conditions, some probes can reach up to 60°C.

Most of the vast bulk of epidemiological evidence supports the assertion that no one anywhere has ever been shown to have been damaged by the ultrasonic energy from a diagnostic machine. The epidemiological evidence relating to the safety of ultrasound in obstetric applications has recently been reviewed[2]. Studies have been conducted relating to possible associations of ultrasonic exposure of the fetus with childhood malignancies, neurological maldevelopment, left-handedness and low birthweight. It seems clear that most of the work supports the notion of there being no association of these outcomes with ultrasound exposure. However, they conclude that on some issues, such as the incidence of left-handedness and low birthweight, no firm conclusions can yet be drawn and hence the recent trend has been towards somewhat more guarded statements than in the past. There is no direct evidence that these effects are harmful but nonetheless it should be noted that the general consensus is that the developing embryo is most at risk, and that this risk is maximised when the embryo is imaged transvaginally using pulsed Doppler. In fact, the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) has issued the following advice which is probably the first contra-indication to diagnostic ultrasound ever published.

> `Routine clinical scanning of every woman during pregnancy using real-time B-mode imaging is not contra-indicated by the evidence currently available from biological investigations and its performance should be left to clinical judgement.
> In view of the possibility of ultrasonically-induced biological effects within tissues in the path of a Doppler beam, routine examinations of the developing embryo during the particularly sensitive period of organogenesis using Pulsed Doppler devices is considered inadvisable at present. It is advisable to minimize output levels and exposure time in pulsed Doppler mode during fetal examinations, and particularly when fetal bone structures lying within the Doppler beam may be preferentially heated'

(EFSUMB 1995)[3]

In this light, it seems clear that the general principle must be to avoid unneccessary ultrasonic exposure of anyone. The use of ultrasound should therefore be to limit the dose to that which is needed to obtain the appropriate clinical information. In other words, it should be governed by the ALARA principle (As Low As Reasonably Achieveable) which applies in conventional radiography.

Electrical Safety

Ultrasonic probes in medicine are subject to the same electrical safety requirements as any other electro-medical equipment. In the UK, they must satisfy the British Standard BS5724 (or its IEC equivalent). This standard is particularly demanding of intra-cavitary devices such as transvaginal probes since they are in close electrical contact with the patient. In general, manufacturers are careful to ensure that their equipment complies with these regulations and problems are rare. However, it is important to bear in mind that it is the whole system which must meet the requirements. Thus, if the scanner with a transvaginal probe is connected to a camera, VCR or computer, then the complete system may fail electrical tests even though its individual components have passed.

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SAFETY CONSIDERATIONS - KEY POINTS

- Ensure ultrasound scans are only performed by **adequately trained personnel.**

- Keep ultrasound dose to the minimum necessary (ALARA principle):

    Use the minimum necessary output power

    Keep the scanning time to a minimum

    Do not rest the transducer on the skin surface when not scanning

    Ensure there is a valid request for the examination

- Pulsed and colour Doppler are associated with increased exposure conditions compared with real-time black & white ultrasound.

    Situations in the female pelvis which require particular vigilance include early pregnancy and scanning of the ovaries.

- Regular quality control on all equipment, to ensure electrical and mechanical safety, with prompt repair of faults.

- Careful and thorough cleaning regime, taking into account manufacturers' recommendations, to avoid risks of cross-infection.

Obviously, any physical damage to the probe or its cable which might reduce its electrical insulation must be recorded and drawn to the attention of the relevant person for repair.

Microbiological Safety

Any piece of equipment coming into direct contact with the patient must be kept clean to avoid cross-infection and this is particularly so for transvaginal probes. Unlike many other intra-cavitary medical devices they cannot be autoclaved. Considerations include the nature of the cleaning method, the type of disinfectant used, the use of probe covers and the need for an aseptic technique. The issue has been the subject of an advisory statement from the American Institute of Ultrasound in Medicine (AIUM) which was recently discussed by Goldstein [4]. The operator must be aware of specific advice from manufacturers, as some probe materials may be irreparably damaged by some antiseptics, such as glutaraldehyde, or lubricants, can effect the silicone in some probe covers.

Mechanical Safety

The nature of transvaginal probes and their usage is unusual in ultrasound practice. There is clearly a need for the probe to be as small and light as possible but this may lead to reduced mechanical strength. There do not appear to be any agreed standards for this and there have been anecdotal reports of probes which have sheared in practice, clearly having the potential for disastrous consequences. Once a probe has been purchased, there is little the operator can do other than keep a vigilant eye on all the equipment in use.

Thus, it is clear that this is another situation in which the operator plays the crucial role. By being aware of the situation and adhering closely to published

Thus, it is clear that this is another situation in which the operator plays the crucial role. By being aware of the situation and adhering closely to published guidelines, the operator can reduce patient exposure in an ultrasound examination many fold. It has often been claimed that:

`In diagnostic ultrasound, the greatest hazard to the patient is that presented by the untrained or poorly trained operator'.

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3. European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) 1995 Clinical Safety Statement 1994, Trondheim, *European J of Ultrasound,* **2:** 77

4. Goldstein SR, Report for cleaning and preparation of endocavitary ultrasound transducers between patients. Ultrasound Obstet Gynecol; *AIUM,* 1996, **7:** 92-94.

2—

Practical Equipment Operation and Technique

Jane A Bates

Practical approach to image optimisation

Choice of approach

Transabdominal (TA) scanning

Transvaginal (TV) scanning

Doppler techniques

Additional techniques

Image recording

The role of the sonographer

Summary

Practical Approach to Image Optimisation

Arguably, the first consideration in choosing a machine is the quality of the image in terms of resolution. Many departments do not have the luxury of a wide choice of ultrasound machines and resources for new or replacement equipment are often elusive. As previously discussed, there are considerable differences in image resolution between machines and the frequency of the transducer may not be a particularly reliable indicator of image quality. The operator must therefore be aware of any limitations which affect the diagnostic capability and must make the best possible use of the available ultrasound system. Intelligent, informed operation of even a basic system is the key to good images and the practical improvements that can be made by the operator to the image are underpinned by an understanding of the theoretical principles outlined at the beginning of chapter 1.

As previously demonstrated using the tissue equivalent phantom (Chapter 1, Figures 1, 4 and 5), the sonographer should optimise the image by use of focal zones, frame rate and line density, frequency manipulation and other image processing options. The pelvic viscera are rarely affected by respiratory or motion artifact to any great degree and the sonographer should take full advantage of this to maximise the image quality by increasing the line density at the expense of a lower frame rate. When a single focal zone is used it is important to place it to affect the depth of interest (Chapter 1, Figure 7). Good spatial resolution can be maintained through a greater depth by increasing the number of focal zones to three or four. This keeps the beam narrow at the expense, again, of the frame rate. A reduced image field in terms of sector width can be accepted when scanning the normal ovary, also resulting in improved line density.

Choice of Approach

The pelvic organs are routinely visualised by two approaches - transabdominal (TA) and transvaginal (TV). The different advantages and limitations of these often mean that the examination may employ both techniques to gain maximum information.

The decision to use TA, TV or both, will depend upon many factors, including the reason for referral, findings on the initial scan, technical limitations and the acceptability of respective techniques to the patient. It is essential for any gynaecological ultrasound service to have both TA **and** TV capabilities.

Most examinations will employ the use of 3.5 or 5.0 MHz for transabdominal, increasing to 5.0 - 7.5 MHz transvaginally to optimise the resolution, (Chapter 1, Figure 6).

Transabdominal (TA) Scanning

The main advantage of TA ultrasound lies in its ability to encompass a comparatively large field of view; ovaries, particularly those sited laterally, can be quickly demonstrated in relation to the uterus, large masses can be accommodated in the relatively wide field of view of the sector or curved array, and peripheral pelvic, iliac fossa or associated renal pathology can be easily surveyed transabdominally using the same transducer, (Figure 1). Highly attenuating lesions, such as fibroids, sometimes obscure vital structures on a transvaginal scan and this problem may often be overcome by using the more varied angulations possible via an abdominal approach.

Preparation

Transabdominal scanning, via a distended bladder, has been used since diagnostic ultrasound began. The full bladder displaces small bowel away from the pelvic viscera and partially retroflexes the normally anteverted uterus to maintain the endometrial echo at a more perpendicular angle to the beam, (Figure 2). Some patients may find the distended bladder too uncomfortable to maintain for long, and some ladies are
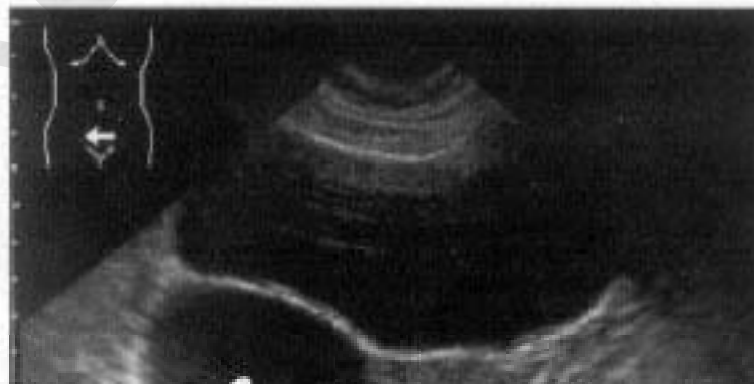
Figure 1—
The advantage of a wide field of view. This
mechanical sector has a variable angle capability,
which can be widened to accomodate masses such
as this right ovarian cyst, c, and can display the
relationship of the uterus and contralateral
ovary (arrow) in the same image.
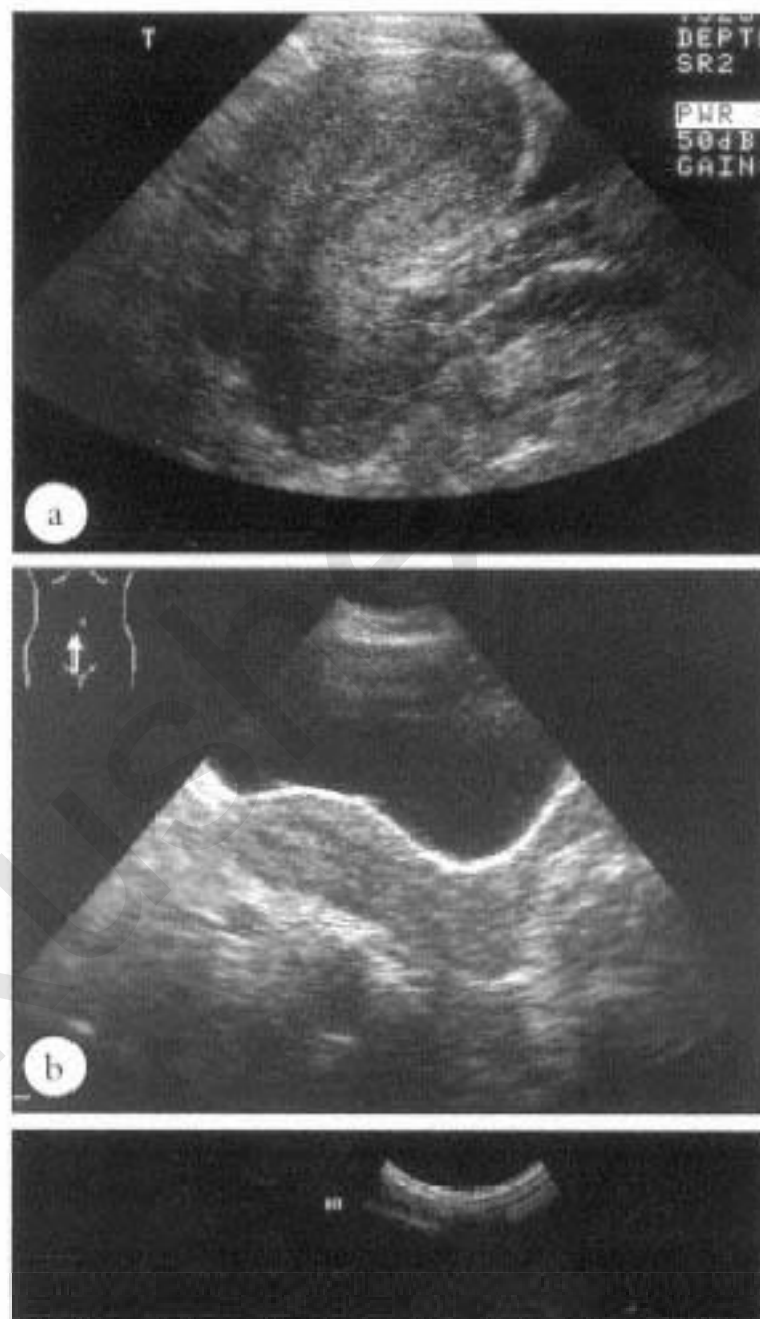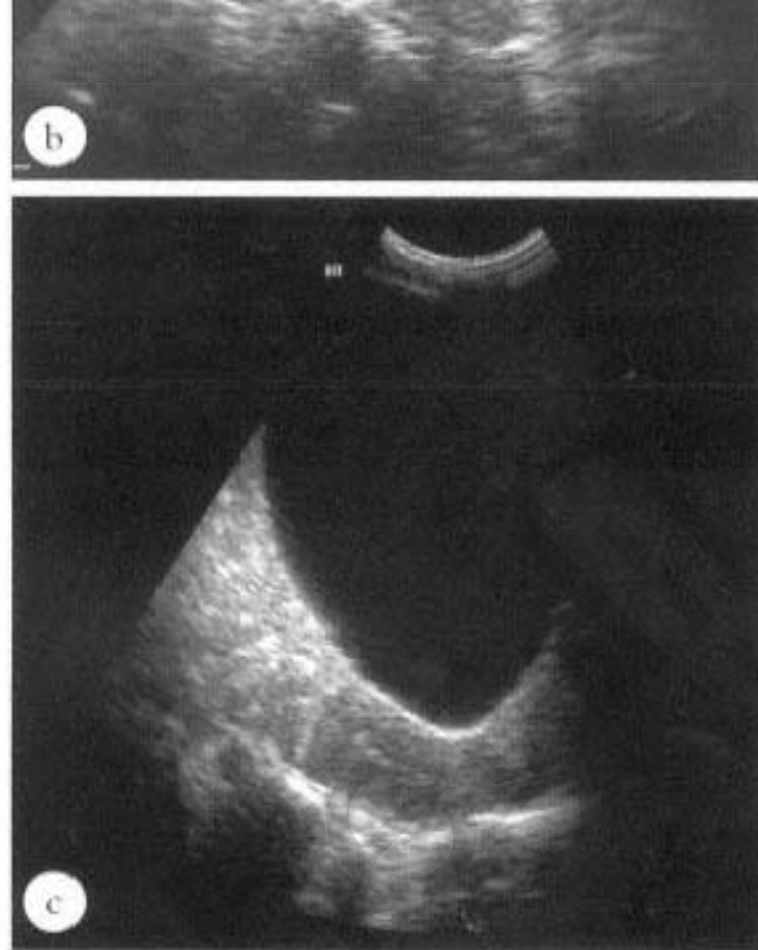
Figure 2—
Bladder filling. *a)* anteverted uterus with an almost
empty bladder. *b)* optimal bladder filling retroflexes the
uterus and displaces bowel. *c,* Typical sonographer's
bladder at the end of a scanning session. An overfull
bladder may compress and displace the pelvic
viscera too far from the transducer.

unable to reach the required degree of filling. Associated medical problems, such as incontinence, renal failure or previous bladder surgery, may prevent adequate filling and transvaginal techniques should be considered for these patients.

The full bladder itself displaces the organs into the far field of the image where the resolution may be inferior. The depth of tissue to penetrate usually requires a transmitted frequency of around 3.5 to 5 MHz, and the attendant limitations of resolution therefore preclude adequate inspection of some structures.

Occasionally, ascites may avoid the need for a full bladder, outlining the uterus, ovaries and broad ligament sufficiently to obtain diagnostic information, Figure 3. It is useful, however, to visualise the bladder itself, particularly when bladder pathology is present, Figure 4, or when trying to distinguish pelvic cysts from structures of vesical origin (e.g., bladder diverticulae).

Transabdominal Technique

Transabdominal Technique

It is invariably necessary to first take a careful history from the patient. This will always include the current menstrual state in addition to current and past gynaecological history.

The patient is usually scanned supine with the distended bladder as a "window" to visualise the uterus and ovaries in longitudinal and transverse sections. The long axis of

Figure 3—
The presence of free fluid allows the pelvic
viscera to be scanned with the bladder empty.
The uterus and ligaments are demonstrated.
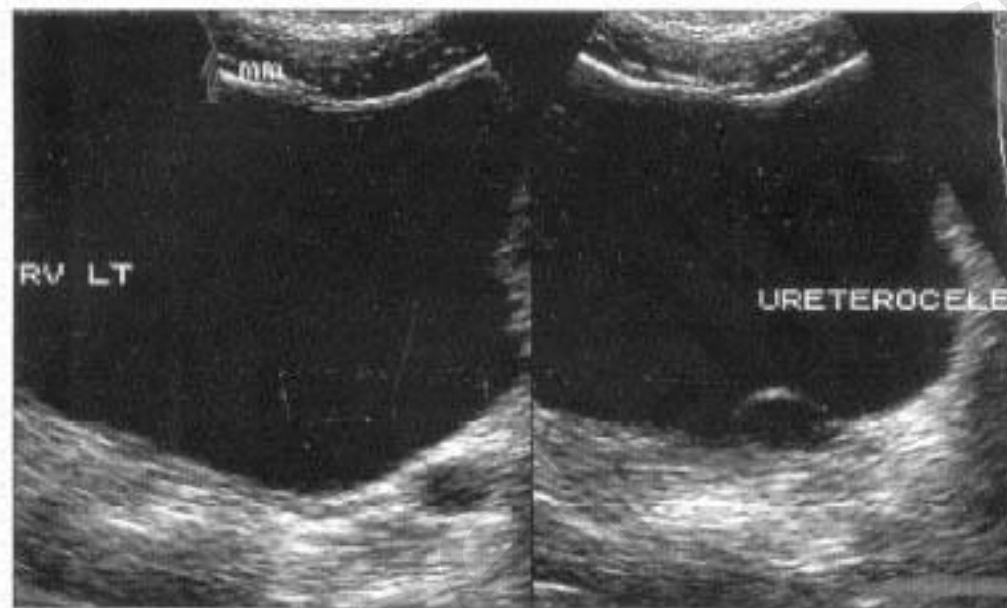
Figure 4—
Filling the bladder has the advantage of being able to detect other,
often unsuspected, pathology such as this uterocoele.
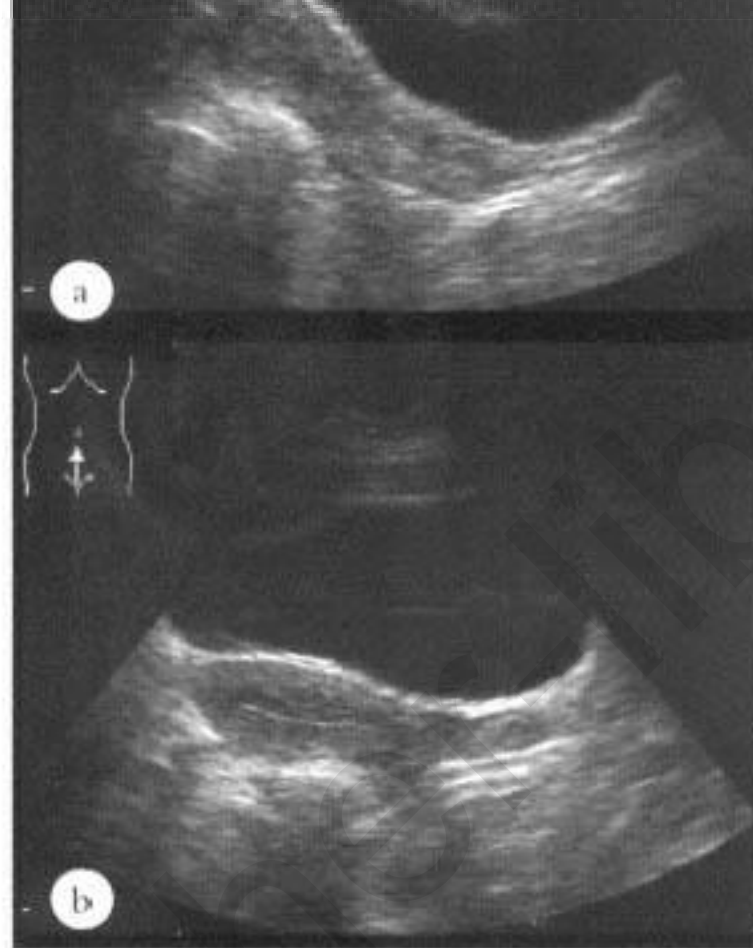
Figure 5—
a) The endometrial cavity echo is poorly
demonstrated because of its angle to the beam.
b) With a cephalic angle, maximum reflection from
this interface is now obtained. (Note how the echo
from the vaginal interface has now disappeared.)

the uterus should first be assessed and maintained along the beam to display the full extent of the endometrial cavity echo. This will be most successful if the endometrium is maintained at an angle approximately perpendicular to the beam, causing maximum acoustic reflection from the interface, Figure 5. The operator may then assess from this the most appropriate angle for transverse sections, which will depend upon the degree of uterine retro- or ante-version, and upon its obliquity, Figure 6.

The ovaries are also imaged by maintaining the bladder as a window. The TA scan can display the relationship of the ovaries to the uterus, best seen in transverse section by maintaining the transducer as perpendicular as possible to the uterine axis. It is often helpful to identify the ovaries first in transverse section by visualising the uterine cornu and scanning slightly inferior to this. Because their position varies, (See Chapter 3), longitudinal scanning of the ovaries may involve considerable angling of the transducer from the midline or contralateral side.

It is often advisable to perform any preliminary measurements (of ovarian volume, masses etc.) at this stage in case visualisation is incomplete or unsuccessful on TV scanning. An ovarian volume estimation requires three measurements truly perpendicular to each other, Figure 7, - easier to achieve

It is often advisable to perform any preliminary measurements (of ovarian volume, masses etc.) at this stage in case visualisation is incomplete or unsuccessful on TV scanning. An ovarian volume estimation requires three measurements truly perpendicular to each other, Figure 7, - easier to achieve with a TA scan, as the planes obtained TV are slightly oblique.

Image Orientation (TA)

Percutaneous abdominal scans are always viewed as though from the patient's right in longitudinal section (patient's head to the left of the screen) and from the feet in transverse section (patient's right side to the left of the screen).
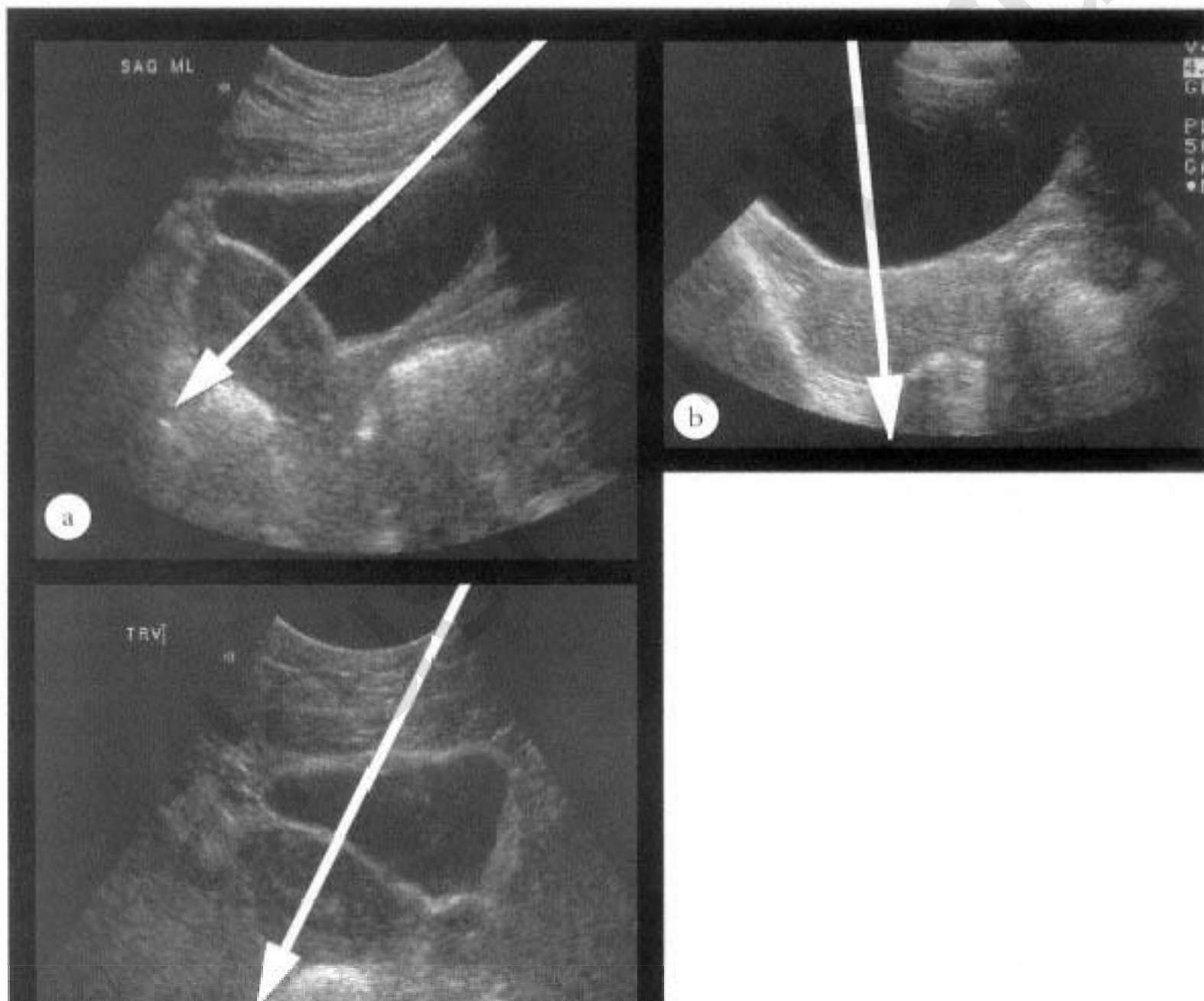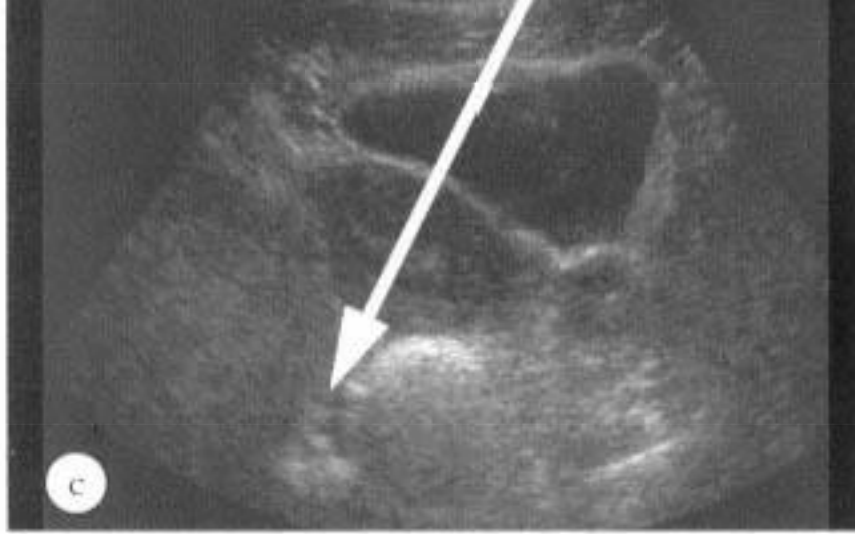
Figure 6—
a, The best angle for transverse section is demonstrated on this anteverted uterus. *b,* A retroverted uterus requires a slightly caudal angle. *c,* This transverse section demonstrates the obliquity of this uterus. Optimum longitudinal sections will therefore require angling towards the patient's right.
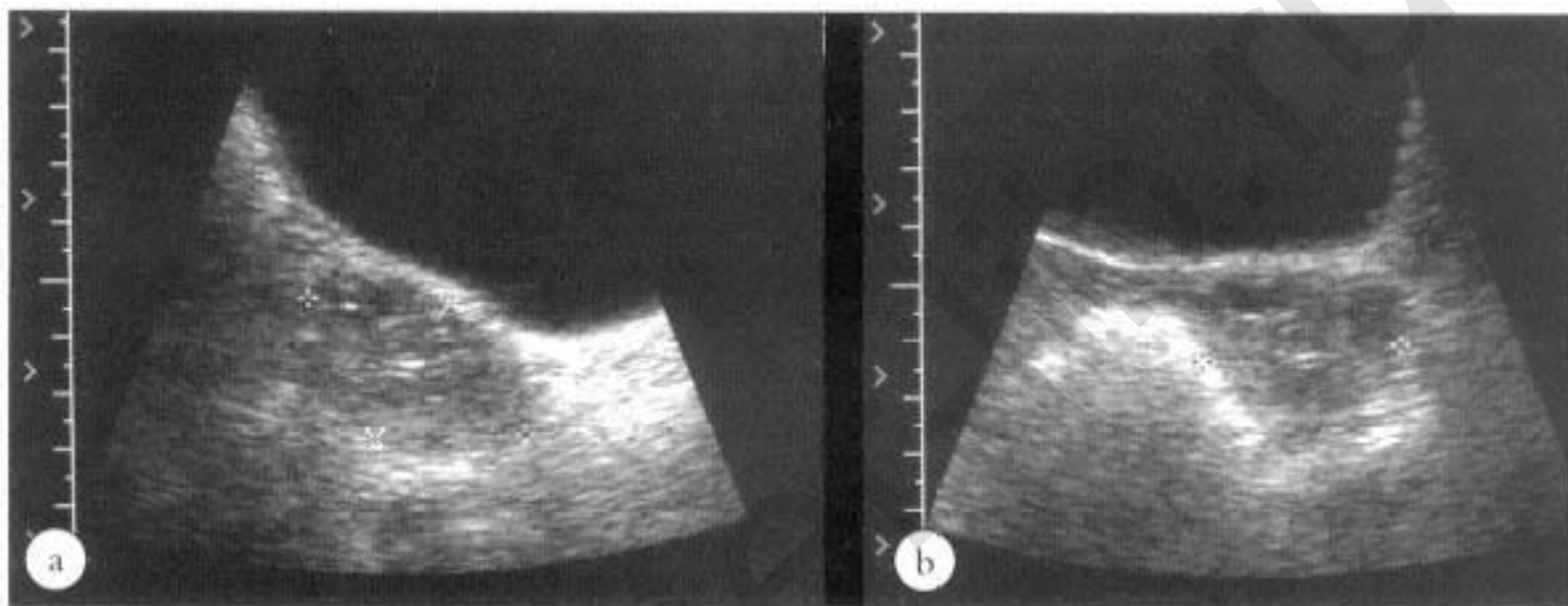
Figure 7—
TAS *a)* longitudinal and *b)* transverse sections through the left ovary with measurements appropriate for
volume calculation (*See Chapter 3*).

Transvaginal (TV) Scanning

It is fair to say that gynaecological scanning has been revolutionised by the routine use of the vaginal probe. This is due to the improved resolution gained by the ability to use a higher frequency. The depth of tissue to penetrate using this technique is minimal, avoiding attenuation through subcutaneous layers, and therefore normal structures may be easily accommodated within the focal zone of a 5 or 7.5 MHz transducer., Figure 8. The bladder should be empty in order to allow the uterus and ovaries to lie close to the transducer within its focal zone, and this has obvious advantages for both patient and operator.

Acceptability to the Patient

Initial concerns that the vaginal scan would be viewed as invasive by the patient appear unfounded. Patient acceptability depends almost entirely on the approach by the sonographer and it is rare for patients to decline. The amount of time necessary to explain the procedure and put the patient at her ease is always well spent, as the benefits of a TV scan in terms of improved acoustic information are enormous. There are very few contraindications to vaginal scanning but these usually include paediatric patients and virgi intactae.

Verbal consent is generally sufficient following an explanation, but it is advisable, particularly for male operators, to perform the scan with a female chaperon - preferably one who is familiar with departmental practices.

Privacy is essential, and reassurance during the examination by the sonographer is good practice. Friendly and professional communication with the patient cannot be stressed too highly, and the majority of litigious cases surrounding TV ultrasound, though few, could probably have been avoided by employing good communication skills.

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Transvaginal Technique

The scan is performed with an empty bladder and usually carried out with the patient semi-recumbent, knees bent, buttocks resting on a pad or pillow. This is usually quite sufficient to allow the operator to manoeuvre the probe satisfactorily. (The use of a lithotomy table, with stirrups for the patient's legs, is normally unnecessary but may be found in some specialised departments, such as assisted conception units.) Alternatively, the decubitus position, particularly in patients who have difficulty lying supine, is useful.

Using a slightly reverse Trendelenburg position encourages any free fluid to collect in the pouch of Douglas, outlining the posterior uterine wall and, in some cases, the adnexal structures.

In the case of the patient's first attendance, the endovaginal scan will often follow a transabdominal survey, which will have given the operator knowledge of the position of the uterus and ovaries and highlighted any masses. (Patients who attend for follow-up scans or regular screening procedures are usually able to proceed straight to TV scans without first filling the bladder.)

The probe should always be covered with a disposable cover - contraceptive condoms are adequate for this
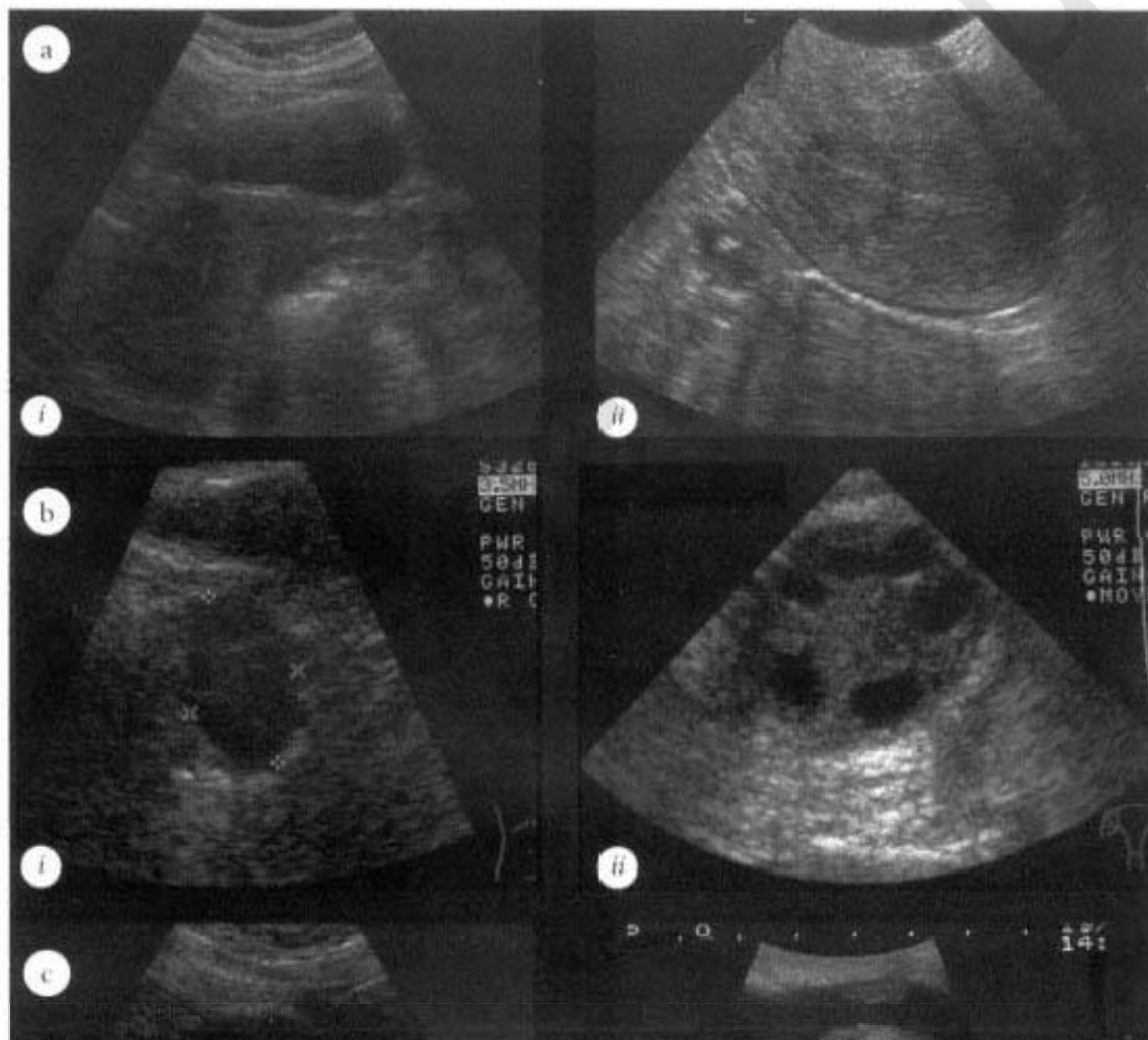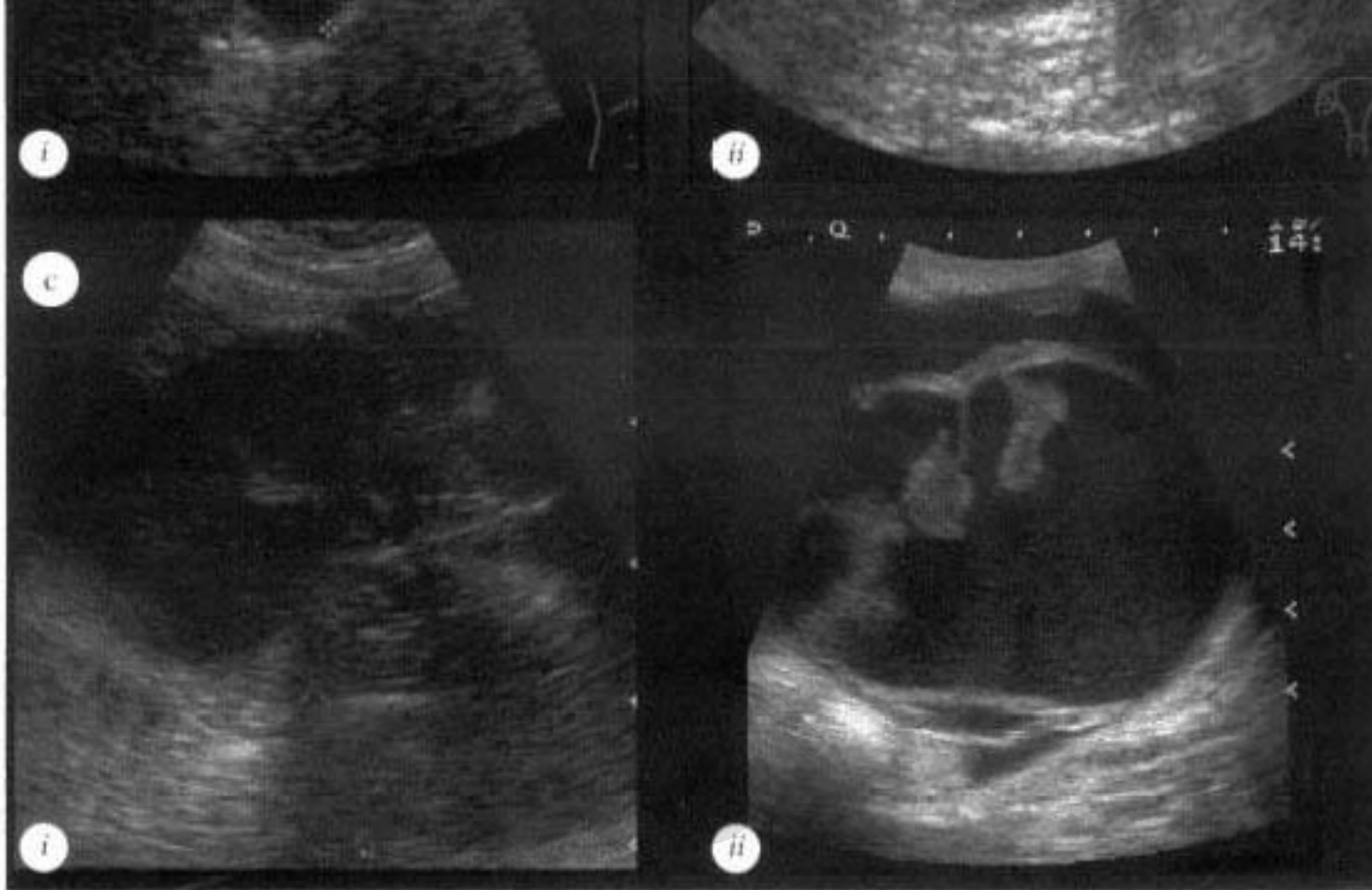
Figure 8—
a) i - The fundus of this retroverted uterus is obscured by overlying bowel on a TAS. ii - TVS
of the same patient, avoiding bowel and displaying the uterus in the near field.
b) i - Detail of this normal left ovary in an obese patient is relatively poor compared to the same
ovary scanned TV, ii - in which the follicles are clearly demonstrated.
c) i - This amorphous adnexal mass TA in an obese patient is transformed when scanned TV, ii -
These appearances are typical of ovarian carcinoma.

LONGITUDINAL SECTIONS

Anterior and posterior

Lateral

TRANSVERSE OR CORONAL SECTIONS

Anterior and posterior

Lateral
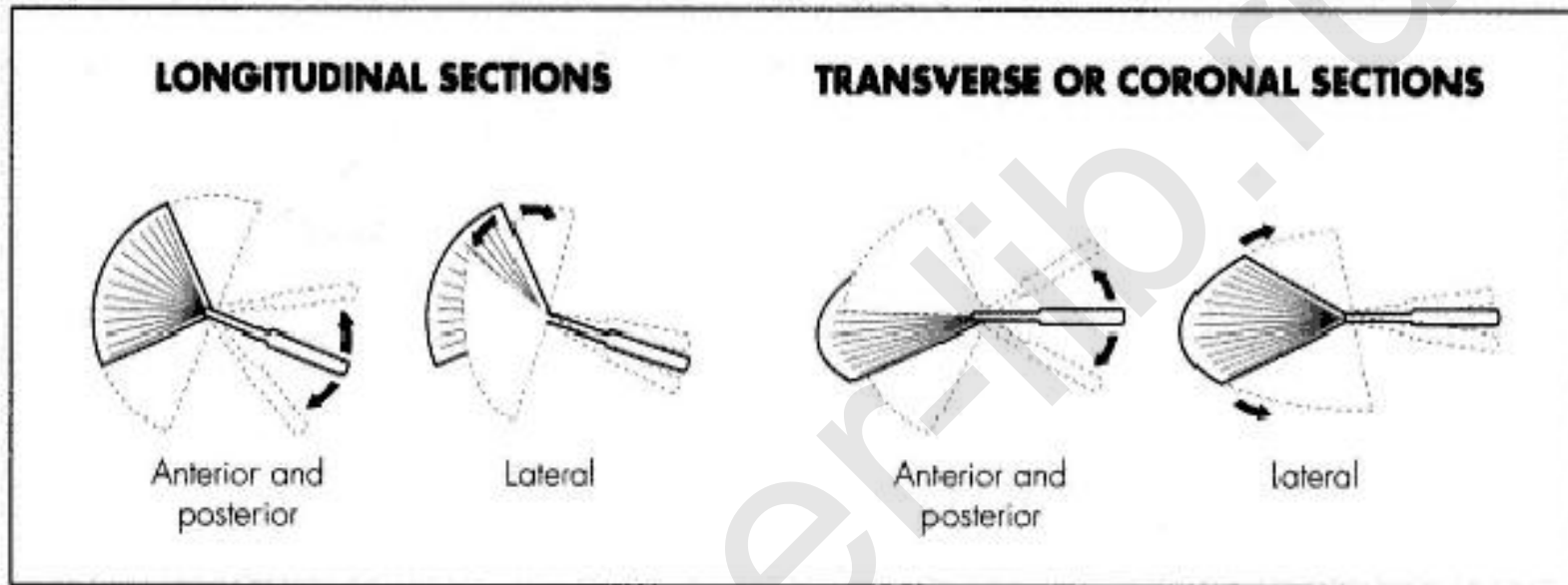
Figure 9—
Basic transvaginal planes of scan

purpose, but those with spermicidal lubrication should be avoided, particularly in assisted conception units. A small amount of coupling gel should first be introduced into the condom, which is then rolled onto the transducer, smoothing any air bubbles away from the transducer face. Gel is then applied to the outside to maintain contact and facilitate insertion of the probe.

The sonographer is responsible for minimising the risk of cross-infection and the probe should be thoroughly cleaned after each procedure using a disinfectant approved by the manufacturer.

In order to become proficient in any scanning technique there is no substitute for experience, and descriptions of how to angle the transducer are invariably unsatisfactory and tedious to read. Diagrams of the transducer movements necessary to achieve different planes of scan, Figure 9, are merely a guide to help the novice operator work out how the beam is behaving according to what the wrist is doing and the technique employed will always be a combination of these planes. (It is sometimes helpful for the learner to imagine the sector beam as a thin fan emerging from, and fixed to, the probe, and then retain this mental image as the probe is turned and angled after insertion.) As with any scanning technique, it is important to adapt to the individual patient and not perform the procedure simply as a technical process.

The probe is inserted gently into the vagina and may be located in the fornix or withdrawn slightly back down the vagina, to display the uterus fully. Because the field of view is comparatively small, it is necessary to angle the probe, sometimes quite considerably, to interrogate all the necessary structures.

Anatomical landmarks such as the internal iliac vessels are useful for locating the ovaries, but it is also valuable to draw upon positional information gained from a previous TA scan if the ovaries are difficult to locate.

Although the problem of attenuation through subcutaneous tissue is avoided by the TV route, large, attenuating masses such as uterine fibroids and overlying small bowel may obscure vital structures. This is a particular problem in post-menopausal women when the uterus and ovaries are atrophied. Gentle

Although the problem of attenuation through subcutaneous tissue is avoided by the TV route, large, attenuating masses such as uterine fibroids and overlying small bowel may obscure vital structures. This is a particular problem in post-menopausal women when the uterus and ovaries are atrophied. Gentle manipulation of the ovaries and bowel transabdominally with the free hand can overcome this problem and may bring superiorly placed ovaries down into the focal zone of the transducer.

A further advantage of TV scanning is the ability to use the probe to gently push the pelvic viscera and establish whether they move freely over the peritoneal surfaces. Known as the `sliding organ' sign, this is a useful clue in the diagnosis of adhesions, which will prevent this free organ movement, if present. Manipulation of the transducer by angling, rotating and sliding movements should obviously be gentle and slow to avoid tension and discomfort. Longitudinal and coronal (or horizontal) sections, where the transducer is turned through 90 degrees, require a combination of transducer movements which will depend on the position of the organs.

Mechanical sector probes with small rounded scanheads are usually easier to manipulate in both planes and those with beam steering capability require a minimum of movement; the larger (older) electronic arrays are more difficult to turn, particularly for coronal sections, and some have a smaller field of view; however these limita-

Summary of Advantages & Limitations of TA & TV techniques

	Transabdominal	Transvaginal
Field size	Large - displays relationship of ovaries to uterus. Accommodates large masses within the image.	Limited - large masses may be beyond focal zone. May not be able to accommodate entire uterine section in the field.
Flexibility	Easy to examine upper abdomen (e.g., kidneys) with same transducer. Bladder & distal ureters can be assessed.	Must use TA transducer for upper abdomen. Bladder not well seen.
`Invasive' nature	Perceived as non-invasive, so is the technique of choice for paediatrics & others.	May be perceived as invasive. Must have good patient/sonographer communication. Privacy essential.
Preparation	Full bladder may be uncomfortable or impossible	No preparation required
Resolution	3.5/5 MHz. Limited resolution especially in far field	5/7.5 MHz. Considerably superior to TA

tions have been largely overcome by manufacturers in modern equipment, (See Chapter 1, Figure 6). The advantage of the electronic array over the mechanical probe is improved resolution with dynamic focusing and Doppler capabilities.

Image Orientation

Unlike TA scans, there is no accepted rule for the orientation of TV scans. Because we are used to looking at images with the transducer face at the top of the screen, with TV scans this means that we are effectively looking at the anatomy the opposite way round to TA scans, as though from the patient's left. Opinion is divided, and it is quite acceptable to reverse the screen orientation to allow the apex of the sector to appear at the bottom of the screen. This is probably an easier way to scan, particularly for learners, as the image is again viewed from the patient's right, as in TA scans.

Doppler Techniques

Both physiological and pathological haemodynamic changes in the pelvis may be demonstrated using Doppler ultrasound.

Doppler information in the pelvis is required to be depth specific - that is from specifically identified vessels. The use of pulsed wave Doppler alone is too limited to be useful in the pelvis, as small, deep vessels cannot be reliably identified. Colour flow and/or power Doppler, however, can display tiny vessels invisible on the black and white image and impart valuable information regarding vascularity of normal and abnormal structures, Figure 10.

The use of transabdominal colour Doppler is usually limited to larger vessels with higher velocity flow, and therefore yields less useful information. The TV approach, because of its higher transmitted frequency, provides better resolution with increased sensitivity to low velocity blood flow, particularly relating to smaller intra-ovarian vessels. Obviously, smaller diameter vessels with low velocities, such as those within the ovarian stroma, are more difficult to visualise and the ability to demonstrate pelvic vessels depends upon several factors, including:

• the sensitivity of the ultrasound system

- the sensitivity of the ultrasound system
- the settings used
- the transmitted frequency
- the angle of the vessel to the beam
- the stage of the hormonal cycle.

Having identified the vessels using colour Doppler, further information may then be obtained from spectral Doppler regarding the downstream resistance and flow velocity.
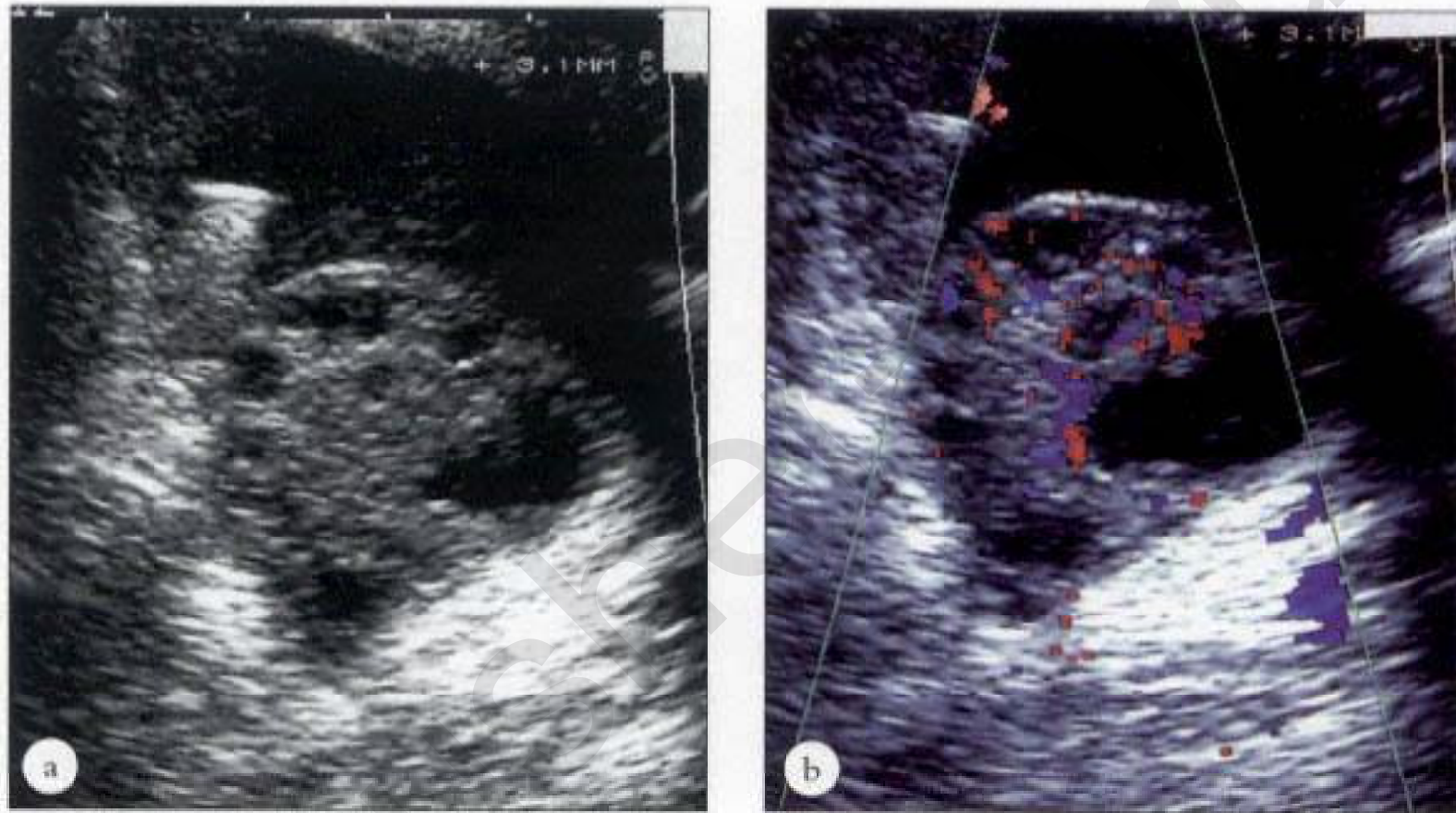
Figure 10—
a) TVS coronal section through a normal left ovary. *b)* with colour Doppler tiny intra-ovarian blood vessels
are demonstrated. Red indicates flow towards, and blue away from the transducer.

The main uterine vessels and major branches may be identified towards the lateral aspects of the cervix. Smaller diameter vessels can be seen within the uterine myometrium and often within the endometrium, depending on both physiological and pathological factors. Vessels may also be identified within and around the ovaries. The visualisation of blood vessels in the uterus and ovaries is highly dependent upon the stage of menstrual cycle, and is usually more difficult in post menopausal women as the organs may be atrophied and "functional" or physiological flow would not normally be present.

To maximise the information, colour Doppler is used on a setting sensitive to low velocities with a low filter value. The colour box should be confined to a restricted area of the image to maintain the frame rate and the focal zone should apply to the relevant depth under investigation. This is then supplemented

To maximise the information, colour Doppler is used on a setting sensitive to low velocities with a low filter value. The colour box should be confined to a restricted area of the image to maintain the frame rate and the focal zone should apply to the relevant depth under investigation. This is then supplemented with a spectral trace.

In practical terms, because the vessels in question are small and somewhat elusive, spectral traces are obtained by identifying the artery with colour, placing the range gate over it and switching immediately to spectral mode. The tiniest transducer movement may result in the vessel `leaving' the range gate with a subsequent lack of signal; rapid and repeated `switching' between colour and spectral mode is therefore usually necessary. Although some machines claim to have simultaneous real-time, colour and spectral Doppler, they achieve this by using a very slow frame rate which can be more difficult to manipulate than simply switching between modes.

The information gained from spectral Doppler in the pelvis relates to the downstream resistance of the vessel in question. A high downstream resistance, such as that encountered in the iliac vessels and normal uterine vessels, Figure 11, has a pulsatile waveform with low end diastolic flow (EDF) and often a notch during early diastole. A measure of this resistance to flow can be made by several indices, the most commonly used being:

Resistance index $\quad-\quad \dfrac{A - B}{A}$

Systolic/Diastolic ratio $\quad-\quad \dfrac{A - B}{B}$

Pulsatility index $\quad-\quad \dfrac{A - B}{mean}$

These indices are angle-independent and therefore particularly suitable for tortuous vessels such as those in the pelvic viscera.
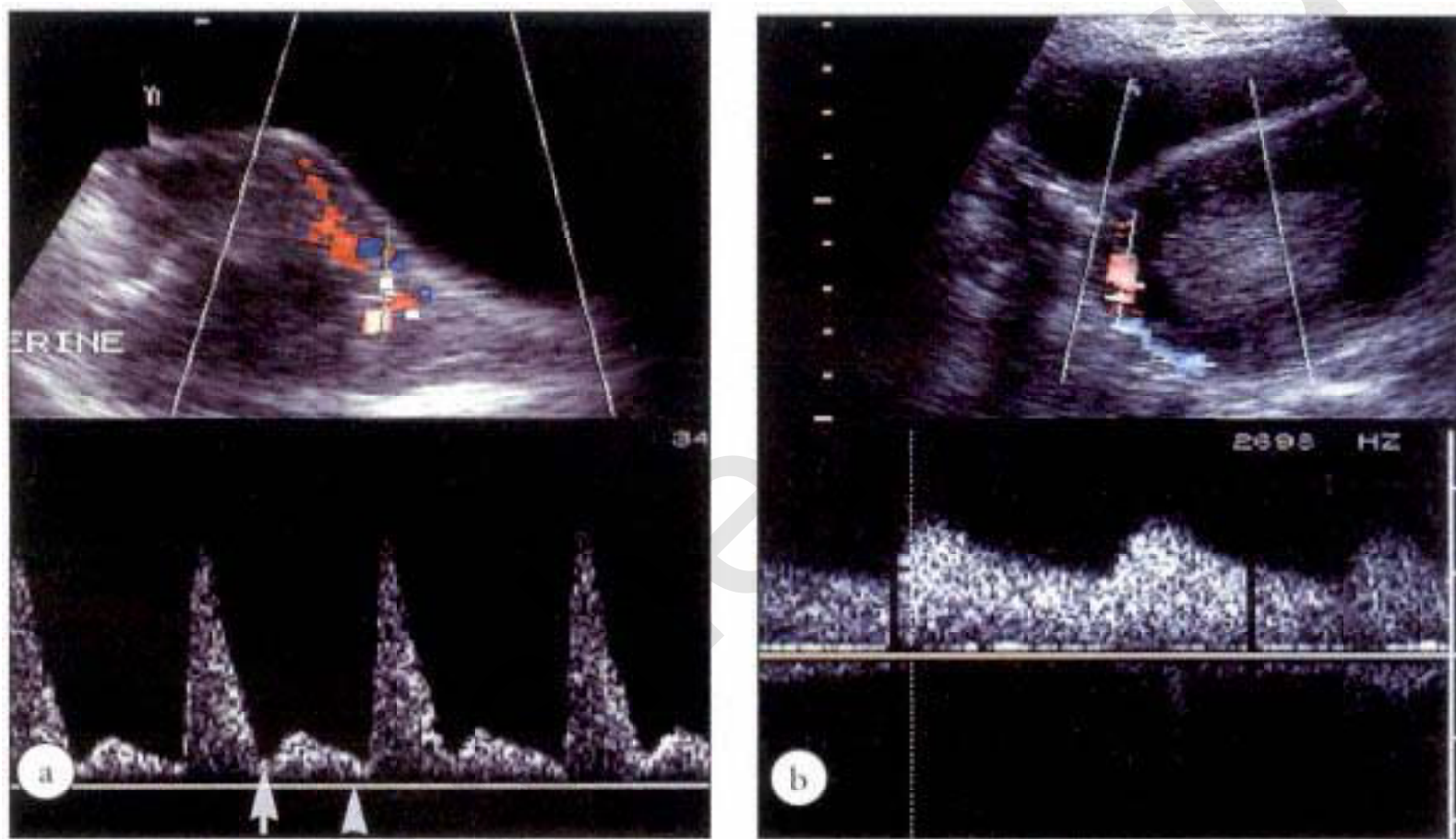
Figure 11—
a) The range gate (sample volume) has been placed over a normal right uterine artery. The resulting
spectrum gives a characteristically high resistance waveform with low end distolic flow (arrowhead) and a
notch (arrow). *b)* This uterine artery has abnormally low resistance (high end diastolic flow, no notch)
in a post-menopausal patient with bleeding from an endometrial carcinoma.

The velocity of blood flow can only be estimated if the direction of flow is taken into account by moving the angle corrector along the line of flow Figure 12. This is prone to error, even in long, straight vessels, and is not usually feasible in the small tortuous vessels within the ovary and surrounding the uterus. Power (or amplitude mode) Doppler, with its increased sensitivity to low Doppler shift frequencies, is potentially useful in the pelvis Figure 13. Its ability to display

Power (or amplitude mode) Doppler, with its increased sensitivity to low Doppler shift frequencies, is potentially useful in the pelvis Figure 13. Its ability to display

IF YOU ARE UNABLE TO OBTAIN ANY DOPPLER FLOW, CHECK THAT:-

- The angle of insonation of the vessel is low - preferably less than 60° to the beam

- The Doppler gain setting is turned up sufficiently

- The filter is on a low setting

- The system PRF is set for low velocities - (i.e., low `range' or `scale' setting)

- The transmitted power is sufficient (within the ALARA principle)

Doppler shift frequencies in vessels perpendicular to the beam is an advantage and although it does not display directional information, this is not usually a disadvantage when scanning the pelvic organs.

Doppler information should invariably be taken in conjunction with morphological findings, and should never be interpreted in isolation.

Additional Techniques

Repeating the pelvic scan after an interval of one or two weeks can be a useful exercise in some cases; the physiological nature of appearances may be confirmed by scanning during a different stage of the menstrual cycle. Differentiation of bowel from gynaecological masses may become clear following a second scan and the need to use bowel preparation is rare, but ocasionally useful in distinguishing faecal loading from dermoid cysts.

Saline contrast hysterosonography, to improve visualisation of endometrial abnormalities, has also been successful, particularly in the investigation of post-menopausal bleeding [1]. The use of contrast media in the investigation of infertility is discussed in subsequent chapters.
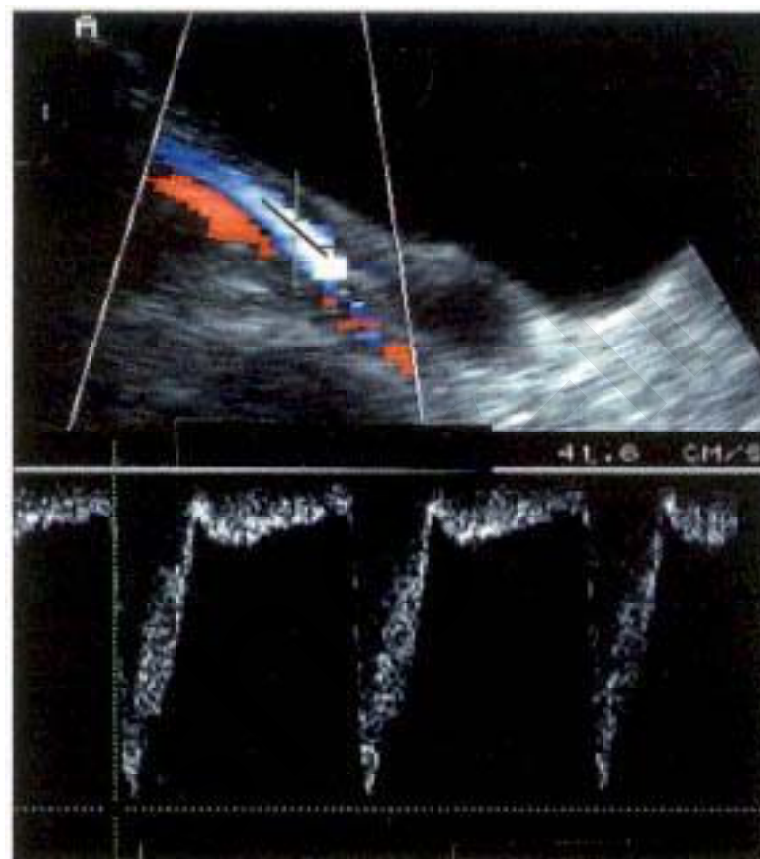
Figure 12—
The angle corrector has been placed approximately
along the direction of flow of this internal iliac artery,
giving a peak systolic velocity reading of just over
0.98 m/sec.

Many probes have the option of a biopsy attachment Figure 14, which enables drainage and biopsy procedures to be carried out with accurate placement of the needle and minimum discomfort to the patient.

It is always good practice to include examination of the kidneys at the first attendance for a pelvic scan. This may demonstrate pelvicalyceal dilatation associated with a distal mass, significant anatomical variants or incidental pathology.

Image Recording

Image Recording

The implications of image recording in terms of cost, storage and retrieval are numerous. There is no universally accepted practice on whether images should or should not be taken, or on how long they should be stored. The choice of recording devices and media depend upon many factors, including quality of image, cost, portability, ease and convenience of use, processing facilities and equipment maintenance, to name but a few.

The gradual introduction of picture archiving and communications systems (PACS) into radiology departments is likely to be followed by a reduction in the need to process and store large numbers of images, by employing a digitised system. Several ultrasound-friendly versions are now available and, eventually, are likely to replace the more resource intense imaging systems. (It is worth remembering that not all PACS have the ability to store colour images at this stage.)

It is not possible to have a comprehensive record of the entire examination unless video recording is used. This is seldom a practical alternative for routine use. Some PAC systems will allow the storage of moving images, but this is expensive in disc storage space. Documentation of most examinations takes the form of representative, still images. These, like the ultrasound examination itself, are only as good as the operator.

Image-taking has several uses. Images may be shown to other specialists for second opinions and to assist in difficult diagnoses; they are an accepted part of quality control programmes, providing a measure of proof that the scan has been comprehensively conducted, and they also form invaluable teaching aids.

Medicolegally images can be invaluable in providing proof that the operator has performed a comprehensive examination in a competent fashion [2].

The Role of the Sonographer

The role of non-medically qualified staff, or sonographers, in gynaecological ultrasound varies throughout the UK. Although no specific references to gynaecological

Figure 13—
Small, peripheral uterine vessels are displayed
with power Doppler. No directional information is
available.
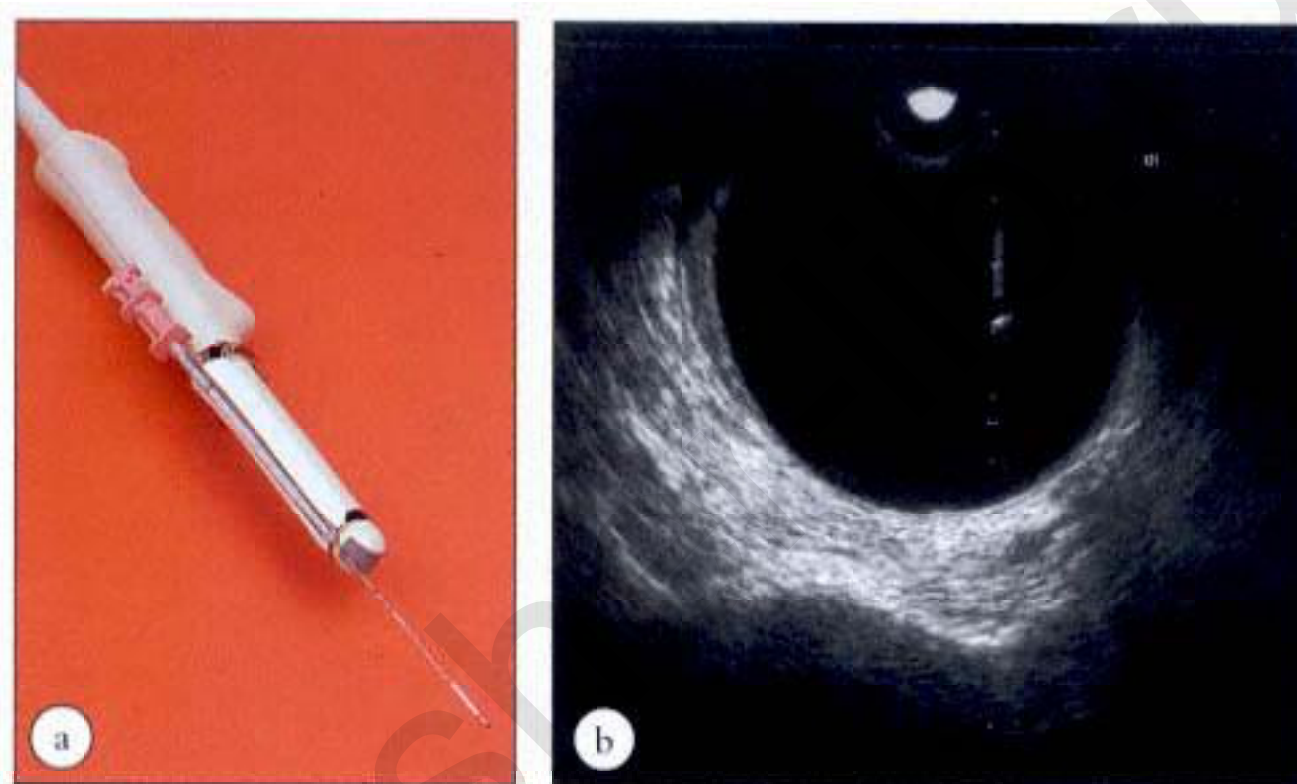
Figure 14—
a) A transvaginal probe with a needle-guide attatchment. (The probe cover has been
ommitted for clarity). *b)* Using the guide, a needle is placed into an ovarian cyst for drainage.

ultrasound exist, it is now accepted practice in many centres that sonographers perform diagnostic ultrasound scans and interpret the images they obtain. [3],[4] Certain prerequisites exist for this, including, most importantly, adequate training in the technical and clinical aspects of scanning and associated issues, such as patient management. It is a well-recognised fact that ultrasound is a highly operator-dependent technique, and one of the greatest hazards in diagnostic ultrasound is not any perceived biological effects on tissues, but its use by untrained personnel.

Any ultrasound practitioner must employ both technical and clinical skills in order to maximise the diagnostic capability of the ultrasound scan, and this invariably requires considerable in-depth training and continuing practical experience. Although still controversial in some quarters,[5] the delegation of scanning, interpretation and reporting of ultrasound examinations by medical staff to sonographers is now common practice in many centres,[3] and has the advantage of maintaining the continuity and standards of service in the face of increasing workloads.

It is, of course, incumbent upon the sonographer in question to maintain and develop the standard of ultrasound service provided, and sonographer-based

It is, of course, incumbent upon the sonographer in question to maintain and develop the standard of ultrasound service provided, and sonographer-based services conducted using guidelines for current best practice[6] are of a high standard. This includes the use of departmental schemes of work, or protocols which provide operators with a framework around which to conduct a comprehensive examination while being flexible enough to allow the scan to be tailored according to the clinical indications.

Summary

An examination of the pelvis with ultrasound should aim to maximise the diagnostic information obtained. This may mean the use of both abdominal and vaginal approaches, Doppler ultrasound and possibly follow-up scans at a different stage of the menstrual cycle. These factors should all be regarded as part and parcel of the ultrasound scan and should not necessarily be viewed as

A SUCCESSFUL SONOGRAPHER-BASED ULTRASOUND SERVICE INCORPORATES:

- Recognised training.

- Continuing education.

- Regular, frequent ultrasound practice.

- Proper delegation by medically-qualified person in charge.

- The use of protocols or schemes of work.

- Good audit and quality control procedures.

PRACTICAL USE OF ULTRASOUND – KEY POINTS

- The basic gynaecological ultrasound service requires both TA and TV capabilities. It should be subject to regular quality control and safety checks.

- Choice of equipment must be informed, taking into account its performance in terms of resolution, penetration and probe selection and design.

- The operator must use a combination of both technical ability and clinical knowledge in order to maximise the diagnostic capability. He/she should have undergone recognised training specific to gynaecological ultrasound and maintain regular scanning experience and continuing development in the field.

- Good, safe practice includes;

  Regular audit and quality control procedures

  The use of current guidelines and schemes of work.

  Operation in accordance with the ALARA principle.

  Recognition of any limitations of the equipment and the technique used.

separate entities. Departmental protocols must be flexible enough to allow the sonographer to make the best use of ultrasound as a whole, permitting the full range of options where necessary.

There are numerous situations in which transabdominal scanning will fail to deliver the required information - assessing the post-menopausal endometrium, for example, is rarely successful using TA scanning and it should be routine in such cases to offer TV examination. Large pelvic masses, on the other hand, will not be accommodated in the field of the TV transducer, which may underestimate their extent.

The strength of the ultrasound examination lies in the fact that it is dynamic. The operator must be both technically skilled and clinically aware, with a flexible approach, using a combination of techniques where necessary. It is essential that the sonographer makes best use of the available equipment to maximise the ultrasound information and that any limitations of both technique and equipment are recognised and taken into account when interpreting the scan findings.

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5. RCR - Board of the Faculty of Clinical Radiology Statement of Reporting in Departments of Clinical Radiology RCR, London, 1995
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3—

Anatomy, Physiology and Ultrasound Appearances

Rosemary Lee

Jane A Bates

Introduction
Vagina
Uterus
Ovaries
Fallopian tubes
Peritoneum and ligaments
Vasculature
Musculature
Bladder and ureters
Anatomical changes related to age
Physiology of reproduction
Haemodynamics of the uterus and ovaries and the use of Doppler ultrasound

Introduction

The female reproductive system is comprised of the vagina, uterus, ovaries and fallopian tubes. The appearances of these structures on ultrasound will depend upon the age of the patient and the stage of the menstrual cycle at the time of the scan. Throughout the female's life, particularly during the functional cycle, the organs are subject to physiological changes brought about by the influence of the hormones.

While the main object of the scan in most situations is to examine the reproductive organs, it is also essential to know and recognise the acoustic appearances of other structures within the pelvis, including muscles, blood vessels, ligaments, rectum and sigmoid colon and the bladder and ureters. Figures 1, 2.

Vagina

The vagina is a mid-line, thin walled, muscular structure approximately 8-9 cm in length, extending from the uterus to the vestibule, Figure 3. It is "H" shaped in cross section, being constructed of longitudinal folds and transverse ridges (rugae) which give it the ability to distend to accomodate the fetus during parturition. In its upper portion, it is contiguous with the uterine cervix and it divides into the fornices - anterior, posterior and right/left lateral. These are important landmarks especially in endovaginal scanning.

During transabdominal scanning the distended bladder, which acts as an acoustic window, does not affect vaginal
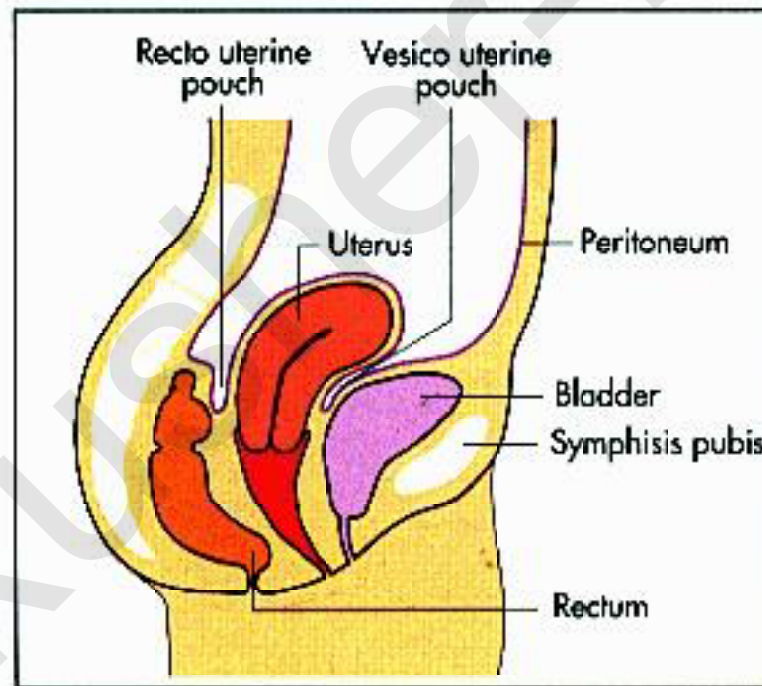
Figure 1—

Figure 1—
Midline sagittal section through the female pelvis

position. The vagina can therefore be used as an effective landmark, even if the uterus does not occupy its familiar position in the pelvis. The bladder also compresses the vagina, producing the hyperechoic mid-line echo, Figure 4. (See Chapter 2.)

Uterus

The uterus is a pear-shaped, muscular, hollow organ situated in the true pelvis. It lies predominantly in the midline, anterior to the rectum and posterior to the urinary

Figure 2—
Transvere section through the body of the uterus
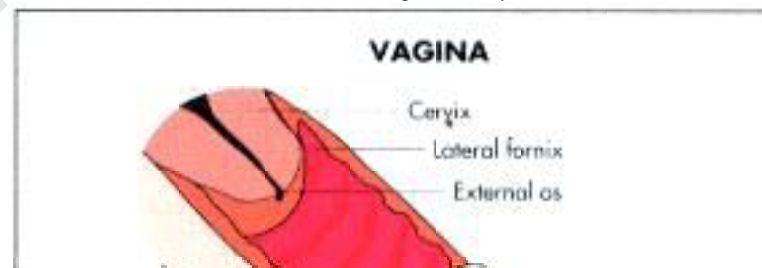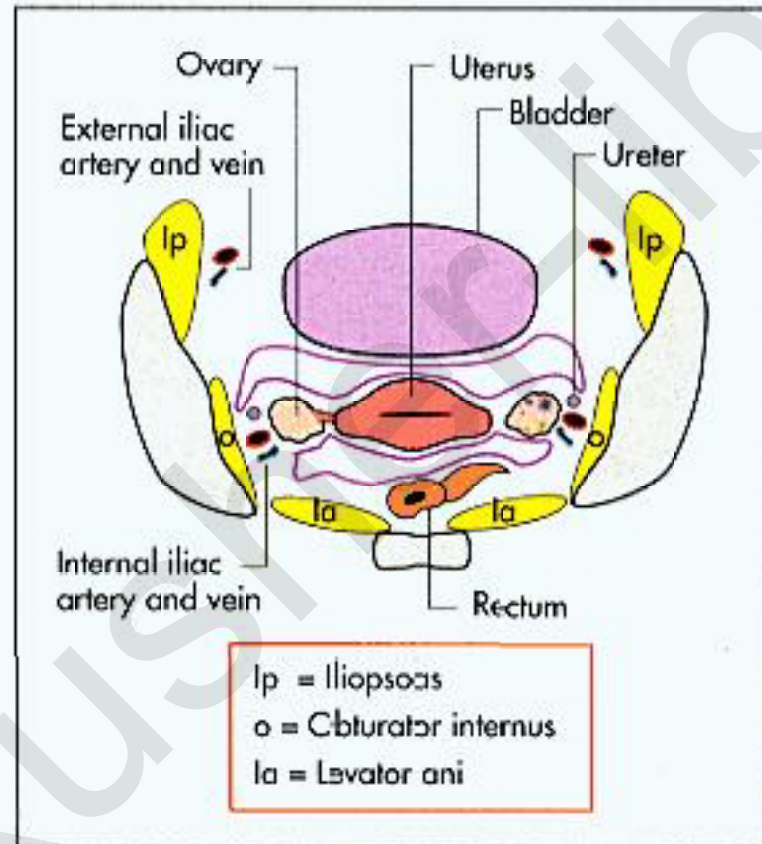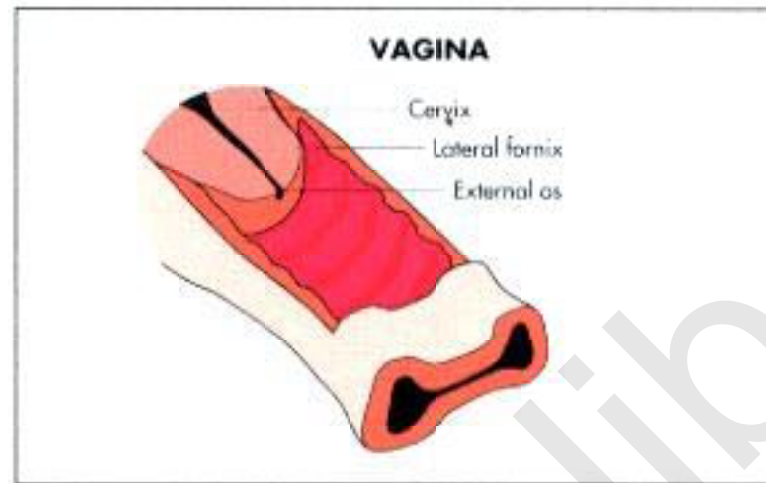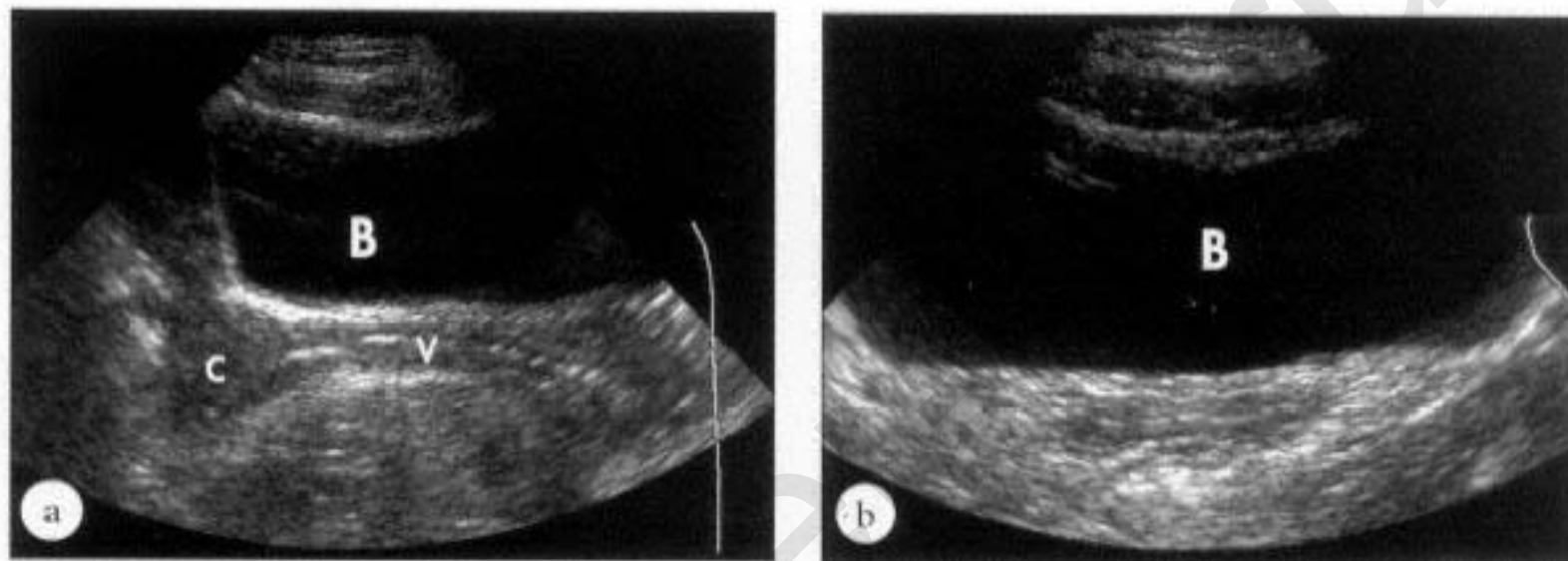
Figure 3—
The Vagina

Figure 4—
a) Longitudinal section through the vagina. The beam has been angled slightly caudad to demonstrate the echo from the vaginal interface. *b)* Transverse section through the vagina. (B= bladder, V= vagina, C= cervix)

Uterine Positions

Normal anteversion   Anteflexion

Retroversion   Retroflexion
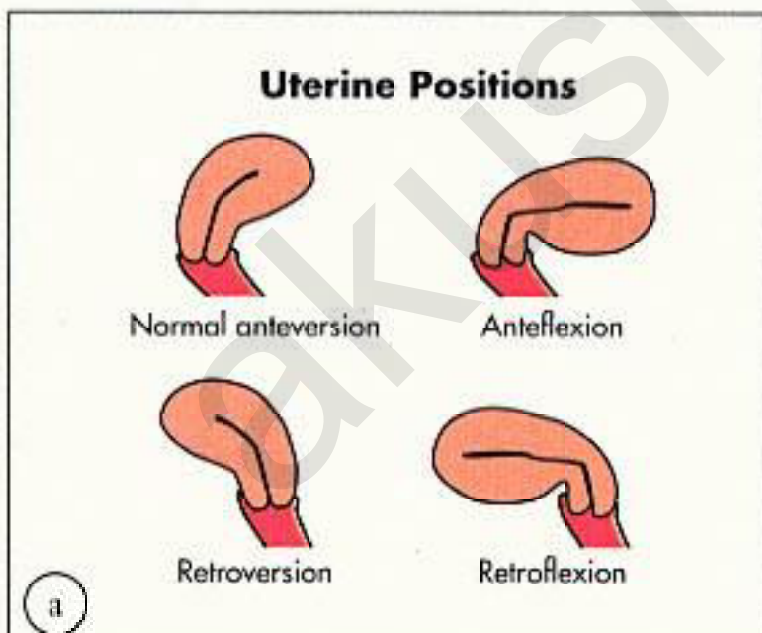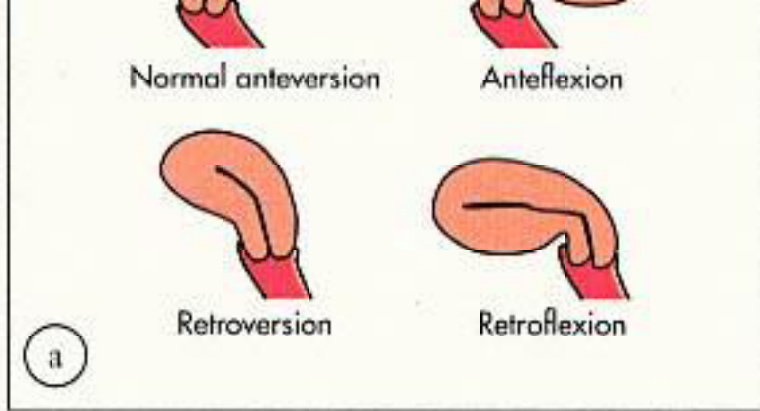
Figure 5—
a) Uterine positions. Ultrasound cannot normally differentiate retroversion from retroflexion. *b)* Normally anteverted and *c,* retroverted uterus
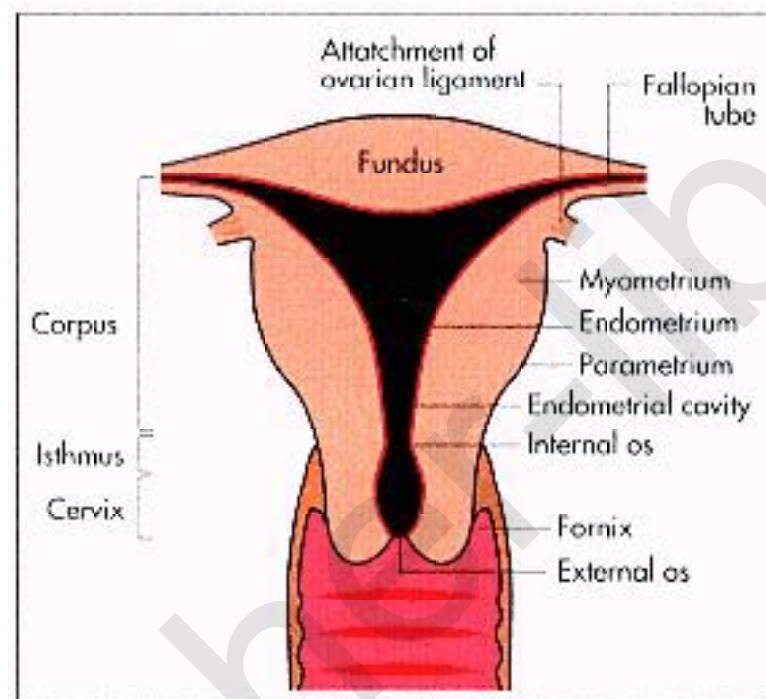
Figure 6—
The Uterus

bladder and is supported by ligaments and muscles Figures 1,2. Typical measurements of the adult uterus are 7 cm in length, 4 cm wide and 3 cm in antero-posterior diameter. These measurements all increase in size, on average by 1.2 cm following pregnancy.

It is generally ante-verted but may present in various other attitudes, Figure 5. It is not usually possible to differentiate a retroverted from a retroflexed uterus on ultrasound. The degree of bladder filling will obviously also have an effect on the flexion of the uterus (See Chapter 2.)

The uterus is divided into four parts - fundus, corpus (body), isthmus and cervix, Figure 6. Confident delineation of the latter is not always possible on ultrasound images as there is no clear acoustic difference in the tissues of the body of the uterus and the cervix.

The fundus of the uterus refers to the dome-shaped uterine roof, which extends superiorly to the entrance of the fallopian tubes.

The corpus, or body is composed of the upper two-thirds and the lower third is the cervix. At the junction of the corpus and the cervix lies the isthmus; it is here that, during the later stages of pregnancy, the lower uterine segment develops.

The two main parts of the uterus have separate functions - the corpus for gestation and the cervix to act as a sphincter.
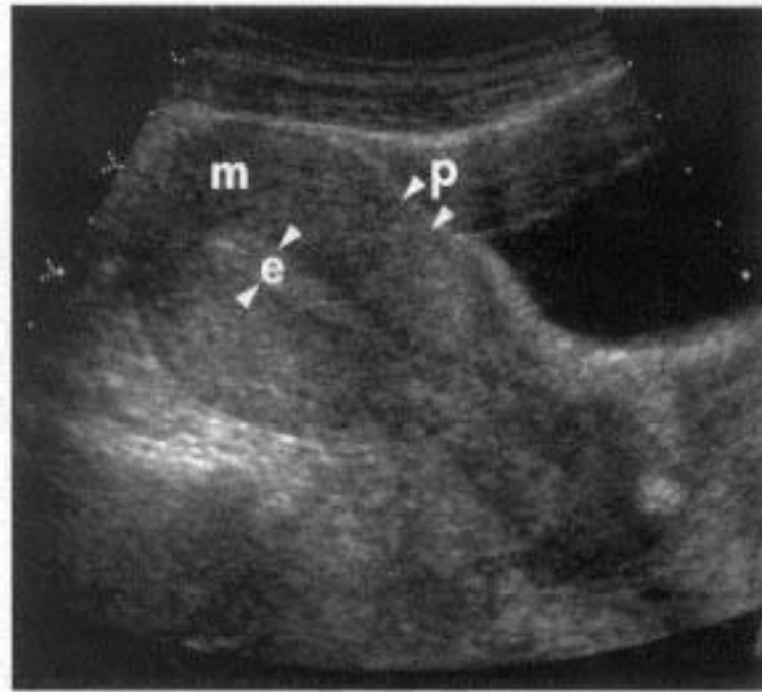
Figure 7—
The acoustic properties of the three uterine layers;
p = parametrium, m = myometrium, e = endometrium

The uterine wall is composed of three layers; the parametrium - the external layer, the myometrium - the thick muscular layer and the endometrium - the inner layer. The different tissues of these layers exhibit different acoustic properties, Figure 7. The parametrium, an incomplete covering layer of peritoneum, produces a highly reflective echo outlining the uterus. Lower level homogeneous echoes are reflected by the thick layer of myometrium and the inner lining, the endometrium, exhibits changing ultrasound appearances throughout the hormonal cycle giving rise to different thicknesses and reflectivities. These cyclical changes of the endometrium and ovaries are described in more detail later in this chapter.

Uterine Anomalies

The reproductive organs develop in the embryo from two tubes, the Mullerian ducts. The caudal portions of these ducts eventually fuse to form the uterus, cervix and superior part of the vagina, while the cranial portions remain separate, forming the fallopian tubes. Development takes place from the third or fourth week of gestation and continues into the second trimester. Interruption to this process causes incomplete fusion, which may result in a variety of structural anomalies [1],[2] and the more common anomalies are demonstrated in Figure 8.
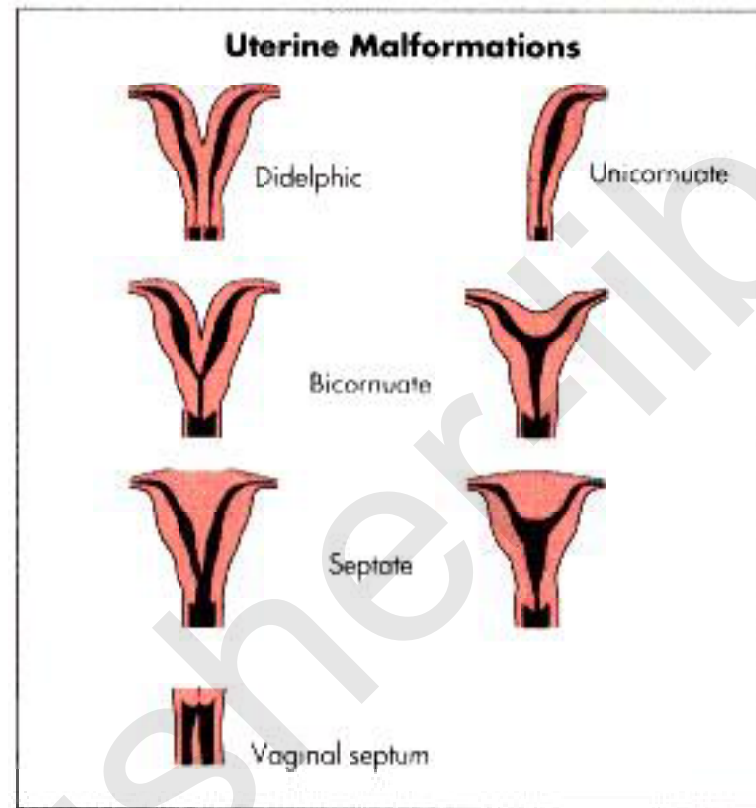
Figure 8—
Uterine anomalies

Until recently these disorders have either gone undiagnosed or were revealed by laparotomy, laparoscopy or hysterosalpingogram during investigations for infertility or failed pregnancies, Figure 9. With the advances in diagnostic ultrasound and MRI, Figure 10, these conditions are now more frequently diagnosed.

It is not always possible to identify the more subtle anomalies by ultrasound. The bicornuate model is most frequently identified on ultrasound in transverse section by demonstrating two distinct cornua, each with its endometrial echo, towards the fundus, Figure 11.

Ovaries

The ovaries are the sex organs; their function is to produce a mature ovum every 28 days and to secrete the female hormones, oestrogen and progesterone, which maintain the reproductive cycle, and to support pregnancy.
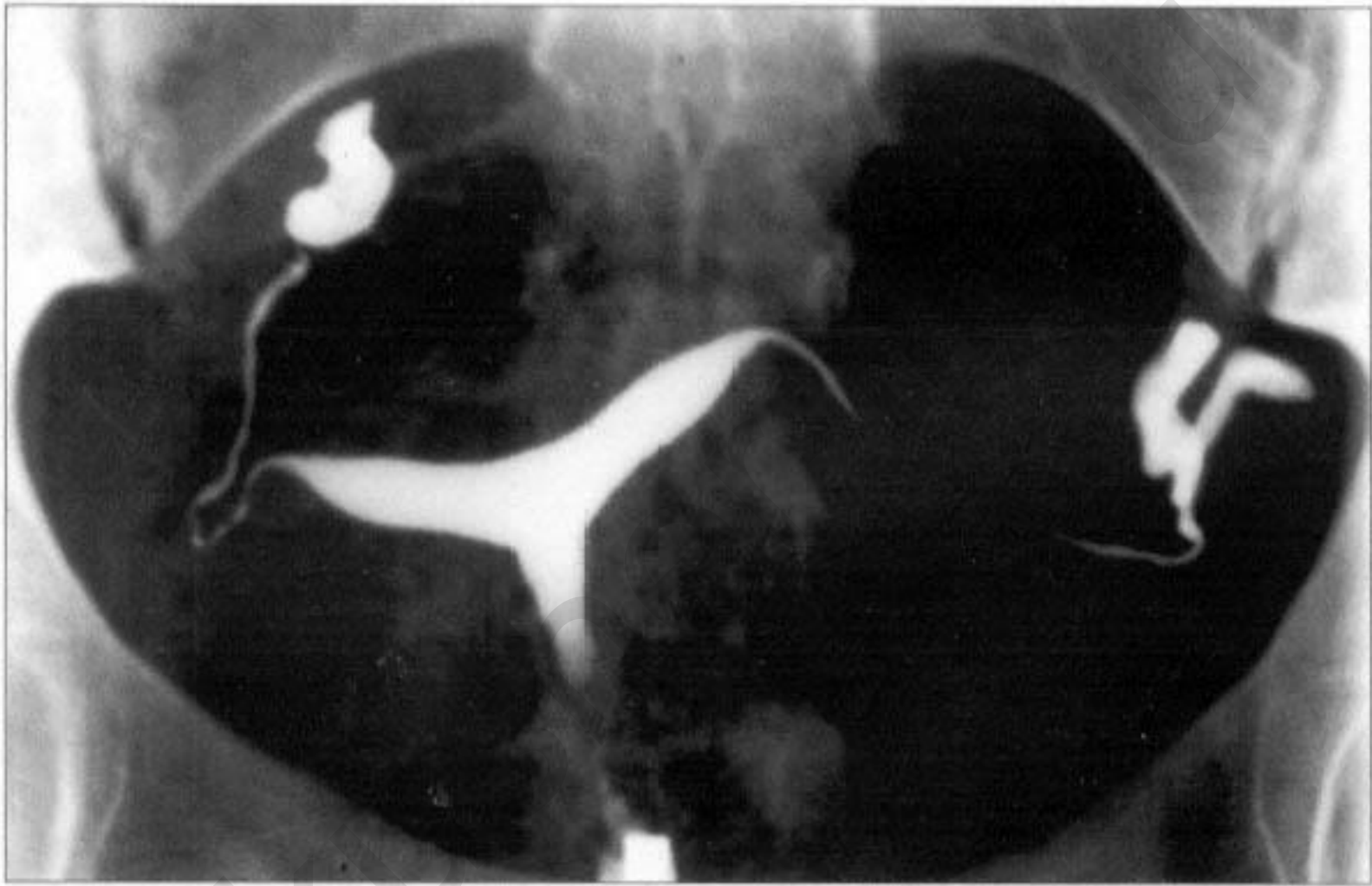
Figure 9—
Contrast Hysterosalpingogram demonstrating a bicornuate uterus. Patent tubes are seen bilaterally with spill of contrast into the peritoneal cavity.
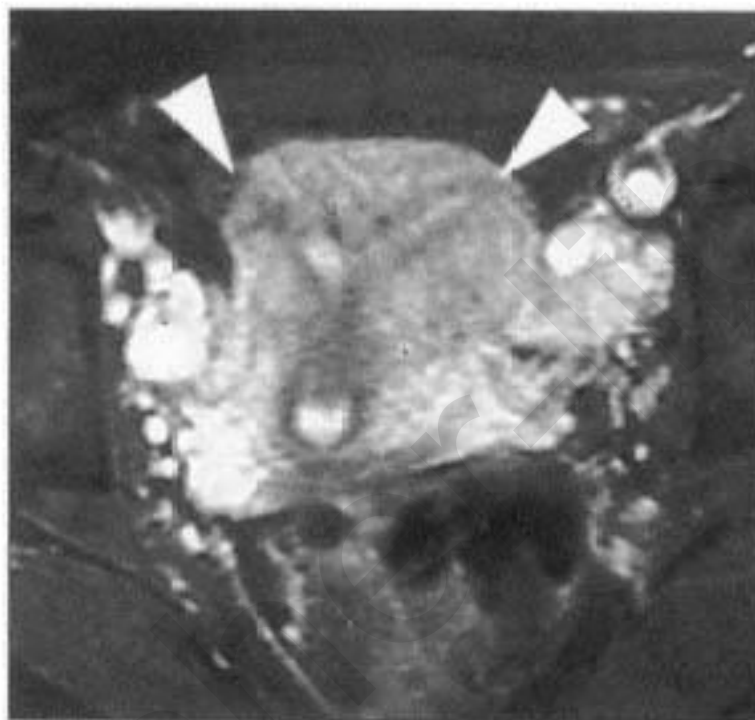
Figure 10—
Magnetic Resonance axial T2 weighted image
demonstrating a bicornuate uterus (arrowheads).
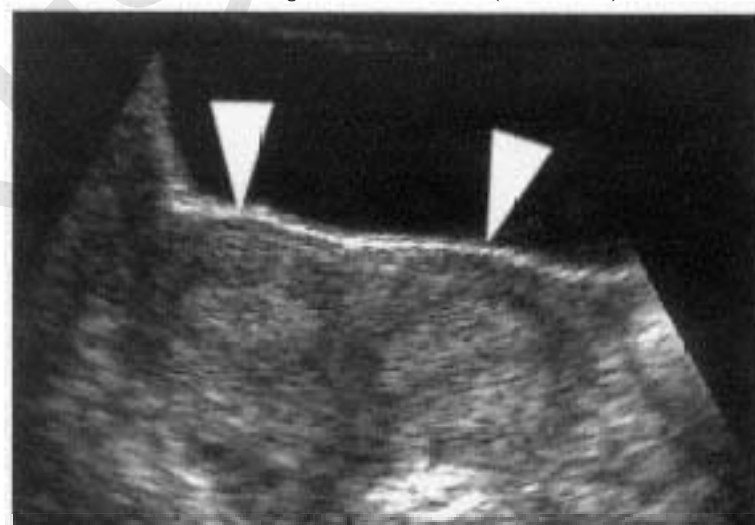
Figure 11—
Ultrasound demonstration of a bicornuate uterus
in transverse section (arrowheads). This may often
be more obvious on transabdominal than
transvaginal scanning, due to the larger field of
view of the former.
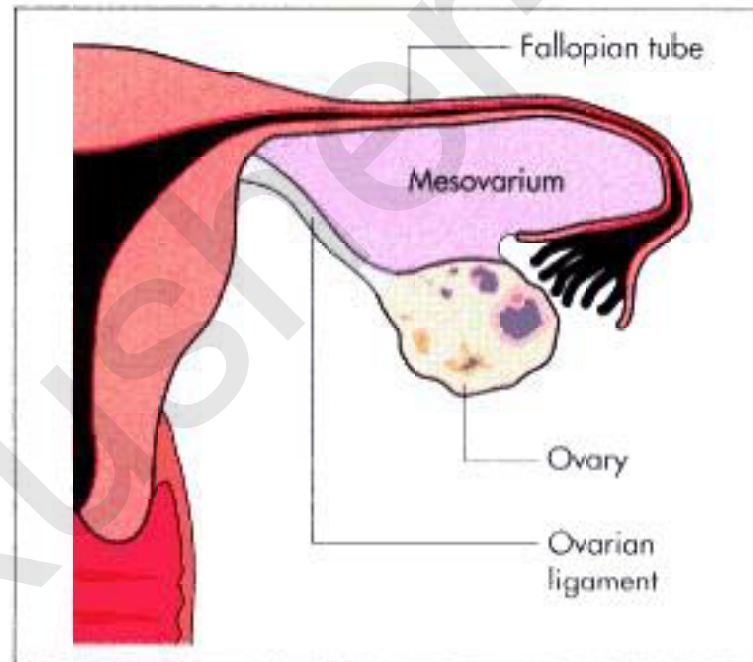
Figure 12—

Figure 12—
Anatomical relations of the ovary
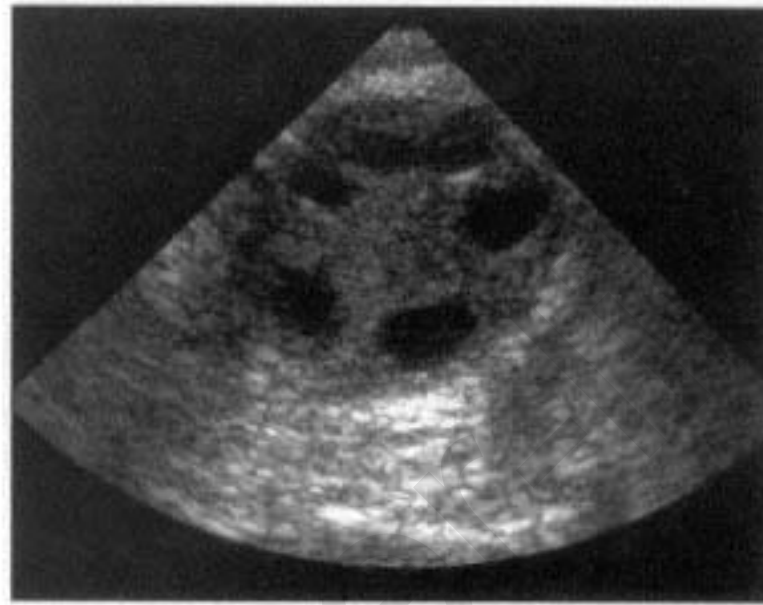
Figure 13—
TVS of the ovary demonstrating peripheral
Graafian follicles within the stroma and the
echogenic central medulla.

Each ovary usually lies posterior and lateral to either side of the uterus attached to the broad ligaments by its own mesentery, the mesovarium, and to the uterus by the ovarian ligament. Its upper surface lies in close proximity to the fimbrial end of the Fallopian tube, Figure 12.

They are oval in shape, usually about the size of a walnut but varying with age. The ovary is made up of the central portion or medulla and the outer cortex (stroma) within which are contained a number of Graafian follicles. It is the follicle which houses the ovum. The blood and lymphatic vessels and nerves are situated in the medulla.

Ultrasonically, the stroma and medulla exhibit quite different appearances; the stroma demonstrates the greater changes during the menstrual cycle. The follicles,
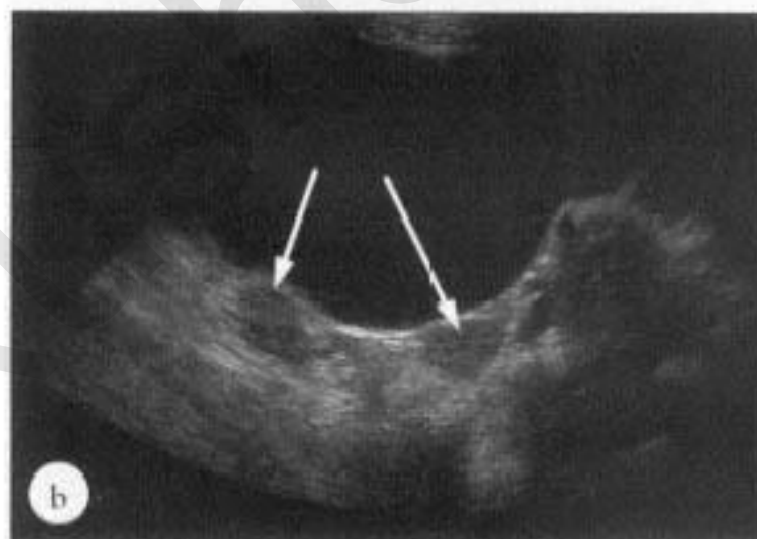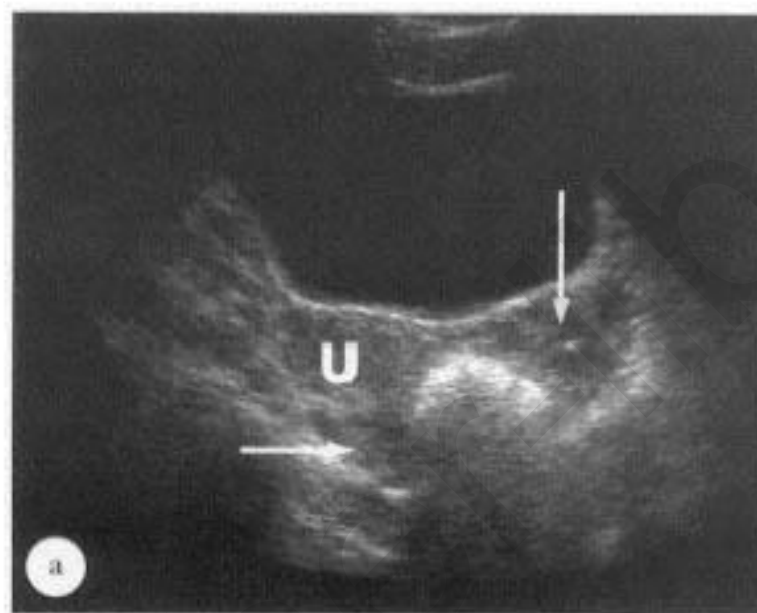
Figure 14—
Transverse sonograms demonstrating varying
ovarian positions (arrows). *a)* the right ovary lies
behind the uterus (U), *b)* the ovaries both lie above
the fundus of the uterus.

a `soft-marker' for ovarian identification, are visualised in a peripheral arrangement as well defined echo-free areas in the stroma, Figure 13. Their size varies and is cyclically dependent. The central medulla appears as an area of relatively strong reflectivity with no definite borders.

Due to the mobile nature of the mesovarium, the exact location of the ovaries is variable and can be subject to bowel and degree of bladder filling, Figure 14.

Indeed, they may alter position during scanning. [3] This together with ovarian atrophy following menopause can present a problem to the sonographer. It is important to use ultrasonic `landmarks' to correctly identify the organs. In most cases, the ovary lies in close proximity to the internal iliac artery which can be visualised passing obliquely lateral to the lower third of the uterus in Figure 15. A less easily recognisable but still useful `landmark' is the position of the Levator ani muscle which marks the most inferior position at which the ovary can be located.

For practical scanning purposes, the ovaries can be visualised in a variety of positions from the pouch of Douglas to the supero-lateral aspect of the uterus. Visualisation is made more difficult when the uterus does not adopt its usual anteverted position in the pelvis.

Fallopian Tubes

The two Fallopian tubes lie either side of the uterus within the superior portion of the broad ligament, Figure 16. Their walls are composed of the same three layers as the uterus.

Each tube is approximately 10 cm in length and passes laterally, posteriorly and inferiorly from the upper part of the uterus. The uterine opening is minute whilst the
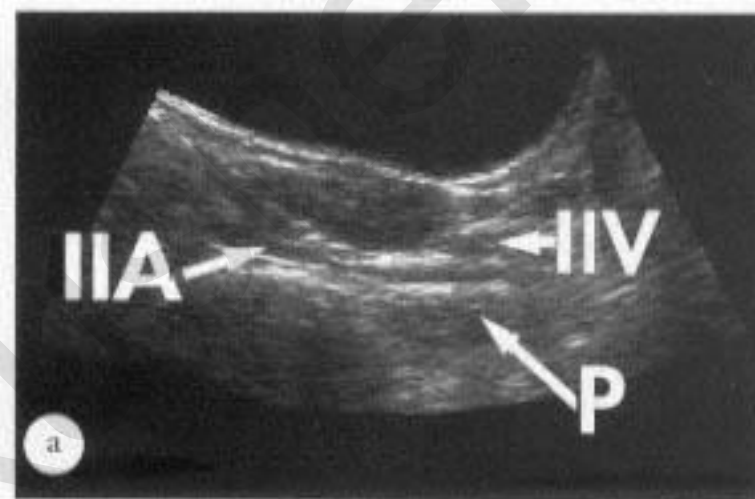
Figure 15—
a) TAS and b) TVS longitudinal sections through the ovary demonstrating the proximity of the internal iliac artery, IIA. IIV = internal iliac vein, P = piriformis muscle
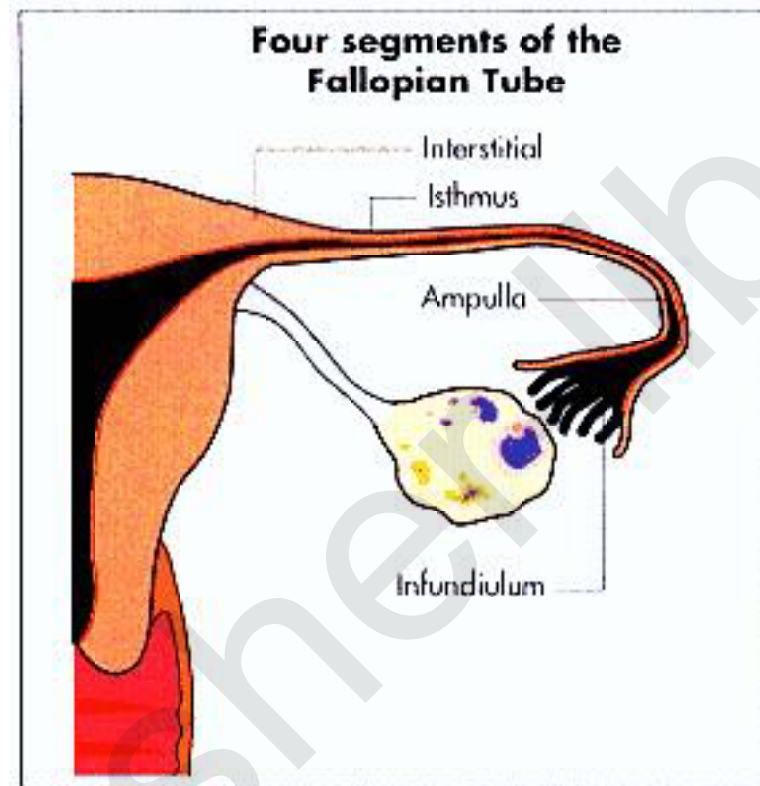
Figure 16 —
The Fallopian tube

abdominal opening, which is in close proximity to the ovary, is larger.

Each tube has four parts:

• the interstitial portion which lies within the uterine wall,

• the isthmus - the medial third extending laterally from the upper part of the uterus,

• the ampulla, which is the widest part of the tube

• the infundibulum which is the dilated funnel-shaped portion close to the ovary. The opening of the infundibulum has tiny projections, known as fimbriae, which serve to guide the ovum into the tube.

The function of each tube is to convey the ovum from the ovary to the uterine cavity. If fertilisation takes place, it usually occurs in the tube.

The normal Fallopian tube is difficult to image sonographically as its tiny diameter is beyond the resolution capabilities of most transducers and it is a

The normal Fallopian tube is difficult to image sonographically as its tiny diameter is beyond the resolution capabilities of most transducers and it is a relatively poor reflector of ultrasound. The overall structure has traditionally been demonstrated after the introduction of contrast during X-Ray hysterosalpingography, Figure 9. Even with the improved resolution of the higher frequency endovaginal transducer, it is almost impossible to visualise the non-dilated tube without the introduction of an ultrasound contrast medium (See Chapter 8). At certain times in the menstrual cycle, pelvic fluid may be present surrounding the tubes, making at least partial visualisation possible, Figure 17.

Peritoneum and Ligaments

The peritoneum surrounds the body of the uterus, forming recesses, or pouches, anteriorally and posteriorally, Figures 1 and 2. The anterior recess between the uterus and posterior bladder wall is known as the vesico-uterine fossa. The posterior recess lies anterior to the rectum and extends down to the posterior fornix of the vagina. It is known as the recto-uterine fossa or pouch of Douglas.

It is not unusual to see fluid in this recess on ultrasound, especially during mid-cycle after ovulation, as this represents a gravity-dependent pocket when the patient lies supine, Figure 18.

Figure 17—
a) The normal (undilated) Fallopian tube is not visible on transabdominal ultrasound. It lies within the superior end of the broad ligament (arrowhead) which can be located between the uterine cornua and the ovary. *b)* When surrounded by fluid, it may sometimes be at least partially located on the transvaginal image in the broad ligament. *c)* In hydrosalpinx, a dilated, fluid-filled, tortuous tube is obvious.
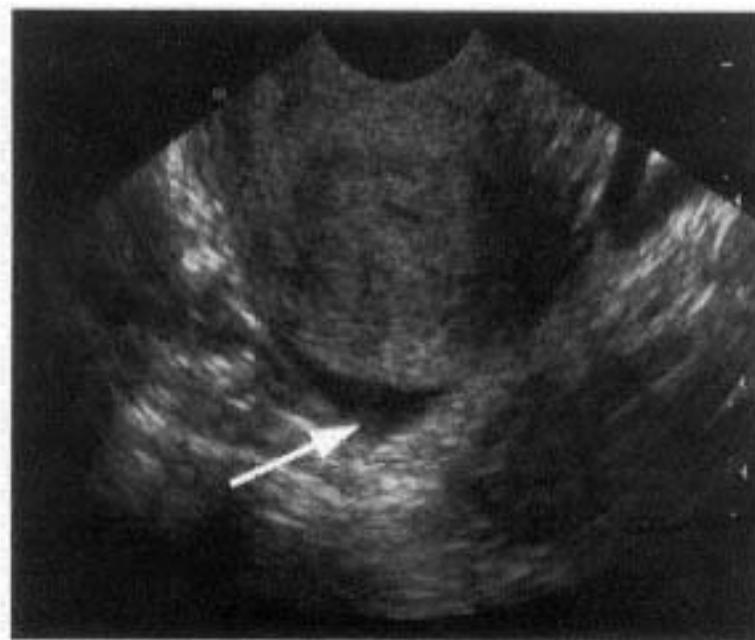
Figure 18—
TV axial section through the lower uterus. Fluid
in the pouch of Douglas (arrow) is a normal
finding mid-cycle.

Ovarian ligament
Round ligament
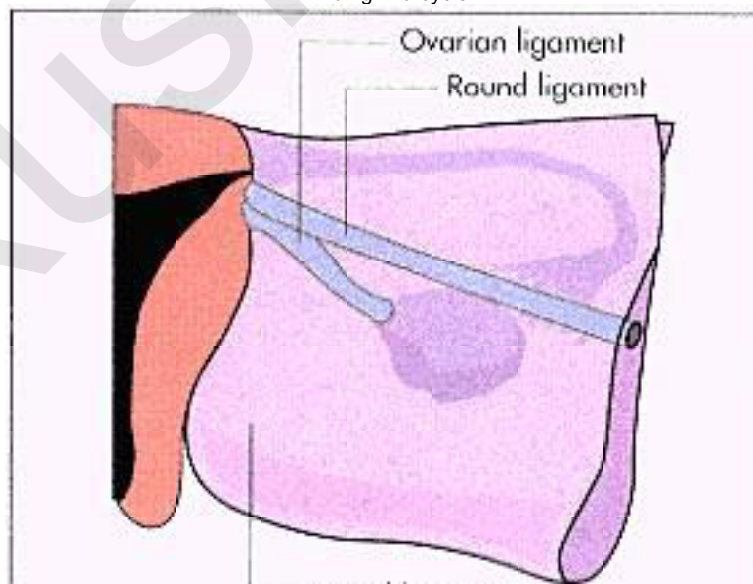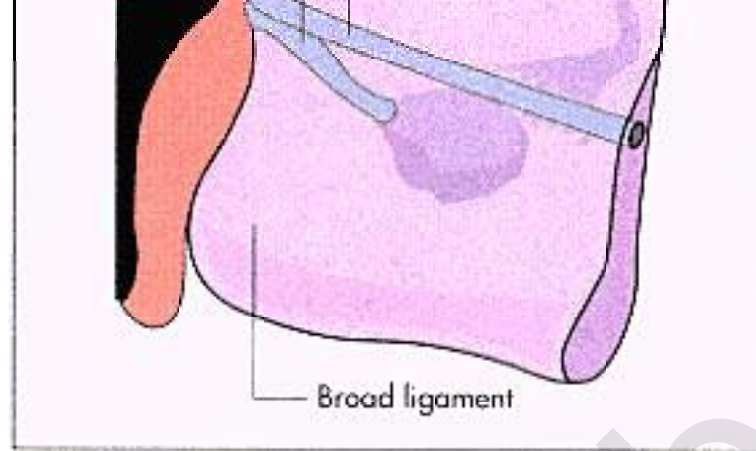
Broad ligament

Figure 19—
The ligaments. The broad ligament is a double
fold of peritoneum in which lie the adnexal structures.

The ligaments attatching the uterus within the pelvic cavity are predominantly extensions of the peritoneum in anterior, posterior and lateral directions. [4] The anterior and posterior ligaments form the vesico-uterine and recto-uterine pouches (see above). Two further peritoneal extensions between the posterior uterine surface and the sacrum form the paired uterosacral ligaments.

The paired broad ligaments are composed of double folds of peritoneum which extend laterally from either side of the uterus to the wall of the bony pelvis. Each ligament contains the Fallopian tube in its superior portion, the round ligament, the ovary with its ovarian ligament, blood vessels and nerves Figure 19. These ligaments are not easy to see ultrasonically. However with careful scanning in the transaxial plane, superior to the uterine fundus, an arc of low level homogeneous echoes can be visualised, which represents the broad ligament and its contents as it arises adjacent to the horn of the uterus, Figure 20a. The paired round ligaments, Figure 20b, are not extensions of the peritoneum, but fibromuscular cords which extend laterally from the region of the uterine cornua and lie within the broad ligament.

Each ovary is also attatched to the lateral wall of the uterus by the ovarian ligament. When free fluid is present in the pelvis it is possible to visualise the ovarian ligament as a highly reflective linear echo in the fluid, Figure 20c.

Vasculature

The two main sources of blood to the reproductive organs are the internal iliac artery and the aorta.

The common iliac artery bifurcates at the sacro-vertebral junction into the external and internal iliac arteries. It is the internal iliac vessel which supplies the pelvic viscera. At the sacro-sciatic foramen, it subdivides into anterior and posterior branches.

The main uterine artery is a branch of the anterior portion. It passes medially, supplying the cervix and ascending the lateral aspect of uterus within the broad ligament. Branches from the main artery further supply the cervix
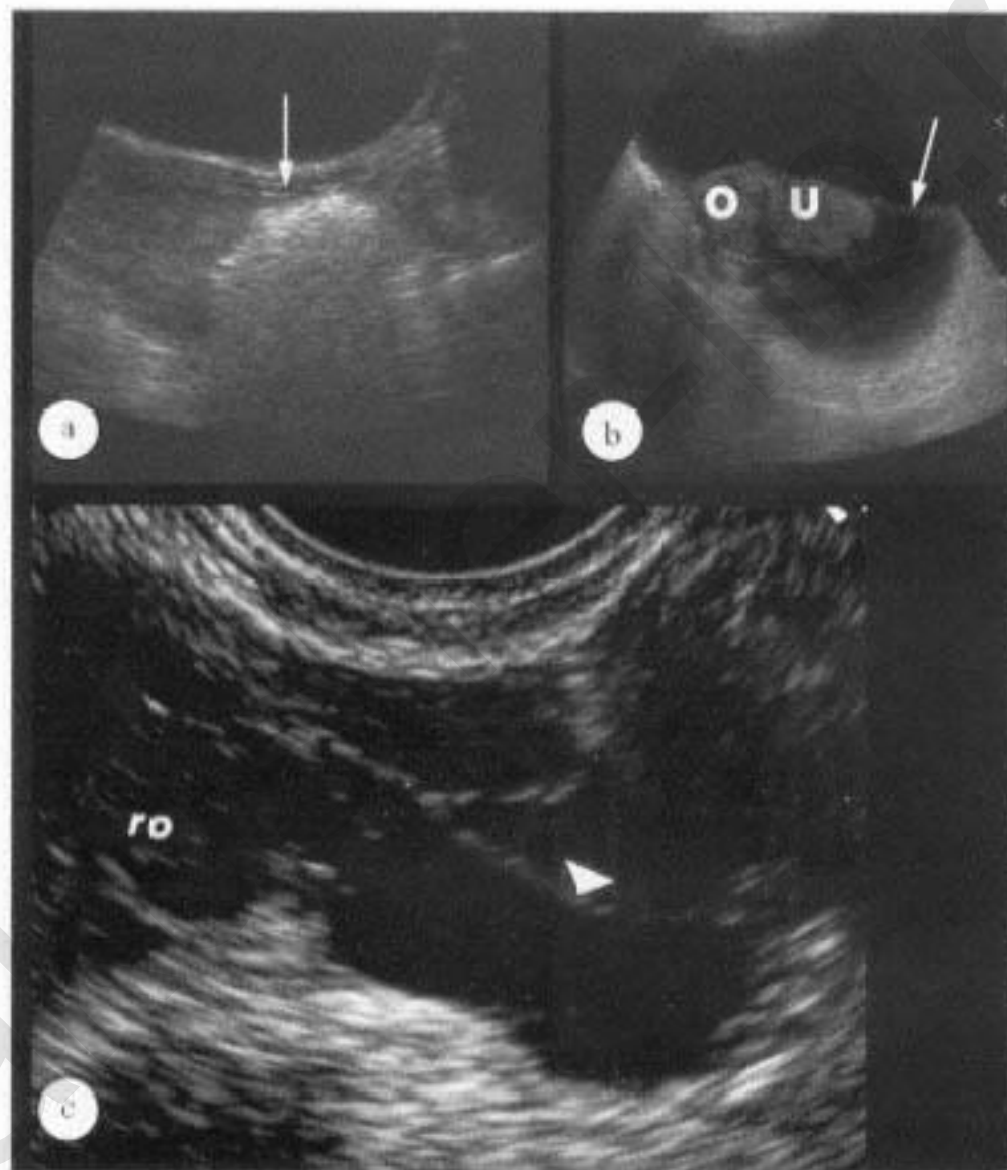
Figure 20—
a) TAS scan of the right adnexal area. The superior portion of the broad ligament (arrow) contains a thin tubular structure which is the ovarian artery. *b)* The left round ligament, (arrow) attaching the uterus to the pelvic side wall, and *c,* the ovarian ligament, (arrowhead) can be demonstrated when surrounded by ascitic fluid.
U =uterus, RO = right ovary.

IIA   Internal iliac artery   VA Vaginal artery
UA Uterine artery   OA Ovarian artery
CA Coronal artery of the cervix
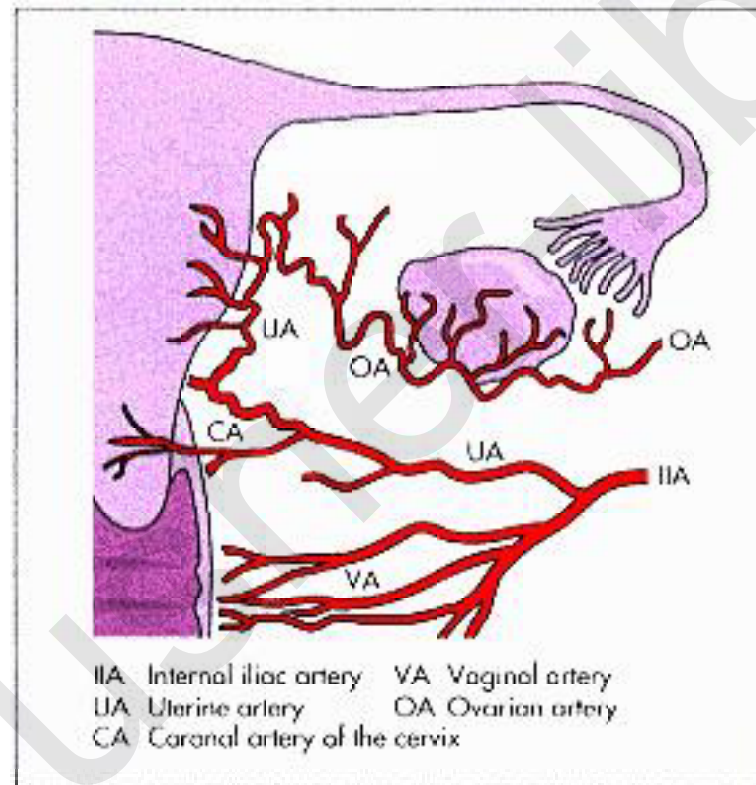
Figure 21—
Arterial supply to the uterus and ovary.

and vagina, Figure 21. The vaginal arteries eventually form the azygos arteries of the vagina as they descend along its surface. These vessels are tortuous and coiled to provide extra length during pregnancy.

The ovary is, in origin, an abdominal organ. Its blood supply is derived from the abdominal aorta. The ovarian artery arises from the anterior part of the aorta immediately below the renal arteries. At the margin of the pelvis, the artery passes between the folds of the broad ligament, Figure 20a. Several of its smaller

The ovary is, in origin, an abdominal organ. Its blood supply is derived from the abdominal aorta. The ovarian artery arises from the anterior part of the aorta immediately below the renal arteries. At the margin of the pelvis, the artery passes between the folds of the broad ligament, Figure 20a. Several of its smaller branches supply the Fallopian tubes and anastomose with uterine arteries.

Venous drainage from the uterus is via the internal iliac vein which, at the level of the sacro-iliac joint, unites with the external iliac vein to become the common iliac vein. These in turn drain into the inferior vena cava.

Venous drainage from the ovaries is into the venous plexus, which lies posterior to the uterus and from which arise the ovarian veins. The right ovarian vein drains into the inferior vena cava, the left ovarian vein into the left renal vein.

Musculature

The function of the muscles of the pelvis is to support the pelvic viscera and to assist in parturition.

There are four main muscle pairs; the Levator Ani and the Coccygeus make up the pelvic diaphragm. The Levator Ani lies between the ischial spines and the posterior portion of the pubis and acts as the floor of the pelvis. [4] It supports the pelvic organs and surrounds the rectum, vagina and urethra which pierce it. The Piriformis lies slightly posterior and superior to the coccygeus, and the Obturator Internus lies against the lateral wall on each side of the pelvis with the insertion point being the greater trochanter, Figure 22.

The ability of ultrasound to visualise the muscles varies from patient to patient. Their position is probably most readily appreciated transabdominally, posterior and lateral to the uterus. However, they are often at least unilaterally obscured by bowel.

Ultrasonically, they are well defined linear structures with low level homogeneous echoes. They may be mistaken for the ovaries (in longitudinal section), bowel or even adnexal pathology when scanning the less than ideal patient, and it is important to always be aware of their location and appearance, Figure 23.

Bladder and Ureters

The bladder is a reservoir for urine and occupies the lower portion of the true pelvis anterior to the uterus. When distended, its wall is a thin, hyperechoic smooth structure on ultrasound and the urine contained within should appear anechoic. It is fixed at its caudal portion (trigone) to the cervix.
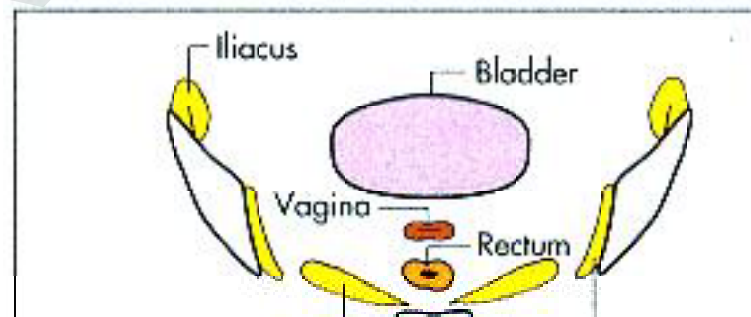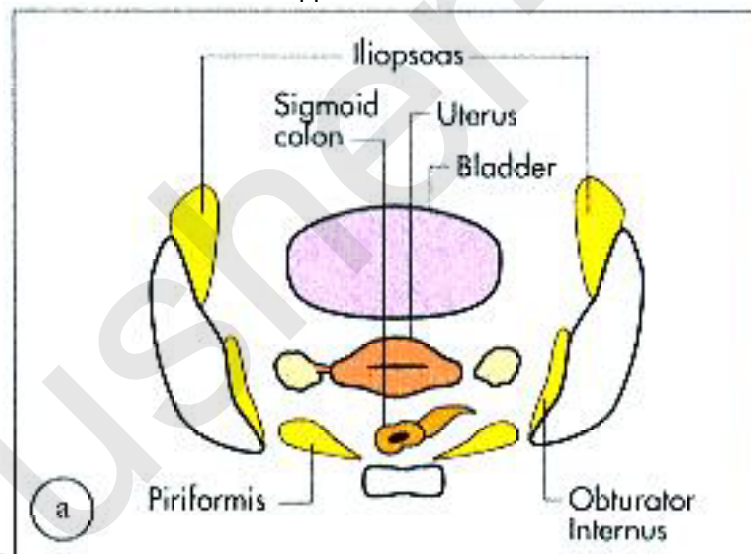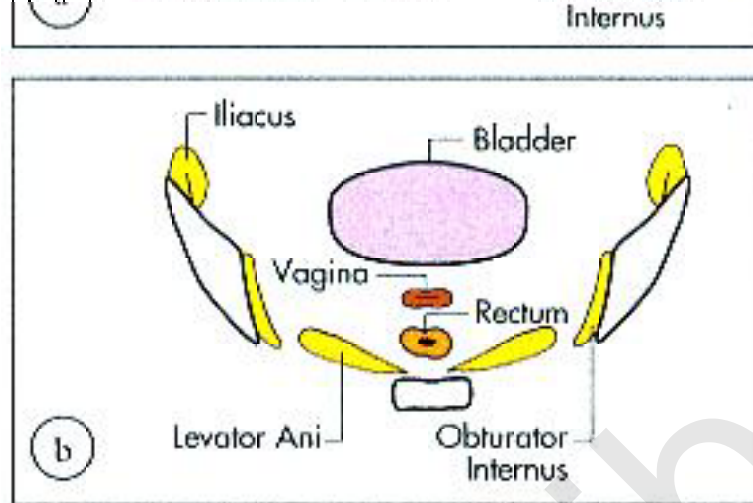
Figure 22—
The pelvic muscles. *a)* Axial section at the level
of the body of the uterus, *b)* axial section at the level
of the vagina.

The ureters are hollow, muscular tubes which accomodate the passage of urine from the kidneys to the bladder. They are approximately 30 cm in length and pass anterior to the internal iliac artery and posterior the the ovary. Their relationship to the reproductive organs is important in cases of pelvic pathology which may give rise to obstructive uropathy.
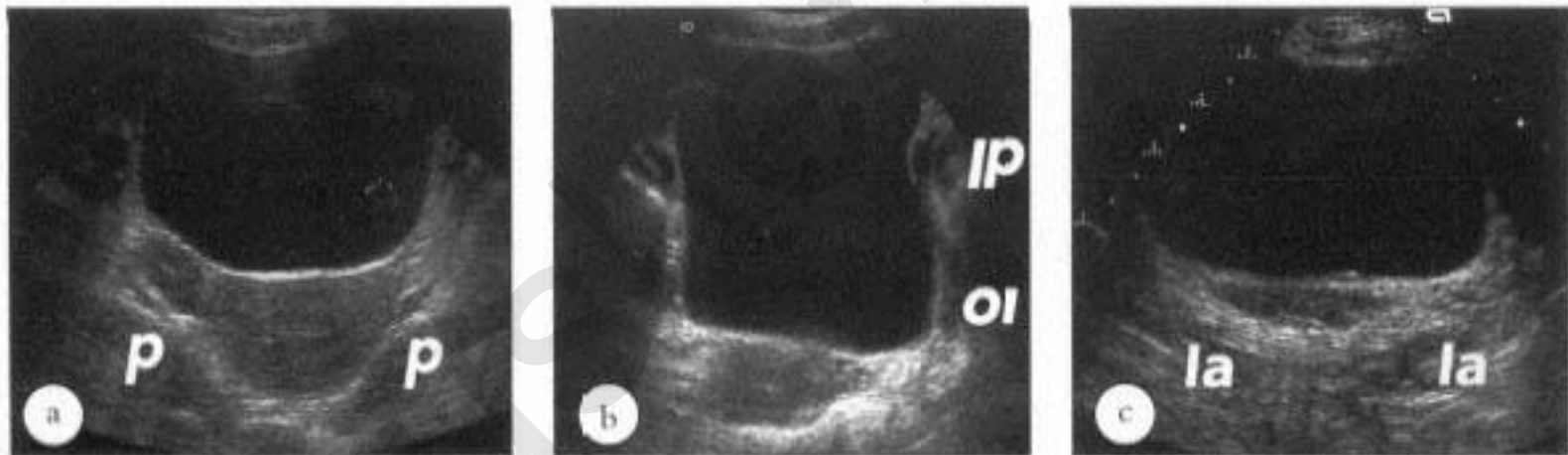
Figure 23—
The pelvic muscles in transverse section; *a)* piriformis, *b,* obturator internus and iliopsoas complex and
c, at the level of the vagina to demonstrate the levator ani.
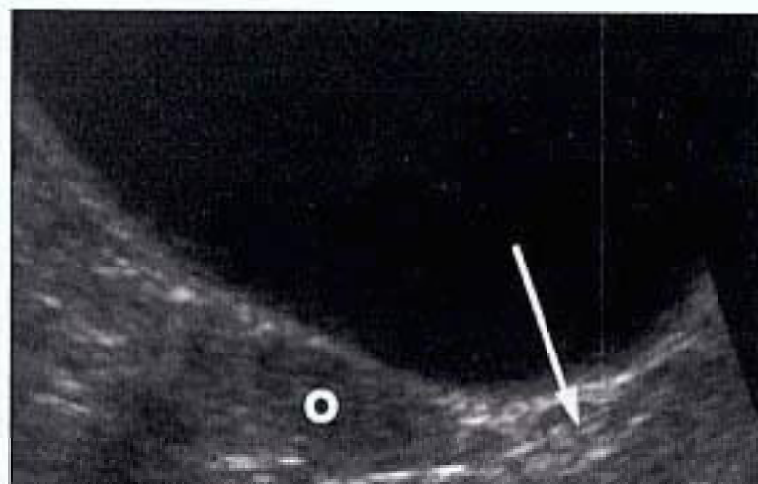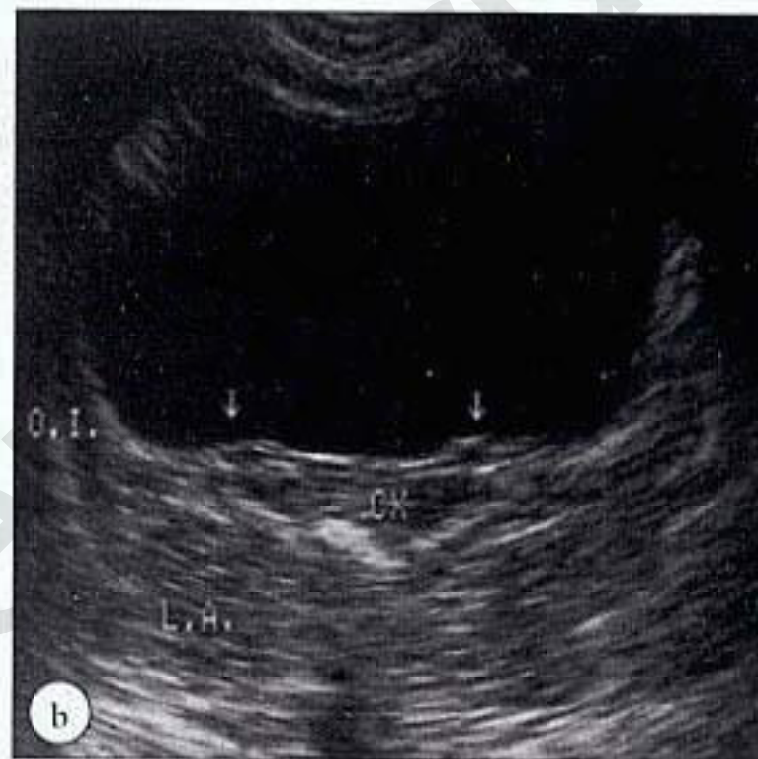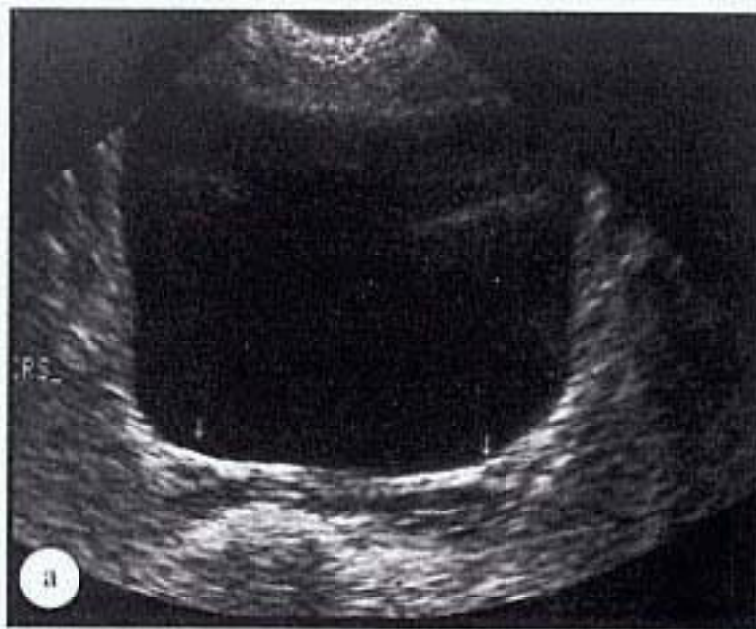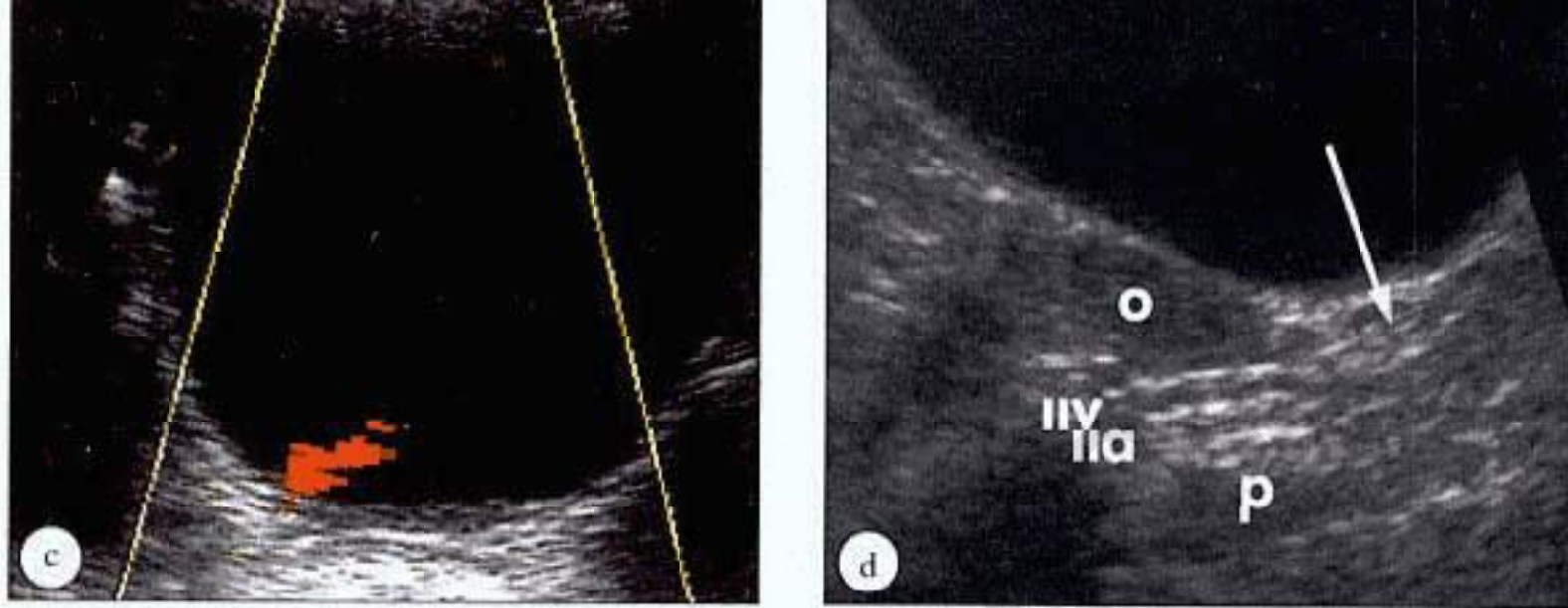
Figure 24—
Ultrasonic appearances of the ureters. In transverse section, the ureters may be traced down as they travel medially, *a)* and enter the bladder base, *b).* At this level the ureteric jets may be demonstrated with colour Doppler. *c).* In longitudinal section, *d),* the ureter may sometimes be seen as a tiny tube (arrow) between the ovary and iliac vessels.

The ureters are difficult to visualise ultrasonically unless dilated. However, they may be seen most easily in the transverse plane as they enter the the bladder at the vesico-ureteric junction, Figure 24, and the ureteric jet may be clearly demonstrated using colour Doppler as it enters the bladder.

Anatomical Changes Related to Age

Subsequent chapters provide the reader with specialist knowledge of the paediatric (See Chapter 9) and post-menopausal pelvic organs (See Chapters 4 & 5) and the difficulties that arise in scanning for pathology in these two age groups. However, it is useful to briefly compare normal anatomical and ultrasound appearances of the female pelvic organs related to age, Table 1.

A simple formula for estimation of ovarian volumes is:

Volume cm^3 = length x width x AP diameter x 0.53

Very early in the neonate's life, due to the influence of the maternal hormones, the uterus and ovaries are similar in appearance to the adult organs. [5] The uterine corpus is wider than the cervix, although miniature in size, and it is possible to image a mid-line endometrial echo. The ovaries are enlarged and follicles may be present.

After a few months, the organs revert to the normal appearances of the pre-pubertal child.

At this stage, the uterus is tear-drop shaped with the cervix larger than the corpus. An endometrial echo cannot usually be visualised. The ovaries are homogeneous and in only a small portion of girls can immature follicles of less than 0.5 cm be demonstrated.

As menarche approaches, the uterus changes shape as the corpus develops and becomes larger than the cervix. With the increasing hormonal influence, the mid-line echo can easily be visualised on ultrasound and the maturing follicles are now more easily demonstrated. The size of the ovary in women of reproductive age varies enormously according to the stage of the cycle and the average has been found to be just under 10 cm. [3,6]

Later in life, at and following menopause, the uterus and ovaries atrophy. This regression in size is a gradual process and in the early post-menopausal phase the organs can appear ultrasonically very similar to those of the reproductive years. As in the premenarchal stage, the cervix is larger than the corpus. In the normal elderly patient, the endometrial echo, although thin, should still be demonstrated. The normal uterus at this stage is of uniform echogenicity but the ovaries become increasingly difficult to image unless cysts are present, Figure 25.

Physiology of Reproduction

The female reproductive years commence at puberty and are completed at the menopause, spanning between 35 and 40 years on average. The standard hormonal cycle is 28 days, although it is widely recognised that this is an arbitary figure and that there are variations to this pattern.

Throughout each normal cycle, the endometrium and ovaries are subject to change brought about by the action of the hormones secreted by the pituitary gland - follicle stimulating hormone (FSH), luteinising hormone (LH) and prolactin. The ovaries themselves are also active and secrete oestrogen and progesterone, Figure 26.

The purpose of these hormones is to produce a mature ovum for fertilisation, to prepare the endometrium for the fertilised ovum and to support the pregnancy in its early stages.

During the initial stages of the cycle, the proliferative phase, FSH influences the immature follicles to develop,

Table 1. A guide to age related differenes in size of the uterus and ovaries

		Infantile	Pre-Pubertal	Reproductive	Post-Menopausal
Uterus	Length (cm)	1.5 - 4.0	2 - 5.4	5 - 12	3.5 - 6.5
	Width	0.8 - 1.0	1.0 - 2.2	4.0	1.2 - 1.8

Uterus					
	Width	0.8 - 1.0	1.0 - 2.2	4.0	1.2 - 1.8
	AP dia.	1.0	1.0	3	1.5 - 2.0
Ovaries	volume (cm^3)	0.7 - 3.6	1 - 6	6 - 12	< 4
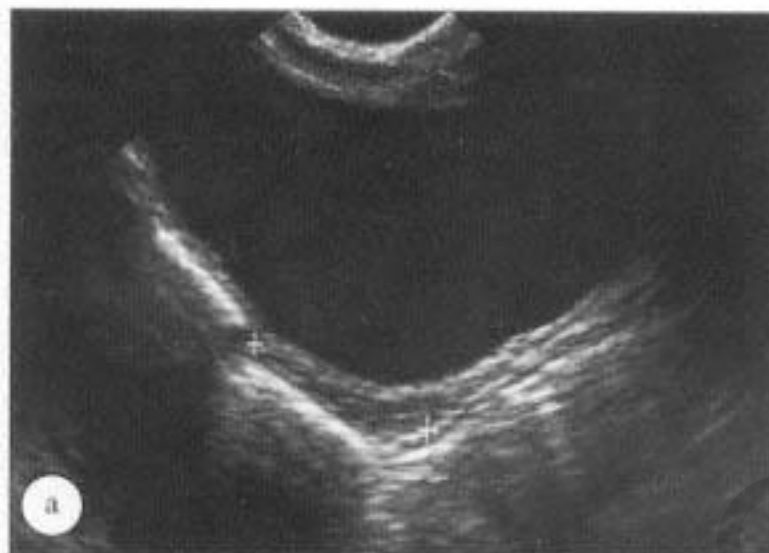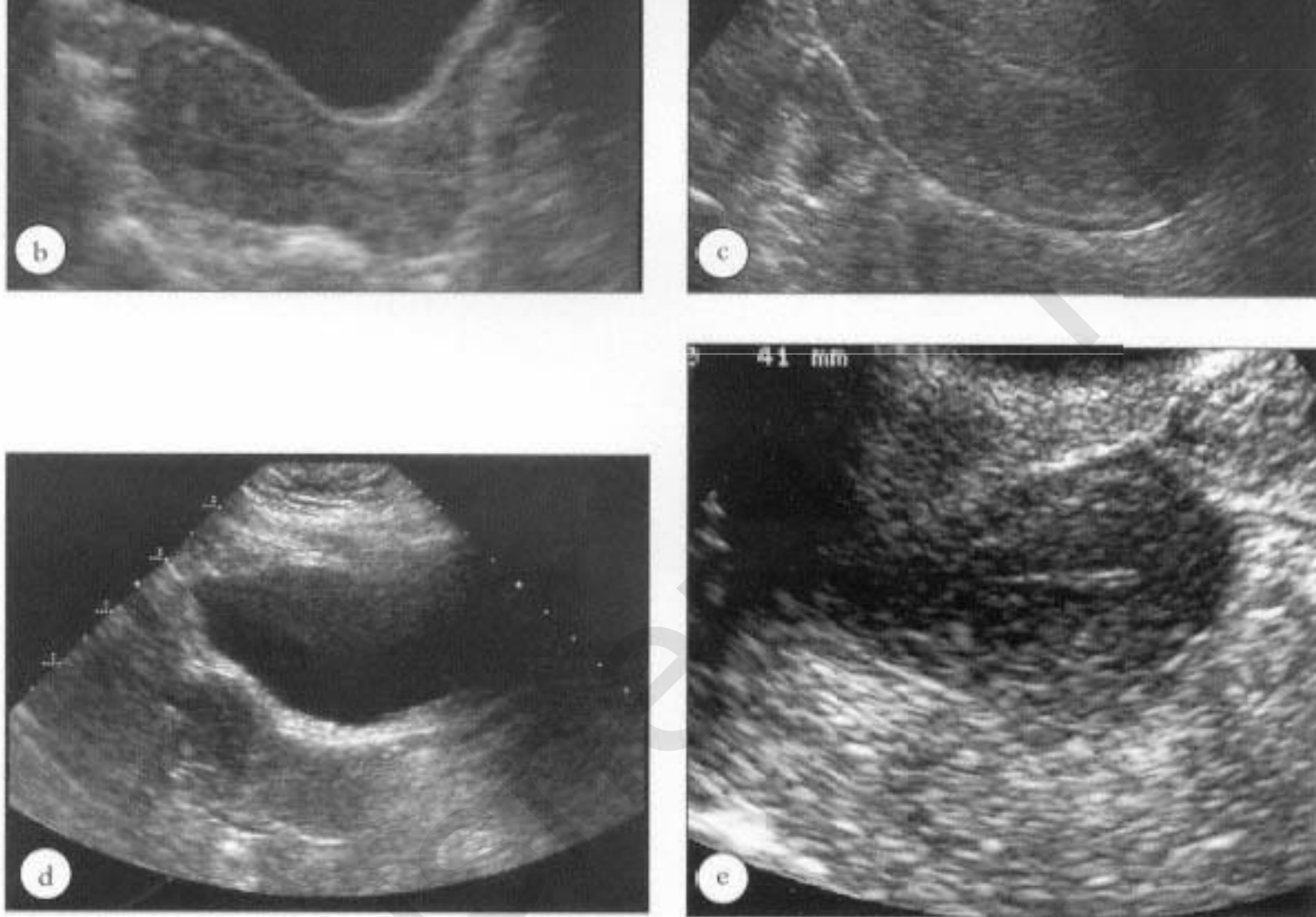
Figure 25—
The differing appearances of the uterus with age: *a)* paediatric, *b)* and *c);* adult uterus TA and TV, *d)* and *e)*; post-menopausal uterus TA and TV.

Influence of hormones

Follicular phase   Ovulation   Luteal phase

ANTERIOR PITUITARY

LH

FSH

Follicle

Progesterone

Oestrogen

Endometrium

Oestrogen

Endometrium

Days 28   7   14   21   28

Regenerative   Periovulatory

Menstruation | Proliferative | Secretory

a
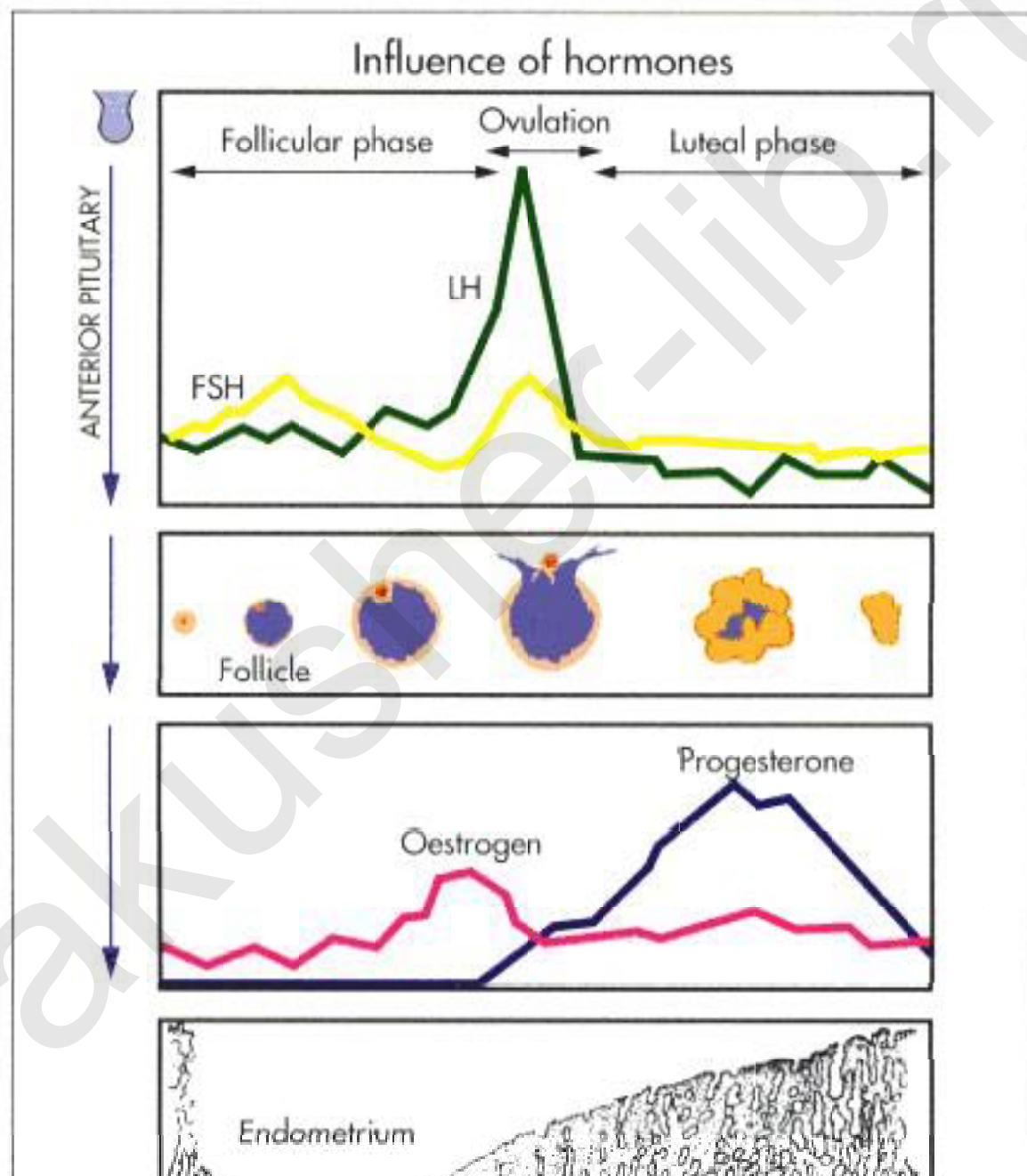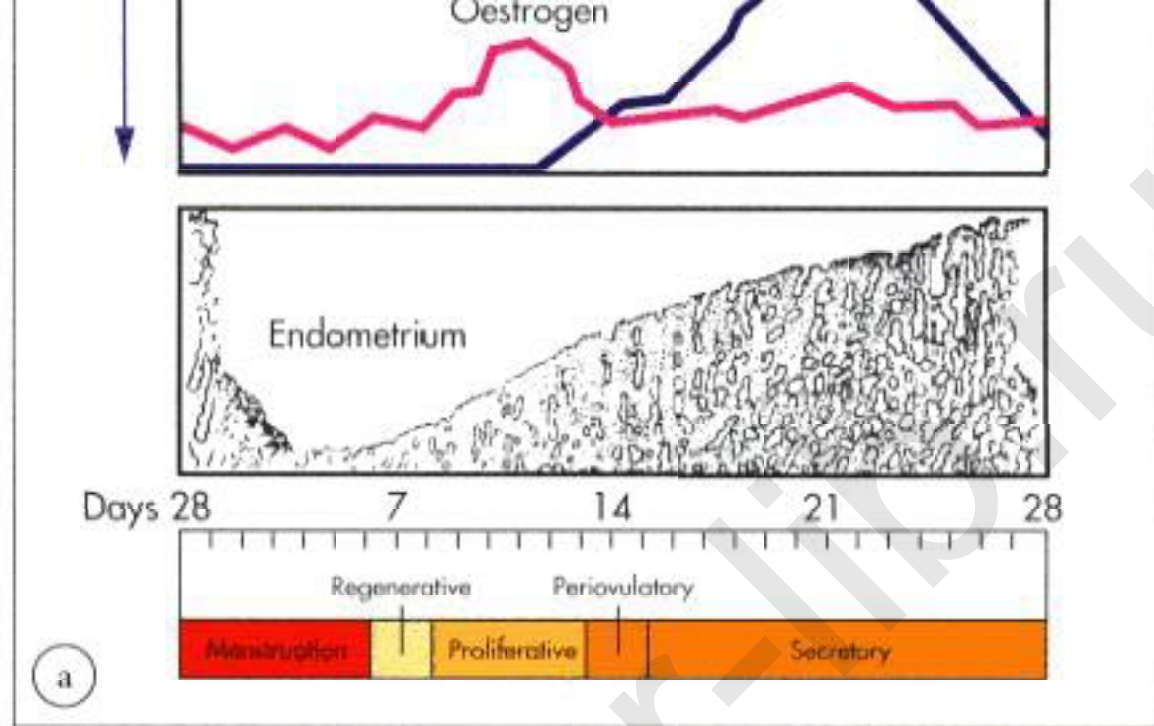
Figure 26—
a) The influence of hormones on the uterus and ovaries. b) page 47 opposite
the appearances of the dominant ovary and c) page 48 the uterus in a normal cycle.
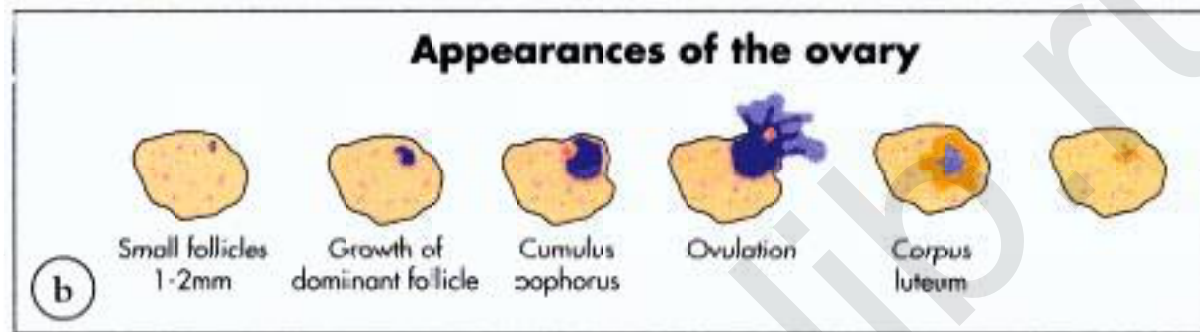
Figure 26—
b) the appearances of the dominant ovary
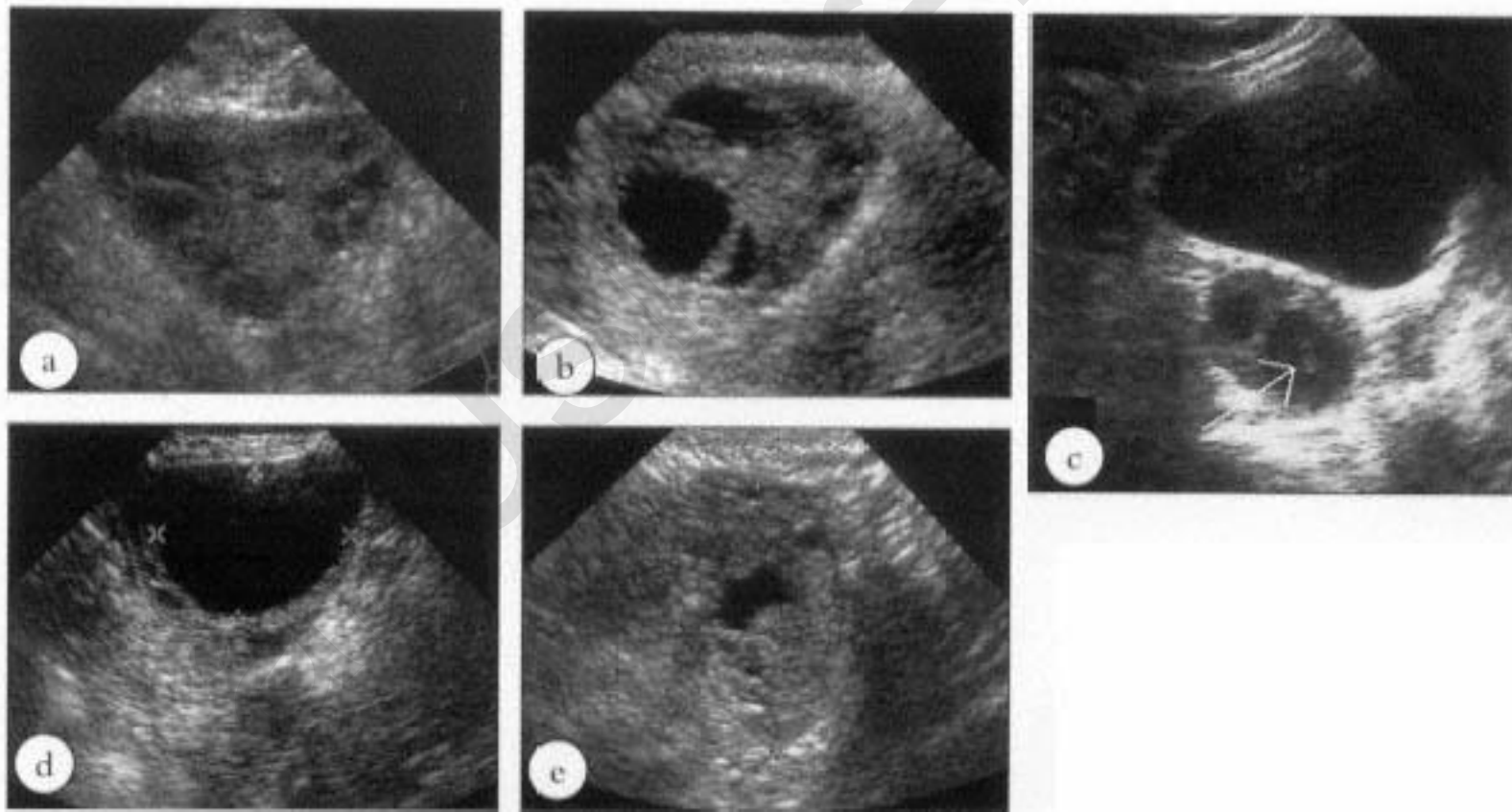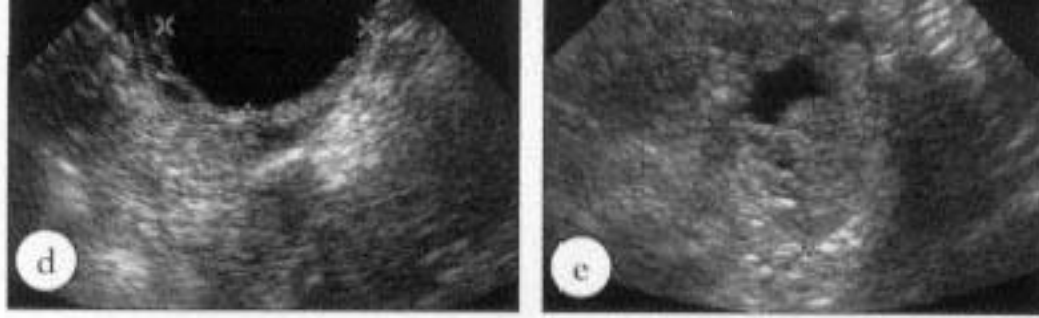
Figure 27—
Ultrasound appearances of the dominant ovary through the cycle. *a)* Regenerative. Small follicles. *b)* Proliferative. Dominant follicle growing. *c,* Ovulatory. Cumulus oophorus seen in dominant follicle. *d,* Early secretory. Corpus luteum. *e)* Late secretory. Regression of corpus luteum.

resulting in a dominant follicle being produced. Around day 14 of cycle, when the oestrogen levels are high, the LH stimulates ovulation. During this period, the endometrium thickens and ripens. Following ovulation, during the secretory phase, the ovary secretes progesterone, the FH and oestrogen levels diminish and the follicular wall collapses forming the corpus luteum. If pregnancy does not occur, the endometrium becomes thickened and menstruation takes place on or around the 28th day.

The changes in the endometrium and ovaries can be well demonstrated sonographically especially when using a high frequency endovaginal transducer, Figures 27 and 28.

The endometrium appears as a thin reflective line in the uterine cavity during the early proliferative or regenerative stage.

At the same stage, the ovaries can be seen to contain several immature follicles, demonstrated as anechoic well defined structures, typically less than 1 cm, within the ovarian tissue.

As the cycle progresses to ovulation, the well defined dominant follicle measuring up to 2.0 cm can be visualised. It is possible to have more than one dominant follicle. In 60 - 65% of cases, the cumulus oophorus can be imaged between 12 - 24 hours prior to ovulation. [3] Ultrasonically, this appears as a small hyperechoic focus adherent to the follicular wall.

Endometrial appearances at ovulation are of a mid-line hypoechoic area surrounded by a prominent highly reflective echo, giving rise to the term "triple line" echo sign.[7]

The collapsed walls of the dominant follicle can be visualised during the early secretory phase. Haemorrhagic

Appearances of the uterus

| Possible fluid in endometrium and POD | Thin echogenic endometrium | Thickening echogenic endometrium, 2-3mm | Peri-ovulatory ring Fluid in POD | 3-6mm thickened endometrium |
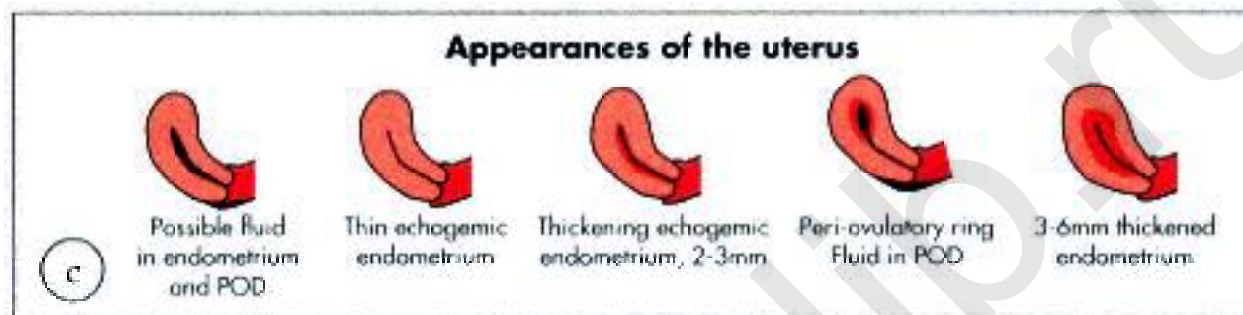
Figure 26—
c, the uterus in a normal cycle.
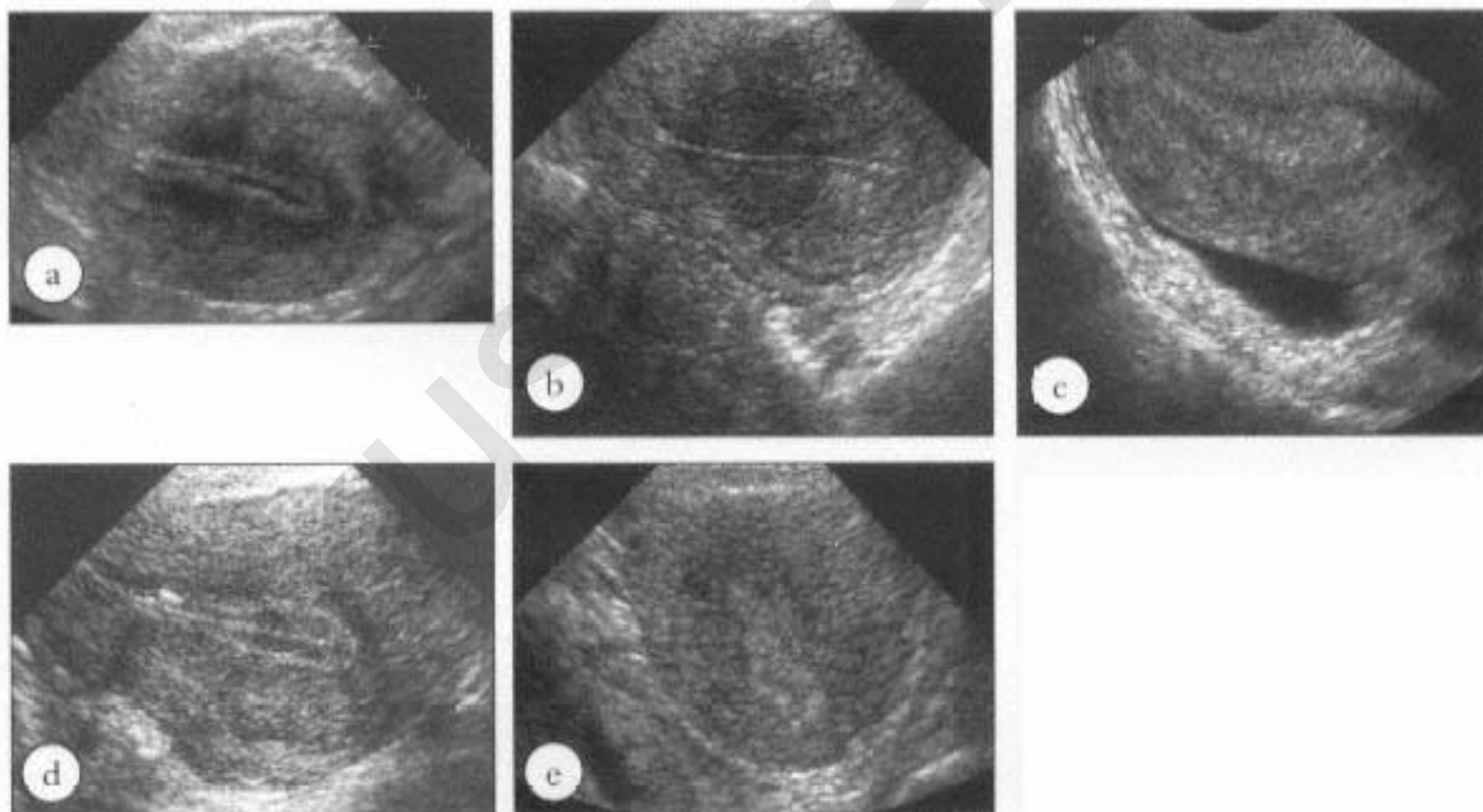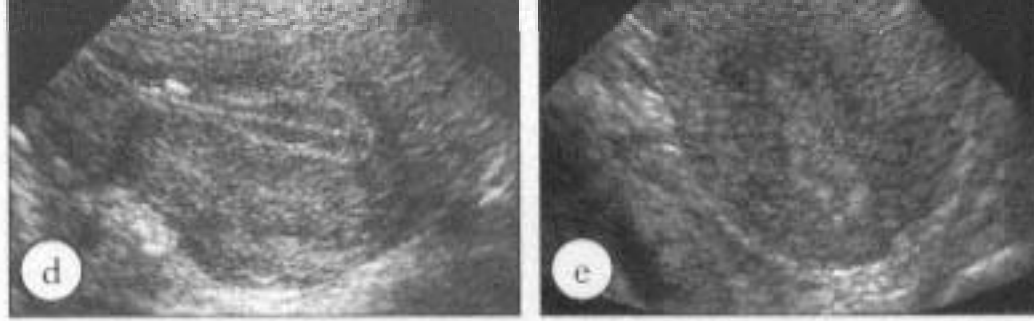
Figure 28—
Ultrasound scans of the normal endometrium through the cycle. *a)* Menstruation (DAY 1-4). Blood is seen within the cavity. *b)* Regenerative/ early proliferative (DAY 5-8). Thin endometrium. *c,* Late proliferative (DAY 9-12). Thickening, increasingly hyperechoic endometrium. *d)* Peri-ovulatory (DAY 12- 15). Hypoechoic with a hyperechoic rim. *e)* Secretory (DAY 16 to menstruation). Irregular and hyperechoic.

changes also occur, demonstrated as low level echoes within the collapsing corpus luteum which also has a less defined outline. In some cases, fluid can also be seen in the pouch of Douglas. [7]

Just prior to menstruation, the endometrium can be visualised as a thick hyperechoic structure passing centrally down the uterine cavity. During menses, it is possible to visualise the endometrial cavity separated by low level echoes representing blood and mucus.

Haemodynamics of the Uterus and Ovaries and the Use of Doppler Ultrasound

The blood supply to the uterus and ovaries fluctuates throughout the normal cycle. These physiological changes can be appreciated using Doppler ultrasound Figure 29.

Both the ovary and endometrium exhibit angiogenesis — the formation of new blood vessels — during the course of the normal cycle. This results in a lowering of the downstream resistance to blood flow which manifests as increased end diastolic flow velocities with consequently decreased resistance indices. This phenomenon is also well recognised in pathological processes, such as the development of malignant tumours, [8] which therefore complicates and severely limits the interpretation of Doppler information, particularly in premenopuasal patients.

Doppler of Uterine Arteries

The main uterine arteries may be found just laterally to the region of the cervix; they have a high resistance pattern with low end diastolic flow and a notch, Figure 30, and should not be confused with the iliac artery, which lies lateral to the uterine artery. The common and external iliac arteries exhibit very high resistance, triphasic flow with a reverse component, the
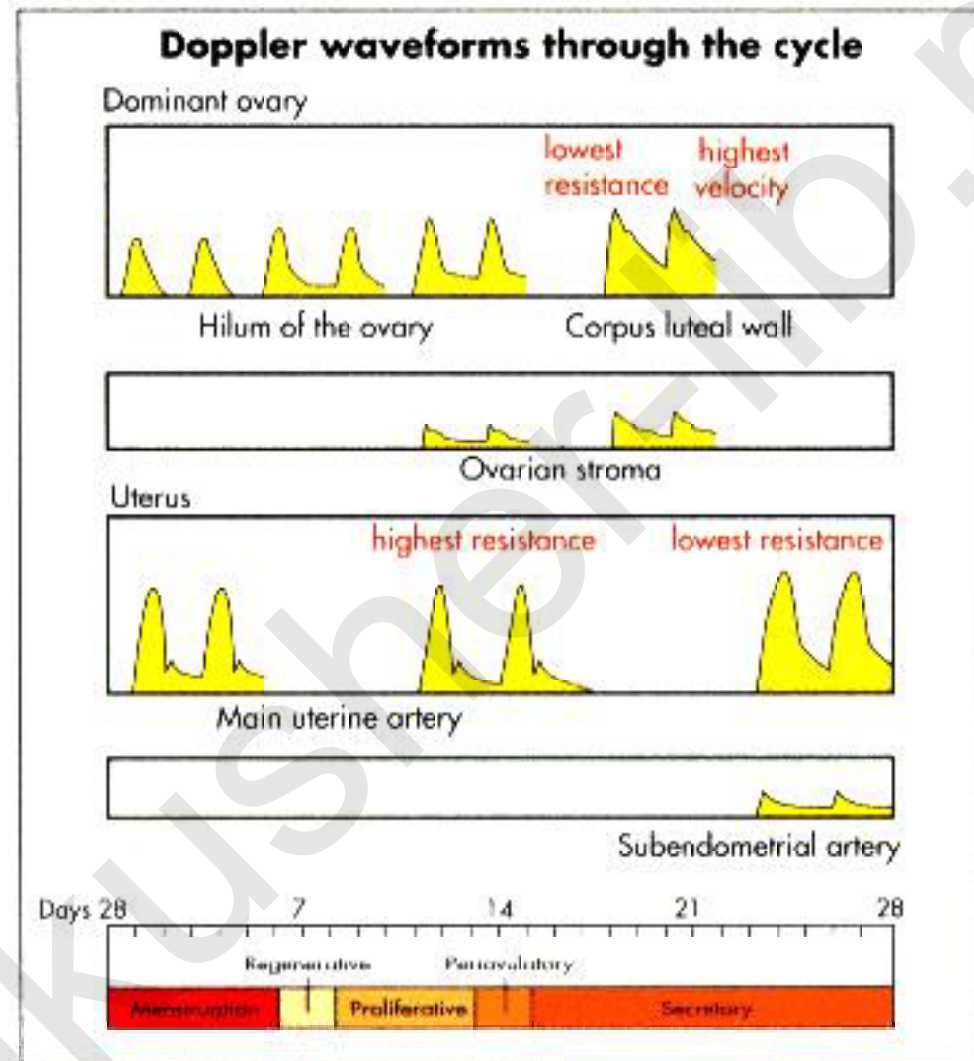
Figure 29—
Doppler spectra of dominant ovarian and uterine waveforms
through the cycle.

Figure 29—
Doppler spectra of dominant ovarian and uterine waveforms
through the cycle.

internal iliac artery is less pulsatile but still exhibits a high resistance, notched waveform with very little end diastolic flow (EDF), Figure 31.

Waveforms and resistance index measurements are more consistently reproducable from the main uterine artery than from its smaller, low velocity, arcuate branches, and the artery tends to be more easily visualised in premenopausal than post-menopausal patients. Vessels situated within the uterus, just below the endometrium, are more difficult to locate as they are of much lower velocity. The Doppler waveforms from these are therefore of low amplitude and tend to have a poorly-defined envelope, making measurements prone to error, Figure 32.

In the normal cycle, the resistance of the uterine artery is at its highest (lowest end diastolic flow velocity) 1-2 days after ovulation — i.e., around cycle day 16. [9],[10],[11] It is at its lowest (having greatest end diastolic velocity) during the mid to late luteal phase. Although it is more difficult to estimate velocity accurately in the tortuous pelvic vessels, an increase in velocity has also been noted during the same period. This is thought to loosely correlate with an increase in uterine perfusion, which would be logical at this time of possible implantation.

Although the uterine artery on the domminant side has been noted to have a slightly lower resistance index than the contra-lateral artery,[11] there is considerable overlap between the values, and the difference is small.

Several factors may be responsible for altering the resistance to flow of the uterine arteries, and these must be taken into account when interpreting Doppler information. Factors likely to decrease resistance include physiological variables, hormone replacement therapy, tamoxifen, the presence of uterine fibroids Figure 33, and malignancy such as endometrial carcinoma or uterine sarcoma. Uterine artery resistance may be increased with age, and may also be associated with infertility including tubal damage and endometriosis.

Doppler of Ovarian Arteries

As with the uterine arteries, but to an even greater degree, the resistance of the ovarian arteries is affected by
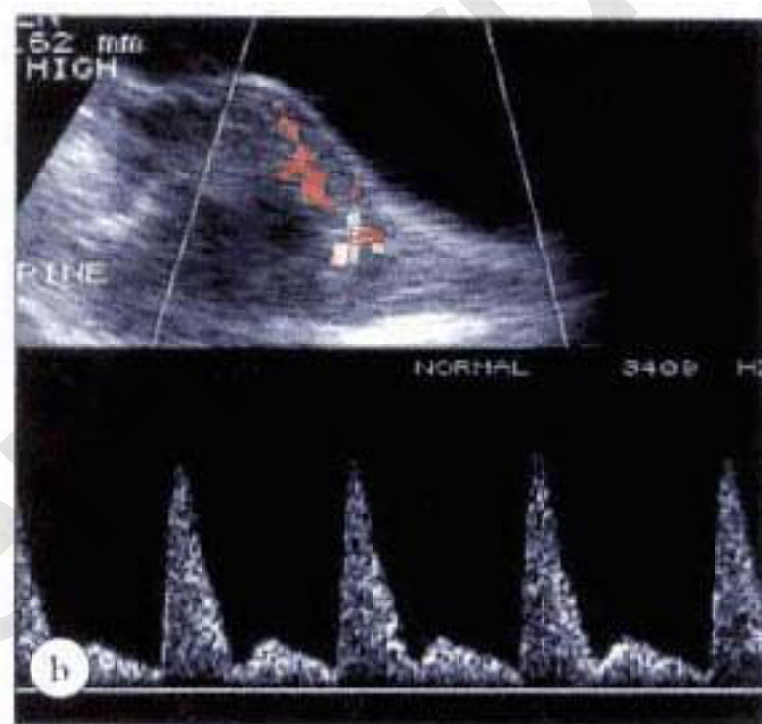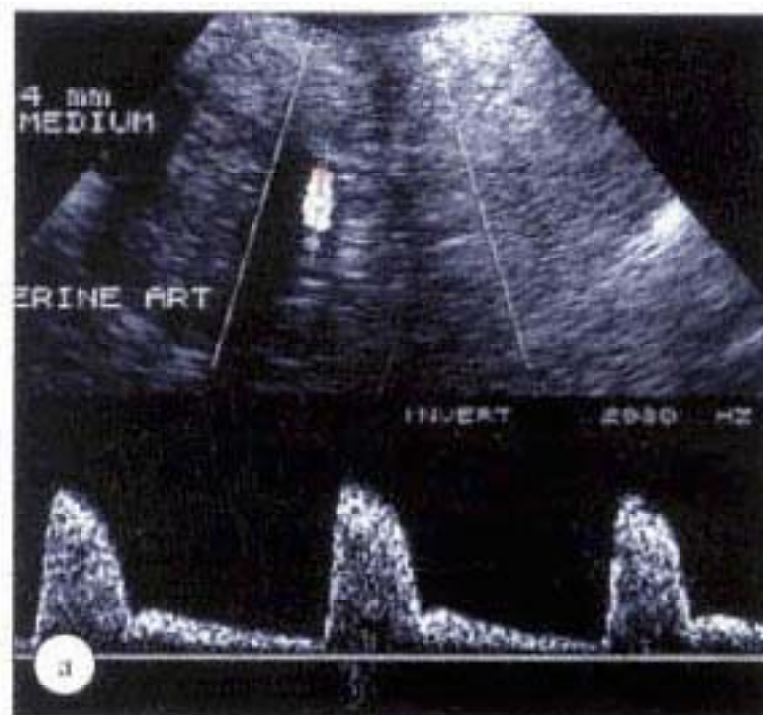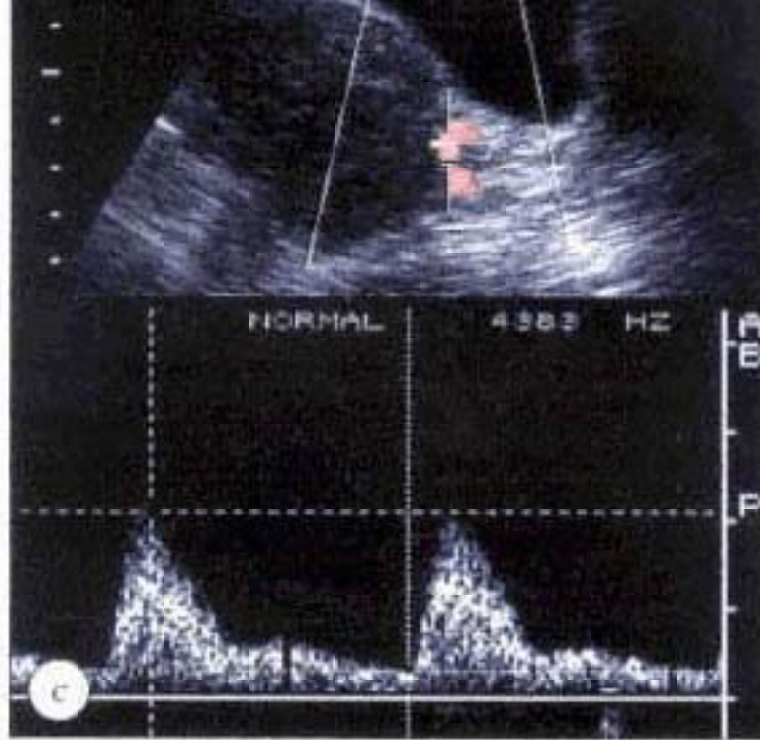
Figure 30—
The uterine artery through the cycle;
a) proliferative phase
b) post-ovulatory phase of highest resistance
c, mid to late secretory (or luteal) phase - lowest resistance
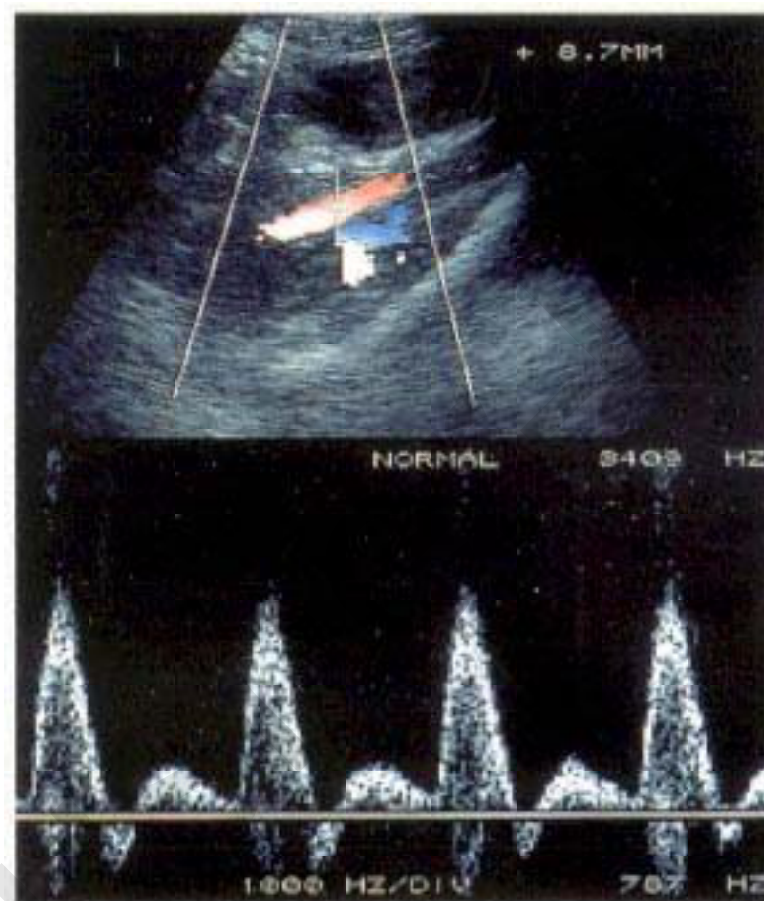
Figure 31—
High resistance, triphasic waveform from the iliac
artery.

Figure 32—
Low velocity waveform from arcuate arteries
within the myometrium.
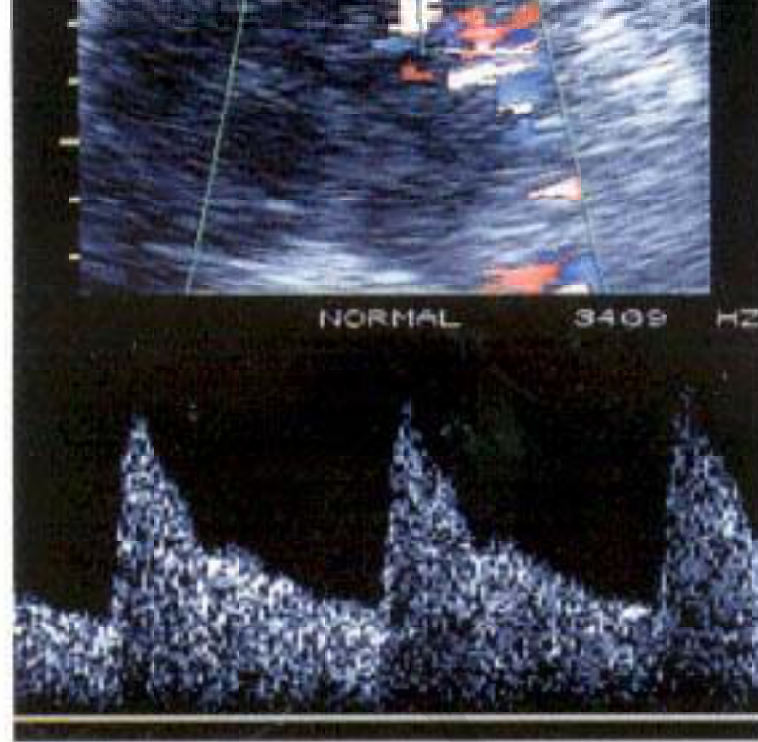
Figure 33—
Decreased uterine artery resistance with fibroids.

cyclical, physiological changes, which are much greater in the dominant than the non-dominant ovary Figure 29. Downstream resistance is greatest (lowest EDF) during cycle days 1-8, with maximum resistance occuring around day 8. [11] (Days 1-8, therefore, make a good "window" during which to examine the ovaries of pre-menopausal women, as low resistance is less likely at this time and misinterpretation of Doppler information is minimised.) Resistance to flow then gradually decreases from day 8 as the dominant follicle develops and ruptures around day 14. Resistance is at its lowest during the luteal phase, days 16 to 21, with the wall of the corpus luteum displaying the most intense colour pattern. It is at this time that the vessels are technically easiest to visualise. A gradual increase of resistance is then observed through to the regenerative phase,[12], [13] Figure 34.

These changes are reflected in the ovarian hilum, stroma and wall of the dominant follicle and corpus luteum, being most pronounced in the latter, Figure 35. Velocity is also noted to increase around day 12-13, continuing to be high during the luteal phase; however, velocity estimation in small, tortuous vessels are fraught with possible error and greater reliability is usually placed on estimation of resistance indices which are largely direction- and angle-independent.[14]
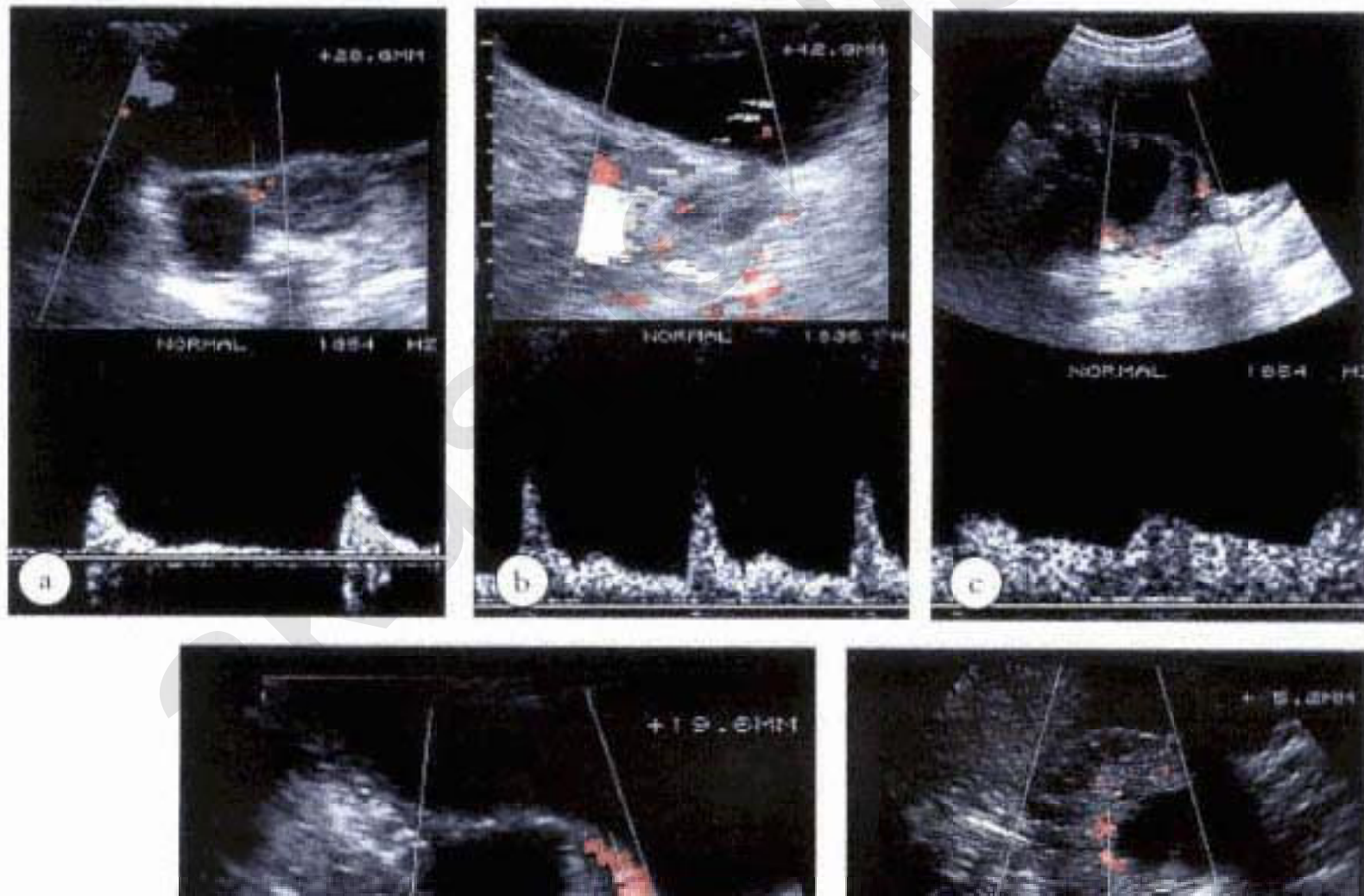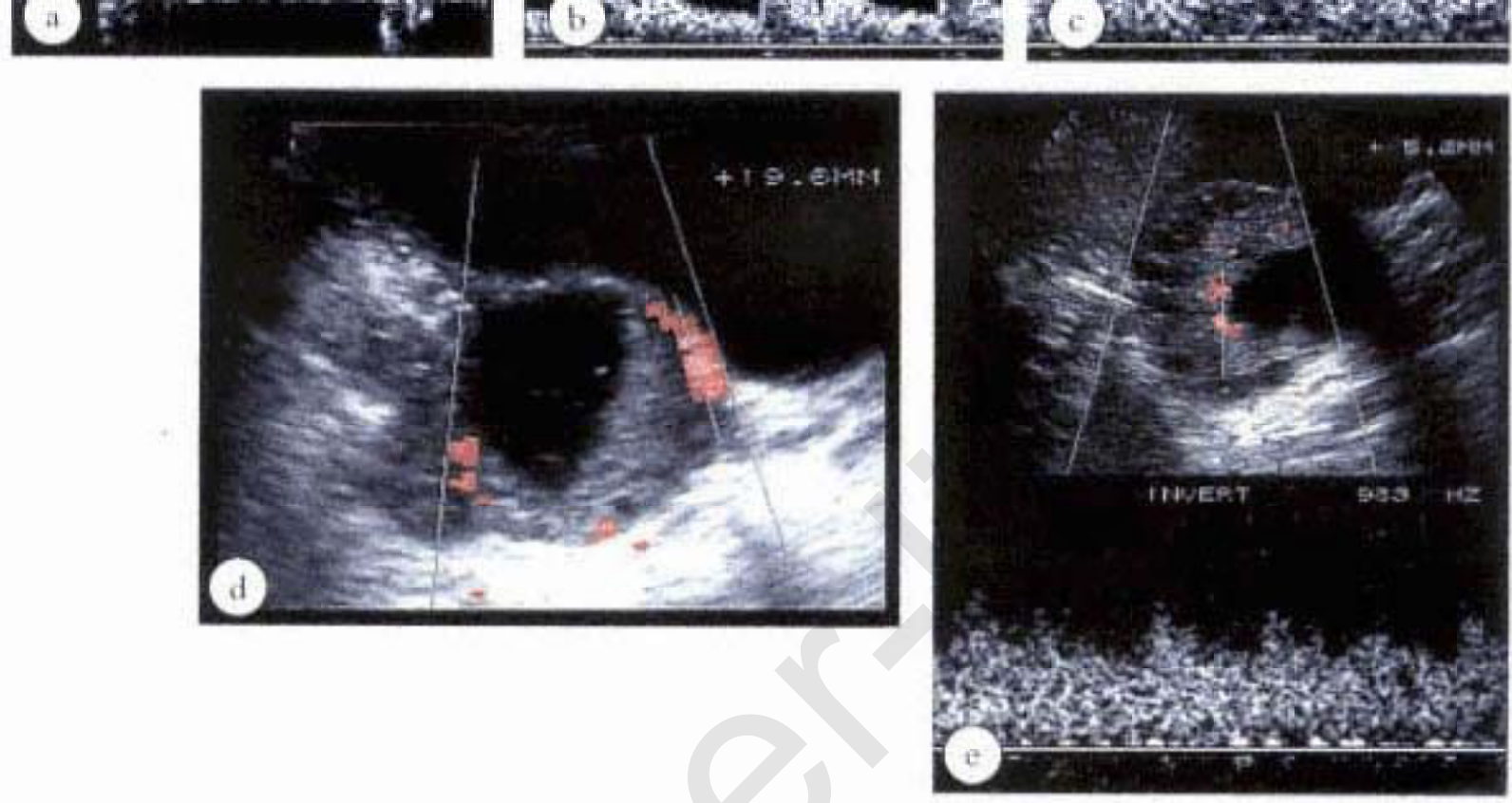
Figure 34—
Decreasing resistance of the ovarian artery through the cycle; *a)* Regenerative; *b)* Early proliferative;
c, Late proliferative; *d)* Peri-ovulatory; *e)* Secretory - wall of corpus luteum.

Figure 35—
Typically increased vascularity around the wall of the
corpus luteum.

The contra-lateral, non-dominant ovary tends to maintain a relatively high resistance and low blood flow velocity throughout the cycle. In fact, it may be quite difficult to demonstrate any colour Doppler at all within the stroma, depending on the sensitivity of the ultrasound system used.
Identification of Doppler signals in the ovaries becomes increasingly difficult in the post menopausal woman and usually demonstrates a low velocity, high resistance pattern.

DOPPLER ULTRASOUND - KEY POINTS

- Doppler information may be used to complement morphological information and should never be interpreted in isolation.

- Recognition of `normal' Doppler waveforms depends on the stage of the menstrual cycle.

- With less sensitive equipment, it may not be possible to visualise any Doppler flow in the ovary, particularly the non-dominant one.

- Physiological and pathological Doppler wave-forms can be indistinguishable.

- False positive Doppler results are therefore less common in postmenopausal women.

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4—

Pathology of the Uterus, Cervix and Vagina

Heather Andrews

Introduction
The uterus
Malignant change
Endometrial disease
Medications
Endometrial carcinoma
Uterine surgery
The cervix
Benign conditions
Cervical carcinoma
Cervical stenosis
The vagina
Vaginal fluid collections
Gartner's duct cyst
Vaginal tumours

Introduction

In the assessment of uterine pathology, transvaginal ultrasound is often the preferred route of examination. However, transabdominal examination must be considered complementary and in some cases superior to the transvaginal approach. Transvaginal ultrasound allows excellent visualisation of the endometrial cavity and its contents, however, in the presence of a large uterine mass, particularly fibroids, it may be impossible to obtain adequate visualisation of the uterus and anexi.

Magnetic Resonance Imaging, (MRI) and Computed Tomography, (CT) are of value in investigating gynaecological malignancy although nowadays MRI has become well established as superior to CT. MRI is also of value in the investigation of benign gynaecological conditions such as fibroids, adenomyosis and duplication anomalies. [1] Despite the superior performance of MRI in many conditions, ultrasound is the initial investigation of choice for the screening of patients with suspected gynaecological disease.

The Uterus

Fibroids (Leiomyomata)

The uterine fibroid is the commonest gynaecological tumour, being present in up to 50% of women over 40 years of age. The majority involve the uterine body, cervical and broad ligament fibroids being rare. The majority of cases of uterine enlargement, excluding pregnancy, are due to fibroids.

Fibroids are benign tumours composed mainly of smooth muscle but with a variable fibrous tissue content. The fibrous tissue is arranged in dense concentric rings which are in part responsible for the characteristic ultrasound appearance. These tumours are hormone-dependent and are associated with relatively high levels of oestrogen. Thus they do not present until well after puberty and tend to shrink post-menopausally. Fibroids may enlarge during pregnancy and with Hormone Replacement Therapay (HRT) and Tamoxifen treatment. Conversely, Gonadotrophin Releasing Hormone antagonists are specifically prescribed in order to shrink large fibroids prior to myomectomy or hysterectomy. Frequently the oral contraceptive pill may cause shrinkage of fibroids. [2]

The clinical mode of presentation is variable but tends to relate to size and position. Fibroids that lie adjacent to the uterine cavity are termed submucosal and those that lie on the outer uterine surface are termed subserosal. Those in an intermediate, intramyometrial position are termed intramural (Figures 1 & 2). The submucosal group only accounts for 5% of the total but by virtue of their position, which produces an increase in endometrial area, this group is the most symptomatic, presenting with menorrhagia and also dysmenorrhea.

A very small number of fibroids are pedunculated and if submucosal, may prolapse into the cervical canal or upper vagina. These may present with intermenstrual bleeding. If subserosal fibroids are pedunculated, they may lie distant to the uterus and, on account of their long vascular pedicles, may undergo torsion and necrosis. Pedunculated subserosal fibroids may present with acute
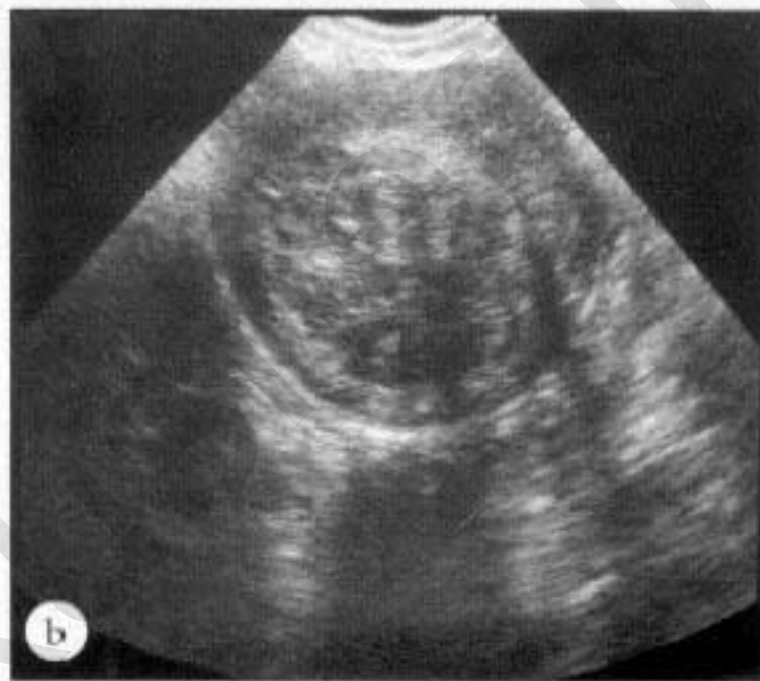
Figure 1—
a) Longitudinal transabdominal scan showing
intramural fibroid. *b)* Transvaginal scan showing
intramural fibroid.

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a) Longitudinal transabdominal scan showing
intramural fibroid. *b)* Transvaginal scan showing
intramural fibroid.

Figure 2—
TVS showing large subserosal fibroid measuring
6 cm.

abdominal pain following torsion. Laterally projecting fibroids may lie within the broad ligament and mimic an adnexal mass.

Fibroids - Ultrasound Appearances

• Single or multiple.

• Focal or generalised uterine enlargement. Individual fibroids are very variable in size ranging from 5 mm to large masses in excess of 20 cm diameter (Figure 1a,b).

• Irregular uterine outline in the presence of subserosal or multiple uterine fibroids (Figure 2).

• Myometrial echotexture is very variable being decreased, increased or isoechoic depending on the size and nature of the fibroid (Figure 3a,b).

• High velocity blood flow may often be demonstrated within the fibroid, particularly if large (Figure 3c). However, blood flow patterns and impedence values vary considerably.

• Calcification, punctate or circumferential may be present. The circumferential form tends to follow pregnancy and the punctate form is more generalised with particularly dense calcification being seen postmenopausally (Figure 4a-c).

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• Necrosis - rarely a fluid filled irregular degenerate central cavity may be seen.

• Some fibroid masses are highly reflective with very reduced through transmission of sound. A typical divergent Venetian blind pattern of acoustic shadowing may be apparent.

• Cystic areas may occur with a smooth outline, with or without internal echoes and fluid/fluid levels (Figure 5).

• Mass effect - a large fibroid mass may compress the ureters or bladder with consequent unilateral or bilateral hydronephrosis.

Diagnostic Difficulties

It may be challenging to prove that an apparent large fibroid mass is indeed uterine in origin. Large masses are best demonstrated transabdominally and an attempt to prove continuity with the vagina should be made. However, this may be difficult as the presence of a large pelvic mass may prevent adequate filling of the bladder.

Conversely, very small fibroids are best imaged transvaginally. TV ultrasound has been shown to be very accurate in identifying submucous fibroids: 12 out of 13 in one series. [3]

A retroverted but otherwise normal uterus may give the false impression of a fundal fibroid when examined transabdominally but TV ultrasound will elucidate.

A bicornate uterus may be misdiagnosed as a normal uterine body with a lateral fibroid particularly in pregnancy due to asymmetrical enlargement of both the pregnant and non-pregnant horns. Identification of the decidual reaction in the non-pregnant horn should allow differentiation.

The pedunculated subserosal fibroid is a clinical problem and must be differentiated from an ovarian fibroma. Every attempt should be made to separately identify the ovaries. As the mass is mobile, it may be very variable in position, intermittently lying either to the left or the right of the uterine body.

Blood Flow Characteristics of Fibroids

Fibroids are often accompanied by reduced impedence in the main uterine arteries - a non-specific finding with many uterine pathologies. High velocity flow may often be demonstrated within the fibroid itself, particularly if large, although fibroids with central degeneration will lack flow in the central portion. The wide range of velocity and impedence values associated with fibroids makes Doppler of limited use, however, the diagnosis of a pedunculated fibroid may be aided by the use of colour flow Doppler to identify the vascular pedicle.

Classification of uterine fibroids may cause difficulties, particularly when of a circumferential nature in pregnancy which may erroneously suggest the presence of a second fetal head. The very dense calcification in the elderly may prevent adequate visualisation of the mass. An
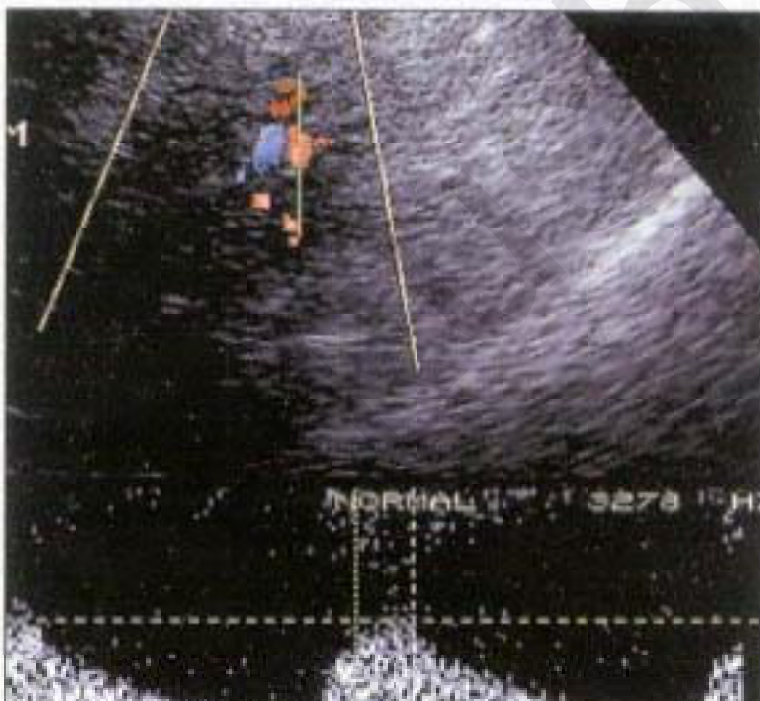
Figure 3—
a) Transverse TAS showing echo-poor submucosal fibroid. *b)* TVS, same case, showing submucosal fibroid more clearly. Note acoustic shadowing. *c,* Well demonstrated high velocity blood flow in an intramural fibroid.
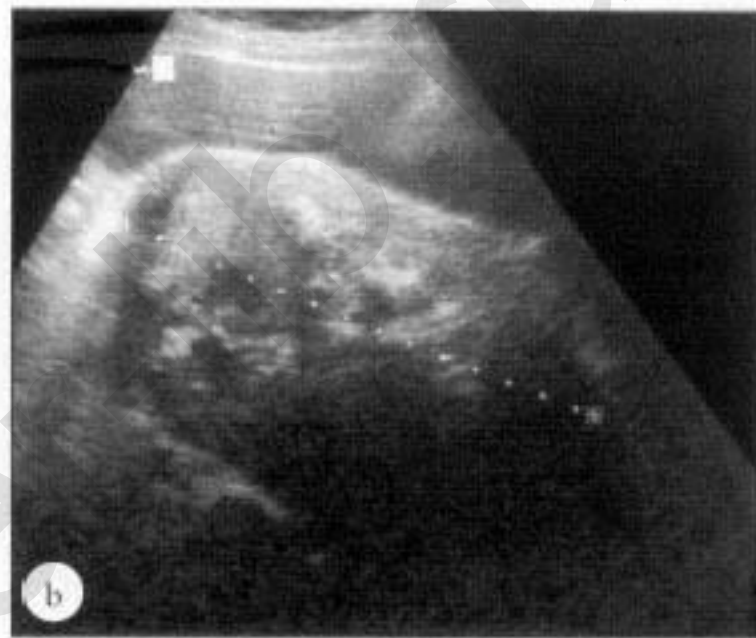
Figure 4—
a) Eighteen week gestation fetus together with calcified uterine fibroid. Note circumferential nature of the calcification which may mimic a fetal head. *b)* Longitudinal TAS heavily calcified fibroid mass. *c)* Similar appearance from faeces-laden bowel, producing a pseudo-pelvic mass with acoustic shadowing.

Figure 5—
TAS. Degenerating fibroid with a large, smooth, fluid-filled cavity. Confluent internal echoes are present.

abdominal radiograph will confirm the typical appearance of a large calcified fibroid mass.

Fibroids Complicating Pregnancy

• Subfertility may result from the presence of uterine fibroids, particularly if submucosal in position. Myomectomy may be necessary in order to return fertility. Although TV ultrasound often allows excellent visualisation of the size and position of the fibroids, MRI is superior and should be used for more complicated cases.

• Most fibroids are unchanged in size during pregnancy although some may enlarge or reduce in size. Those that increase in size may outgrow their blood supply and undergo degeneration and central necrosis. This may present with a painful uterine mass and although generally treated expectantly, occasionally emergency myomectomy is required.

• Pedunculated fibroids are more likely to tort during pregnancy due to the presence in the pelvis of a rapidly enlarging uterus.

• Spontaneous first and second trimester abortions may occur.

• Third trimester complications include placental retention and abruption, ante-and post-partum haemorrhage, premature rupture of membranes and fetal malpresentation.

• Cervical fibroids may cause obstructed labour.

MRI of the Uterus

T1 and T2 weighted images allow excellent visualisation of the uterus. T2 weighted images allow detailed examination of the zonal anatomy of the uterus and are particularly useful in the mapping of uterine fibroids and their relationship to the endometrial cavity which is critical when planning surgery. Optimum contrast is achieved on T2 weighted images where the fibroids are of lower signal intensity than the adjacent myometrium, [4] Figure 6.

Differential Diagnosis of Fibroids

•	Small intrauterine	– adenomyoma
		– endometrial polyp-generally echogenic.
•	Large pelvic mass	– solid ovarian mass
		– faeces-laden colon, (Figure 4c).
		– large bowel tumour, lymphoma, lymph nodes, pelvic kidney and other pelvic masses.
	Pedunculated	– any adnexal mass, especially ovarian fibroma.

• Braxton Hicks contractions in pregnancy may simulate a fibroid, but if the uterus is scanned over a 20 minute period of time the transient deformity caused by a contraction will disappear.
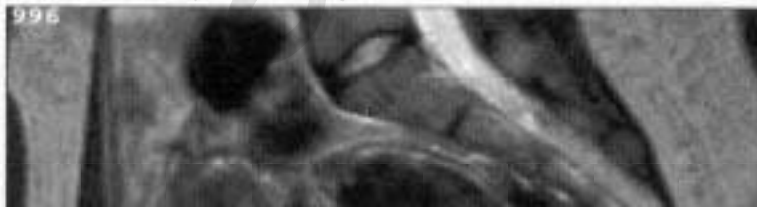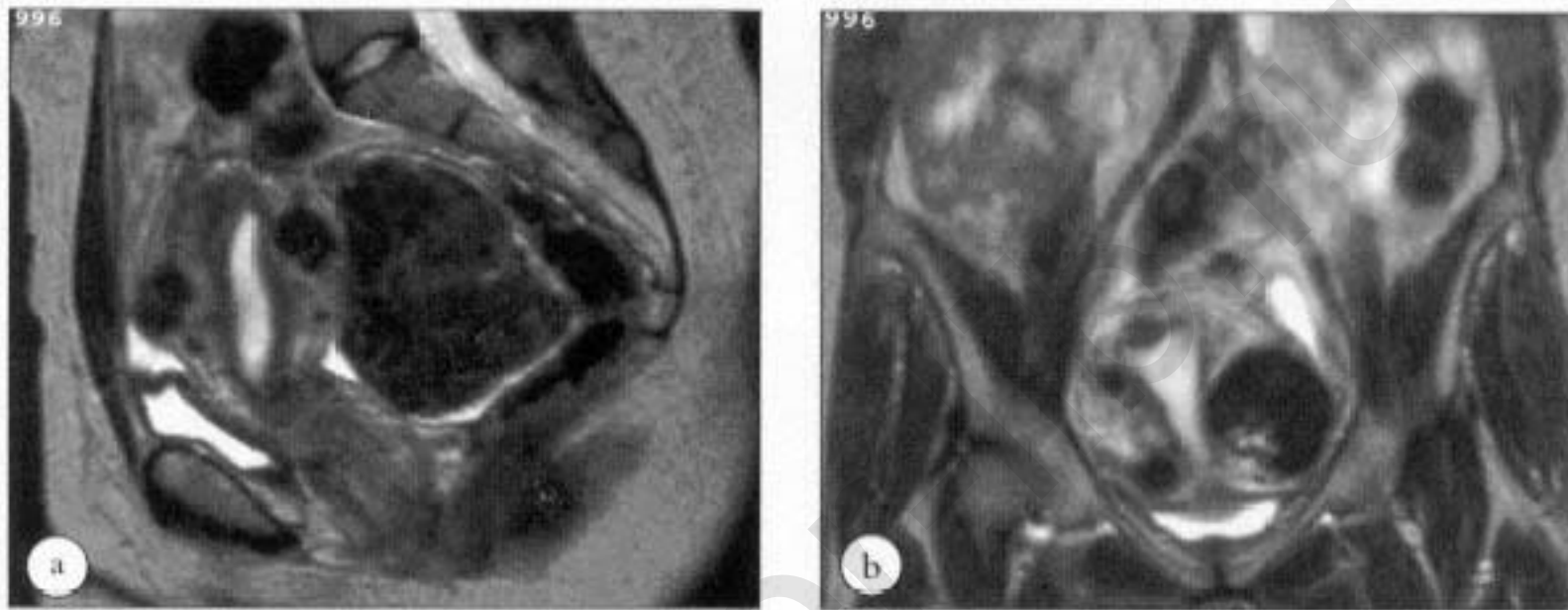
Figure 6—
a) MRI. Sagittal T2 weighted image showing multiple intramural fibroids, including a very large posterior subserosal fibroid. *b)* Coronal T2 weighted imaging showing the relationship of multiple fibroids to the uterine cavity.
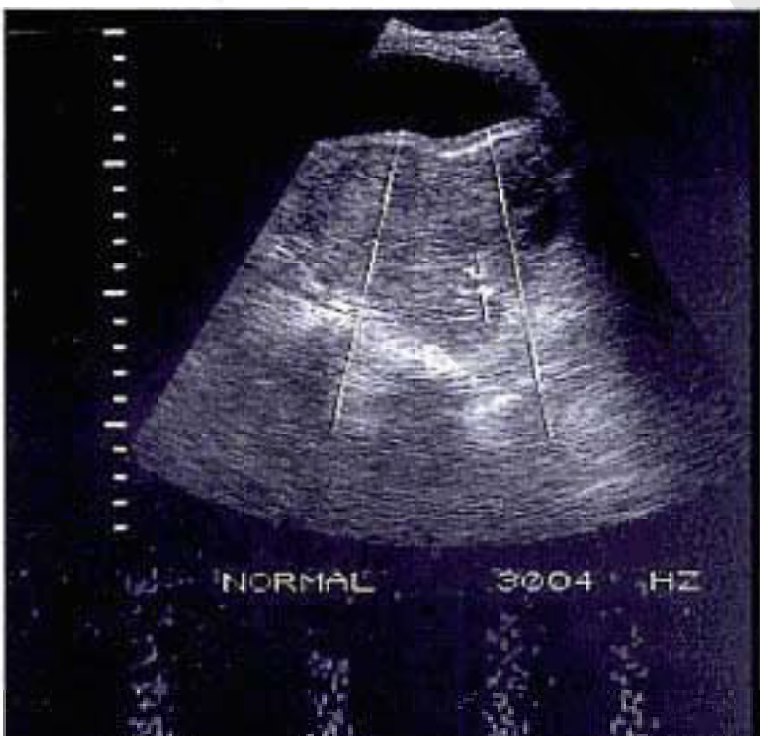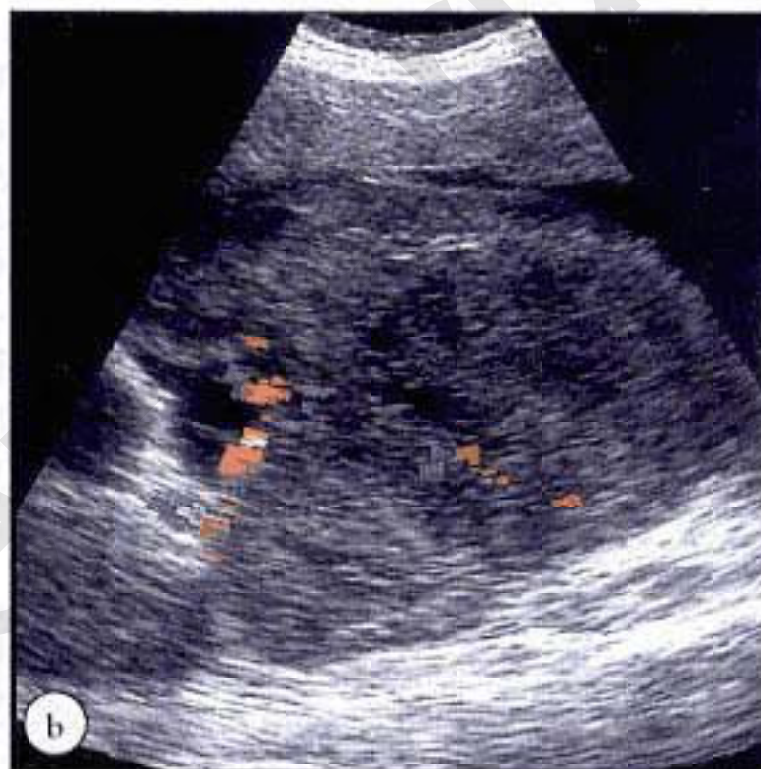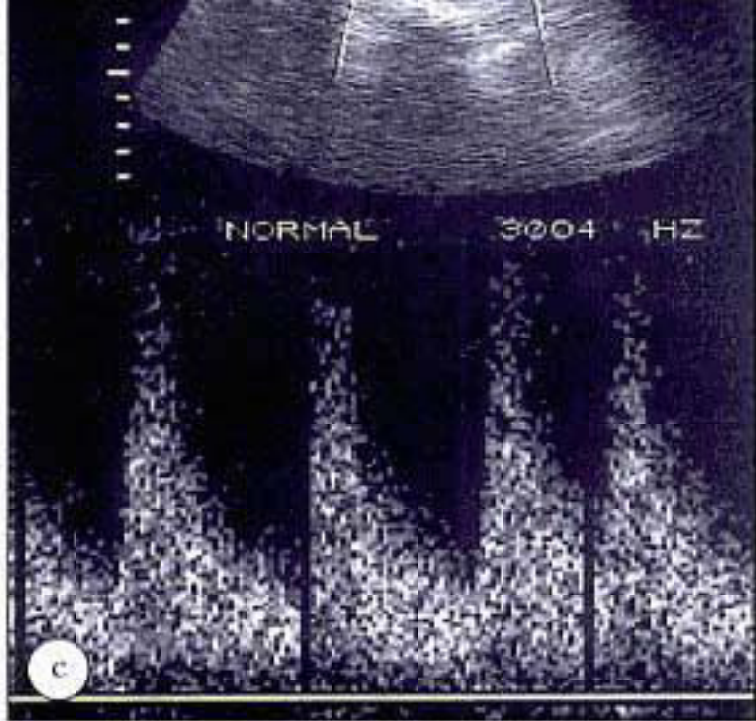
Figure 7—
a) Uterine sarcoma, transverse TAS, showing complex partly-cystic, partly-solid mass. *b)* Disorganised pattern of high velocity blood vessels within a uterine sarcoma. *c,* Spectral Doppler demonstrates high velocity, low impedance flow in the sarcoma.

Malignant Change

Uterine Sarcoma

Sarcomatous degeneration of a fibroid is very rare, the true incidence being unknown. Although a uterine sarcoma may arise de novo, the vast majority arise from a pre-existing fibroid, usually presenting in the fifth and sixth decades of life. Most uterine sarcomata present with abnormal uterine bleeding together with a pelvic mass. The diagnosis of uterine sarcoma should be seriously considered when there is rapid growth of a fibroid mass in a post-menopausal woman.

The ultrasound appearances are variable. A large central pelvic mass of heterogeneous echotexture, often with areas of cystic change, can be expected (Figure 7a). The diagnosis is generally made histologically, however, there may be evidence or local of distant spread and/or obstructive hydroureter and hydronephrosis. [5]

Blood Flow Characteristics of Sarcoma

The uterine sarcoma demonstrates easily visible, high velocity flow with low impedence, (Figure 7b and c). The pattern of vessels within the mass is usually disorganised.

Other Uterine Tumours

All are rare:

Mixed Müllerian Carcinoma

Histologically this tumour is part carcinoma and part sarcoma arising from pluri-potential cells of the Müllerian duct system. These are rapidly invasive tumours with a poor prognosis and very variable ultrasound and MRI appearances.[6]

Uterine Metastases

These are uncommon, but primary breast and stomach carcinomata may rarely spread to the uterus. Ovarian metastatic disease may be associated with it. Generally, single or multiple masses of varying echogenicity are found. Abnormal uterine bleeding is the usual mode of presentation.[7]

Lymphoma

Lymphomatous infiltration of the uterus and cervix usually presents as part of a generalised lymphomatous disorder. Ultrasound will normally show a focal echo-poor uterine mass or infiltrate.[8]

Lipoma

A rare condition affecting mainly post-menopausal women with a characteristic, well-defined, highly echogenic appearance. The MRI appearance is also characteristic of a fatty tumour.[9]

Choriocarcinoma

A trophoblastic tumour associated with hydatidform mole. This is a rapidly growing, aggressive tumour which metastasises early to the lungs. The ultrasound appearance is variable but commonly is that of a complex uterine mass of varying echogenicity.[10] The disease is monitored with serum b HcG levels, which allow excellent assessment of the response of the disease to treatment. MRI and CT are useful to check for distant spread, most particularly to the lungs. Chemotherapy produces an excellent response with a 90% cure rate.

Endometrial Disease

The endometrium is a specialised form of mucus membrane which varies in appearance according to the patient's menstrual status. Endometrial disease commonly causes abnormal uterine bleeding. The endometrium is best visualised transvaginally due to the much superior resolution of a high frequency probe and this must be considered the investigation of choice. The aetiologies of endometrial disease are very variable and are in part age-related. Although the patient presents with a history of vaginal bleeding, the source of the blood is most likely to be uterine in origin with cervical and vaginal causes being less

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Aetiology of Abnormal Vaginal Bleeding

- Uterus   – fibroids

  – adenomyosis

  – endometrial pathology:

      – hyperplasia

      – polyp

      – carcinoma

  – PID – chronic endometritis

  – oestrogen producing ovarian tumour

  – post–menopausal atrophic endometritis

- Cervix   – chronic cervicitis

  – polyp

  – carcinoma

- Vagina   – atrophic vaginitis

  – infection

  – foreign body (retained tampon, pessary)

  – trauma

  – carcinoma

- Other   – haematuria   } mistaken for
                 – rectal bleeding   vaginal bleeding

  – bleeding disorders

– bleeding disorders

–medications: heparin, warfarin

It is essential to obtain an accurate menstrual and clinical history before investigating the cause of abnormal bleeding. If the bleeding is post-coital, a diagnosis of chronic cervicitis might be considered. Conversely if the bleeding is intermenstrual, then a diagnosis of endometrial polyp or endometrial carcinoma should be entertained. Menorrhagia may result from uterine fibroids or adenomyosis. Dysfunctional uterine bleeding must also be considered in ultrasound negative menorrhagia. Any post-menopausal bleeding must be regarded as abnormal because of the significant risk of endometrial carcinoma and must be further investigated.

Ultrasound Appearances of the Endometrium

These are very variable and depend on the aetiology. Individual pathologies will be detailed later in the chapter. During the menstrual years, an endometrial thickness of up to 14 mm may be considered normal and up to 5 mm post-menopausally.

I Thin   –   premenarche

     –   cyclical change during menstrual cycle

     –   oligomenorrhoea/amenorrhoea

     –   oral contraceptive pill

     –   post transcervical endometrial resection

II Thick   –   cyclical change during menstrual cycle

     –   endometrial hyperplasia

     –   endometrial polyp

     –   endometrial carcinoma

     –   medications : HRT

     : Tamoxifen

     –   dysfunctional uterine bleeding

     –   apparent   : retained products of conception

     : trophoblastic disease

     : haemato/pyometra

The Post-Menopausal Uterus

Endometrial atrophy is the norm post-menopausally with the endometrium being seen as a thin line. When measuring the endometrium, both anterior and posterior layers are measured together, perpendicular to the uterine cavity in the sagittal plane. The width of any fluid in the cavity is not included. Thus, if there is no fluid in the cavity, then a single AP measurement is made. If intracavity fluid is present the summation of the anterior and posterior endometrial layers is used.

An AP endometrial thickness of 5 mm has been generally accepted as a fairly arbitrary upper limit of normal. [11] If this figure is used, very few endometrial carcinomata will be missed ultrasonographically. Some authorities rely on the ultrasound measurement alone, others combine the measurement with histology, and yet others use histology alone when investigating post-menopausal bleeding.

A small amount of fluid in the cavity of the post-menopausal uterus is a normal finding and has been reported in up to 12% of normal examinations,[12] (Figure 8). This finding does not imply malignancy unless there are other signs such as endometrial thickening. Neither is the presence of a small amount of cavity fluid associated with cervical stenosis.

In some elderly patients, and particularly those with diabetes, multiple punctate, peripherally arranged calcific foci may be seen in the myometrium. This is vascular calcification involving the arcuate uterine arteries and is indicative of Monckeberg's median sclerosis (Figure 8).

Endometrial Hyperplasia

Endometrial hyperplasia results from excessive oestrogen stimulation unopposed by progesterone. The end result is usually, but not always, abnormal endometrial bleeding, often with alternating periods of amenorrhea and continuous uterine bleeding.

Figure 8—
Longitudinal TAS of post-menopausal uterus showing fluid within the uterine cavity, no endometiral thickening and multiple peripheral calcific foci due to vascular calcification.

Figure 8—
Longitudinal TAS of post-menopausal uterus
showing fluid within the uterine cavity, no
endometiral thickening and multiple peripheral
calcific foci due to vascular calcification.

Aetiology

• medications   - HRT

                                 - Tamoxifen

• polycystic ovary syndrome
• obesity
• oestrogen producing tumours, i.e., granulosa cell tumour of the ovary

Ultrasound Appearances

• endometrial thickening >1 cm [13] and occasionally up to 5 cm

  • echotexture   - increased endometrial echogenicity

                              - ± small cystic areas (Figure 9)

• ± associated endometrial polyps
• mild overall uterine enlargement if the cavity is very distended due to thickened endometrium or myometrial enlargement simply as a response to excess oestrogen levels
• functional ovarian cysts are not uncommon

Endometrial Polyp

Endometrial polyps are common, being present in up to 10% of women. Polyps are often associated with endometrial hyperplasia. Endometrial polyps may be sessile or penduculated and the latter may prolapse through the cervical canal into the vagina. Histologically,

Figure 9—
TVS showing endometrial hyperplasia (2 cm AP).
A small cystic area is shown within.

the polyps are composed of fibrous stroma and glands and are almost always benign. Most polyps are asymptomatic but may present with abnormal uterine bleeding, particularly of an intermenstrual nature.

Ultrasound Appearances

• single or multiple

• small- generally <1 cm

• echogenic

• ± associated endometrial hyperplasia

• ± intracavity fluid, (Figures 10, 11)

Figure 10—
Sagittal TAS showing echogenic polyp within
endometrial cavity surrounded by a small amount of
intracavity fluid. No endometrial thicknening.

Figure 11—
TVS showing a polyp with endometrial cavity

Polyps are often missed ultrasonographically but most commonly so when associated with endometrial hyperplasia. The presence of intracavity fluid may aid the diagnosis as it may outline the polyp. This observation has led to the development of a technique known as hystersosalpingography, whereby saline is introduced into the uterine cavity at the time of TV ultrasound in order to outline any intracavitary pathology. Hysteroscopy will allow the visualisation of polyps and/or other submucosal pathology, such as small fibroids, and may aid their subsequent removal.

Blood Flow Characteristics

Small blood vessels can be demonstrated within a polyp, particularly if it is large. Sometimes the main feeder vessel can be shown on colour flow Doppler, particularly if the stalk is outlined by fluid. The impedence of the main uterine arteries may also be reduced from normal.

Medications

Oral Contraceptive Pill

Generally, oestrogen and progesterone are combined and are administered in a cyclical fashion. The endometrium may be expected to be thin and varies little during the menstrual cycle. Occasionally, slight uterine enlargement may be noted and multiple, small, functional, randomly arranged cysts may be seen in the ovaries.

Hormone Replacement Therapy (HRT)

HRT is commonly used particularly in peri-menopausal women to supplement waning natural hormone levels. HRT is also used in the treatment of premature ovarian failure. Many preparations are available but most combine oestrogen and progesterone and are given in a cyclical, sequential manner. Consequently, cyclical changes in endometrial thickness are observed ultrasonographically with a thickness of up to 15 mm in the oestrogen phase with the endometrium being relatively less thick in the progesterone phase, (Figure 12). Accordingly, ultrasound assessment of endometrial thickness is best performed immediately after the progesterone phase of the cycle when the endometrium is likely to be thinnest.

Women taking the combined pill are unlikely (15%) to have an endometrial thickness of greater than 8 mm, as opposed to those taking an oestrogen only preparation, where 50% will have an endometrial thickness greater than 8 mm. [14] It is well-known that endometrial carcinoma is associated with unopposed oestrogen and thus a combination form of HRT will generally be prescribed.

Figure 12—
Sagittal TVS showing endometrial thickening.
Patient receiving HRT. Scan obtained during
oestrogenic phase.

Tamoxifen

Tamoxifen is an oral synthetic anti oestrogen compound with mild oestrogenic properties. Its exact mechanism of action is not understood. Tamoxifen is used as an adjuvant chemotherapeutic agent in the treatment of breast cancer and as such is used by a large number of women. There are many and varied side-effects but Tamoxifen notably causes endometrial metaplasia, hyperplasia and carcinoma[15],[16] In patients receiving Tamoxifen therapy, the normal risk of developing endometrial carcinoma is increased six-fold, with both pre- and post-menopausal women being affected.[17] Fifty per cent of women taking Tamoxifen will develop some type of endometrial pathology after 6-36 months of treatment.[18]

In a series of 38 asymptomatic women taking Tamoxifen, 61% had an ultrasound abnormality, four having endometrial hyperplasia and 20 having endometrial polyps. If the endometrium was greater than 10 mm in thickness, endometrial pathology was always present.[19]

Ultrasound Appearances

- Endometrium   –   thickened, almost always

    >10 mm

  –   echogenic

  –   ± irregular in outline

  –   ± cystic areas (<5 mm),

    (Figure 13)

  –   polyps, ((Figure 14)

• Endometrial polyps are the characteristic feature of Tamoxifen therapy. These polyps tend to be large and cigar-shaped, conforming to the normal elliptical potential shape of the uterine cavity.

Figure 13—
Transverse TVS shows a cystic endometrial
hyperplasia in patient receiving Tamoxifen therapy.

Figure 14—
Transverse TVS showing 2 cm polyp in patient
receiving Tamoxifen therapy.

However, these polyps may be very difficult to distinguish from endometrial thickening unless there is intracavity fluid. [20],[21] Hysterosonography may be of value in this situation.

• Mild uterine enlargement may occur due to the oestrogenic effect of Tamoxifen.

Blood Flow Characteristics

Doppler interrogation of endometrial blood vessels often shows a low vascular impedance to flow with a low RI (<0.4).[22] Unfortunately, this information is not clinically very helpful because similar figures may be obtained in patients with endometrial carcinoma and thus Doppler has not yet been shown to be convincingly accurate in distinguishing between benign and malignant endometrial pathology. More work in this field is in progress.

In another series, uterine artery PI and RI were significantly lower than in control groups and were similar to those found in post-menopausal women taking oestrogen replacement therapy.[19]

Endometrial Carcinoma

Endometrial carcinoma is the commonest gynaecological tumour with 75% presenting in post-menopausal women in the sixth and seventh decades of life. This disease is increasing in incidence, due in part to the increasingly elderly population and in part to the increasingly prescribed medications for the treatment of post-menopausal symptoms and breast cancer.

The oestrogen status of the patient is important with many tumours being related to excessive oestrogen levels, whether endogenous or exogenous.

Contributing Factors

• late menarche
• polycystic ovary syndrome
• oestrogen secreting granulosa cell tumour of the ovary
• early menopause
• obesity
• diabetes mellitus
• medications
    – Tamoxifen
    – oestrogen only HRT

These tumours are slow growing with 75% being confined to the uterus at the time of diagnosis. Spread to the broad ligaments and pelvic sidewalls or to the endocervix and upper vagina is relatively late, as is spread to the regional lymph nodes. Haematogenous spread is generally very late in the natural history of the disease.

The majority are adenocarcinomata, which may be of a polypoid or invasive type. Histologically, most tumours are well differentiated with prognosis

The majority are adenocarcinomata, which may be of a polypoid or invasive type. Histologically, most tumours are well differentiated with prognosis depending not only on the differentiation but also the presence and depth of myometrial invasion. The majority of patients present with post-menopausal bleeding, which in approximately one-tenth can be expected to have a malignant origin. Pre-menopausal women mainly present with menstrual irregularity, particularly intermenstrual bleeding.

The diagnosis is generally made clinically with a biopsy. However, ultrasound has a valuable role in the management of these patients. Transvaginal ultrasound allows excellent visualisation of the endometrium, allowing assessment of the endometrial morphology, measurement of endometrial thickness and Doppler evaluation of the uterine and endometrial blood vessels.

The tumour is staged clinically using the FIGO classification:

Stage   I   –   Carcinoma confined to the corpus

        IA   –   The length of the uterine cavity is 8 cm or less

        IB   –   The length of the uterine cavity is greater than 8 cm

Stage   II   –   Carcinoma has involved corpus and cervix but has not extended outside the uterus

Stage   III –   Carcinoma has extended outside the uterus but not outside the true pelvis

Stage   IV –   Carcinoma has extended outside the true pelvis or has obviously involved the mucosa of the bladder or rectum

        IVA   –   Carcinoma has spread to adjacent organs

        IVB   –   Carcinoma has spread to distant organs

The depth of myometrial invasion can be assessed with ultrasound, but overall MRI is the imaging modality of choice, particularly in respect of adnexal and more distant tumour spread. [23],[24] Treatment is generally by radical hysterectomy, (Figure 15).

Ultrasound Appearances of Endometrial Carcinoma

- endometrium

    – increased thickness: >5 mm in the post-menopausal woman, (Figures 16, 17)

    – irregular margins

    – increased echogenicity

    – polyps may be associated

    – cavity fluid – although alone this is not an indicator of malignancy, (Figure 18)

- myometrium

  - there may be evidence of tumour invasion

  - ± generalised uterine enlargement

- Large tumours may present as a pelvic mass of indeterminate origin with no particular distinguishing features.

Blood Flow Characteristics

Doppler studies show altered vascularity involving the uterine arteries with both PI and RI being significantly reduced,[25] (Figure 19). Angiogenesis can also be demonstrated in the endometrial mass with a high sensitivity system and is also of low impedance.

When considering the role of ultrasound in the investigation of post-menopausal women, it is reassuring to know that, if the endometrial thickness is less than 5 mm, then the bleeding usually results from benign pathology or
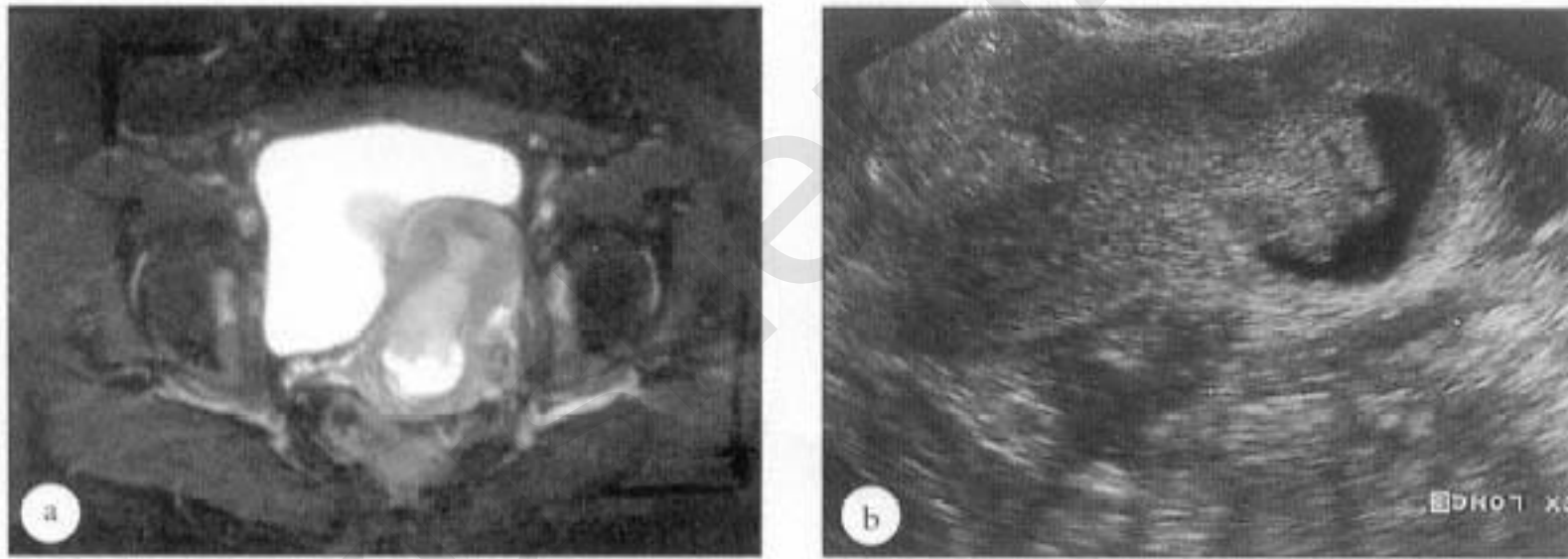
Figure 15—
a) Sagittal axial T2 weighted MRI image showing endometrial tumour extending from endometrial cavity into the cervical canal. The tumour is outlined with fluid in the cervical canal. b) TVS of the same patient shows similar appearance to MRI.

Figure 16—
Sagittal TVS showing large echogenic endometrial
carcinoma expanding the uterine cavity.

Figure 17—
Transverse TVS showing endometrial carcinoma with
an irregular echogenic endometrial mass with small
amount of associated fluid. There is early myometrial
invasion.

endometrial atrophy. [26] Conversely, in a post-menopausal woman, significantly thickened endometrium is likely to be associated with malignancy unless she is receiving a medication which causes endometrial hyperplasia. In one series, the average endometrial thickness for a patient with endometrial carcinoma was 17.7 ± 5.8 mm[27].

Adenomyosis

Adenomyosis may be considered a variant of endometriosis with the two conditions known to co-exist in 20% of affected patients. Histologically, ectopic endometrial glands and stroma are found in the

Figure 18—
Transverse TAS. Uterine cavity is expanded with
fluid and an irregular echogenic mass.

myometrium. The typical patient will be a multiparous woman in her 40s, presenting with menorrhagia and dysmenorrhoea. This presentation contrasts with that of endometriosis whereby a nulliparous, infertile woman in her 20s or 30s is most likely to be affected. Adenomyosis may be associated with previous

myometrium. The typical patient will be a multiparous woman in her 40s, presenting with menorrhagia and dysmenorrhoea. This presentation contrasts with that of endometriosis whereby a nulliparous, infertile woman in her 20s or 30s is most likely to be affected. Adenomyosis may be associated with previous D&C, Caesarean section, or elevated oestrogen levels. The disease is usually generalised, but occasionally, a localised focus, termed an adenomyoma, may be found.

Ultrasound Appearances

The ultrasonic diagnosis of adenomyosis may be very difficult, if not impossible, even transvaginally.[28] The uterus will usually appear ultrasonographically normal, however, generalised enlargement of a smooth spherical nature is not uncommon.[29],[30] Sometimes small cystic areas measuring a few mm may be seen within the myometrium. These represent menstrual products. The endometrium will appear normal. Rarely a focal echo-poor mass representing an adenomyoma may be identified but it may be very difficult to distinguish from a fibroid, which in any case may be co-existent, (Figure 20).

MRI may be helpful in identifying adenomyosis. MRI is accurate in distinguishing between adenomyosis and fibroids in up to 90% of cases (Figure 21). However, as with ultrasound, it is more difficult to distinguish between a focal adenomyoma or a fibroid with MRI.[31],[32] High signal areas may suggest areas of haemorrhage within the myometrium. Generally, however, the diagnosis is made histologically, post-hysterectomy.
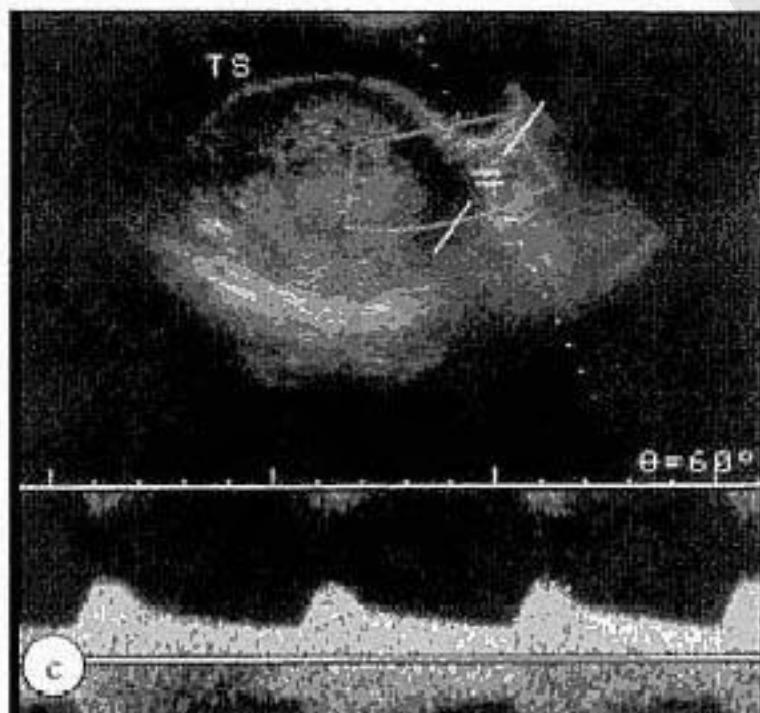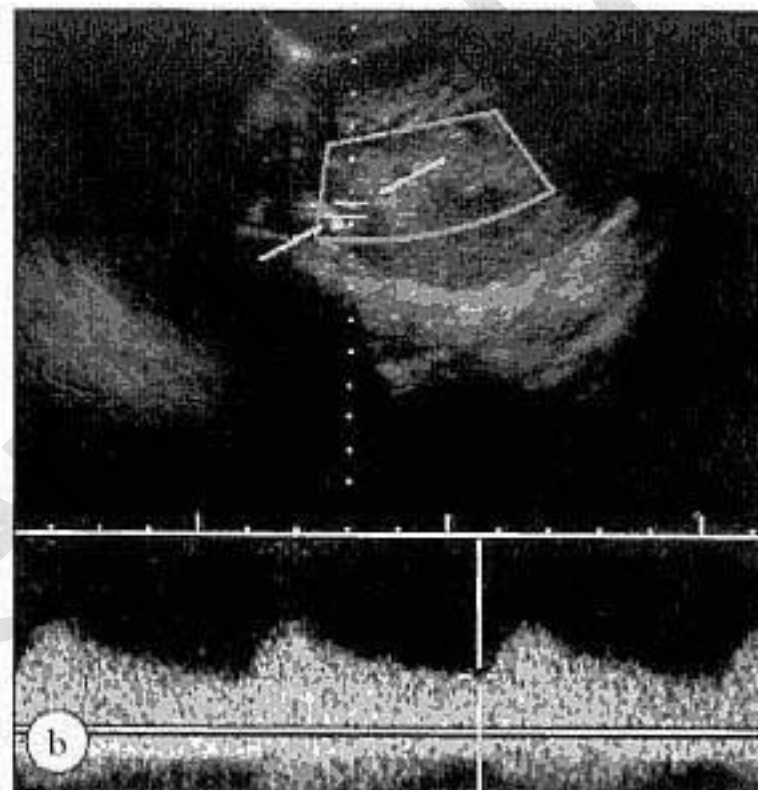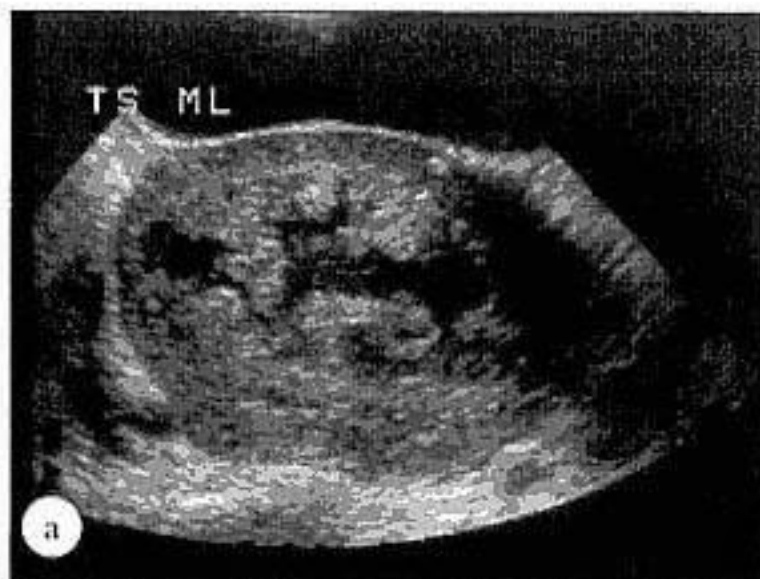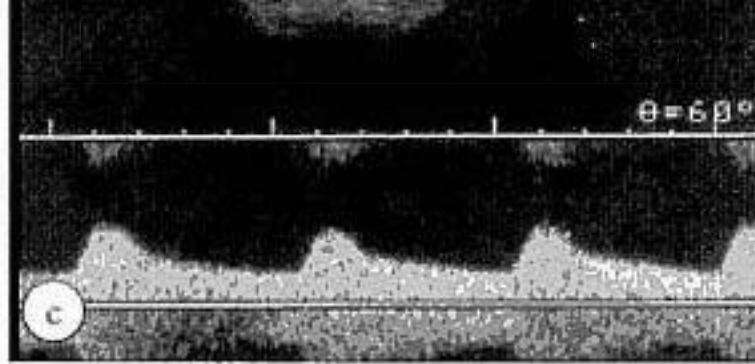
Figure 19—
a) endometrial carcinoma stage II. b) and c) the right and left uterine arteries show flow of decreased resistance with good forward end diastolic flow velocities.

Figure 20—
Sagittal TAS showing spherical uterus with an adenomatous mass posteriorly which is difficult to distinguish from a fibroid ultrasonographically.

Figure 21—
Sagittal T2 weighted MRI shows infiltrative
nature of posterior uterine mass in adenomyosis.

Endometritis

Endometritis is an acute or chronic infective process of the endometrium. This may be related to generalised pelvic inflammatory disease (PID) or, in the acute phase, is most common in the post-partum period and is associated with retained products of conception or premature rupture of membranes. Endometritis may also develop following uterine instrumentation, such as dilatation and curettage or the insertion of an intra-uterine contraceptive device. When associated with chronic PID, endometritis results from an ascending venereal infection with the most common causative agents being Chlamydia trachomatis or Neisseria gonorrhoea. Due to its cyclical shedding process, the endometrium is relatively more resistant to infection than the cervix and thus endometritis is less common than cervicitis. With acute PID, the patient will classically present with lower abdominal pain, tenderness, fever and a vaginal discharge.

Ultrasound Appearances

Seventy-five per cent of patients with biopsy proven endometritis will have a normal ultrasound examination. [33] However, even when ultrasound is negative, there is usually specific uterine tenderness.

When ultrasound is positive, some or all of the following signs can be expected:[34]

- uterus

  - enlarged

  - indistinct outline

  - endometrium   : ± thickened

                           : increased or decreased echogenicity

- endometrial cavity

  - may contain fluid, (Figures 22, 23)

  - ± irregular outline

  - ± internal echoes and debris

  - gas if there is a gas forming organism

- extrauterine

  - pelvic fluid

  - adnexal mass

  - tubovarian abscess

- tubovarian abscess

- pyosalpinx
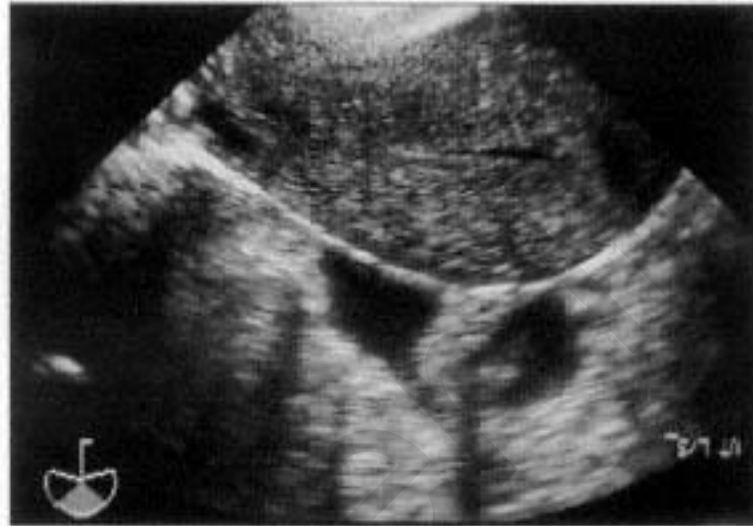
Figure 22—
Sagittal TVS PID showing small amount of
intracavity fluid and small amount of free fluid in
the pelvis.

Figure 23—
Sagittal TVS showing IUCD and pyometra.

DOPPLER IN DIFFERENTIATION OF UTERINE PATHOLOGY - KEY POINTS

- Doppler cannot be used to distinguish uterine masses as there is considerable variation and overlap in patterns and impedance values.
- Uterine malignancies tend to have significantly lower resistance (in both the uterine arteries and within the mass itself) than benign conditions, but the overlap in values limits this as a practical diagnostic tool at present.
- Decreased resistance in the **main uterine arteries** is associated with:

Fibroids
Polyps
Endometrial hyperplasia
Endometrial carcinoma
Other malignancies - choriocarcinoma, sarcoma

- Blood vessels can be demonstrated within most of the above masses depending on size and system sensitivity. Low impedance wave-forms may be expected.
- Doppler information should never be used in isolation but may provide information additional to the morphological ultrasound appearances.

Uterine Surgery

Hysterectomy

This is a very common surgical procedure which generally involves removal of the uterus and cervix with ovarian conservation. Radical hysterectomy (Wertheim's hysterectomy) is a more extensive procedure involving hysterectomy and bilateral salpingo-oophorectomy, together with lymph node clearance of the pelvis. Postoperatively, the vagina will appear blind ending although very occasionally small fluid-filled retention cysts will be demonstrated at the vaginal vault. Immediately post-operatively, pelvic or vaginal fluid collections may be apparent. These will have the typical ultrasound appearance of fluid with or without internal echoes. The majority will be haematomata which may or may not be infected (Figure 24). Infected haematomata are likely to present with pelvic pain, fever and depending on the site, there may be vaginal bleeding. Draining of such a fluid collection is possible under ultrasound control either transabdominally or transvaginally. A late complication of hysterectomy is the development of an intraperitoneal
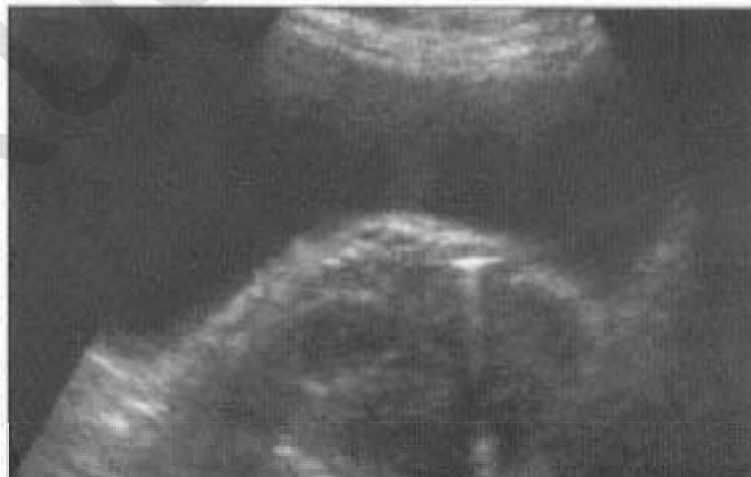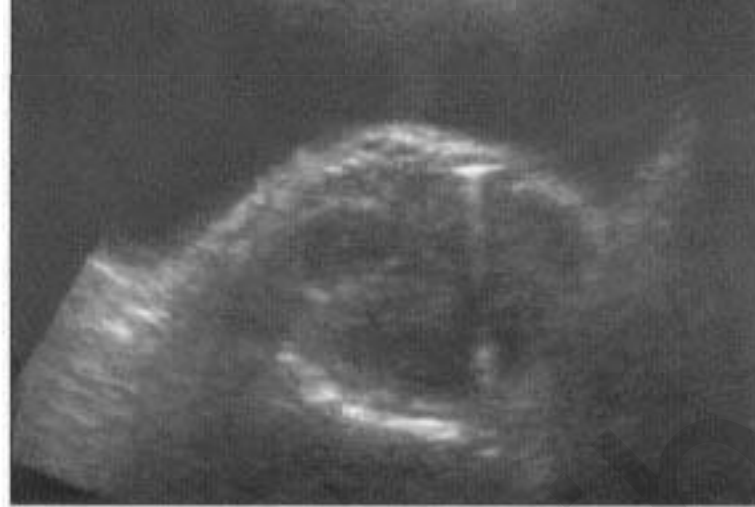
Figure 24—
Transverse TAS view of vaginal vault
haematoma post-hysterectomy.

lymphocoele. At ultrasound this has the appearance of a well defined fluid collection with or without internal loculations.

Nowadays, subtotal hysterectomy is a rarely performed procedure. Ultrasonographically, the residual cervix will have the appearance of a relatively echo-poor stump at the upper end of the vagina.

Transcervical Resection of the Endometrium (TCRE)

Transcervical resection of the endometrium has recently been undertaken in the treatment of intractable menorrhagia where medication has failed and hysterectomy is not contemplated. Using either electrocautery or laser therapy, an attempt is made to remove the whole of the endometrium. Post-procedure ultrasound examination of the uterine cavity should show it to be completely denuded of endometrium with an infinitesimally thin cavity line. However, occasionally, fluid filled cavities of varying size extending into the myometrium may be apparent. These may be single or multiple, with or without internal echoes,(Figure 25a,b).

Caesarean Section

Following a Lower Segment Caesarean Section, the uterus will usually appear entirely normal after six weeks. But in a small minority of patients, a small anterior deformity will be seen at the junction of the middle and lower uterine segments at the site of the surgical incision. This may have the ultrasound appearance of a small fibroid, but its site and the clinical history should suggest the diagnosis. This minor abnormality is clinically insignificant, (Figure 26).
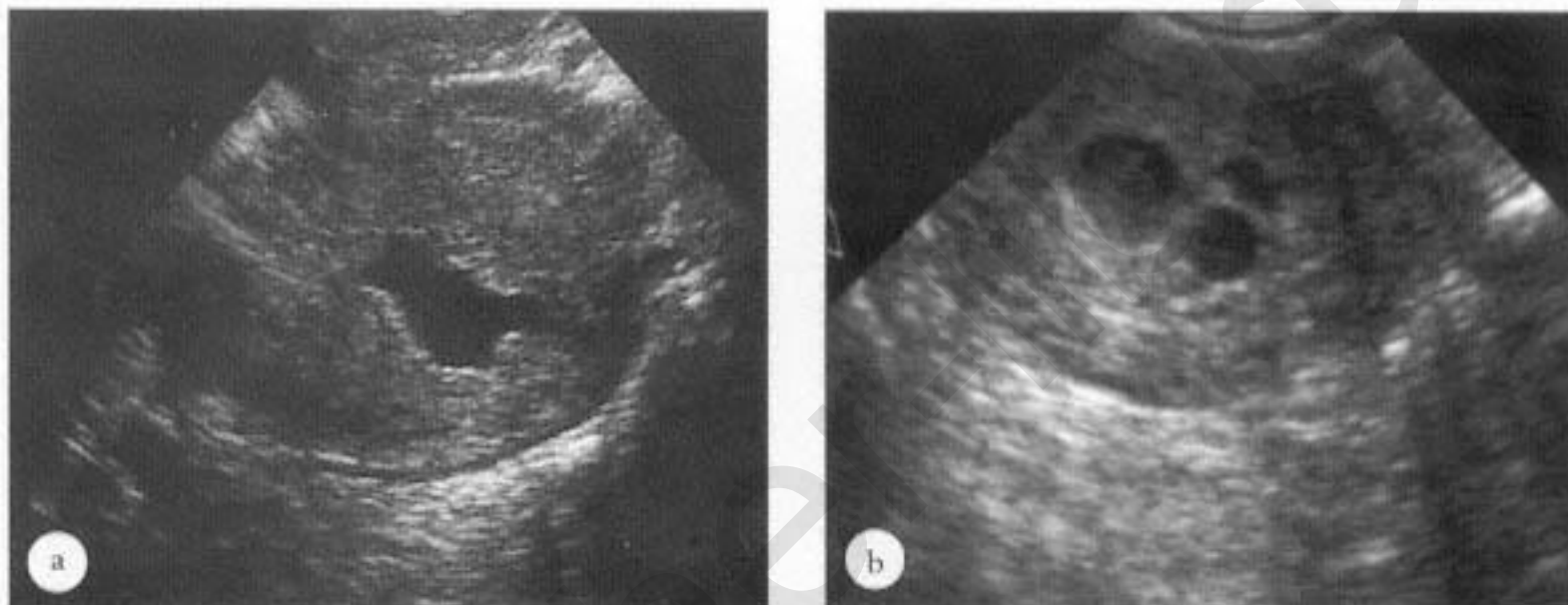
Figure 25—
a) Sagittal TVS shows irregular fluid-filled endometrial cavity post TCRE. b) Transverse TVS shows several
cavities extending into the myometrium post TCRE.

Figure 26—
Sagittal TAS shows irregular mass extending from
the anterior surface of the uterus into the bladder at
the site of a Lower Segment Caesarean Section scar.
Biopsy of the mass showed ectopic endometrium.

Figure 27—
Sagittal TVS shows multiple echogenic foci
relating to endometrial cavity in Asherman's syndrome.

Asherman's Syndrome

Intrauterine synechiae or adhesions result from overenthusiastic endometrial curettage during or following pregnancy. During the pregnancy, the endometrium is more friable than normal and this may allow the complete removal of focal areas of endometrium. As a result, single or multiple bands of fibrous tissue completely or partially traverse the endometrial cavity. Similar adhesions may develop post-myomectomy or post-Caesarean section and in association with infection, i.e., endometritis, TB and schistosomiasis.

These adhesions may be an incidental finding at ultrasound, but the patient may present with a history of dysmenorrhoea, oligomenorrhea, infertility or recurrent miscarriage.

These adhesions may be an incidental finding at ultrasound, but the patient may present with a history of dysmenorrhoea, oligomenorrhea, infertility or recurrent miscarriage.

At ultrasound, the adhesions are usually seen as very small echogenic foci related to the endometrial cavity, [35] (Figure 27). If there is fluid in the cavity, the adhesions may be better and more conclusively demonstrated.

Generally, the diagnosis will be confirmed at hysterosalpingography or hysteroscopy, at which time the adhesions may be divided (Figure 28).
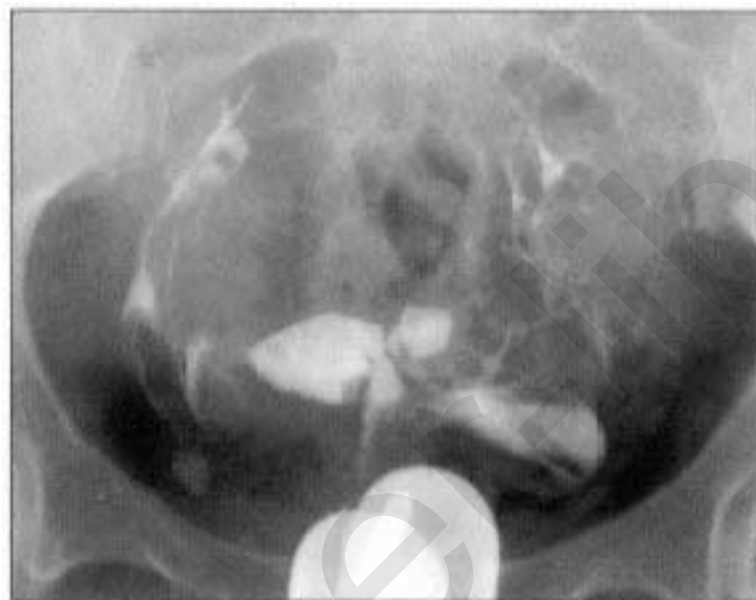
Figure 28—
HSG showing multiple intrauterine adhesions.

Intrauterine Contraceptive Device

An intrauterine contraceptive device (IUCD) is a commonly used form of contraception, whereby uterine implantation of the embryo is prevented by either mechanical or chemical means.

Ultrasound is used to check the correct position of the device in the uterine cavity and is generally requested when the marking strings of the device cannot be visualised hanging down through the cervical canal. Usually, the strings have retracted into the uterine cavity and ultrasound will show the device to be normally sited. Less commonly, the device will have either been expelled or, less commonly still, will have completely or partially penetrated the uterine wall. This penetration will usually have taken place at the time of insertion.

The risk of perforation is 1:1-2000 and in 20% of these the device will be embedded in the myometrium. Following complete perforation (80%), the device will lie freely in the peritoneal cavity, generally in the pelvis but occasionally high in the abdomen, even in a sub-diaphragmatic position. Visceral perforation is rare but damage to the colon, rectum or bladder have been reported. [36] When the device is embedded in the uterine wall, hysteroscopy may be required to aid removal.

The Lippes loop is an older form of device but is still often seen, even after 20 years in situ. It has a serpiguous appearance in contrast with the more usual Cu7 or CuT, which both have a long and a short arm. Recently, a new form of device, the Mirena intrauterine system (IUS) has been introduced. This is a `T' shaped progestagene impregnated device. From the ultrasound point of view, the Mirena IUS has the disadvantage of being relatively

Table 1. Echogenic uterine masses – Differential Diagnoses

Table 1. Echogenic uterine masses – Differential Diagnoses

Myometrium	–	fibroids ± calcification
	–	vascular calcification
	–	rare tumours, e.g., lipoma
Cavity	–	endometrial hyperplasia
	–	endometrial polyp
	–	endometrial carcinoma
	–	Asherman's syndrome
	–	IUCD
	–	gas (infection or post instrumentation)

Other pelvic mass mimicking uterine mass

less echogenic than other forms of device and greater care needs to be taken when trying to identify it ultrasonographically.

Ultrasound Appearances

An IUCD will be best seen transvaginally and this is the investigation of choice. The device should lie centrally in the fundal aspect of the uterine cavity, generally 10-15 mm from the apex of the fundus. The device is markedly or moderately echogenic and produces a variable amount of acoustic shadowing. The Lippes loop in sagittal section is seen as a row of high echogenic spots, (Figure 29), but may appear serpignous in the coronal uterine plane.

Copper T/7 in sagittal section is seen as fundal dot with distal long arm, (Figure 30).

If the IUCD appears to lie eccentrically, then uterine anomaly, deformation of the cavity by fibroids, or myometrial penetration of the device should be considered. When there are a large number of fibroids, confirmation of correct siting of the device may be very difficult. When the device is embedded in the myometrium, it will be seen to lie at an angle to the cavity fully or partially within the myometrium, (Figure 31). If the device lies low in the cavity, it will be ineffective and the patient should be warned of the risk of pregnancy at the time of the examination.

Despite the presence of a normally sited device, pregnancy may occur and the device may be visualised adjacent to a gestation sac,[37] (Figure 32). If the device cannot be identified, then an abdominal radiograph should be obtained in an attempt to locate it. Generally, an intraperitoneal IUCD cannot be seen ultrasonographically although very occasionally it may be identified as an intensely echogenic focus in the pelvis if it lies close to the uterus.
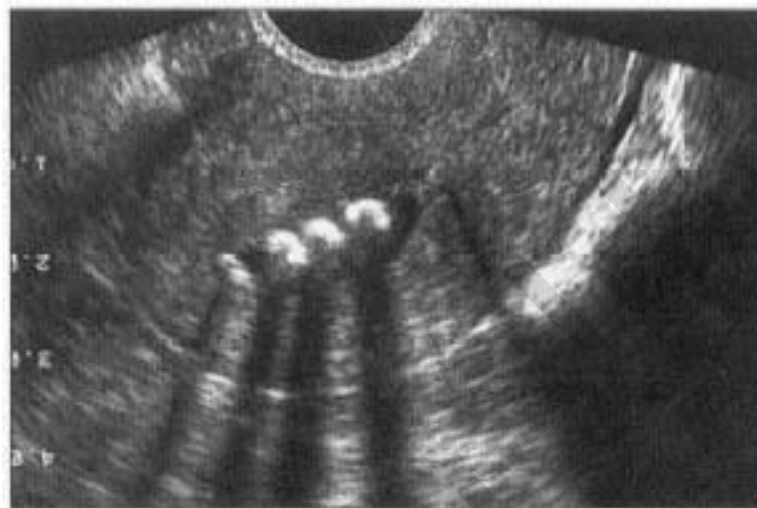
Figure 29—
Sagittal TVS showing typical dot-like appearance
of Lippes loop. Note acoustic shadowing.

Figure 30—

Figure 30—
Sagittal TVS showing typical spot and line
appearance of C7 IUCD.

Figure 31—
Sagittal TVS showing IUCD penetrating
myometrium.

Figure 32—
Sagittal TAS showing 7 week gestation sac at
uterine fundus and low-lying ineffective IUCD.

The Cervix

The cervix is not always well demonstrated ultrasonographically due to its significant distance from the transducer with the transabdominal approach and, conversely, due to its close proximity to the transducer with the transvaginal approach. Various benign cervical conditions will be demonstrated ultrasonographically, but MRI is the imaging modality of choice for malignant disease.

Benign Conditions

Nabothian Cysts

These are epithelial inclusion cysts which develop in the endocervical canal, being most commonly found in the perimenopausal period. These cysts develop as a result of chronic cervicitis which causes obstruction of the endocervical glands resulting in retention of secretions. Nabothian cysts are asymptomatic and clinically insignificant.

Ultrasound Appearance

• central position relating to cervical canal (Figure 33)

• single or multiple, (Figure 34)

• size varies from a few mm to several cm but generally <1 cm

• generally echo-poor, but some will contain confluent internal echoes. [38]
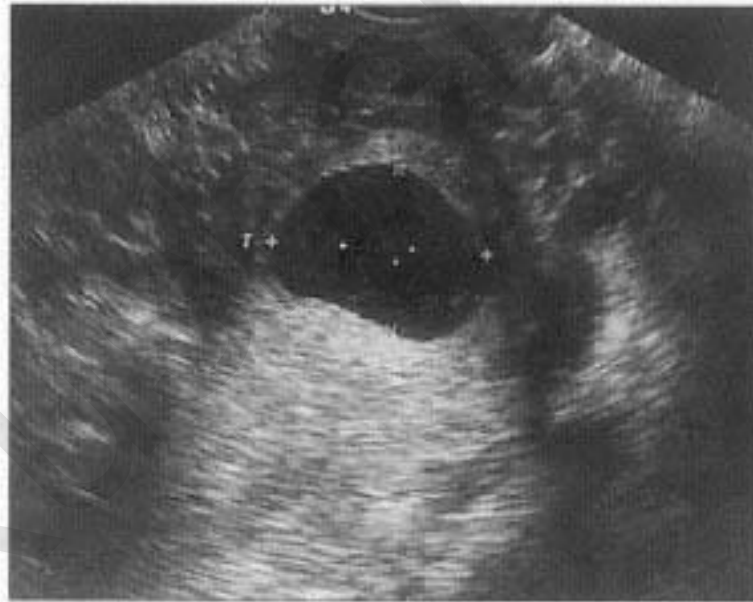
Figure 33—
Transverse TVS - large (3 cm) single Nabothian cyst.

Figure 34—
Transverse TVS of cervix showing multiple
Nabothian cysts arranged around the cervical canal.

Figure 35—
Sagittal TAS showing 20 week fetus together with

Figure 35—
Sagittal TAS showing 20 week fetus together with
8 cm echo-poor cervical fibroid.

Cervical Fibroid

Cervical fibroids are uncommon, accounting for 8% of the total, the majority being in the uterine body. Most are small and asymptomatic with the same ultrasound features as the uterine fibroids described earlier in this chapter. However, when large, cervical fibroids may be symptomatic due to their mass effect by producing either bladder compression with urinary frequency or in the pregnant patient by causing obstruction to labour, (Figure 35). MRI may be of value in clearly defining the position and size of the fibroid, particularly in late pregnancy where ultrasound may not provide adequate visualisation of a cervical mass.

Figure 36—
Transverse TVS of cervix showing a small cervical
polyp within a fluid-filled cervical canal.

Cervical Polyp

Clinically, cervical polyps are asymptomatic or present with intermenstrual bleeding. These polyps are benign and develop from hyperplastic cervical epithelium which results from chronic cervitis. The polyps are generally small, measuring less than 1 cm, and appear echogenic ultrasonographically (Figure 36). They may be pedunculated and, occasionally, may prolapse into the vagina where they may be mistaken for pedunculated endometrial polyps or pedunculated submucosal fibroids. Occasionally, colour flow Doppler may demonstrate a vascular pedicle.

Cervical Carcinoma

Cervical carcinoma is the second commonest female malignancy in the UK with 4000 new cases per year. This disease is often associated with multiple sexual partners from an early age and, as such, is increasing in frequency. Both cervical carcinoma and the pre-invasive forms are associated with the human papilloma virus and herpes simplex type 2 virus. The average age of diagnosis is 45 years but, increasingly, younger women are involved. Histologically, 90% are squamous cell carcinomas arising from the ectocervix, with 10% being endocervical adenocarcinomata. Other forms of tumour are very rare.

The diagnosis is generally made clinically and histologically with many patients being identified by the national screening programme. Carcinoma-in-situ is a pre-cancerous condition and can be regarded as curable. Patients with advanced disease present with abnormal uterine bleeding whether intermenstrual or post-menopausal and/or with a vaginal discharge.

The tumour spreads via the lymphatics to the parametra and to local pelvic lymph nodes. Subsequently, there will be spread to the iliac and para-aortic lymph nodes. The tumour metastasises haematologically to the liver and lungs but this is a late occurrence. Due to the close proximity of the tumour to the ureters, entrapment and invasion are common. This leads to hydroureter and hydronephrosis with subsequent uraemia. Nephrostomy or ureteric stenting may be required in order to delay the onset of renal failure.

Although transvaginal and transrectal ultrasound may be of value in the staging of cervical carcinoma, [39] MRI must be regarded as the gold standard. Clinical

Although transvaginal and transrectal ultrasound may be of value in the staging of cervical carcinoma, [39] MRI must be regarded as the gold standard. Clinical staging and MRI may be combined in the management of the disease. The well-accepted FIGO staging is detailed below.

Stage	0	–	Carcinoma-in-situ
Stage	I	–	Carcinoma confined to cervix
	IA	–	Micro-invasive (only diagnosed histologically)
	IB	–	Clinically invasive carcinoma confined to cervix
Stage	II	–	Carcinoma extends beyond the cervix but has not extended to the pelvic side wall. The carcinoma involves the vagina but not the lower third
	IIA	–	No obvious parametrial involvement
	IIB	–	Obvious parametrial involvement
Stage	III	–	Carcinoma has extended to the pelvic side wall and/or the lower third of the vagina
	IIIA	–	Lower third of the vagina involved
	IIIB	–	Extension to pelvic side wall and/or hydronephrosis, (Figure 37)
Stage	IV	–	Carcinoma has extended beyond the true pelvis and/or has clinically involved the bladder or rectum
	IVA	–	Biopsy proves bladder or rectal tumour
	IVB	–	Distant metastases beyond the pelvis

Generally stage I and IIA tumours will be treated surgically with our without adjuvant radiotherapy. Stage IIB and more advanced tumours will generally be treated with radiotherapy whether external, intra-cavitary or both.

Ultrasound Appearances

Early tumours will not be ultrasonographically identifiable. Slightly more advanced tumours may be evidenced by cervical enlargement with a variable alteration in echotexture. At this stage, the tumour may be mistaken for a cervical fibroid.

Figure 37—
Pathology specimen of stage three carcinoma of
cervix.

Irregularity of the cervical margin suggests parametrial invasion. Generally the uterine body and endometrial canal will appear normal. However, when cervical stenosis results from tumour infiltration of the cervical canal, an obstruction of the cervical canal and endometrial cavity may result in a collection of fluid, (Figure 38). Generally the amount of fluid in the cervical canal is small, although more significant collections may occur in the uterine cavity and a pyometra or haematometra may develop. Regional lymphadenopathy
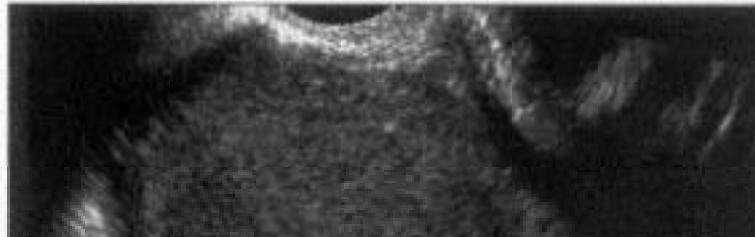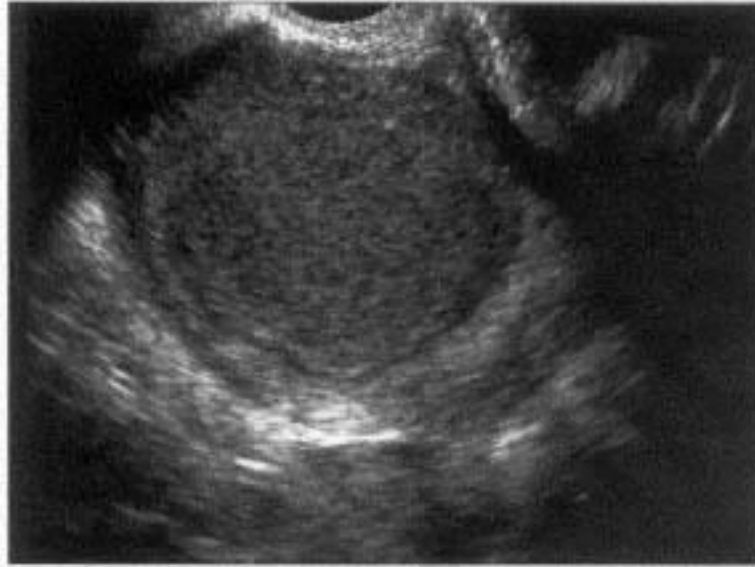
Figure 38—
Haematocolpos resulting from cervical stenosis
following radiation treatment for cervical carcinoma.
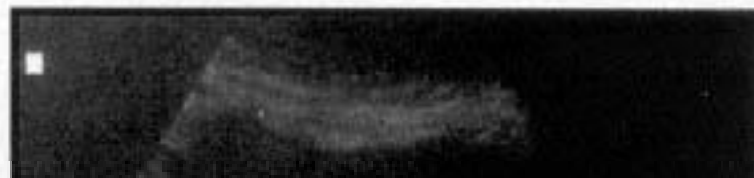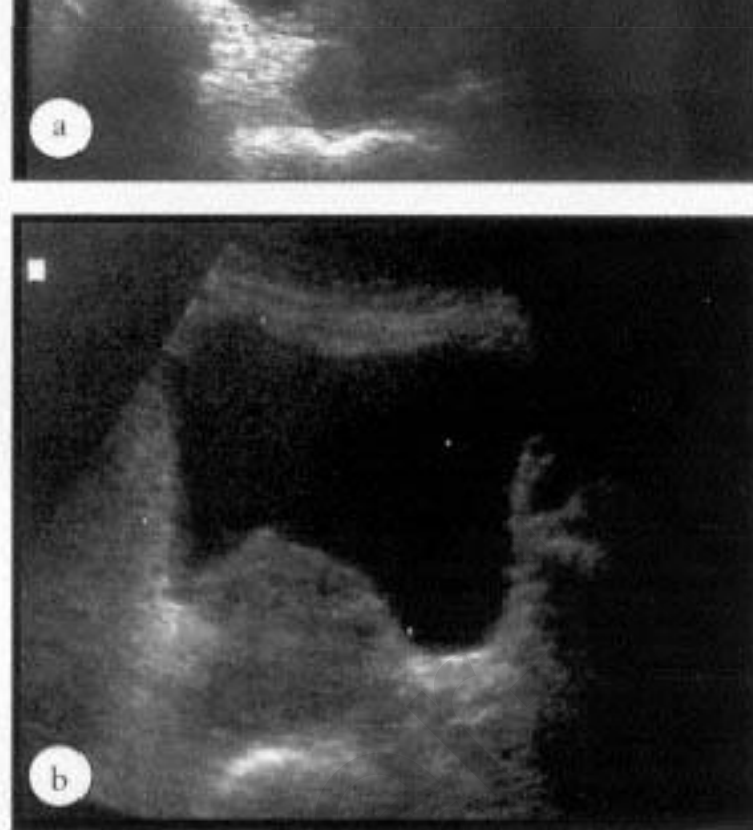
Figure 39—
a) Sagittal TAS showing irregular echo-poor
pelvic mass invading the bladder due to recurrent
cervical carcinoma post-hysterectomy.
b) Transverse TAS, the same patient.

may be apparent with enlarged pelvic lymph nodes being best visualised transvaginally. The examination should be extended to the upper abdomen in order to visualise the kidneys to check for hydronephrosis. The para-aortic area should be examined for lymphadenopathy and the liver examined for metastatic disease.

Hydrometra and pyometra may be seen either at the time of diagnosis, post-treatment or, in the elderly patient, often many years after the successful treatment of the disease. Fluid collects in the uterine cavity due to chronic cervical narrowing, in part due to radiation damage, but also due to cervical atrophy relating to the patient's age, (Figure 38). Advanced primary or recurrent disease may present with haematuria and urinary symptoms and ultrasound may show evidence of bladder invasion by the tumour, (Figures 39a,b).

Thus it can be seen that ultrasound is of no value in the diagnosis of early disease. MRI is used for staging in preference to CT where the soft tissue contrast is poor ,although CT may be of value in assessing for lymphadenopathy. MRI is generally superior to ultrasound in follow-up imaging post-treatment, although ultrasound is of course excellent for the diagnosis of hydronephrosis.

Cervical Stenosis

Aetiology

- malignancy – cervical carcinoma
  – endometrial carcinoma
- iatrogenic – cone biopsy
  – post radiotherapy
  – obstetric trauma
- post-menopausal atrophy
- benign utero-cervical pathology
  – polyp
  – fibroid

The causes of cervical stenosis are varied and a full clinical history is often required in order to elucidate. However, whatever the cause, the clinical picture and the ultrasound appearance is likely to be similar. When obstruction allows a significant amount of fluid to collect within the endometrial cavity, according to the type of fluid, the appearance is variously named as follows:

- hydrometra – serous fluid
- haematometra – blood
- pyometra – pus

In the case of pyometra, if gas forming organisms are the cause of infection, then gas may be seen in the uterine cavity. Generally however, it is not possible to distinguish the type of fluid with ultrasound.

Uterine Fluid Collections

Uterine Fluid Collections

- infancy and childhood

        – hydro/haematometrocolpos

- physiological

        – menstruation

        – post-menopausal

- pregnancy   – normal early pregnancy

        – ectopic

        – haemorrhage

        – retained products of conception

- post instrumentation

- cervical stenosis (see above)

- intra-uterine pathology

        – endometrial carcinoma

        – endometrial hyperplasia

        – endometrial polyp

- PID   – endometritis

Ultrasound Appearances
• uterine enlargement
• distention of the endometrial cavity with fluid
• ± distention of the cervical canal
• the fluid may contain internal echoes, debris or fluid-fluid levels or gas, (Figure 40)
• an associated tumour mass may be apparent, i.e., endometrial carcinoma outlined by fluid.
When the reason for the uterine fluid collection is benign, then dilation of the cervical canal is a relatively straightforward procedure which will allow drainage

When the reason for the uterine fluid collection is benign, then dilation of the cervical canal is a relatively straightforward procedure which will allow drainage of the uterine contents. However, where malignancy is involved, appropriate further investigations will be required prior to treatment.

Figure 40—
Sagittal TAS showing intracavity gas and
pyometra related to cervical stenosis following
treatment for cervical carcinoma.

The Vagina

Vaginal pathology is generally recognised and investigated clinically. However, vaginal abnormalities are often diagnosed coincidentally at ultrasound examination, generally transabdominally, as the vagina is not well visualised transvaginally due to its close proximity to the probe.

Air may be visible in the vagina following instrumentation or sexual intercourse. This has the typical appearance of gas and is seen as flashing bright echogenic foci in the upper vaginal vault, (Figure 41) and may outline the cervix, as seen in axial section. Similarly, an air containing tampon may be visualised in the vagina transabdominally at ultrasound as a strongly reflective lower structure producing acoustic shadowing, (Figure 42).

A vaginal pessary used in the treatment of uterine prolapse will be readily identified transabdominally, the superior and inferior margins of the ring being seen in the upper vagina on a sagittal section and the two lateral margins of the ring being seen in an axial plane. The ring will produce strong acoustic shadowing, (Figure 43a,b).

Bladder calculi may ulcerate into the upper vagina and may be apparent. Vaginal calculi may develop de novo in association with a vaginal stricture or septum and may also be related to urinary incontinence. These calculi have a typical echogenic appearance with acoustic shadowing.

Vaginal Fluid Collections

A small collection of fluid is not an uncommon finding at transabdominal ultrasound. This is most commonly seen at the time of menstruation. In a small child, small

Figure 41—
Sagittal TAS showing the vaginal vault containing
air following instrumentation.
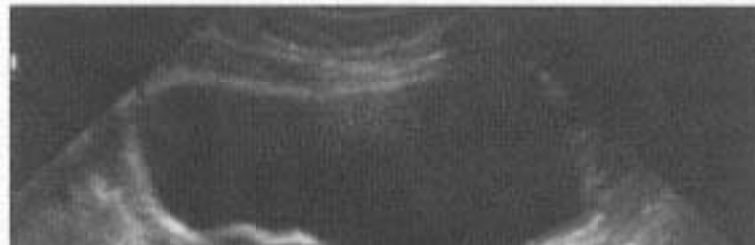
Figure 42—
Sagittal TAS showing echogenic linear vaginal
tampon producing acoustic shadow.

amounts of urine may occasionally be visualised following micturition. In the adult, urinary incontinence, a urinary fistula or an ectopically sited ureter may result in urine pooling in the vagina. Occasionally, extravaginal fluid collections, such as paravaginal haematoma or urethral cyst, may compress the vagina and give the erroneous impression of a vaginal fluid collection.

Haematocolpos

Obstruction of the vagina will allow collection of fluid within. This usually occurs in young women postmenarche whereby the monthly menstrual blood collects in an obstructed vagina. The obstruction may lie distally at the level of the introitus due to an imperforate hymen, or may result from a more proximal vaginal atresia, stenosis or the presence of a vaginal septum. These patients generally present with cyclical, low abdomimal pain and amenorrhea, lasting for some years after the expected date of the menarche. A lower abdominal mass may also be present. A similar condition is sometimes seen in the infant or young child, and has been diagnosed antenatally. In this group of patients, the influence of the maternal hormones may be partially responsible for the condition. When haematocolpos is associated with an anomaly of the genital tract a thorough examination of the urinary tract is essential, as in approximately a third of cases a renal anomalies may be expected. Unilateral renal agenesis or renal ectopia are the most likely anomalies to be found.

Ultrasound Appearances

A medium to large sized cystic mass may be seen lying centrally in the lower abdomen. It should generally be
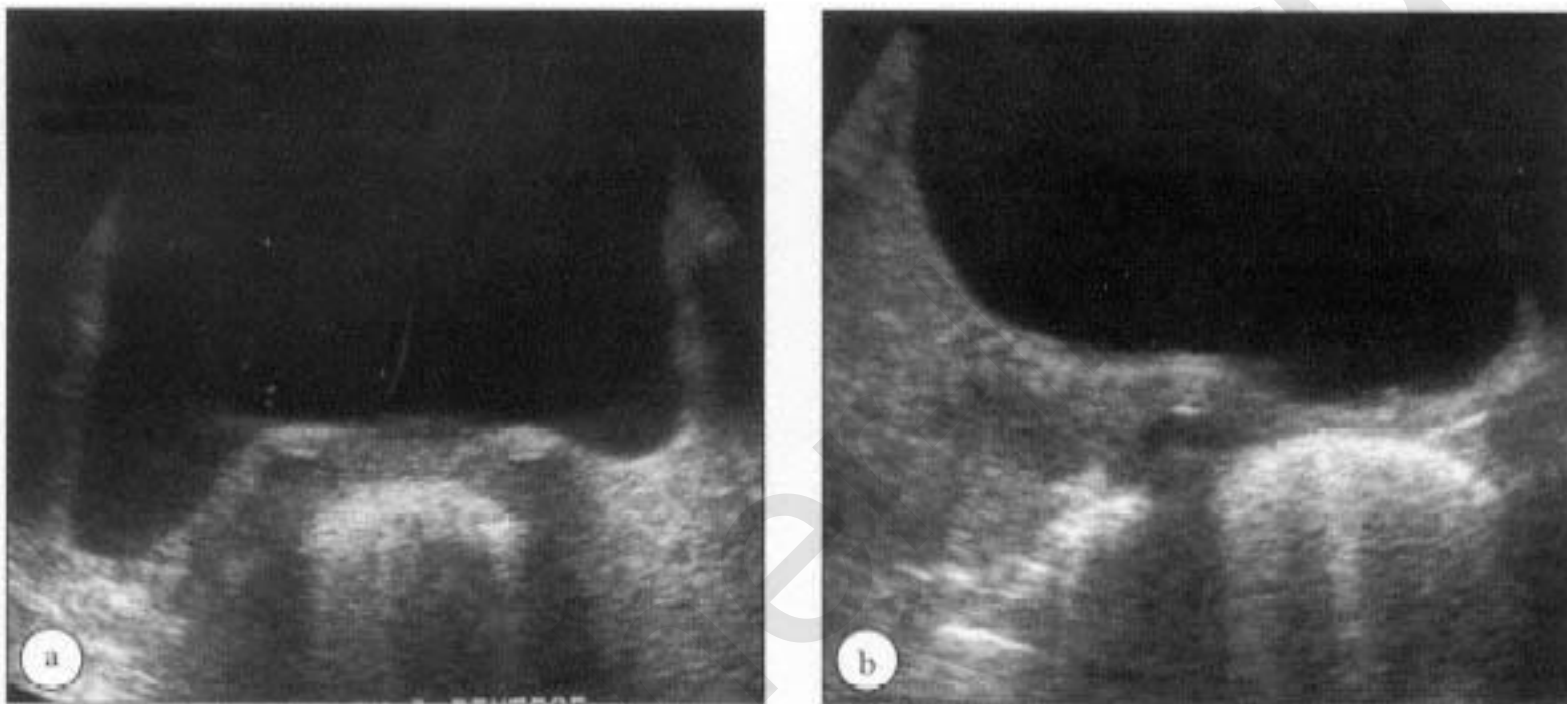
Figure 43—
a) Transverse TAS showing vaginal ring pessary producing acoustic shadowing. b) Sagittal TAS showing small post-menopausal uterus and ring pessary in vagina.
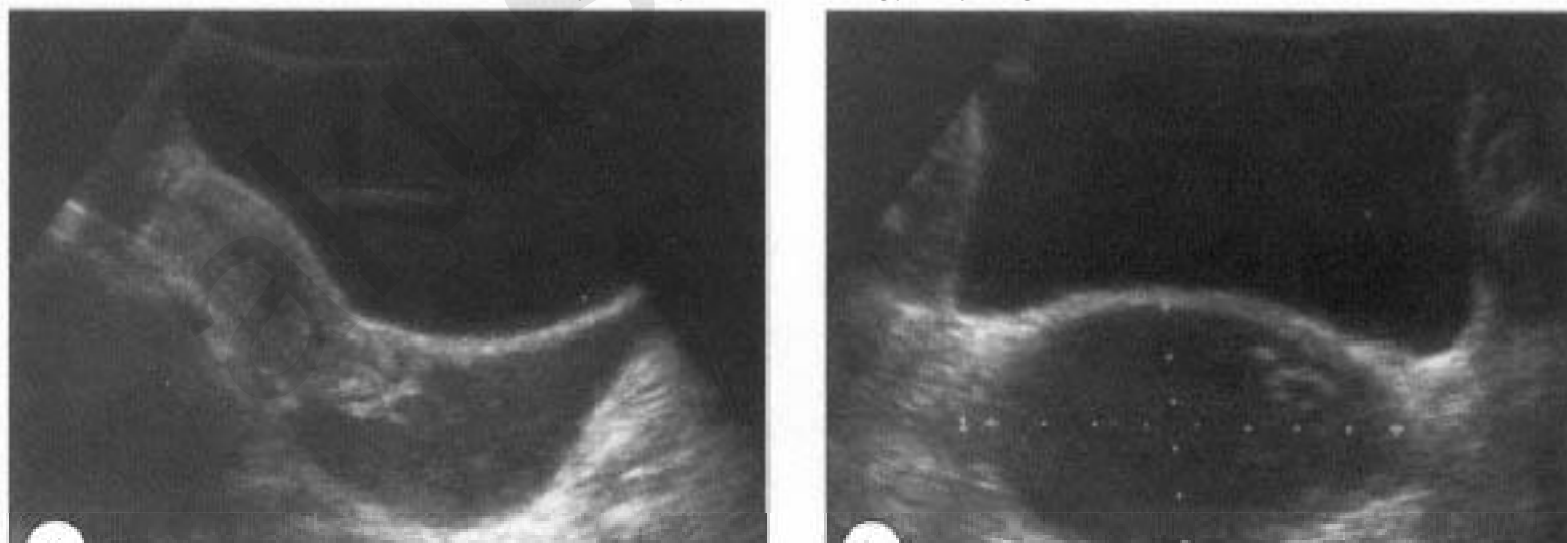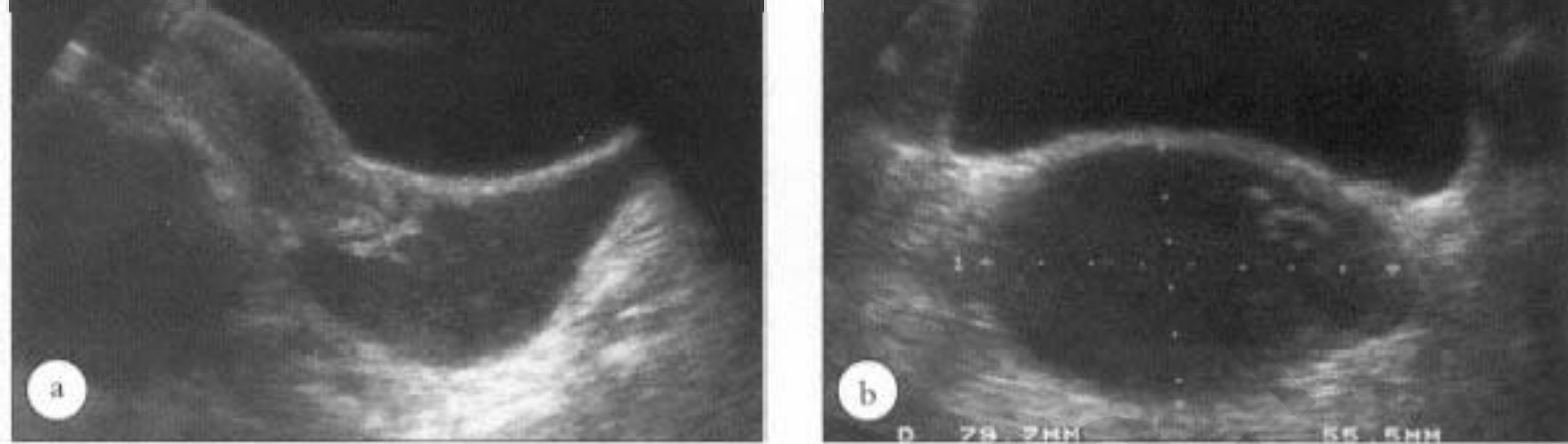
Figure 44—
TAS *a)* Sagittal, — Haematocolpos due to distal vaginal septum. Echogenic fluid present in the upper vagina and outlines the cervix. The uterus is normal. *b)* Transverse view of fluid-distended upper vagina.

possible to demonstrate continuity with the uterus and, indeed, the fluid may outline the ecto cervix, (Figure 44a,b). The mass has a thin wall and may contain fine internal echoes due to the presence of altered blood. The appearance of the fluid may be very similar to that of an endometriotic cyst. Translabial ultrasound may be of value in demonstrating the length of the stenotic segment from the introitus. [40] MRI is also of value in this situation, with the information obtained allowing for accurate planning of reconstructive surgery.

Gartner's Duct Cyst

These are the commonest vaginal cysts and are usually asymptomatic. They are most commonly observed when ultrasound is being performed for another reason. These cysts arise from vestigial remnants of the mesonephric or Wolffian duct symptoms.

Ultrasound Appearances

These cysts are generally small but may measure up to 5 cm in diameter and occasionally may be multiple. Gartner's cysts may outline the ectocervix, (Figure 45) or, when large, bulge through the introitus, in which case an erroneous diagnosis of haematocolpos may be made. Ipsilateral renal agenesis is an association and thus the kidneys must always be examined.[41]

Vaginal Tumours

These rare tumours occur in the elderly, accounting for only 1-2% of gynaecological malignancies. Risk factors include radiation for cervical carcinoma and vaginal ring pessary. In the younger patient, a history of maternal treatment for recurrent miscarriage with diethylstilbiestrol should be sought. The majority of vaginal tumours (90%) are squamous cell carcinomata, with adenomacarcinomata and melanoma being much less common. The majority of these tumours present with vaginal bleeding. As the majority appear in the upper vagina, the ultrasound appearance is similar to that of cervical carcinoma. Bladder invasion may be demonstrated. Generally, however, ultrasound is not particularly helpful and these tumours are best staged with MRI.

Rhabdomyosarcoma, a rare sarcomatous tumour of childhood developing from the vagina, always presents before the age of five years and is discussed further in Chapter 9. The child will generally present with a lower abdominal mass and pv bleeding. Tumour growth is very rapid with early invasion of the uterus, bladder and other pelvic organs. The ultrasound appearances are variable

Figure 45—
Sagittal TAS Gartner's cyst. Fluid in the upper
vagina outlines the cervix.

bu,t generally, a large complex cystic pelvic mass is apparent.[42] Even at the time of diagnosis, hydro-ureter and hydro-nephrosis may be present. This tumour is best staged with MRI.

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5—

Pathology of Ovaries, Tubes and Adnexae, and Non-Gynaecological Pelvic Pathology

Louise Gaunt

Introduction
Clinical presentation
Benign physiological cysts
Benign ovarian lesions of mixed echogenicity
Benign solid ovarian tumours
Ovarian malignancy
Polycystic ovaries
Endometriosis
Pelvic inflammatory disease (PID)
Diseases of the Fallopian tubes
Pelvic manifestations of non-gynaecological disease
Intervention in ovarian pathology
Conclusions

Introduction

Throughout life, from puberty to the menopause and beyond, the ovaries are subject to a regular cycle of change. Much of the pathology of the ovaries is related to this cyclical change, or is a manifestation of related local disease, e.g., endometriosis involving the ovaries as well as the adnexae. This chapter discusses the manifestations of benign and malignant ovarian pathology and presents a strategy for the pre-operative diagnosis of these lesions.

Clinical Presentation

The clinical manifestations of ovarian disease are often reflected in changes to the menstrual cycle or present as infertility. Ovarian malignancy, however, is very often not clinically manifest until an advanced stage of disease, when the prognosis is poor, with approximately 30% 5 year survival for advanced disease. The prognosis for early disease is much better with five year survival for stage 1 disease reaching 80% - 85%. Screening for ovarian malignancy is covered in Chapter 6.

Clinical Presentations of Ovarian Disease

• Pain — either constant or cyclical.

• Menstrual irregularity.

• Infertility / sub-fertility.

• Dyspareunia.

• Abdominal distension - local effect or ascites.

• Incidental finding - clinical or ultrasound examination.

Pain — constant pain is less frequent as a presenting symptom than either cyclical or intermittent pain and dyspareunia. Cyclical pain related to menstruation suggests endometriosis with cyclical bleeding into an endometrioma. Dyspareunia may be related to an ovarian cyst in the pouch of Douglas, or local disease in the pelvis, e.g., endometriosis or pelvic inflammatory disease.

Menstrual disorders — ovarian disease may lead to changes in cycle length and development of amenorrhoea, or present as oligomenorrhoea in the case of polycystic ovary syndrome.

Infertility / sub-fertility — ultrasound of the ovaries is important early in the investigation of infertility, as many cases are directly related to ovarian problems, e.g., polycystic ovary syndrome, where appropriate treatment can be instituted.

Abdominal distension — this may be due to either gross enlargement of either a benign or malignant ovarian lesion, or to the presence of ascites. However, in my experience the clinical request `Abdominal distension? ovarian cyst', has a very low diagnostic yield as there are usually clinical indicators of ovarian disease associated with the generalised distension.

Ovarian pathology may present as an incidental finding with no related symptoms either during a pelvic examination for unrelated reasons, or more frequently, as a chance finding during an ultrasound examination for unrelated pathology. This chance finding may be either a fortuitous early diagnosis of an ovarian malignancy or present a clinical dilemma, such as how to manage a small simple cyst in a post-menopausal woman?

When a patient presents with a clinical history suggesting ovarian disease it is important to have the following clinical information to allow a full examination to be performed and to enable a correct interpretation to be made from the findings in relation to the clinical history:

Necessary clinical information

• Patient's age.

• Date of last menstrual period plus length of cycle.

• Presenting complaint, e.g., pain, menstrual irregularity.

• Menstrual status — pre or post-menopausal.

• Oral contraceptives / Hormone Replacement Therapy.

• Oral contraceptives / Hormone Replacement Therapy.

• Past gynaecological history.

• History of previous gynaecological surgery.

Examination Technique

Both transabdominal and transvaginal examinations are valuable in the diagnosis of ovarian and adnexal pathology. The transabdominal examination with a full urinary bladder is very useful for assessing overall pelvic anatomy, determining position of the ovaries, and demonstrating any distant pathology which may not be visualised by a transvaginal scan, e.g., ascites, para-aortic nodal disease, hydronephrosis or pleural effusions. However, detailed examination of ovarian morphology and the detection of blood flow to ovarian masses is more accurately performed via the transvaginal route. Associated manual palpation with the non-scanning hand to bring the ovaries into the field of view may prove necessary. There is no contra-indication to transvaginal examination in the post-menopausal patient, although extra care with transducer lubrication may be required in the presence of atrophic vaginal mucosa.

Using ultrasound, information about both the structure and physiology of the lesion may be obtained by assessing the morphology with grey-scale, then obtaining information about the blood flow to the affected ovary with both Colour flow and pulsed wave Doppler.

Benign Physiological Cysts

Follicular Cysts

The most frequently encountered ovarian mass lesion is the simple cyst. Cysts can be demonstrated in the ovaries at all ages, and have been detected ante-natally, even as early as 19 weeks. Post-menopausal cysts are also frequently seen, with approximately 15% of post-menopausal women examined with ultrasound demonstrating benign simple cysts. The first question to answer on detecting a small unilocular fluid filled structure within the ovary is whether this is a physiological phenomenon i.e., a developing follicle, or is it a pathological entity i.e., a follicular cyst?

Size will help in determining this - most follicles will rupture when between 20-25 mm in diameter. A useful rule of thumb is anything over 3 cm in diameter may be considered pathological.

Follicular cysts are the result of a mature follicle failing to ovulate, and have a smooth, thin wall, and contain clear fluid. Typical ultrasound appearances are of a thin walled, unilocular cystic structure containing hypoechoic fluid. Size varies from 3 cm upwards, but follicular cysts rarely attain sizes of greater than 10 cm. The natural history is for resolution over 2-3 cycles, and repeat ultrasound in the next cycle will usually show complete resolution or reduction in size.

Blood flow may not be detected within the cyst wall, and when detected will show a high impedance waveform, [1] (Figure 1).

Corpus Luteal Cysts

These can present with more complex ultrasound appearances. The corpus luteum has been described as the great imitator of ovarian pathology, a fact which should be borne in mind when examining the ovaries of all women of menstrual age. The corpus luteum is formed after rupture of the mature follicle, undergoing a series of changes during the luteal phase of the cycle, leading to the menstrual stage at the end of a normal cycle. The four stages of development of the normal corpus luteum are; proliferation, vascularisation, maturity and regression. If this final phase does not occur a corpus luteal cyst will develop. During normal evolution of the corpus luteum it begins as a hypoechoic structure, with an irregular inner wall, and may contain some internal echoes. Normal size attained is 15 - 20mm,
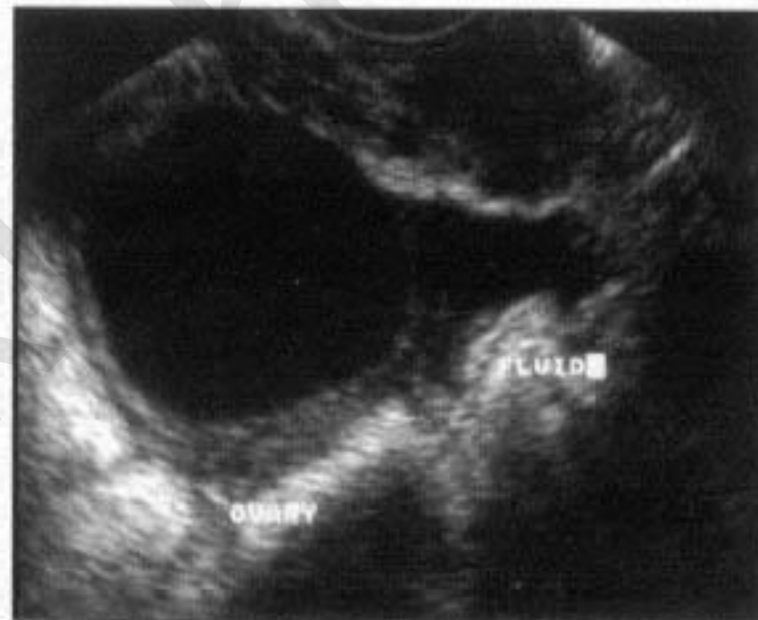
Figure 1—
Follicular cyst - a 4 cm diameter unilocular thin
walled cyst. There is no evidence of internal echoes
or septation. There is a small volume of free fluid
adjacent to the ovary.

although it may become as large as 30 mm. in diameter. Haemorrhage occurs in up to 60% of cases, and this can produce a solid-looking or complex mass. The presence of free fluid does not help in the determination of the cause of the lesion as there is usually fluid in the pouch of Douglas following ovulation. The volume of fluid is greater than that released from the follicle, and is felt to be due to hormonally regulated secretion from the ovarian surface.

When the final, or regression phase, fails to progress a persistent corpus luteum then exists. This may be as large as 10 cm in diameter, and have a variety of appearances, with both cystic and solid inner components. Septae and papillae may be observed, both of which can be considered features of malignancy. This can make the accurate diagnosis of malignancy in menstruating women difficult.

Blood flow studies of corpus luteal cysts do not help resolve the problem of benign versus malignant lesion, due to the physiology of the luteal phase of the cycle. The impedance to flow in the ovarian arteries decreases during the luteal phase, much of this decrease being related to angiogenesis in the corpus luteum, so in a persisting corpus luteum there will be low impedance flow giving easily demonstrated vessels on colour flow with low pulsatility and resistance indices on pulsed wave Doppler.[2]

If a lesion is suspected of being a persistent corpus luteum rather than an ovarian malignancy, a repeat ultrasound in six weeks is advised to assess if there has been resolution of the lesion. Disappearance or reduction in size of greater than 50% of the previously measured volume indicates the lesion is benign and functional rather than of more sinister nature. (Figures 2-4)
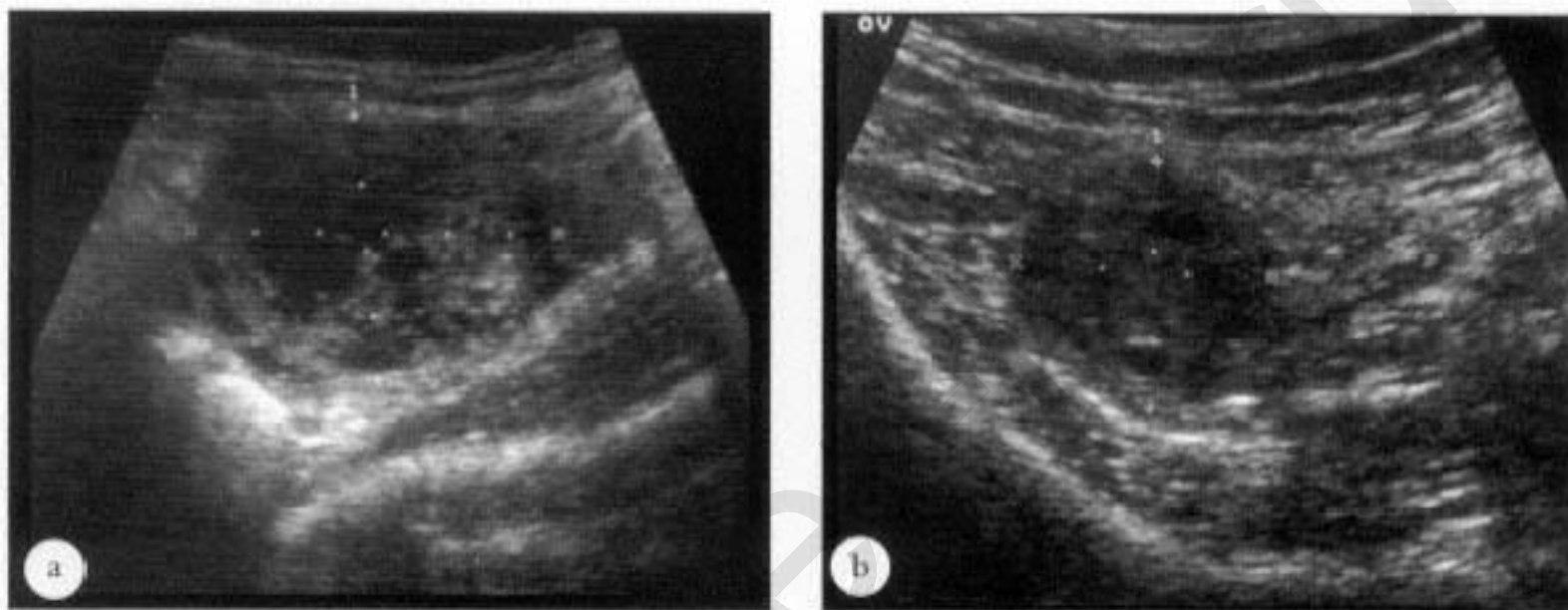
Figure 2—
a) A 4 cm diameter mixed echogenicity mass in the right ovary of pre-menopausal, post-hysterectomy patient, with right iliac fossa pain. Clinical assessment of the stage of her cycle is not possible due to her hysterectomy. Ultrasound appearances are compatible with a corpus luteal cyst. b) Repeat examination six weeks later when the patient is pain free. The right ovary has returned to normal, confirming the previous diagnosis of a corpus luteal cyst.
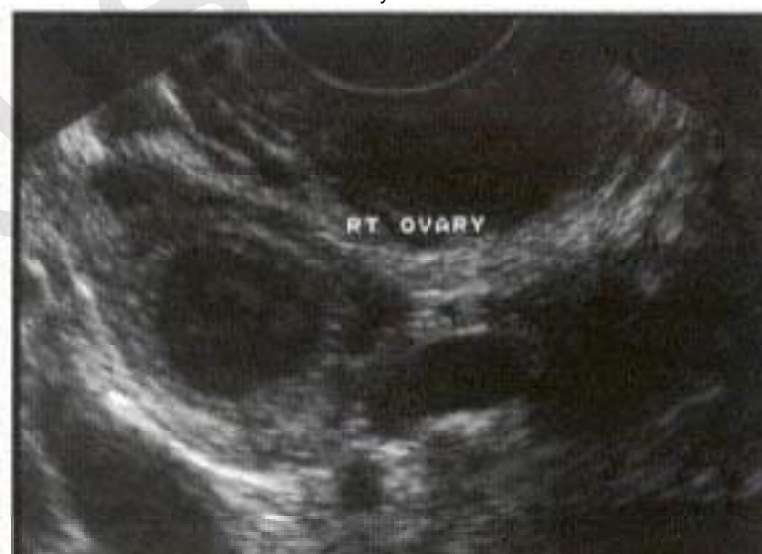
Figure 3—
A small corpus luteal cyst demonstrating an
irregular internal cyst wall with an internal echogenic
focus compatible with
recent haemorrhage.

Benign Ovarian Lesions of Mixed Echogenicity

Mucinous Cystadenoma

Of the benign ovarian tumours this is the most common, and tends to occur in the younger age group, which is one distinguishing factor from ovarian malignancy.

It usually has a slow, insidious onset, and may be extremely large at presentation, appearing as a pelvic mass or abdominal distension. When very large, the tumour may arise from a thin pedicle and therefore be likely to undergo torsion, presenting as an acute abdomen, due to either tumour infarction or haemorrhage into the mass.

Pathology of the mass shows a large, single cystic space containing semi-solid mucus. There is usually a local thickening of the cyst wall which contains multiple smaller cysts in a thickened fibrous stroma. These smaller cysts also contain mucus. The cause of these cysts is unknown, as the cells lining the cyst are not typical of normal ovarian cells, raising the possibility that the cyst is a form of ovarian metaplasia.

Occasionally, the cyst may rupture with leakage of the mucin into the peritoneal cavity. There may also be seeding of leaked cells onto the peritoneum, leading to multiple small foci of mucin production, causing dense adhesions around peritoneal structures. This state is called pseudomyxoma peritonei, and although all due to benign disease, carries a relatively poor prognosis due to the local complications of bowel and urinary tract obstruction.

Ultrasound Appearances

The mass can usually be examined by the transabdominal route, as it may be several centimetres in diameter at presentation. There may be a small amount of free fluid around the tumour, but not the volume of ascites associated with an advanced ovarian neoplasm. There will be a large single component, with a relatively thin

Figure 4—
32 year old woman with recurrent right iliac fossa pain, post hysterectomy. *a)* A small haemorrhagic corpus luteum. *b)* Doppler studies show high impedance flow throughout the cardiac cycle. The appearances are in keeping with flow in a corpus luteum in the vascular phase of development.

wall and low echogenicity centre reflecting the mucus content of the major cyst. Due to the viscid nature of the mucus there may be a degree of layering

wall and low echogenicity centre reflecting the mucus content of the major cyst. Due to the viscid nature of the mucus there may be a degree of layering within the cystic component, with a more reflective layer posteriorly. Occasionally, papillary projections into the major cyst component may be seen. It is usually possible to demonstrate the local wall thickening with related small cyst formation. The tumour may also be bilateral.

Blood Flow Characteristics

Due to the presence of thickened intratumoural stroma, blood flow can be detected in the centre of a mucinous cystadenoma, as well as flow within peripheral vessels. Of all benign ovarian tumours, mucinous cystadenomas are probably the most difficult to categorise as benign on both morphological and blood flow criteria, as they have mixed appearances on ultrasound and also show abnormal blood flow patterns.

In up to 60% of cases vessels can be detected with colour flow Doppler in the solid elements of the cyst walls of mucinous cystadenomas. When flow is detected it tends to be of low impedance with values of RI as low as 0.4 [3] and PI of less than 1.0.[4] These are values also seen in malignant ovarian lesions, therefore, often blood flow studies will not help in the prediction of benign disease. However, the size of mucinous cystadenomas alone and the associated risk of complications e.g., rupture or torsion, are indications for surgery whether ultrasound suggests the lesion is benign or malignant, (Figure 5).

Serous Cystadenoma

This is also a lesion of younger, pre-menopausal women, but is less common than the mucus cystadenoma.

They are usually bilateral, and may be large, measuring up to 10 cm in diameter. Pathologically there is a single cyst containing clear fluid but with multiple small papillae projecting from the inner cyst wall. The cysts grow relatively slowly, and do not usually attain the same size as a mucinous cystadenoma. There is a tendency to rupture, allowing peritoneal seeding of the papillary debris, which then goes on to form multiple small papules around the peritoneum, usually accompanied by ascites.

True carcinoma develops more commonly in serous than in mucinous cystadenoma.

Ultrasound Appearances

Unilateral, or bilateral, predominantly cystic mass with some internal projections. If septation or daughter cyst formation occurs the walls are thin, apart from areas of papillary formation. If there has been leakage from the
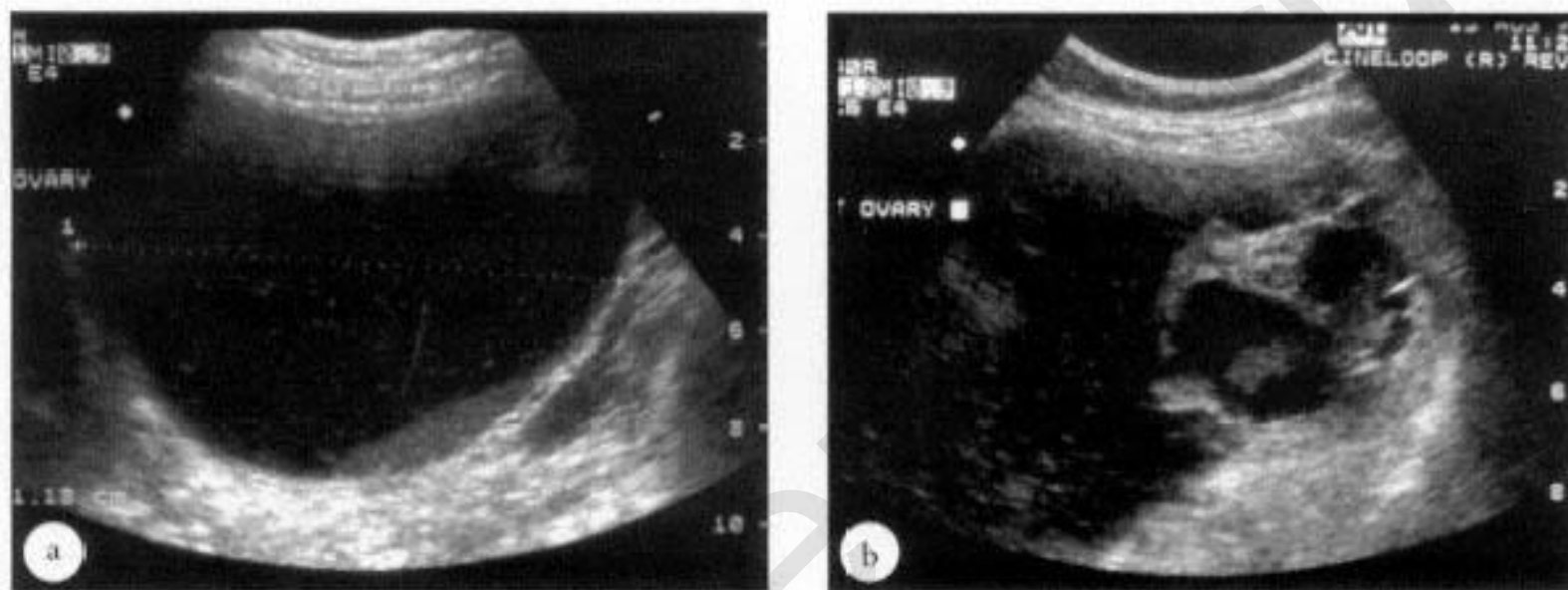
Figure 5—
A large clinically palpable mass arising from the pelvis extending to the level of the umbilicus in a 20 year old girl. *a)* 11 cm diameter cyst with a thin, regular wall, with no evidence of internal papillary projections. The cyst fluid contains multiple tiny particles which are seen layering on the posterior cyst wall. *b)* A group of smaller cysts close to the lateral wall of the mass. No flow was detected in the solid elements or the cyst walls. The ultrasound appearances are those of an ovarian mucinous cystadenoma. The combination of the patient's age plus no blood flow within the lesion suggested benign rather than malignant pathology, despite the morphology. Due to its size the mass was removed. Histology confirmed the ultrasound diagnosis of a benign cystadenoma.

cyst the mass will be accompanied by ascites. These features on morphological grounds will point to a malignant rather than benign lesion.

Blood Flow Characteristics

Flow may not be detected at all or, if seen, be of high impedance indicating a benign lesion. However, approximately 30% of cases will show either high peak systolic velocities (greater than 16 cm/sec) [5] or low pulsatility index, (less than 1.0). Both of these parameters are typically felt to be indicative of malignancy, therefore the pre-operative diagnosis of benign disease may be difficult on ultrasound alone.

Ovarian Teratoma/Dermoid

These fall into two categories, the cystic and the solid types. Cystic are much more common than solid, with the commonest being benign dermoid cysts. In common with teratomas arising elsewhere in the body, ovarian teratomas have all cell types within them except gonadal tissue. Cystic teratomas vary greatly in their cellular complexity, although epidermal structures e.g,. sweat glands, sebaceous glands and hair are the commonest. If there is a solid component it will contain teeth, bone, cartilage, smooth muscle, alimentary tract glandular tissue and very occasionally nervous tissue and mammary glands. When

These fall into two categories, the cystic and the solid types. Cystic are much more common than solid, with the commonest being benign dermoid cysts. In common with teratomas arising elsewhere in the body, ovarian teratomas have all cell types within them except gonadal tissue. Cystic teratomas vary greatly in their cellular complexity, although epidermal structures e.g,. sweat glands, sebaceous glands and hair are the commonest. If there is a solid component it will contain teeth, bone, cartilage, smooth muscle, alimentary tract glandular tissue and very occasionally nervous tissue and mammary glands. When composed entirely of thyroid tissue, the mass is known as a struma ovarii. Diagnosis on abdominal radiographs is not uncommon, due to either the fat content or the demonstration of teeth within the pelvis.

Ultrasound Appearances

Due to the complexity of the tissues within a teratoma the ultrasound appearances are also very complex. Echogenicity within the mass is a common finding, with the following three ultrasound patterns suggesting an ovarian dermoid:

1) An echogenic mass within a relatively echo-poor cystic structure.

2) Echogenic particles within a low echogenicity fluid background, producing a `mesh-like' appearance

3) Cyst with a fat-fluid level.

Caspi *et al*[6] have produced a simple classification for ovarian dermoids, based on these three criteria, which in their series allowed accurate diagnosis in 97.45% of cases. They divided the group with an echogenic mass into three sub-groups to allow more detailed analysis of tumours that contained an echogenic mass, as they form the majority. Their sub-divisions are:

1A — The borders of the echogenic mass are all clearly defined.

1B — The majority of the border of the echogenic mass is visible.

1C — Only the anterior border of the echogenic mass is visible.

Sub-group 1B was shown to be the commonest appearance on ultrasound, occurring in approx. 60% of cases analysed. The group with a fat-fluid level was the least

Figure 6—
27 year old woman three days
post-appendicectomy Ultrasound was indicated
as her pain had not improved
post-operatively. transvaginal ultrasound revealed
an enlarged right ovary containing two well
defined echogenic foci, with little evidence of
acoustic shadowing. The appearances are
typical of a type 1A ovarian dermoid cyst (the
borders of the echogenic foci are visible all round).
Histology confirmed the ultrasound diagnosis.

frequently seen, appearing in only 3.4% of cases. Acoustic shadowing, which accompanies all types, occurs in 81%. Almost half of the cases investigated demonstrated more than one echo-pattern. They felt that the presence of an acoustic shadow plus one of the other echo patterns should strengthen the diagnosis of ovarian dermoid. Doppler studies were added towards the end of their series, where they were able to detect flow in all the masses investigated, showing an RI of greater than 0.4, which they considered as indicative of benign disease. (Figures 6 and 7.)

Benign Solid Ovarian Tumours

Granulosa Cell Tumour

This tumour is so called because it contains cells which resemble granulosa cells in Graafian follicles. The cells secrete oestrogens and show changes of luteinisation. The tumour is usually unilateral and well encapsulated. They may be small measuring only a few millimetres in diameter, up to approximately 5 cm across. The mass is usually solid but may contain multiple tiny cysts. Granulosa cell tumours can occur at any age but are most frequent after the menopause. Due to their hormone secreting effects, they may present as post-menopausal bleeding, due to endometrial hyperplasia.

Figure 7—
a) 2.5 cm well-defined echogenic focus in the left ovary.
b) Vessels leading into the centre of the mass.
c, Spectral Doppler shows flow of moderate impedance.
Ultrasound diagnosis - features characteristic of a dermoid.
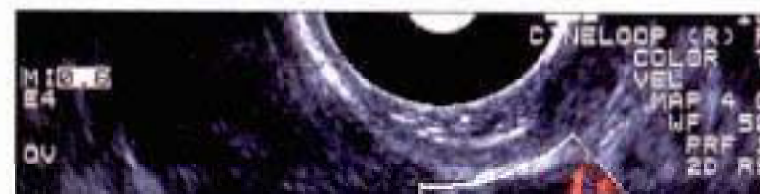
Prolonged unopposed oestrogen on the endometrium may lead to the development of endometrial carcinoma. When granulosa cell tumours occur in childhood the hormonal effects can lead to precocious puberty .

Fibroma of the Ovary

This is one of the commonest solid ovarian tumours. The mass is hard, may be slightly nodular, and can be quite large, typically measuring 5 - 10 cm in diameter. It may have a pedicle which will predispose to torsion and strangulation, especially when the tumour is large. Fibromas are the commonest ovarian tumour to be related to Meig's syndrome which presents as weight loss, ascites and a right sided pleural effusion. These appearances may lead initially to a diagnosis of metastatic ovarian malignancy. The extra-ovarian features of Meig's syndrome resolve after removal of the ovarian tumour. (Figure 8.)

Brenner Tumour

This is a rare, benign, solid tumour of the ovary, and may vary in size from a few millimetres to 20 cm in diameter. It is firm and of uniform density, and on initial examination resembles a fibroma. It is slow growing, and often may be discovered by chance during examination of the pelvic organs for an unrelated reason. They only rarely show evidence of hormonal activity.

Ultrasound Appearances

All of the solid, benign ovarian tumours have similar ultrasound appearances, as they all present as well defined solid masses of relatively uniform echotexture, which is of greater echogenicity than the surrounding ovarian tissue. The diagnosis is usually made by the patient's age and presenting symptoms i.e., Meig's syndrome suggests a fibroma, hormonal effects suggest a granulosa cell tumour, and no symptoms suggest a Brenner tumour.

Blood Flow Characteristics of Solid Ovarian Tumours

The detectable blood flow tends to vary with the nature of the lesion, which probably reflects the cell type of the mass. However, as solid ovarian tumours are relatively uncommon, there is not a great deal of information in the literature to suggest a typical blood flow pattern. It would seem though that most fibromas do not exhibit flow at all, and when flow is detected it is of high impedance, in keeping with the benign nature of the lesion. [7],[8]

Ovarian Malignancy

The commonest form of ovarian malignancy is epithelial carcinoma, although sarcomas and germ cell tumours do occur. Ovarian carcinoma is the commonest malignancy

Figure 8—
Typical ultrasound appearances of an ovarian
fibroma. The tumour is solid with small blood vessels
within it.

of the female genital tract, and is the fourth commonest cancer in women in England and Wales. It is the cause of 5% of all new cancers per annum, and accounts for 6% of cancer deaths in women per annum. As previously stated the prognosis is poor, despite improvements in treatment, with 5 year survival for all stages of disease of approximately 30%, although survival is much better for early disease. The incidence rises with increasing age and increased affluence, both of which are felt to have contributed to the increased incidence over the last 20 years. Some of this increase may be spurious, due to more accurate death certification allowing more accurate disease classification. This is balanced by a decreasing incidence in the under 50 age group, which is felt to be related to the use of oral contraceptives. There may be a rise in the future as many women are less willing to take combined oral contraceptives because of the apparent risks of thrombo-embolic diseases and increased risk of breast cancer.

Are there specific risk factors related to the development of ovarian malignancy?

Yes, it is thought the underlying cause is related to longer periods of ovulation, a theory which is supported by the following apparent risk factors:

1) *Parity* — the risk of developing ovarian cancer decreases with rising numbers of pregnancies.

2) *Age at which first birth occurs* — the risk is increased if the first child is born after the age of 35.

3) *Duration of menses* — risk is increased with early menarche and late menopause.

4) *Ovulation induction.*

5) *Family history.*

6) *Oral contraceptives* — use of combined oestrogen / progesterone preparations which stop ovulation appear to have a protective effect.

What is currently understood of the natural history of ovarian cancer?

There are several theories relating to the development of ovarian malignancy, but no single factor has been identified. It has been suggested the cancer may arise from an inclusion cyst, as there are increased numbers of inclusion cysts in ovaries showing malignant change in comparison with non-malignant ovaries. A further suggestion is there may be abnormalities in the epithelium of the ovary. This is based on studies of identical twins, where one has developed ovarian cancer and the other twin is shown to have abnormal ovarian surface epithelium. There is no clear evidence that unequivocally benign cystadenomas undergo malignant change, but there is a group of both serous and mucinous cystadenomas of borderline malignancy, some of which may go on to develop frank malignancy. Such change is more common in the serous type. There is also evidence that malignancy may arise in foci of endometriosis; this is of two cell types - endometrioid and clear cell carcinomas. It is thought that 15 - 20% of all ovarian endometrioid cancers arise in pre-existing endometriosis.

Familial Ovarian Cancer

The main gene to be isolated that is known to be related to ovarian cancer is the BRCA-1 gene which is situated on chromosome 17. It is also one gene implicated in familial breast cancer, and indeed the two malignancies form a hereditary syndrome. The defect is autosomally dominant and may be passed down both the male and females sides of the family, which explains the apparent "missing" of some generations, which have no female offspring to express the gene. (Screening for ovarian cancer is dealt with in Chapter 6).

Ultrasound Diagnosis of Ovarian Cancer

Many ovarian cancers present late in the course of the disease and the first indication for investigation may be increasing abdominal distension with associated weight loss. The distension is due to a combination of one or more large ovarian masses plus ascites. Suspicious looking mass lesions may be seen by chance, raising the possibility of opportunistic early diagnosis of ovarian malignancy. Ovarian malignancies tend to be more complex than benign lesions and may contain several different sonographic features within one lesion. Simple cystic ovarian carcinomas are very rare, but can occur. Typical sonographic features suggesting malignancy are:.

1) *Size* — malignancies tend to be larger than benign lesions, although an early stage 1 or 2 lesion will be small and well contained within the ovary.

2) *Complexity of the mass* — this can be divided into the following areas:

a) *Cyst wall* — typically the walls of a malignant cyst are thickened (greater than 3 mm.), have irregular contours and may have papillary projections into the cyst itself.

b) *Intra-cystic septation* — this again will show thickening and irregularity.

c) *Solid elements* — irregular mass lesions projecting from the cyst walls, which may contain echogenic foci. These foci are not as dense or well defined as the densities seen in dermoids, and do not have areas of calcification. (Calcification may develop in malignant masses after local radiotherapy or systemic chemotherapy.)

d) *Mixed echogenicity cyst fluid.* This may be confused with haemorrhage from a benign lesion, although haemorrhage may also occur into malignant cysts.

3) *Ascites* — this is a common finding with advanced disease due to peritoneal metastases although ascites can occur with benign tumours (Meig's syndrome).

Blood Flow Characteristics

Blood flow is usually easily detected in the majority of ovarian malignancies. Difficulties may arise due to compression of tumour vessels in the presence of a

Blood flow is usually easily detected in the majority of ovarian malignancies. Difficulties may arise due to compression of tumour vessels in the presence of a very tense cystic component or tense ascites. Vessels in tumours are characteristically more primitive than normal vessels, and have decreased smooth muscle content in their walls. Decreased vascular tone ensues, which leads to decreased vascular impedance. Consequently, tumours in all parts of the body, including ovarian carcinomas, have high velocity, low impedance blood flow, with forward flow throughout the cardiac cycle, and decreased pulsatility and resistance indices. (Figure 9). There is evidence that the degree of flow increases with increasing malignancy, the greatest volumes and velocities of flow being recorded in tumours that have metastasised to the ovaries (Krukenburg tumours). There is no fixed value below which malignancy can be accurately predicted, although an RI of 0.4 or lower and a PI of 1.0 are suggested as values likely to give a high positive predictive value with a low false negative value.

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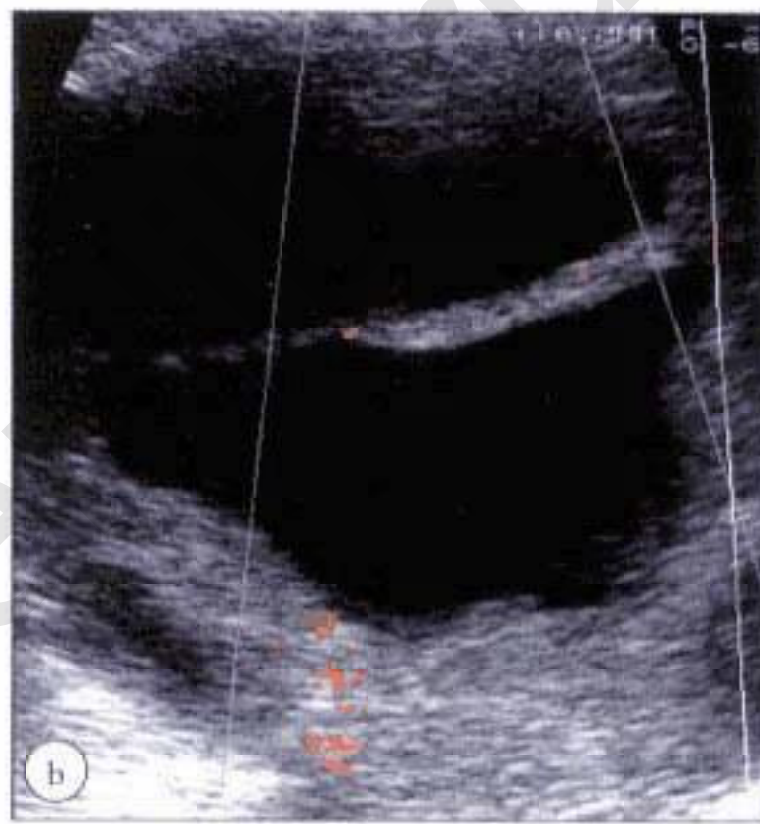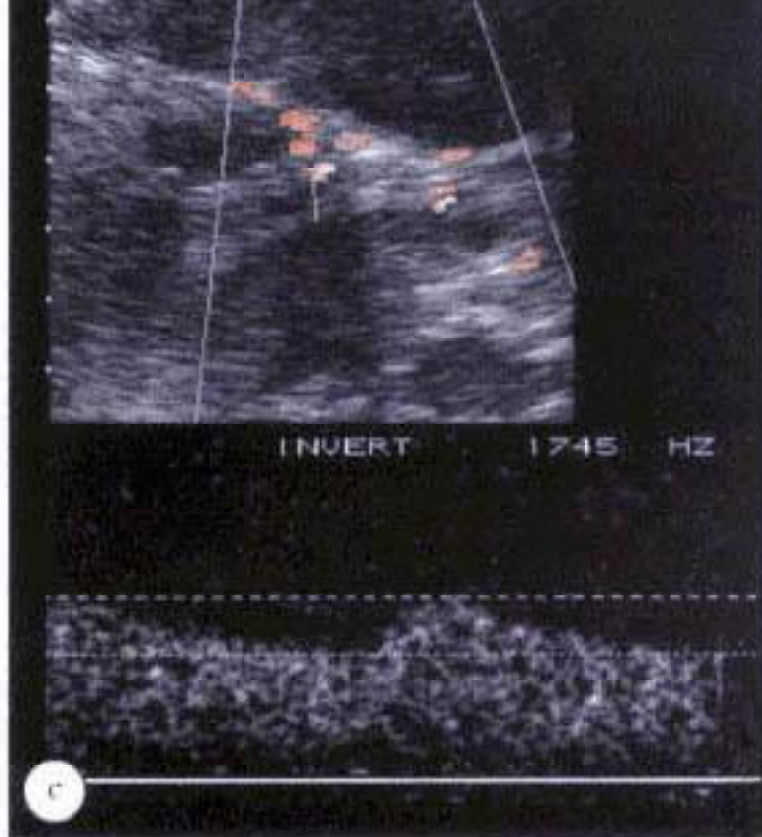
Figure 9—
a) TVS of an ovarian carcinoma showing a solid component within a predominantly cystic mass.
Blood vessels are seen within the solid material. *b)* Thickened septum in an ovarian carcinoma, demonstrating
small blood vessels. *c,* Typical low resistance flow from within an ovarian carcinoma.

Assessment of Spread of Malignancy

More than 80% of epithelial ovarian cancers will have metastasised by the time of diagnosis. Even apparently small tumours may have widespread associated disease. Spread occurs in three ways - lymphatic, haematogenous and, most importantly, spread across the peritoneum with tumour nodules appearing on the peritoneal surface. The actual mechanism of spread appears to be two fold, with both diffusion of cells within peritoneal fluid and migration of tumour cells in response to chemo-attractive agents playing a part in tumour dissemination. Once a small colony of cells have attached to the peritoneum new vessels are formed which invade the peritoneum and allow continued growth of the secondary deposits. One of the peritoneal responses to this is the production of extra fluid leading to the development of ascites.

On ultrasound these changes will manifest as ascites plus multiple peritoneal nodules, which are much easier to see in the presence of a large amount of intra-peritoneal fluid. Very advanced disease may also have lymphadenopathy, with both the internal iliac and para-aortic nodes being involved. The two groups of nodes are involved due to the dual blood supply and subsequent lymphatic drainage of the ovary. The main blood supply comes via the ovarian artery which is a branch from the aorta, arising just below the level of the renal arteries. There are also small vessels to the ovary from the uterine arteries, which arise from the internal iliac arteries. Metastases may also occur in the liver and spleen. There may also be pleural involvement, with small pleural effusions being easily detected with transabdominal ultrasound.

Ultrasound Prediction of Pathological Nature of an Ovarian Lesion.

The most frequently asked question on demonstrating an ovarian or adnexal mass lesion is, *Is this an ovarian malignancy?*

Unfortunately, we do not yet have a simple, reliable non-invasive way of answering this question with a high degree of confidence. Several methods have been advanced for the determination of whether a lesion is benign or malignant. The data and current thinking on each of these methods is reviewed below, and a strategy for the clinical and ultrasound assessment of ovarian lesions is developed.

The major methods in current use are:

1) Tumour markers - the main one in common use being CA 125.

2) Morphology assessment using high resolution grey scale ultrasound.

3) Assessment of blood flow and vascular impedance using both colour flow and pulsed wave Doppler ultrasound.

CA 125

This is the most extensively studied of the tumour markers associated with ovarian cancer. It is a glycoprotein, which was first described in 1981, which occurs in small amounts in many healthy adults, being secreted by pleura, pericardium, peritoneum, fallopian tube epithelium, endometrium and endocervical tissue. All these are derived from either the Müllerian duct system or from coelomic epithelium. A level of 35 U/ml or greater is considered pathological, and raised levels will be found in 78% of all ovarian cancer sufferers. However, levels may also be raised above 35 U/ml in benign ovarian lesions, as well as with other non-ovarian pathologies, e.g. pancreatic, breast, lung and colorectal cancer, pregnancy, endometriosis and PID. Raising the cut off to 65 U/ml does not decrease the detection of ovarian malignancy but does decrease the number of false positives. As a sole screening agent for the diagnosis of ovarian malignancy it is not accurate enough. CA 125 assessment, does however, play a part in the assessment of disease response to chemotherapy, as falling levels indicate reduction in tumour size and activity, and rising levels after successful treatment indicate disease recurrence. It is also useful in the pre-operative assessment of post-menopausal women with an ovarian mass lesion, as a raised level plus a mass in a post-menopausal woman carries a much higher chance of being due to an ovarian malignancy than in a pre-menopausal woman. It is known though that the incidence of ovarian cancer is much greater in post-menopausal women, therefore is this fact surprising ?

Ovarian Morphology

Several different methods for the assessment of ovarian morphology have been advanced in an attempt to give a numerical score which will predict benign or malignant disease. All of the systems devised are based around the assessment of the following parameters: wall thickness, inner wall structure,

Several different methods for the assessment of ovarian morphology have been advanced in an attempt to give a numerical score which will predict benign or malignant disease. All of the systems devised are based around the assessment of the following parameters: wall thickness, inner wall structure, characteristics of septae and echogenicity of the lesions. Sassone *et al.* in 1991 [9] demonstrated a reasonable degree of accuracy in separating benign from malignant lesions, but there was considerable overlap between the two groups, due to the highly variable appearances of many complex benign lesions. The prediction of malignancy was accurate, but there were too many false positives in the benign group, which diminished the scoring system's effectiveness. Work was then done by Lerner, Timor-Tritsch *et al.* [10] to assess if weighting some of the parameters would

improve accuracy. From analysis of the Sassone scoring system as applied to their study population they were able to show that wall thickness was not significant, but two new variables, acoustic shadowing and papillae, were. Therefore, these were added, producing improved accuracy in diagnosis of dermoids with acoustic shadowing, and more accurate diagnosis of malignancy with papillae. Table 1. shows the system suggested.

They assigned a score of three or more as a cut off for determining if a lesion was benign or malignant. This produced a sensitivity of 96.8% and specificity of 77%, PPV for malignancy of 29.1% and NPV of 99.6%.

This shows that despite adding a weighting to the various ultrasound features there is still considerable overlap, but with high accuracy for the prediction of benign disease.

Other systems have been advanced, but there does not seem to be a simple numerical scoring system which will accurately differentiate benign from malignant disease. Purely cystic lesions and very complex obviously malignant lesions may be predicted with a high degree of accuracy, but lesions which have morphology lying between these two extremes are much more difficult to classify.

Blood Flow Assessment with Colour Flow and Pulsed Wave Doppler

The basis for use of these parameters is the presence of angiogenesis and neo-vascularisation within ovarian lesions. Angiogenesis is the formation of new blood vessels under controlled conditions in physiological processes i.e. corpus luteum formation, the response to inflammation and in benign lesions. Neo-vascularisation is the term applied to the uncontrolled development of primitive vessels with very little normal wall musculature which develop in all malignant tumours.

Several studies have shown that no detectable flow in a lesion is a predictor for benign disease, e.g., Chou *et al.* [11] found flow in only 59% of the histologically benign tumours in their study of 108 adnexal masses. Salem *et al.*[4] excluded seven lesions from further study as they were unable to detect flow. All seven proved benign at operation. Anandakumar *et al.*[7] in 1996 found that no flow gave a negative predictive value for malignancy of 91.2%, i.e., if there was no detectable flow in a lesion it was highly likely to be benign. However, there is considerable evidence to show that detection of flow with Colour Doppler does not have the same high predictive value, as in many series flow can be detected in both benign and malignant lesions. There is some evidence to suggest that the site of flow may be helpful, as benign tumours tend to have more flow around the periphery of the lesion, although some benign tumours have flow within the centre. The vast majority of malignant tumours will exhibit flow within the centre of the mass lesion.

With increasing interest in the detection of flow within ovarian mass lesions, attention then turned to evaluation of vascular impedance, based on the fact that tumour vessels have less impedance to flow than normal vessels. The parameters which reflect this are the pulsatility and resistance indices.

The normal flow to the ovaries during the menstrual cycle has been described in Chapter 3. From the previous descriptions, it will be obvious that in pre-

Table 1. – Scoring system for ovarian malignancy.

Parameter	Score			
	0	1	2	3
Wall structure	Smooth / small irregularities less than 3 mm	–	Solid or non-applicable	Papillae of 3mm or greater in thickness
Shadowing	Yes	No	–	
Septa	None or thin < 3 mm	Thick > 3 mm	–	
Echogenicity	Sonolucent or low-level	–	–	Mixed or high

| Echogenicity | Sonolucent or low-level echoes, or echogenic core | – | – | Mixed or high |

menopausal women the examination of flow to the ovary is best assessed early in the cycle to avoid misinterpreting the physiological low impedance flow to the corpus luteum as pathological flow in a tumour.

Initial studies were very enthusiastic about the value of measurement of vascular impedance as a predictor of malignancy, and values were assigned to both RI and PI as suggested cut off points. These values were RI of 0.4 and PI of 1.0. Subsequent studies based on these two figures have not demonstrated the initial high degree of accuracy. In a review of 11 recent papers published over the last three years, there is very little confidence in the ability of blood flow studies alone to predict the presence of malignant ovarian disease. The major problems arise due to the degree of overlap between benign and malignant lesions as expressed as both PI and RI.

Below are values for RI from six different series to demonstrate the degree of overlap between benign and malignant disease, (Table 2).

Due to this marked overlap between benign and malignant blood flow impedance this cannot be used as a useful tool for the pre-operative prediction of malignant disease.

Hata *et al.* [5] studied peak systolic velocity as a marker of malignancy. They found that the intra-tumoural peak systolic velocity increased with increasing malignancy, although there is no set value above which malignancy can be accurately predicted.

In conclusion, therefore, the presence of forward flow through the cardiac cycle, with marked end-diastolic flow, is not a useful marker for distinguishing benign from malignant disease.

Pre-Operative Assessment of Ovarian Lesions

The assessment needs to take into account the following parameters to allow a reasonably accurate prediction of benign versus malignant disease. However, ultimately there is no conclusive method for 100% prediction, and a false positive rate for malignancy must be accepted to allow all cases of malignancy to be detected using current methods. The parameters to be considered are:

1) *Clinical history* — age of the patient (ovarian cancer is unusual in young women but does occur).

2) *Menstrual status* — stage of cycle, pre or post-menopausal.

3) *Clinical examination* — size of the mass lesion, presence of ascites or distant metastases.

4) *Biochemistry* — CA 125 levels.

5) *Ultrasound findings* —

a) *Morphology score* — < 3 = benign, > 3 suggests malignancy. The higher the numerical score, the more likely the lesion is to be malignant.

b) *Doppler studies* — is there flow, and if there is what are numerical values for PI and RI?

Table 2 – Resistance index values in ovarian lesions

Author year	RI (Mean) Benign	Range	RI (Mean) Malignant	Range
Levine *et al* 1994[3]	0.57	0.33 – 0.87	0.47	0.32 – 0.66
Anandakumar 1996[7]	0.62	0.44 – 0.80	0.46	0.3 – 0.6
Hata *et al* 1995[5]	0.56	0.39 – 0.74	0.49	0.37 – 0.61
Hamper *et al* 1993[12]	0.77	0.31 – 1.09	0.5	0.27 – 0.67

Hamper *et al* 1993[12]				
Brown *et al* 1994[8]	0.62	0.34 – 0.90	0.39	0.25 – 0.50
Chou *et al* 1994[11]	0.68	0.36 – 0.89	0.41	0.18 – 0.68

Taking all these parameters into consideration, an accurate prediction can be made as to the nature of the lesion. The final diagnosis can only be made on histology, but one of the major contributions of ultrasound to clinical management is in the prediction of those lesions which are benign and may safely be treated either conservatively or by laparoscopic aspiration if symptomatic.

Post-Menopausal Patients

There has been a considerable degree of interest recently in the management of ovarian lesions in post-menopausal patients. In the past, before imaging of the female genital tract was widespread, the clinical approach to an ovarian mass in a post-menopausal patient was that this should be considered malignant until proven otherwise, and the standard treatment was abdominal hysterectomy and bilateral oophorectomy. This resulted in many operations being performed for benign disease. With increased use of ultrasound in all age groups, there were increasing numbers of ovarian cysts seen in post-menopausal patients, which created a dilemma - what to do with non-symptomatic small ovarian lesions and the possibly enlarged post-menopausal ovary?

Before considering treatment options, we must first define what is normal and what is pathological in the post-menopausal patient. The ovaries undergo atrophy after the menopause, a process which is gradual and takes place over three to five years in most patients. The process will be slowed down or completely stopped in women who are taking hormone replacement therapy. The ovaries may be difficult to image using both transabdominal and transvaginal examination with series quoting detection rates in transvaginal scanning as low as 46%, [13] although 60 -70%[14] demonstration rate for both ovaries is felt to be more realistic. Does it matter if the ovaries are not demonstrated ? Opinion on this is divided, although the feeling at present is that if the ovaries cannot be visualised using high resolution transvaginal technique then it is unlikely that there is significant i.e., malignant pathology related to the ovaries. Views also vary as to the value of measuring dimensions of the ovary alone or assessing total ovarian volume. Campbell *et al*.[15] used ovarian volume in their series of post-menopausal women, other groups have used dimensions without volume calculation. The suggested volume above which pathology should be suspected has still not been agreed — Campbell *et al* found a volume of 4.33 cm^3 ± 1.91 (SD), where as Gollub and colleagues[13] and Merz *et al*.[14] found ovarian volumes of 3cm^3, decreasing to 2.5 cm^3 at more than five years post-menopause.

It is the present author's opinion that if the morphology and blood flow are in keeping with normal ovaries or benign disease then the absolute volume is probably less important, and if there is doubt then a repeat scan in three months to assess if there has been an increase in ovarian volume would be an acceptable approach, combined with measurement of CA 125 level.

Small simple cysts are frequently found with either clinical examination or pelvic ultrasound for another reason. The incidence of such cysts in a group of post-menopausal women with no additional risk factors for ovarian malignancy appears to be between 14 and 17%.[16] There is now evidence to suggest that if a cyst smaller than 5cm in diameter is morphologically benign, (i.e., hypoechoic, thin walled, without any mural irregularities, and has high impedance blood flow) with a serum CA125 of less than 35 U/ml, it can be managed conservatively, with regular follow-up at three monthly intervals. The natural history for such cysts is that they either remain the same size or gradually reduce in size. An increase in dimensions or development of internal echoes would be an indication for surgery. The length of time for follow-up has not yet been determined, but 2-3 years appears reasonable, combined with serial CA 125 estimations (Figure 10).

Concern has been expressed in the past regarding the morbidity from pelvic masses due to the risk of torsion, haemorrhage or rupture. There does not appear to be an increased risk of complications in small post-menopausal ovarian cysts, therefore, conservative management again would appear reasonable. Parker *et al*.[17] evaluated the use of laparoscopic oophorectomy in post-menopausal women, and they concluded that if a lesion were felt to be benign on imaging this was an acceptable alternative to open oophorectomy, and had the advantage of delivering a complete ovary to the pathologist rather than just fluid from an aspirated cyst, as there is a small false negative rate from cytology of cyst fluid for the diagnosis of malignancy.

In conclusion the suggested management plan for small cysts in a post-menopausal woman is conservative treatment with regular ultrasound and CA 125 estimation for a period of no less than 2 years. Surgery is indicated if there is an increase in size of the cyst, change in morphology or blood flow characteristics, or elevation in the CA 125 level.

Polycystic Ovaries

Polycystic Ovaries

Polycystic ovaries alone must be distinguished from the polycystic ovary syndrome as described by Stein and Leventhal. Polycystic ovaries (PCO) may be seen on ultrasound in approximately 20% of normal women.[18] Polycystic ovary syndrome (PCOS) occurs when there
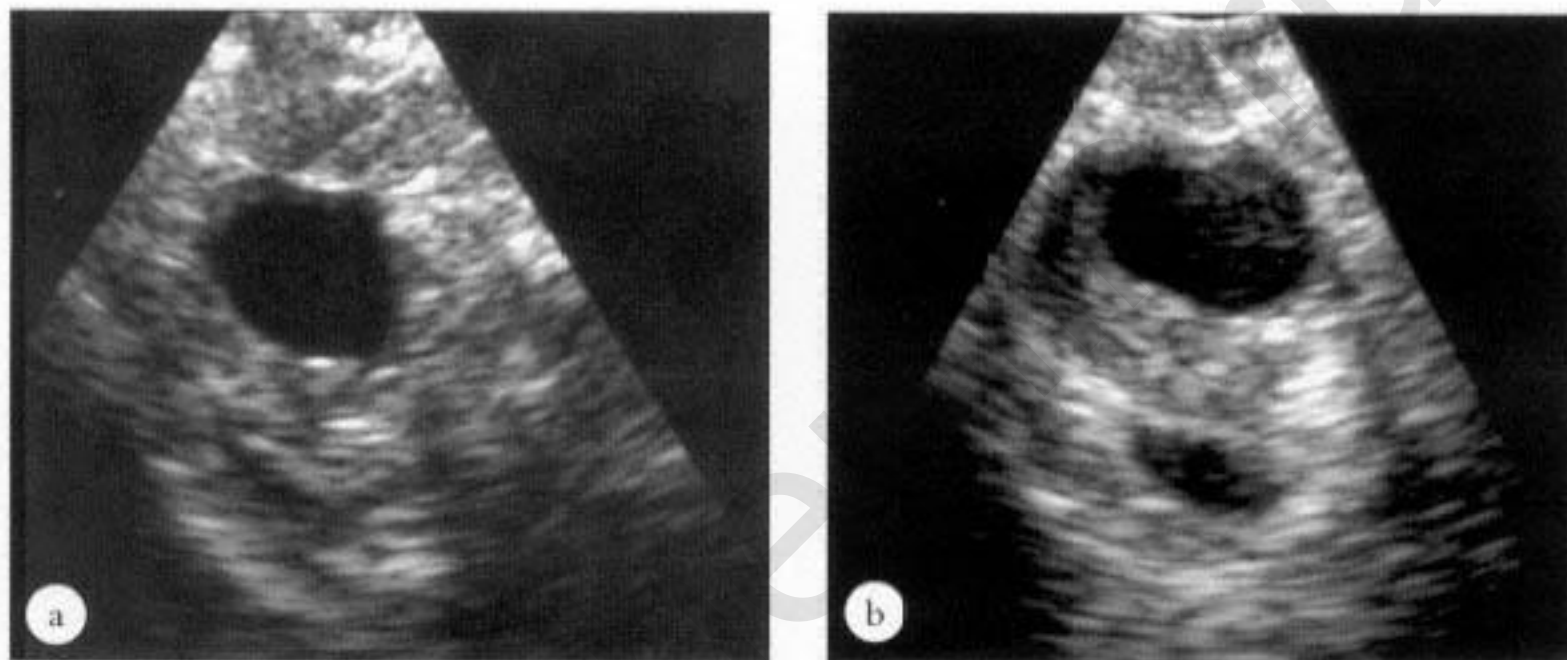
Figure 10—
Two examinations six months apart in a post-menopausal woman with severe lung disease rendering anaesthetic potentially hazardous. *a)* First examination revealed a small simple "inclusion" cyst in the left ovary. No internal echoes, septations or papillae were seen. High impedance flow on Spectral Doppler. CA 125 level below 35 U/ml. *b)* Repeat examination six months later the cyst has not changed in size. Blood flow was now difficult to detect and appeared to have decreased. CA 125 levels remain low. The patient is now on 6 monthly follow-up.

is hormonal disturbance plus abnormal ovarian morphology, leading to a clinical syndrome characterised by obesity, hirsutism, amenorrhoea/oligomenorrhoea and infertility. The cause of PCO and PCOS is not fully understood, but there is evidence to suggest a genetic component as demonstrated by Hague *et al.* [19] who found PCO in 91% of first degree relatives of women with PCOS. The hormonal changes associated with PCOS are increased levels of luteinising hormone (LH), decreased levels of follicle stimulating hormone (FSH), and increased levels of circulating androgens. This combination of hormones leads to decrease or cessation in ovulation plus the development of obesity and hirsutism.

Ultrasound Appearances of Polycystic Ovaries

The ovaries will appear the same on ultrasound whether there is clinical evidence of PCOS or not. This has important consequences in the investigation and management of non-ovulatory patients without hormonal evidence of polycystic ovary syndrome. Finding abnormal ovarian morphology does not always provide the correct diagnosis.

The ovaries will appear the same on ultrasound whether there is clinical evidence of PCOS or not. This has important consequences in the investigation and management of non-ovulatory patients without hormonal evidence of polycystic ovary syndrome. Finding abnormal ovarian morphology does not always provide the correct diagnosis.

Typical ultrasound features:

1) Increased ovarian volume - usually 2-4 times the expected normal for age.

2) Increased echogenicity of ovarian stroma. This may be assessed by comparison with the adjacent myometrial echogenicity, as normal ovarian tissue should be hypoechoic when compared with myometrium. In PCO the stroma is of similar or increased echogenicity when compared with myometrium.

3) Multiple small cysts - these may be arranged either around the ovarian periphery (rosary pattern) or be scattered throughout the stroma.

In obese patients the demonstration of the ovaries may be difficult on transabdominal examination, therefore it is recommended that wherever possible a patient with suspected polycystic ovaries should have a transvaginal scan to allow conclusive visualisation of the ovaries and more accurate assessment of ovarian morphology.

The degree of hormonal disorder is not related to either the size of the ovaries or the number of cysts.[20] The vascularity of polycystic ovaries is different from normal ovaries, in that there is low impedance flow detectable throughout the menstrual cycle.[21] This has been suggested as another feature to help in the ultrasound diagnosis. However, as the appearance of PCO is not typical for any other pathology routine blood flow studies to confirm the diagnosis are not indicated, (Figures 11-13).

Figure 11—
Polycystic ovaries — 29 year old woman with
irregular periods but no clinical features of PCOS.
Both ovaries are a little enlarged and demonstrate
echogenic stroma with several small cysts scattered
throughout the stroma.

Figure 12
— Incidental finding of polycystic ovaries on ultrasound for pelvic pain. The ovaries show echogenic stroma with multiple small cysts arranged around the periphery of the ovary (rosary appearance). In addition there is a developing follicle in the right ovary confirming normal ovulation.

Endometriosis

Endometriosis is the term given to the presence of endometrial glandular tissue which has migrated outside the endometrial cavity. The development of these lesions is multi-factorial, and there appears to be a genetic component, with associated immunological and
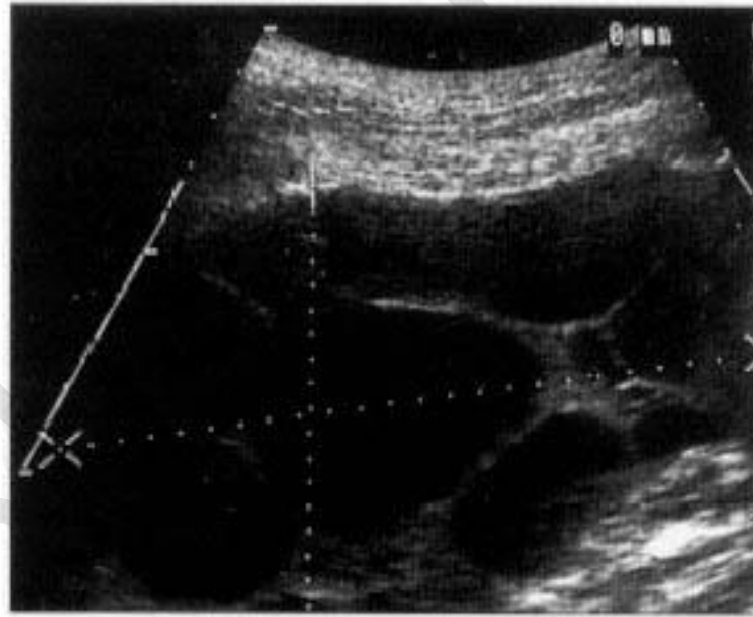
Figure 13—

Figure 13—
Woman with known PCO who conceived naturally.
On clinical examination at 13 weeks of gestation was
found to be `large for dates'. Both ovaries were
enlarged with multiple large cysts and echogenic
stroma between the cysts. There was no history
of follicle stimulation prior to conception. These
appearances therefore appear to be due to the
hormonal effects of pregnancy on PCO.

endocrine factors, to allow the proliferation of tissue outside the endometrium. It is a relatively common condition, occurring in 5% of all women presenting to a gynaecologist. 10-15% of women have disease at laparotomy being performed for other causes, and it occurs in approximately 40% of women investigated for infertility.

How does Endometriosis Occur?

Retrograde menstruation, i.e., the passage of blood from the endometrial cavity into the Fallopian tubes and out into the peritoneum, is thought to occur in the majority, if not all, women and has been observed as a frequent phenomenon at laparoscopy. It is not completely understood why in some women this then goes on to the development of endometriosis. The normal peritoneal response to invasion by cells not native to the endometrium is to incapacitate the foreign cells, destroy them and then remove the dead cells by macrophages. It is suggested that there is a defect in this defence mechanism, possibly at the macrophage stage which does not allow complete removal of endometrial cells. In addition, there may be a component from the peritoneal fluid, as the volumes of fluid in the peritoneum are higher in women with endometriosis as compared with normal controls. Once the cells have colonised the peritoneum they then attach to the peritoneal lining, and there is evidence of a molecular angiogenic agent which stimulates new vessel formation allowing the development of endometrial plaques.

Clinical Presentations

The commonest presenting feature is dysmenorrhoea, occurring in 75 - 80% of all patients with endometriosis. The pain occurs both pre and post-menstrually, and is often progressive in nature.

Pelvic pain occurs in approximately 40% of patients, and varies in both type and severity. The site of pain often does not bear any relation to the major site of disease.

Deep dyspareunia occurs in one third of patients, usually due to deposits on the utero-sacral ligaments.

Other manifestations include spotting, inter-menstrual bleeding and menorrhagia. Cyclical rectal bleeding and haematuria are very uncommon but are pathognomonic when they do occur.

Endometriosis is a disease linked to the reproductive years, and is not found before the menarche, a factor which supports the retrograde flow/implantation theory of development. It is believed to regress after the menopause, but may be reactivated by hormone replacement therapy. All of the current treatment regimes seem to halt progression of the disease but do not produce resolution.

The commonest sites for endometrotic implants are:

• The peritoneum close to the ovaries (this is also close to the fimbrial ends of the tubes, again supporting the retrograde flow/ implantation theory).

• Along the utero-sacral ligaments.

• In the ovarian fossae.

• In the pouch of Douglas.

• Implants may occur elsewhere in the peritoneum, and have been found in extra peritoneal sites, e.g., in the pleural cavity.

Ultrasound Appearances of Endometriosis

The appearances of endometriosis are very variable, and are related to the nature of the disease process, and present a changing pattern of features depending on the stage of the menstrual cycle and the duration of the disease. In the early stages, a pelvic ultrasound may be completely normal. As endometriosis progresses adhesions develop within the pelvis, causing some distortion of the normal pelvic anatomy and, although definite plaques of disease are not always demonstrated, such distortion in a patient with a history compatible with endometriosis should raise the clinical suspicion. The type of distortion to expect is marked retroversion of the uterus, or retroflexion of the fundus of the uterus due to its being tethered by a focus of endometriosis. Due to the presence of disease close to the ovaries one or both of the ovaries, may be pulled down into the pouch of Douglas and appear either closely applied to the uterine wall or be seen deep in the pouch of Douglas. Scanning transvaginally the ovaries can be seen to be fixed and immobile on palpation against the transducer. There is often an increased amount of fluid in the pouch of Douglas in association with any of the above features, or as the sole ultrasound feature. Birnholz [22] described an increase in the overall density of the pelvis, due to diffuse disease, which he attributed to an increase in collagen asa response to continued low grade haemorrhage. This is best seen as loss of clarity of the uterine margins, which is most marked in the pouch of Douglas, (Figure 14). There may be associated increased arterial pulsation as a consequence of increased local vascularity to encourage removal of endometrotic debris from the pelvis. A similar appearance will be seen with acute pelvic inflammatory disease.

Ovarian endometriosis is often described as a separate entity, but in 90% of cases it is the manifestation of a plaque of endometriosis which has implanted on the peritoneal surface of the ovary, and then due to local scarring has invaginated the capsule. It, therefore, is not a true cyst as there is no epithelial lining, and what was thought in the past to be a local rupture of the cyst is, in fact the pore at the mouth of the invagination. The behaviour of these lesions is exactly the same as all other endometrotic plaques, with regular cyclical bleeding and
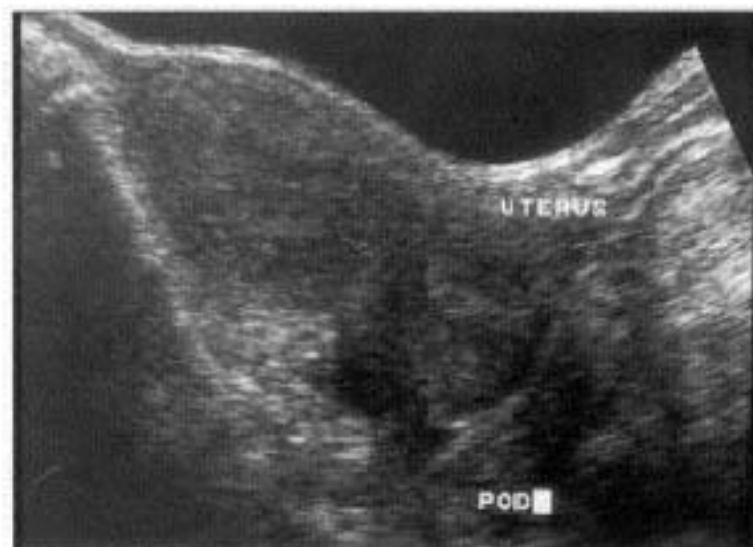
Figure 14—
30 year old woman with a long history of deep
dyspareunia, pelvic pain and irregular menstrual
bleeding. Ultrasound revealed loss of clarity of the
posterior wall of the uterus with a small volume of
free fluid, plus a soft tissue mass in the pouch
of Douglas. Laparoscopy confirmed extensive
endometriosis in the pouch of Douglas and along
the utero-sacral ligaments.
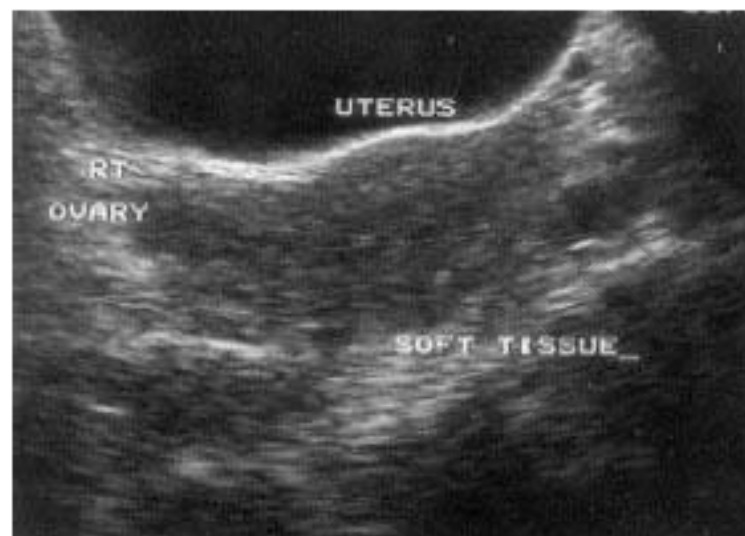
Figure 15—
32 year old woman with a history of severe
dysmenorrhoea and chronic pelvic pain.
Ultrasound demonstrates loss of clarity of the tissue
planes between the ovaries and the uterus, the right
ovary closely applied to the lateral uterine wall and a
definite mass of lower echogenicity than the
myometrium in the pouch of Douglas. The
appearances are those of endometriosis which
was confirmed at laparoscopy.
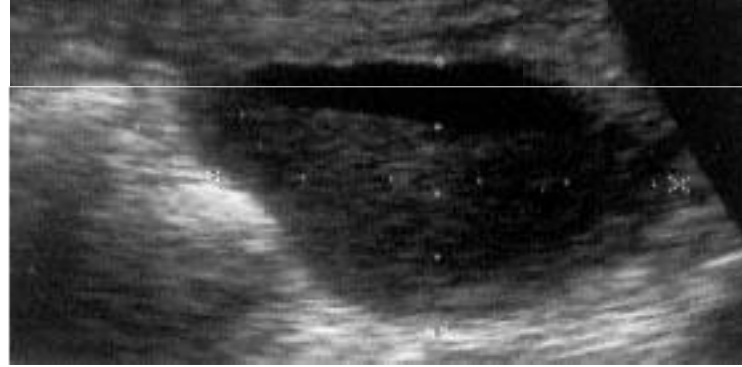
Figure 16—
Irregular walled cystic mass in the pouch of
Douglas with a fluid /fluid level within it. These are
the appearances of an endometrioma which has
undergone recent haemorrhage.

fibrosis and scarring between periods. The ultrasound appearances of ovarian endometriomas are the most extensively documented as they are more easily demonstrated than disseminated disease.

In a review of 51 patients with 55 endometrotic masses Fried *et al*[23] found the following features:

1) Size of the endometriomas was variable ranging from 2 cms. to 20 cms., the mean being 6.1 cms.

2) 30% were purely cystic.

Figure 17—
Patient with known endometriosis who presented
with increased pain in the left iliac fossa. Ultrasound
revealed a 3 cm. diameter, slightly irregular cyst
containing uniform low level echoes, in keeping with
resolving haemorrhage into an endometrotic ovarian
cyst.

3) 62% were complex, with degrees of internal septation or debris.

3) 62% were complex, with degrees of internal septation or debris.

4) 8% were largely solid.

Surgical examination of the lesions revealed that those of cystic appearance contained clear fluid, those with gravity dependent components contained viscid fluid plus particulate matter in keeping with resolving haemorrhage. The septated masses were shown to be multiple small foci of endometriosis aggregated together, either with thick walls between or solid areas of ovarian tissue, giving a complex appearance to the mass. Solid lesions were either very thick, proteinacious fluid or solid ovarian tissue.

Faced with this multiplicity of appearances how can a diagnosis of endometriosis be confidently made on ultrasound? It is not certain that it can. The clinical history of cyclical pain or deep pelvic pain, plus the patient's age, will help in the assessment, but the final diagnosis may only be made on direct examination of the lesions at laparoscopy, (Figures 15-17).

Does Imaging have Anything else to Offer?

Yes, magnetic resonance imaging has potential for the non-invasive diagnosis of endometriosis by revealing the haemorrhagic nature of lesions within the peritoneum as well as the ovaries.[24] A further area for possible investigation is MRI in assessing response to treatment, reducing the need for second look laparoscopy.

Pelvic Inflammatory Disease (PID)

This is a term applied to a variety of infections of the female genital tract, and presents as either an acute or chronic form. The actual incidence of pelvic inflammatory disease is not truly known, although it is thought to be approximately 1% amongst all women, with a higher incidence in young, sexually active women. The mode of infection is usually through ascending infection of the genital tract, although a small number of cases arise from local spread of infection, i.e. from ruptured acute appendicitis and diverticular disease. Infection may be introduced through instrumentation, e.g., after abortions, introduction of intra-uterine contraceptive device, and invasive investigative procedures. Well defined sterile techniques should decrease the incidence of iatrogenic disease. A recent audit in my own institution did not find any evidence of iatrogenic pelvic infection following hystero-salpingography. Routine antibiotic prophylaxis was not used, even with a positive history of previous pelvic infection.

Most cases, however occur, in sexually active people and there is evidence to suggest the organisms may be transmitted through the genital tract via sperm, as certain bacteria have been shown to attach to sperm. This theory is strengthened by the fact that PID is less common in women whose partners have low sperm counts or have had a vasectomy. The commonest organisms causing acute pelvic infection are Neisseria gonorrhoea, and chlamydia, with several other bacteria also commonly occurring in the vaginal secretions of women with PID.

Acute PID will present as severe lower abdominal pain, a raised temperature and white cell count, with evidence of local tenderness, pain on cervical movement and possibly a palpable mass in the adnexa.

The chronic form is more insidious and many women may not realise they have had an infection, but are diagnosed during infertility investigations or during investigation for low grade pelvic pain or menstrual disorders. This is usually the result of chlamydia infection which may be difficult to irradicate.

The role of ultrasound is different in the two presentations. In the acute disease, imaging is often not required, as the diagnosis is evident on clinical grounds. However, ultrasound will demonstrate the size of an inflammatory mass and may be required for percutaneous drainage of an abscess.

In the chronic form of disease, there are several subtle signs on ultrasound which will help point to the diagnosis of pelvic inflammatory disease. The changes produced by pelvic infection are related to the development of adhesions secondary to local fibrinous exudates around the adnexae.

Ultrasound Appearances Suggestive of Pelvic Inflammatory Disease

• Fluid in the pouch of Douglas.

• Soft tissue thickening around the posterior wall of the uterus and along the tubes.

• Tethering of one or both ovaries within the pouch of Douglas/ along uterine walls.

• Hydrosalpinges - these will appear as tortuous fluid filled structures extending from the uterine cornua.

• Local tenderness in the region of the cervix or vaginal fornices - this is more obvious on transvaginal than transabdominal examination.

The ultrasound features of chronic pelvic inflammatory disease can be very similar to those of endometriosis, and the diagnosis may often only be made by consideration of the clinical presentation as well as the ultrasound findings, although again there is overlap, as many women will present with menstrual irregularities, menorrhagia, low grade pelvic pain and dyspareunia, (Figures 18 - 21).

Occasionally, there may be haematogenous spread of infection, either with respiratory tract organisms or with tuberculosis. The adnexae may also be involved in local intra-peritoneal tuberculosis. This should always be considered in the differential diagnosis of adnexal disease on ultrasound in women from the Asian sub-continent,

Diseases of the Fallopian Tubes

Normal Fallopian tubes are not usually visualised on ultrasound as they are relatively small and do not normally contain fluid to allow their tubular structure to be appreciated separately from the surrounding soft tissues. Therefore, if the tubes can be visualised there is usually evidence of local pathology.

Infection will produce acute salpingitis, which forms part of the complex described as pelvic inflammatory disease, and ultrasound does not play a great part in the diagnosis of acute salpingitis.

Figure 18—
TVS of the pelvis in a woman with known pelvic
inflammatory disease. The right ovary and uterus
cannot be demonstrated as separate structures, and
there is a little extra soft issue in the right adnexal
region in keeping with pelvic adhesions as a result
of chronic pelvic infection.
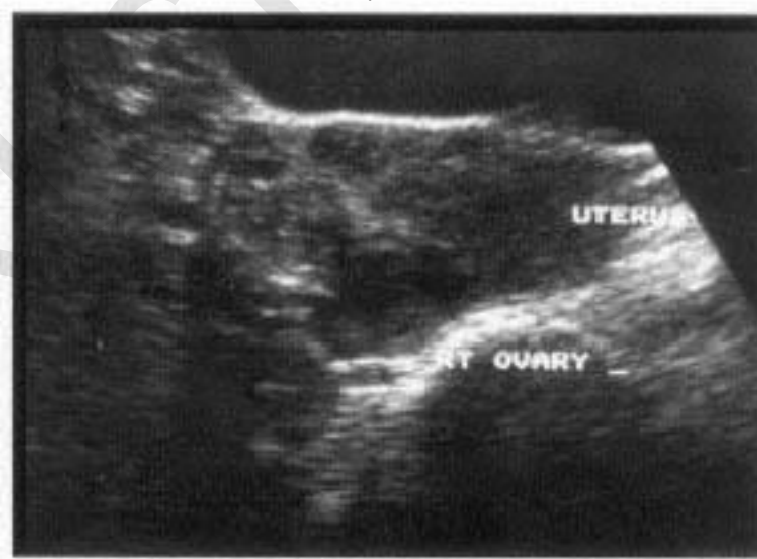
Figure 19—
25 year old woman with chronic pelvic pain due
to PID. The uterus and right ovary are closely applied
to one another and the right ovary appears pulled
down into the pouch of Douglas. There is a mixed
echogenicity focus lateral to the right ovary which at
laparoscopy was seen to be an inflammatory mass
around the outer end of the Fallopian tube.

Figure 20—
Ectopic pregnancy in the left adnexal region with
extra soft tissue in the pouch of Douglas due to
pelvic adhesions. The patient was known to have had
previous pelvic inflammatory disease.

Figure 21—
Hydrosalpinx of the right tube in a woman with a
past history of pelvic inflammatory disease.

Hydrosalpinx

Tubal occlusion due to adhesions from any cause will lead to fluid collection within the tubes and subsequent tubal dilatation. The fluid may be either clear or slightly turbid. The tubes will appear as rather serpiginous, fluid filled structures extending across the pelvis - the ultrasound probe may need to be rotated around the fluid filled structure to demonstrate the tubular nature, as often they may be mistaken for a collection of separate cysts in the adnexa. Colour flow will only be useful by demonstrating that there is no flow, therefore excluding a vessel as the cause of the appearance.

Chronically Ruptured Ectopic Pregnancy

Usually, an ectopic pregnancy will present as an acute event or have been diagnosed due to local pain. However, in a small number of cases the tube may rupture less acutely, with the development of a para-tubalhaematoma. This may be found on ultrasound as a complex mass, separate from both the ovary and uterus, with the final diagnosis only being made at operation, (Figure 22).

Carcinoma of the Fallopian Tubes

This is a rare malignancy of the female genital tract, representing only 0.3% of all gynaecological malignancies. It tends to occur in older women, usually in the fourth to sixth decades of life, and the aetiology is unknown. 90% are adenocarcinomas, but rarely squamous lesions and sarcomas have been reported. The clinical presentation is non-specific, with menstrual disturbance or irregular bleeding, weight loss or paraneoplastic symptoms, e.g., cerebellar degeneration. Onset of symptoms is usually insidious with a rapid course and it carries a poor prognosis.

Ultrasound Appearances

• Local tubal enlargement, which is usually unilateral.

• Cystic / fluid filled component.

• Complex adnexal mass. Figure 23

The differential diagnosis should include ovarian neoplasm, genital tuberculosis and local infection/ inflammation.

Figure 22—
Mixed echogenicity mass in the right adnexa
separate from the right ovary. This was shown to be
a chronically ruptured ectopic pregnancy at operation.

Pelvic Manifestations of Non-Gynaecological Disease

Due to the close proximity of large and small bowel to the genital tract, local bowel disease may produce both symptoms and signs which are very similar to gynaecological disease. Also, any diffuse disease of the peritoneum may first present on ultrasound in the pelvis, due to the dependent nature of the pouch of Douglas when examining a patient in the supine position.

Free fluid in the peritoneum is often the first sign of developing local or generalised disease. The finding of small amounts of fluid in the cul-de-sac of ovulating and menstruating women is not unusual, but fluid in pre-pubertal or post-menopausal females should not be ignored, and should prompt a careful search of the peritoneum for signs of local or systemic disease if the genital tract appears normal on ultrasound. The clinical history again will be helpful in reaching a final diagnosis, as a history or either cardiac or renal disease may produce fluid in the peritoneum, juat as a history of malignancy will suggest a possible cause for peritoneal fluid.

An adnexal mass, although most likely to be gynaecological in nature, may be due to either an appendix mass if on the right, or from diverticular disease if on the left.

Intervention in Ovarian Pathology Aspiration

Transvaginal ultrasound is used in infertility for oocyte retrieval. Cysts may also be aspirated transvaginally in patients who may not be suitable for, or may not wish, to

have laparascopic surgery. The technique is well tolerated and, as it is performed without anaesthetic, may be used on a day-case basis allowing patients the option to go home almost immediately.

It is a technique I have also used for palliative de-bulking of recurrent ovarian malignancy in patients who are no longer responding to chemotherapy, but are getting pressure symptoms on bowel or bladder from enlarging ovarian recurrence. In one example there were multiple drainages without any evidence of seeding of the tumour along the needle track. The same approach may also be used for aspirating post-hysterectomy haematomas and pelvic abscesses close to the vaginal vault.

Patient Preparation

Fast for 6 hours — reduces risk of aspiration in the event of vomiting.

Clotting studies performed — as for any percutaneous interventional procedure.

Antibiotic prophylaxis — intravenous broad spectrum cephalosporin plus metronidazole to cover anaerobic infection. This should be started 30 - 60 minutes prior to commencing the procedure, and continue to be infused slowly during the intervention.

Sedation — this is optional and should be discussed with the patient. A short acting intravenous benzodiazepine would be suitable.

Technique

Initial transvaginal scan — to assess size and position of cyst /collection to be aspirated.

Vaginal speculum — to visualise vaginal vault and cervix and then clean area with suitable anti-septic preparation.

Local anaesthetic — a long acting preparation is advisable to reduce post-procedure discomfort, e.g., Marcain. This should be liberally injected into vaginal mucosa around proposed point of needle insertion.

Equipment — transvaginal biopsy attachment advisable, but not essential.

The major problem with using a biopsy attachment is that they are generally long metal tubes which attach to the superior surface of the probe, and will only allow a long needle, e.g., Jessop oocyte retrieval needle, down the channel. A co-axial approach is more difficult down such a biopsy channel. I have found guiding a soft catheter/trocar along the probe/my finger as effective. This then allows the transvaginal probe to be pulled back

Figure 23—
Right sided mixed echogenicity adnexal mass in
46 year old woman. No specific ultrasound features
to suggest tubal pathology. Histology revealed a
carcinoma of the Fallopian tube.

from the vault but still allows direct visualisation of the cyst during aspiration.

The needle is introduced through the vaginal vault, via the vaginal fornix, and under direct visualisation can be seen entering the cyst/fluid collection. The fluid may then be aspirated to dryness as confirmed by continuous scanning during the procedure.

Post-procedure observation: regular monitoring of blood pressure and pulse to detect haemorrhage, and regular temperature measurement to detect immediate infection.

There may be a small amount of fluid leakage per vaginum which will settle in two to three days.

The patient may be allowed home on the same day as the procedure.

Having introduced a soft catheter into a large fluid collection, the vaginal vault may then be visualised again through a vaginal speculum and, using a co-axial approach, a small pigtail catheter may be inserted to allow vaginal drainage of pelvic abscess if surgical drainage is not a suitable option.

Conclusions

Ultrasound of the ovaries and adnexae presents an interesting and complex challenge. The correlation of the ultrasound findings with a comprehensive clinical history is vital to allow the correct diagnosis to be reached, giving ultrasound an important role in the management of women with ovarian and adnexal disease.

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6—

The Role of Ultrasound in Gynaecological Screening

Michael J Weston

Introduction
Screening for ovarian cancer
Epidemiology of ovarian cancer
Screening for endometrial cancer

Introduction

The object of screening is to reduce the mortality and morbidity arising from the condition being screened. This is perhaps self evident and yet demands for a screening program can be made by public opinion prior to any satisfactory proof from randomised controlled trials. There is a burden upon the investigator to ensure that the benefit to each person being screened outweighs the possible harm. There is a view that screening is an infringement of personal liberty as it can only be achieved by coercion and deception. [1] The deception arises because the implications of a test result, positive or negative, are not often explicit and usually not as straight-forward as the lay public expects. Alternatively, one can take the view that effective screening, particularly for blood pressure, smoking and breast cancer, will increase the likelihood of a patient living a free and healthy life. [2] Austoker, [3] in her articles on cancer prevention in primary care, details some of the benefits and disadvantages of screening. The benefits include an improved prognosis for some cases detected by screening. Cases with early stage disease probably require less radical treatment and there is reassurance for those with negative test results. Against this is the potential for overtreatment of questionable abnormalities and false reassurance for those with erroneous negative results. There is a `lead time' effect of screening so that screening appears to increase the survival from time of diagnosis but not from the time the patient would have presented clinically. This can produce a longer period of morbidity in those whose prognosis is unaltered by early detection. All screening tests will also produce false positive results and hence provoke unnecessary treatments and anxiety until such time as the true, disease free state comes to light. Finally, a screening program requires resources which might otherwise have been used elsewhere. From all of this it is apparent that an ill-conceived program has a huge potential to cause harm.

The World Health Organisation[4] has established, as long ago as 1968, several criteria for screening.

• The condition should be an important health problem.

• The natural history of the disease should be known.

• An early stage should be identifiable.

• Early treatment should be of more benefit than treatment started at an late stage.

• There should be a suitable test that is accept able to the population.

• Adequate facilities for diagnosis and treatment should exist.

• The interval between screens and who is to be screened should be known.

• The chance of physical or psychological harm should be less than the likelihood of benefit.

• The financial costs should be balanced against the benefits.

How well ovarian cancer and, to a lesser extent, endometrial cancer fulfil these criteria will be discussed.

Screening for Ovarian Cancer

Epidemiology of Ovarian Cancer

Ovarian cancer is a significant health problem, being the fifth most common cancer in women and also the leading cause of death from gynaecological malignancies. In 1992, 4360 women died of ovarian cancer in the United Kingdom[3] and in 1994 in the United States there were approximately 13,600 deaths.[5] However, to place these large figures in perspective, the disease prevalence is between 30 and 50 cases per 100,000 population and the lifetime incidence is one in 70 women, (the lifetime risk of breast cancer is in comparison one in 12). It is uncommon in black women.[6] Most cases occur after the age of 45.

Survival depends on the stage of the disease at diagnosis. The early stages of the disease do not have any specific symptoms and so nearly 60% of women present with disease that has already spread with abdominal metastases such as in the omentum (Stage III) or with distant metastases outside the peritoneal cavity (Stage IV). These women only have a one in 10 chance of surviving for five years. Conversely those women (25%) who present with the disease confined to the ovary (Stage I) have a six or seven in ten chance of surviving for the same period. Stage II disease with ovarian spread confined to the pelvis

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Risk Factors for Ovarian Cancer

The cause of ovarian cancer is not known, though there are women who are at higher risk than others. Risk factors include greater age, nulliparity, northern European or North American descent, and a family history of ovar-

Table 1 – Abbreviated FIGO staging of ovarian carcinoma

Stage		
I	Confined to ovary	Asymptomatic. Good prognosis after surgery. Diagnosed by screening or during investigation for other symptomatic conditions.
II	Spread confined to the pelvis	Usually asymptomatic. Diagnosed as above.
III	Abdominal metastases – omentum, lymphadenopathy, peritoneal implants – e.g., liver surface	Presents with abdominal enlargement or symptoms from distant metastases. Poor five year survival.
IV	Distant metastases – liver parenchyma, lungs.	

ian cancer. There is a theory that ovulation itself is a causative factor, as the risk of ovarian cancer appears to be decreased by pregnancy, breast feeding and oral contraceptives, all of which suppress ovulation.

Women who have one close relative with ovarian cancer have a threefold increase in lifetime risk, whereas those with two close relatives have a dramatic increase to a 40% lifetime risk. As many as 5% of ovarian cancers occurring before the age of 50 may be due to familial cancer. [6] Mutations in the genes BRCA1 and 2 may account for most of these families.[7] This raises the intriguing prospect of genetic testing, to enable individuals to learn if they carry a cancer predisposing mutation. Not all those at risk want such testing, though those from a higher socio-economic class and those with more relatives affected are more likely to request the test.[8] The implications of a positive test need to be explored fully before testing, including factors such as difficulties in obtaining a mortgage or life insurance. Furthermore, whether a positive genetic predisposition should lead to active ovary and breast screening or even prophylactic bilateral oophorectomy (and subcutaneous mastectomy) would need to be discussed.

Screening Tests

There are three main methods of screening;

• The bimanual pelvic examination.

• serum marker antigens, notably CA125.

• Ultrasound, both transabdominal and transvaginal.

Screening strategies have been proposed using one or other or a combination of these methods. As the overall incidence of ovarian cancer is low, any stratagem requires a high specificity to be acceptable, especially as the consequence of a positive screening result is surgery. A positive predictive value of 10% results in ten operations for each cancer detected. It has been estimated that to achieve a positive predictive value of 10% in ovarian cancer with its incidence of about 1 in 2500 in the over 45 year olds, would require a test with 100% sensitivity and 99.6% specificity.[3] If a high risk group with a greater incidence of disease can be identified then a lower specificity on testing becomes acceptable.

Pelvic Examination

The bimanual pelvic examination is part of the general assessment of women in gynaecological clinics and yet it is accepted that its sensitivity and specificity for ovarian pathology is too poor for it to be used alone in a population screening program. It can, however, be used as a first step along with CA125 in a

The bimanual pelvic examination is part of the general assessment of women in gynaecological clinics and yet it is accepted that its sensitivity and specificity for ovarian pathology is too poor for it to be used alone in a population screening program. It can, however, be used as a first step along with CA125 in a screening program to limit the number of women requiring ultrasound. Adonakis *et al.*[9] have shown in their screening study of 2000 asymptomatic Greek women without any family history that the positive predictive value of pelvic examination for ovarian cancer is only 3.39% with a sensitivity of 66.6%. The high sensitivity is a reflection of the small number of cancers found in the study, only three, and the relatively large size of the two cancers that were palpable, eight and ten centimetres diameter respectively. This study was also only a single round of screening so that the number of

tumours found indicates the prevalence of disease in the population, whereas any subsequent screening round on the same women would attempt to determine the incidence of new tumours. It is possible that any new tumours that arose would not have grown so large and hence be harder to palpate. Other studies have shown that tumours detected by ultrasound are often impalpable. There is a high false positive rate when bimanual examination is done by experienced gynaecologists, which becomes even higher when done by general practitioners and nurses. Bimanual pelvic examination should not be done as a routine screening procedure on asymptomatic women.

Serum Tumour Antigens

No tumour antigen has been identified that is expressed uniquely by ovarian cancer. All antigens that have been described (e.g., HMFG1, DUPAN-2 and CA19-9) are tumour associated rather than tumour specific. This applies equally to the best of them, CA125. Elevated levels of CA125 can be found in benign conditions such as pelvic inflammatory disease, endometriosis and early pregnancy, as well as in cirrhosis of the liver. Furthermore, whilst CA125 is elevated in over 90% of ovarian cancer with disease spread beyond the ovary, when the tumour is confined to the ovary (Stage I) serum CA125 levels are only elevated in 50% of cases. This is because, although there is high tissue expression of CA125 in stage I cancer, the serum level is dependant on a breech in the normal blood/tissue barriers allowing the release of the antigen into the circulation. A screening program relying on only serum CA125 is obviously rendered poorly sensitive and specific for the early disease that is being particularly sought. Screening strategies have to combine it with another test, usually ultrasound. [10],[11]

Ultrasound

There is no doubt that ultrasound has a very valuable role to play in the characterisation of adnexal masses. There are proponents for the use of various morphological, spectral and colour Doppler criteria both transabdominally and transvaginally in the differentiation of malignant from benign ovarian disease. Morphological scoring systems have been proposed by several authors.[12],[13] They all have in common the association of malignancy with the presence of a large size (over 10 cm), a solid or partly solid content and papillae, (Figure 1). Fine septations and daughter cysts are associated with benignity. Sassone[12] reviewed a series of these scoring systems and found the sensitivities to range from 62 to 100%, the specificities from 73 to 95% and the positive predictive values from 31 to 83%. Using their own criteria they could obtain 100% sensitivity, but only at the cost of a low specificity of 37%. This was caused by abscesses, teratomas and haemorrhagic cysts being indistinguishable from malignant tumours on appearance alone, (Figure 2). It is this low specificity of morphology that prompted the search for Doppler criteria of malignancy. Initial reports of the use of resistance and pulsatility indices were very encouraging, but as with all new techniques there was a backlash with a series of reports showing that spectral Doppler is not helpful because there is too great an overlap in the indices between benign and malignant disease, (Figure 3).[14],[15],[16],[17] With time however, Doppler's true role, particularly colour Doppler, is becoming clearer. Buy and colleagues[18] in their study of 132 adnexal masses in 115 women used the presence or absence of colour flow in sections of a mass thought morphologically indeterminate or malignant to predict whether or not the mass was truly malignant. If a mass was morphologically thought benign then the presence or absence of colour flow was disregarded. This technique improved the confidence level, specificity and positive predictive value of grey scale sonography, specificity rising from 82 to 97% and the positive predictive value from 63 to 91%. The same study also confirmed the limited value of spectral Doppler indices. Our experience with our own cohort of patients in Leeds[19] concurs with the poor results obtainable from spectral Doppler indices, but also indicates that an experienced observer with access to all the ultrasound information can outperform any of the individual scoring systems. This multiparameter analysis by experienced observers is also now advocated by Kurjak[20] and he goes on to describe the need for `artistic rendering' in obtaining and interpreting results, (Table 2).

The parameters used in these various studies all refer to a highly selected population with a very high prevalence of ovarian cancer. They may be poor predictors when applied to the general population with its low prevalence of disease.

Ultrasound Screening Studies

The earliest screening studies on asymptomatic women involved transabdominal ultrasound. Initial studies at King's College Hospital, London, had

The earliest screening studies on asymptomatic women involved transabdominal ultrasound. Initial studies at King's College Hospital, London, had determined a nomogram of mean ovarian volume against years postmenopause from 2221 women. From this basis they proceeded to a large scale prospective study,[21] screening 5479 self selected volunteers for ovarian cancer. The women, aged 18-78 years, attended for three annual transabdominal scans. Those found to have an abnormality either went onto surgery or had a repeat ultrasound at six weeks. 10.5% of women had an abnormal scan at the first study which had resolved by the time of the repeat scan. 326 (5.9%) of the women had persistent findings indicating a need for surgery, of which five women had a primary ovarian cancer. Four of these five women were
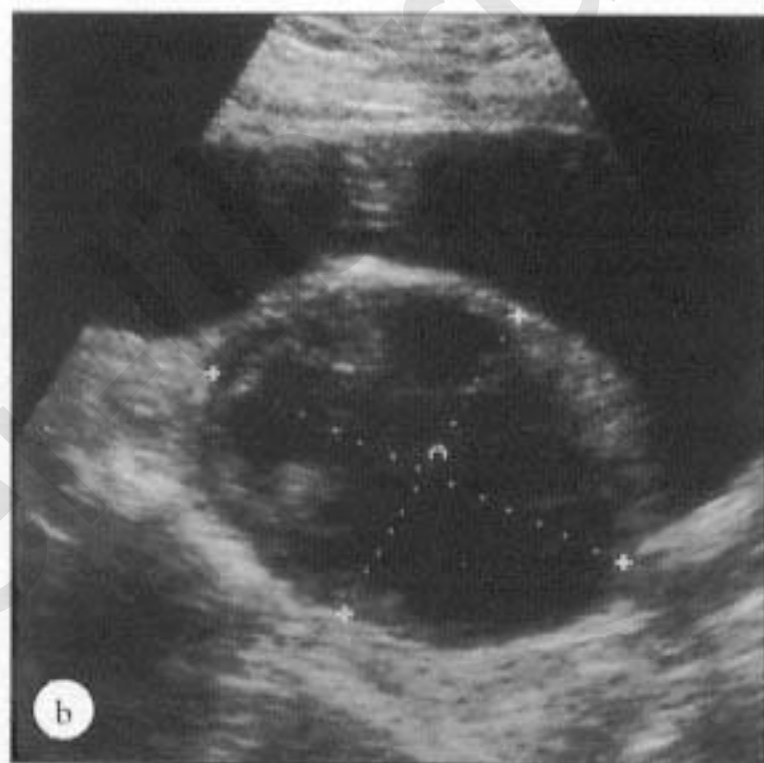
Figure 1—
Typical patterns of malignant morphology, *a)* large complex cystic and solid lesion on transabdominal scanning in a 52 year old, *b)* thick walled cyst with internal nodules or papillae lying behind the bladder in a 56 year old, *c,* relatively simple cyst with a fine septum but also with a small solid component in an 80 year old. All these lesions were malignant.
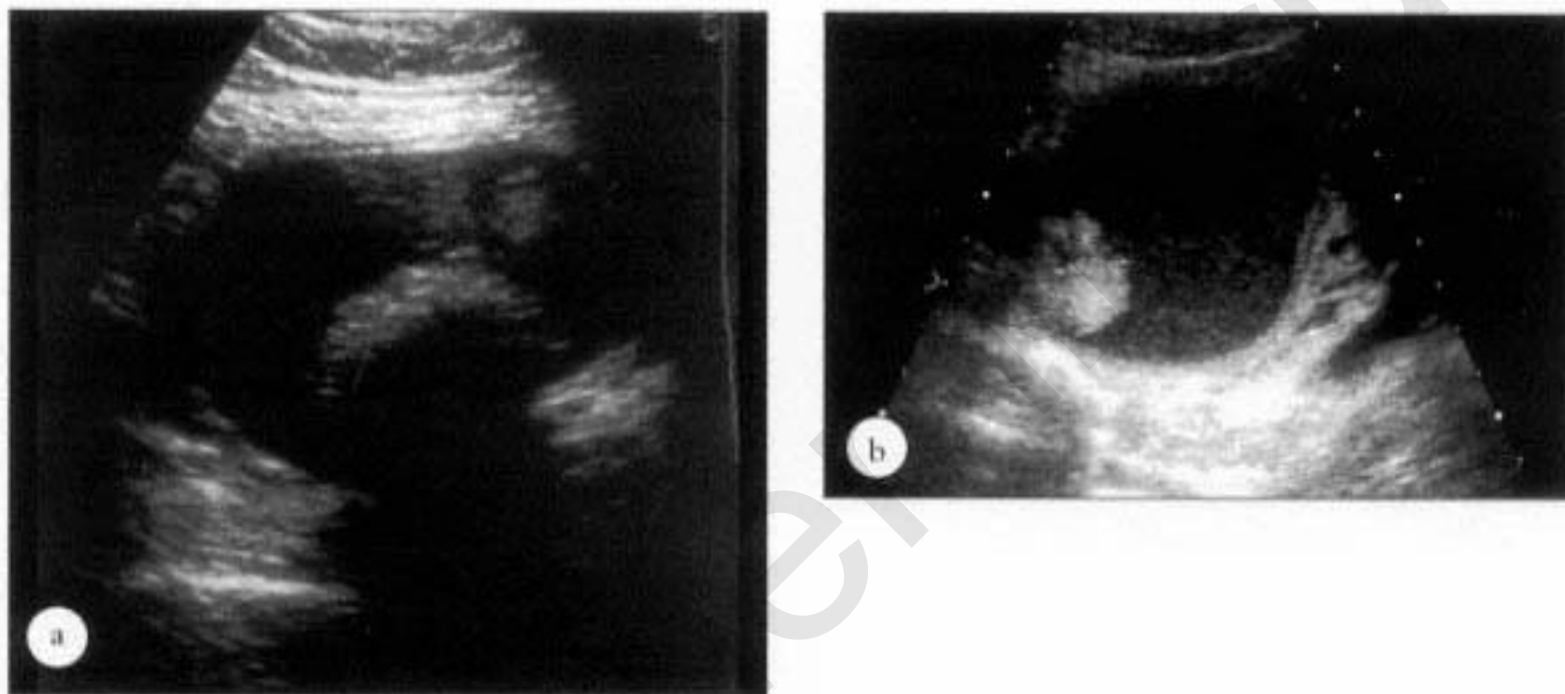
Figure 2—
Benign conditions may mimic malignant morphology, *a)* this lesion with a dense shadowing nodule is a benign dermoid, *b)* the apparent nodule in this lesion is due to clot retraction in a benign hemorrhagic cyst.
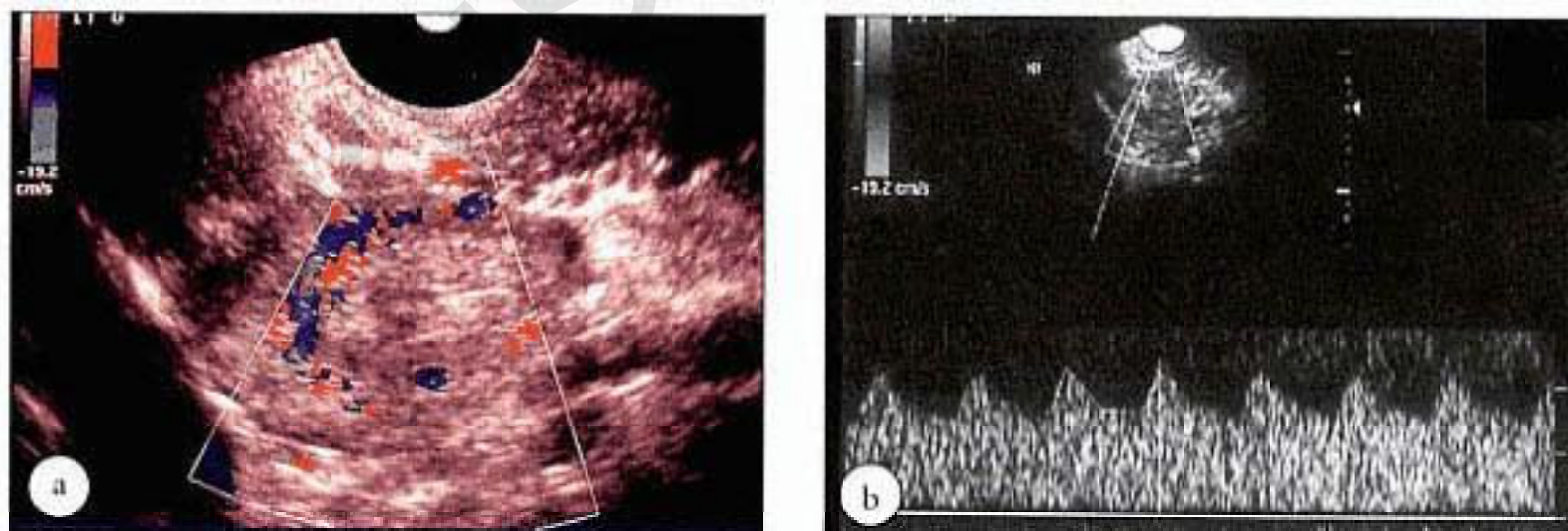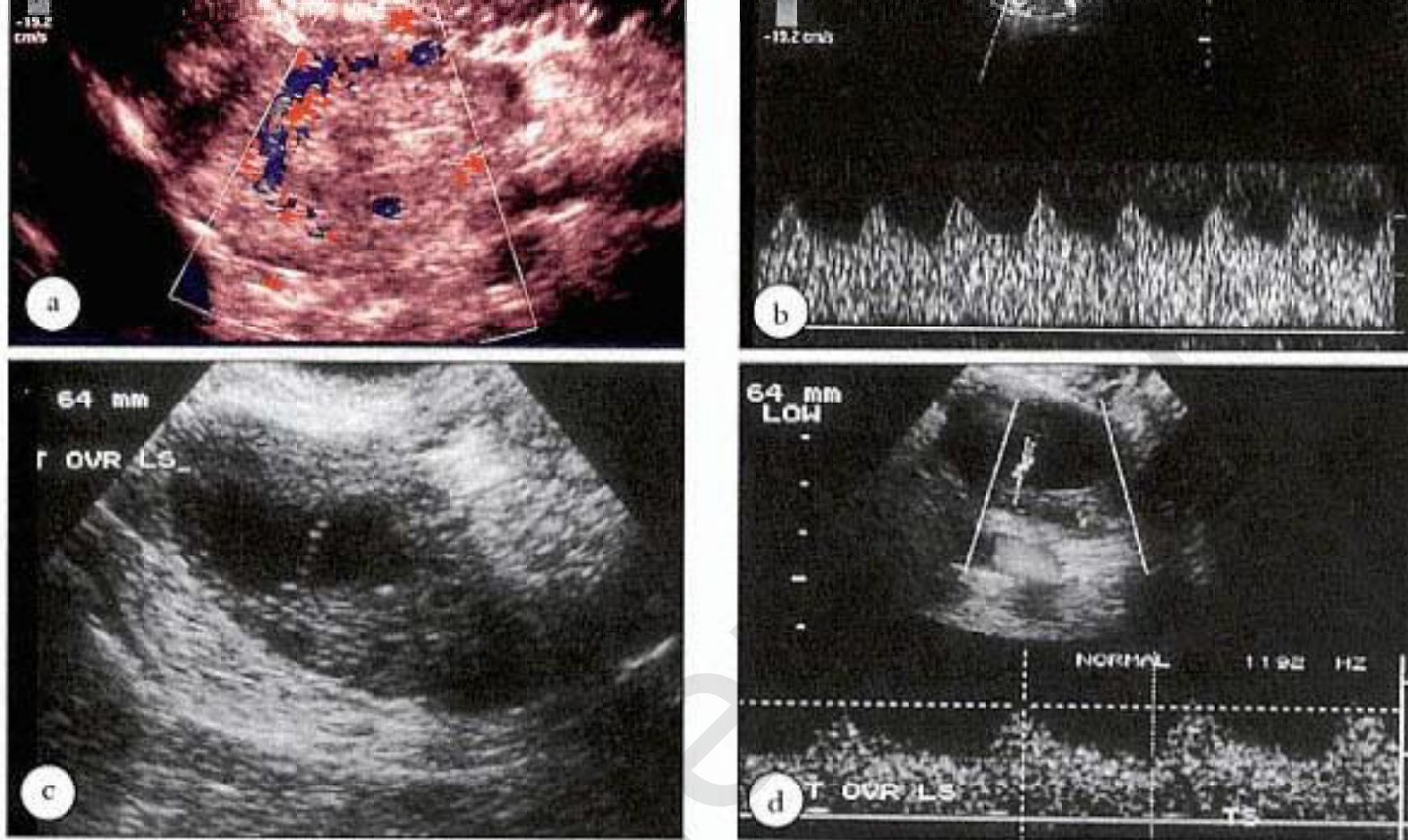
Figure 3—
In the pre-menopausal woman there are many physiological states that lead to low impedance flow within
the ovaries, rendering the use of spectral Doppler indices alone a poor indicator for malignancy; *a)* colour and
b) spectral Doppler of a normal ovary on day six of the cycle showing a low impedance peripheral flow.
c, Transvaginal ultrasound and *d)* spectral Doppler of an ovary with two follicles separated by a fine septum.
A low impedance trace can be obtained from this septum. This ovary is normal.

Table 2 Ultrasound features used in scoring systems to differentiate benign from malignant ovarian masses

MORPHOLOGY:

Size	Larger masses more likely to be malignant.
Wall thickness	Thick walled masses score more highly for malignancy than those with thin walls.
Composition	Complex, mainly fluid masses score more highly for malignancy than simple cysts. Papillae & thickened septae score highly.
DOPPLER	
Presence/Absence	Non-vascular masses more likely to be benign.
Distribution	Confined to the wall or with a regular pattern are more likely to be benign than masses with irregular vascular distribution throughout.
Resistance	Low resistance (high end diastolic flow velocity) scores more highly for malignancy.

post-menopausal. All the cancers were Stage I, which is surprising as more late stage tumours might be expected at the first screening round, though it probably indicates that women who volunteer for this sort of study are also more likely to present with early disease. There were also six cases with metastases to the ovaries and many benign masses found. In summary, the study was able to produce odds of a positive screen on transabdominal ultrasound being associated with any ovarian mass of 1 in 3, with any ovarian cancer, primary or metastatic of 1 in 37 and with primary ovarian cancer of 1 in 67 (PPV 1.5%). This odds ratio of 67 operations for each primary ovarian cancer found is too poor. The difficulties arise because of the poor specificity of morphological findings, particularly as a third of the malignant lesions in the study were found in simple unilocular echo-free cysts.

Transvaginal ultrasound with its close proximity of the probe to the ovary allows for a higher frequency, greater resolution image to be obtained, (Figure 4). Even so, most workers have tried to improve their pick up rate by either combining it with Doppler or by examining a high risk group or both. Kurjak *et al.* [22] screened 5013 asymptomatic women over the age of 40 with transvaginal ultrasound and colour and spectral Doppler. Their criteria for abnormality was either a persistently enlarged ovary over two scans, (Figure 5) or abnormal blood flow with a resistance index below 0.4. If a cyst persisted and had a diameter greater than 5 cm then surgery was indicated. They found 424 abnormal ovaries. 404 of these were cysts, of which 18 persisted and were operated on, yielding one cancer. 12 had a mixed cystic and solid lesion, of which two were cancer. Eight had solid lesions, of which one was cancer. Overall 5013 women provoked 38 operations and yielded four ovarian cancers all of which were Stage I. This is a greatly improved odds ratio (1:9.5) from the transabdominal ultrasound study. Non screening studies continue to affirm the ability of transvaginal colour Doppler to detect early stage ovarian cancer.[23]

If the transvaginal technique is used in women with a family history of ovarian cancer, then just using morphological changes and their persistence on a repeat scan three to six weeks later yields an odds ratio of 1:14. (776 high risk women leading to 47 operations and yielding three cancers).[24] Van Nagell *et al.*[25] also found a similar odds ratio using annual transvaginal ultrasound in asymptomatic post-menopausal women; 1300 women screened leading to 27 operations and two ovarian cancers; odds 1:13.5. This reasonable odds ratio is achieved by excluding the pre-menopausal group, who with their changes in the ovarian morphology through the menstrual cycle would be expected to give rise to more false positive results. Holbert[26] advocates that post-menopausal women who attend a gynaecological clinic for a yearly check up should have transvaginal ultrasound by the gynaecologist as an extension of the usual

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NORMAL   937   HZ
P.F
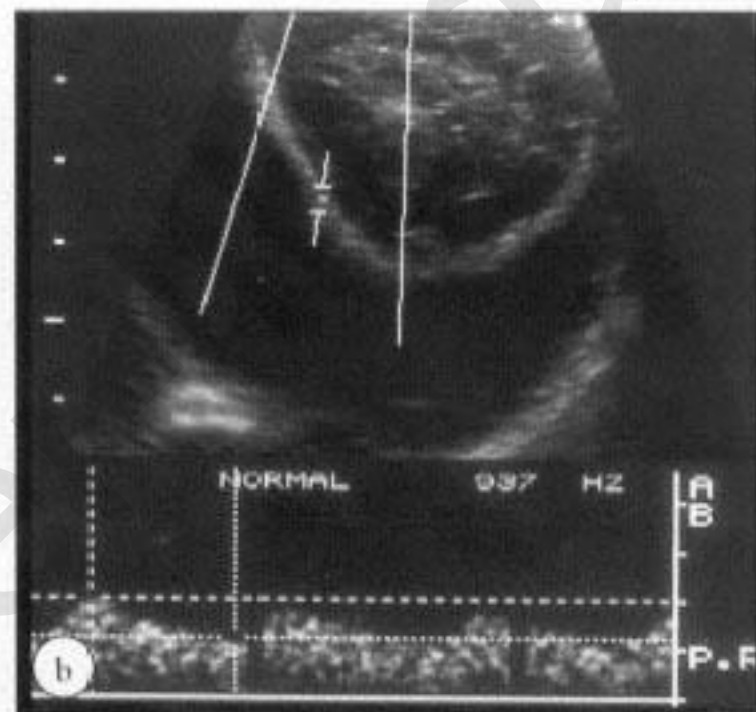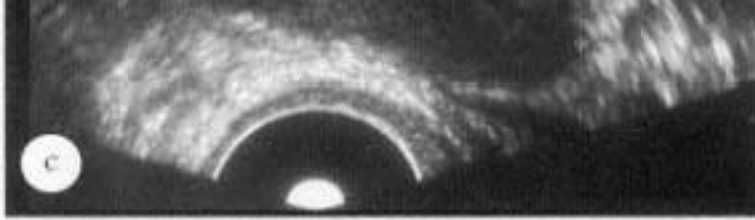
Figure 4—
Transvaginal ultrasound with its higher frequency allows much greater detail to be seen. *a)* Transabdominal and *b)* transvaginal images of the same ovarian lesion showing much better morphological detail of the cyst content on transvaginal scan and also allowing detection of flow in the septum. This lesion was benign. *c,* Transvaginal scan of an haemorrhagic cyst allowing detection of the fine low level echoes from the blood in the cyst.

Figure 5—
Bulky ovaries in postmenopausal women that persist in having a large volume are suspicious. Transvaginal images of the same ovary from *a)* 1992 and *b)* 1996 showing a persistent large volume of over 20 mls. This ovary has been similarly large on each of the intervening yearly scans. The patient has opted for continued ultrasound surveillance rather than removal.

(in much the same way as cardiologists use a stethoscope). Over a two year period, scanned 478 women, of which 11 underwent surgery, to yield one Stage I cancer.

The King's group extended their study of women with a family history to include colour Doppler [27] on the transvaginal scan. 1601 women were screened. The odds of finding ovarian cancer at surgery were increased from 1:50 in the general population to 1:12 due to the higher prevalence of disease. By prospectively applying a combination of a high morphology score and a pulsatility index below 1.0 on the last 500 women, the odds were reduced to 1:9.

Another high risk group is women who have had breast cancer, and a screening study[28] on 600 such women provoked 12 operations to yield three primary ovarian cancers (odds 1:4), as well as one woman with metastatic disease to the ovary. These odds ratios achieved in high risk groups are probably acceptable, though it should be remembered that women who perceive themselves to be at high risk will tend to request surgery more often in the face of equivocal findings, especially those who are hospital personnel.[26] Against this view, is the fact that the number of surgical interventions in the various screening studies have decreased with the use of transvaginal ultrasound and colour.[20] Campbell,[21] using transabdominal ultrasound on volunteers surgically intervened in 6%, whereas Kurjak,[22] using transvaginal ultrasound with colour Doppler, also on volunteers, only operated on 0.8%.

Although one can conclude that ultrasound is of benefit in screening high riskgroups it still has limitations. An important factor is the need for expensiveequipment and trained staff. Screening ultrasound also only appears to have a shortlead time over the clinical diagnosis and so requires the interval between screeningepisodes to be short.[11] In an attemptnot only to increase the specificity of the screening program but also to limit thenumber of expensive ultrasounds required, the Royal London Hospital instituted astepwise screening program.[10] Approximately 22000 asymptomatic post-menopausal volunteers had their CA125 measured. Of these, 340 had a CA125 of over 30 U/ml and went on to have ultrasound. 41 of these scans were abnormal and provoked surgery, to yield 11 ovarian cancers (odds 1:3). However, during the year of follow up three cases of ovarian cancer were diagnosed in the screen negative group giving a screen sensitivity at one year of 78%. Longer follow up has yielded more cases of screen negative ovarian cancer, reducing the sensitivity to only 50%.

The choice at present is between screening all post-menopausal women using a stepwise scheme of CA125 then ultrasound to give a good odds ratio of finding disease with a positive screen at the expense of poor sensitivity, or to use ultrasound as the first line screening test but only in women with high risk factors. This high risk approach would only include 1-10% of ovarian cancer patients in the screened population.

It is not all straightforward, even if one of the above strategies is adopted, as early experiences of a new screening centre may be disappointing. Muto *et al.*[29] screened 386 women with a family history of ovarian cancer using both CA125 and transvaginal Doppler. 42 women had a CA125 over 35U/ml, of whom two had increasing levels on repeat testing. These two were operated on and had normal ovaries. 89 women had an abnormal ultrasound at first visit, of which 15 had a persistent abnormality at follow up ultrasound. All 15 of these had benign pathology at surgery. A further 19 patients opted for prophylactic oophorectomy and all these ovaries were also normal. In other words, all this activity has failed to yield any women with ovarian cancer. Our own experience in Leeds in screening 300 women with a family history has been equally disappointing. The only case of ovarian cancer in the cohort so far has been an interval cancer in a woman who missed a screening visit.

Conclusion

(See summary box, opposite)

There is a consensus that there is as yet no evidence that either CA125 or any form of ultrasound can be effectively used for screening of the general population to reduce mortality from ovarian cancer.[3,5] High risk groups of women should only be offered screening as part of a defined study protocol, by centres who have the opportunity to acquire adequate experience. To quote Taylor and Schwartz,[6] `it is unlikely that ultrasound will become the initial screening test of choice for ovarian cancer; rather, more sensitive and specific serum tumour markers will become available that can define a population with a higher prevalence of the disease in which endovaginal ultrasound will be cost-effective'.

Screening for Endometrial Cancer

Screening for Endometrial Cancer

Introduction

The incidence of endometrial cancer is low in women younger than 50, but then rises to a peak in women between the ages of 65-74 years. Approximately 3700 women have endometrial cancer diagnosed each year in the UK.[24] Not all of these present with post-menopausal bleeding. Asymptomatic endometrial cancer is thought

SUMMARY OF MAIN POINTS: SCREENING FOR OVARIAN CANCER

• Lifetime risk is approximately 1 in 70 women.

• Screening tools include: bimanual palpation

          genetic testing
          CA 125 levels
          Ultrasound

    • Screening currently suffers from low sensitivity (cancers are missed) and low specificity (too many false positive results) which cause unnecessary intervention and distress.

    • Sensitivity & specificity are improved when the screened population is restricted to high risk women - > 45 years or with a family history of ovarian or breast cancer.

    • False positive results due to physiological masses are minimised by scanning in the early part of the cycle (days 1-8) or by selecting only post menopausal women for the screening program.

• The role of ultrasound is enhanced by using transvaginal and colour Doppler techniques.

    • Although scoring systems have had some success the best results are obtained using knowledgable and experienced interpretation.

• There is no evidence to support screening of the general population.

to occur with an incidence of around 1.5 per 1000 screened post-menopausal women. [30] Early stage endometrial cancer has a better prognosis than later stage cancer at diagnosis, (Figure 6).

Symptomatic Studies

Ultrasound, both transabdominal and transvaginal, is a standard part of the investigation of women with post-menopausal bleeding, though only 10% of those so presenting will have endometrial cancer.[31] The thickness of the endometrium is related to the chance of finding endometrial abnormality. Most centres describe a `double
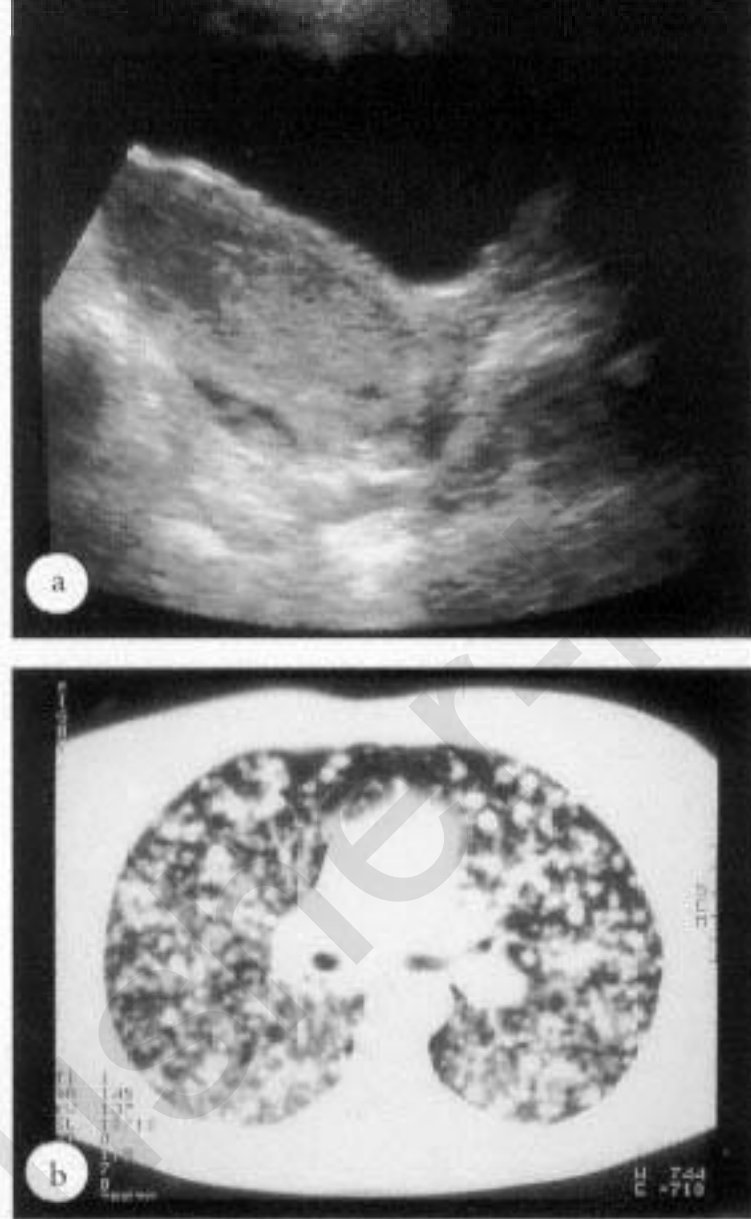
Figure 6—
Advanced endometrial cancer has a poor prognosis.
This postmenopausal woman presented with widespread
disease. *a)* Transabdominal longitudinal view of the uterus
showing a thickened endometrium invading through the
surrounding myometrial halo. There was also tumour within
the vagina. *b)* CT scan of her chest revealed

Figure 6—
Advanced endometrial cancer has a poor prognosis.
This postmenopausal woman presented with widespread
disease. *a)* Transabdominal longitudinal view of the uterus
showing a thickened endometrium invading through the
surrounding myometrial halo. There was also tumour within
the vagina. *b)* CT scan of her chest revealed
innumerable lung metastases. These were also visible on
chest X-ray.

layer' measurement of the endometrium from one myometrial interface to the other with the uterus imaged in longitudinal section. Some exclude any fluid content from the measurement. Studies using sonohysterography, with instillation of fluid into the cavity, often only quote a single layer endometrial thickness. Studies in women with post-menopausal bleeding have either concentrated on a thickness of endometrium which gives a good positive predictive value for cancer,[24] or more recently tried to define a thickness of

endometrium that has a good negative predictive value and would thus obviate the need to go on to endometrial biopsy. [32],[33] In the first case, a value of over 8 mm indicates significant pathology and should be pursued, the 14 women in the study[24] with endometrial cancer having a range of thicknesses from 8 to 41 mm. There is overlap with patients without cancer, particularly those on hormone replacement therapy, so that a significant false positive rate is generated. When ultrasound is used for its negative predictive value then thicknesses of 4 mm or less can exclude malignancy with reasonable certainty. Karlsson *et al.*[32] in their study of 1168 women undergoing endometrial curettage, had no cases of cancer with a thickness of less than 5mm. They calculate the 95% confidence limit (the worst interpretation of their results) of finding pathological endometrium with thicknesses of 4mm or less as 5.5%. Dijkhuizen *et al.*[33] suggest a cut off limit of 3mm which in their study of 69 post-menopausal women would have saved 29 (42%) of the women from having to undergo endometrial biopsy.

Spectral and colour Doppler have been used in assessment of the endometrium and the supplying arcuate arteries, (Figure 7). 91% of endometrial carcinomas are said to display intratumoral or peritumoral blood flow.[31] Resistance indices are lower than normal. However the value of these indices in distinguishing benign from malignant disease is still open to debate, and although Kurjak[22] has advocated Doppler of the endometrium in women attending for ovarian screening, there are no formal trials of its use in an endometrial screening population.
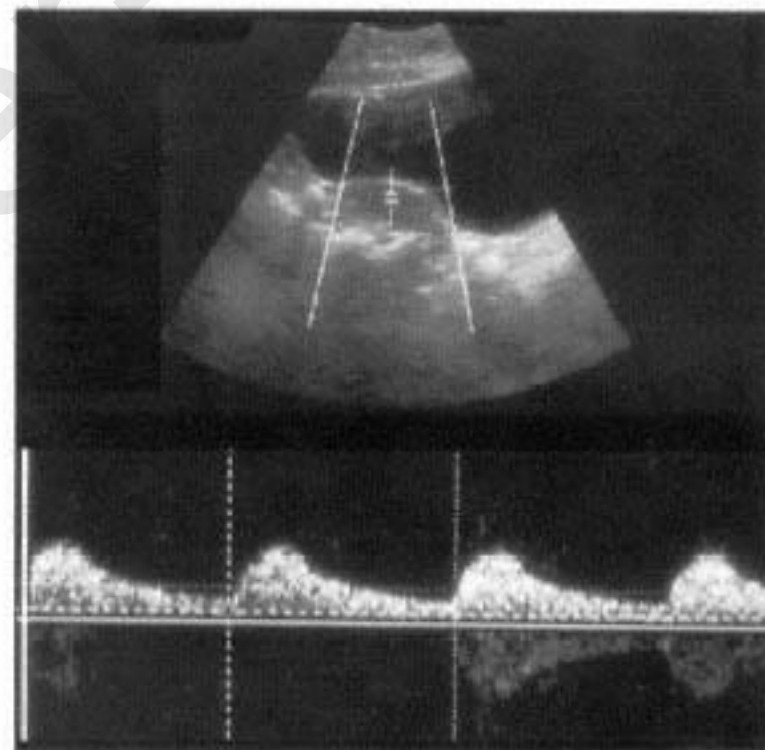
Figure 7—
a) Transverse view of the uterus in a postmenopausal woman showing a very thickened endometrium and a small posterior wall fibroid. *b)* Doppler of the arcuate arteries demonstrates reduced impedance flow. This was an unusual case of a carcinosarcoma of the endometrium.

Screening Studies

Various screening strategies have been suggested; all women attending for ovarian cancer screening could also have endometrial ultrasound, all women requesting hormone replacement therapy could be screened prior to starting treatment, or all post-menopausal women could be invited for screening.

Hormone replacement therapy affects the thickness of the endometrium.[34] Women on unopposed oestrogen regimes or on sequential oestrogen and progesterone have a higher percentage of endometrial thicknesses over 8 mm (over 50%). There is a known increased risk of cancer on unopposed oestrogen regimes. These women require more careful follow up when a thickened endometrium is found. In contrast, women on sequential oestrogen and progesterone regimes show a variation of endometrial thickness through the cycle, and it is recommended that any measurement of endometrial thickness in these women be confined to either the beginning or end of the cycle when it will be at its thinnest.

Shipley *et al.*[35] recruited 52 asymptomatic post-menopausal women using a newspaper advert. They used transvaginal ultrasound and endometrial biopsy with the Pipelle technique on 50 of these. Eight patients (16%) had abnormal ultrasounds with thicknesses over 7 mm (8 mm for those on HRT) and all of these had endometrial abnormalities subsequently diagnosed though none were of cancer. The unexpected finding was the poor sensitivity of the Pipelle biopsy technique, only finding three (6%) abnormalities. They concluded that ultrasound would be a better method of screening than biopsy in an

asymptomatic population. There has only been one study to evaluate the endometrium in a large unselected group of women, other studies of comparable numbers recruiting their women from those attending for annual cervical smears. Gull *et al*[36] invited a random sample of 1000 women aged 45-80 drawn from the population register of the city of Goteborg, Sweden, to attend for transvaginal ultrasound. 827 women responded, of whom 559 were post-menopausal. This post-menopausal group formed the study population. 82% had an endometrial thickness of less than 4mm. 11% had a thickness of 57mm. 5% (26 women) had a thickness of 8mm or greater. 2% had an unmeasureable thickness. The 26 women with thickened endometrium underwent hysteroscopy and curettage. The only endometrial cancer found was in a woman with regular withdrawal bleeds who had taken HRT for 15 years. The group of women with thickness 5-7mm as well as the unmeasureable group were followed up a year later and, although further endometrial biopsies were done in 14, no cancers were found. The patterns of different HRT change described above were also confirmed in this study. The authors conclude that the results do not support generalised screening of endometrial thickness in the general population to diagnose endometrial cancer.

Conclusion

(See summary box below)

Endometrial ultrasound is still best applied in an opportunistic fashion to those attending gynaecological clinics with symptoms or requests for HRT. There is no

SUMMARY OF MAIN POINTS: SCREENING FOR ENDOMETRIAL CANCER

- Endometrial cancer is predominantly a post-menopausal disease which usually presents with vaginal bleeding.
- Transvaginal ultrasound concentrates on the endometrial thickness, which correlates well with the presence of endometrial abnormalities in the symptomatic population.
- HRT alters the endometrial thickness. Different types of HRT require different vigilance.
- Doppler of the endometrial and uterine arteries is still of unproven value in differentiating benign from malignant endometrial disease.
- Screening asymptomatic women has not proved useful because of the low detection of endometrial cancer in this group.

evidence to support screening of asymptomatic women otherwise.

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7—

The Use of Ultrasound in Acute Pelvic Pain

Delia Martinez

Introduction
Acute pelvic pain in the non-pregnant patient
Acute pelvic pain in the pregnant patient
Conclusion

Introduction

This chapter focuses on the patient presenting with acute pelvic pain. Although a few paediatric cases are included, the majority of paediatric pathology is covered in Chapter 9 and causes of chronic pelvic pain are also considered elsewhere in the book.

The main causes of acute pelvic pain are summarised in Table 1.

Technique

Before beginning the examination of the patient a short history should be taken. The onset, duration and localisation of the pain and the date of the last menstrual period are important. Ascertaining whether there is any possibility of pregnancy and the result of a recent pregnancy test is vital. In addition any past history of similar pain or of previous gynaecological problems should be obtained. This may, for example, prevent a fruitless and embarrassing search for an ovary long since removed! This history-taking not only gives important information, but also helps establish rapport with the patient prior to this quite intimate examination.

All patients should undergo transabdominal scanning prior to transvaginal scanning. Although in a number of patients a transabdominal scan will be limited due to a partially filled or empty bladder, it is a very quick and effective way to examine the whole pelvis from the midline out to both iliac fossae. This will locate large masses or cysts which may be beyond the depth of visualisation of the transvaginal probe; many large ovarian cysts in the iliac fossae have been missed because only the TV ultrasound was performed. In addition in isolated transvaginal scanning it is a common error to focus on the pelvic organs without visualising the surrounding areas such as the pouch of Douglas and the precaution of an initial transabdominal scan will help prevent this. Both renal areas should be a routine part of the examination and additional information may be gained by extending the examination to a full upper abdominal examination in some cases.

It is important to remember that pelvic pain may be referred from elsewhere, for example ureteric calculi, and that vice versa pelvic pathology may refer symptoms elsewhere, for example ovarian cysts presenting with thigh pain.

Table 1 – Causes of acute pelvic pain

	NON PREGNANT PATIENT	
Uterine	–	Degenerating fibroid
	–	Haemorrhagic fibroid
	–	Torted fibroid
	–	Endometritis
Adnexae	–	Ovarian cyst
	–	Haemorrhage
	–	Torsion
	–	Oophoritis

	–	Torted normal ovary
	–	Acute salpingitis/pyosalpinx
	–	Tubo-ovarian abscess
Gastrointestinal	**–**	Appendicitis
	–	Inflammatory bowel disease
	–	Diverticular disease
Genitourinary	–	Infection
	–	Calculi
Post-operative patient	–	Haematoma/Inflammatory collection

PREGNANT PATIENT

Pain related to pregnancy	–	Threatened/inevitable abortion
	–	Ectopic pregnancy
	–	Trophoblastic disease
Pain incidental to pregnancy	–	Degenerating fibroid
	–	Ovarian cyst accident
	–	Urinary tract

Acute Pelvic Pain in the Non-Pregnant Patient

Gynaecological

Uterus

Uterine leiomyomata or `fibroids' are very common and the incidence is probably higher than initially thought as more are found on TV ultrasound than were previously on transabdominal scanning alone. It is important to remember the well known adage that fibroids in themselves do not cause pain. Acute pain from fibroids is due to degeneration or haemorrhage within the fibroid and, occasionally, torsion of a pedunculated fibroid. In these cases an ultrasound may show an increase in size from any previous examinations and/or cystic change within the fibroid. Eliciting localised tenderness with the probe is strong substantiating evidence that the fibroid is the source of the pain. Indeed, the skilled operator may be able to detect which of multiple fibroids is that which is responsible for the pain, (Figure 1).

Although pelvic inflammatory disease (PID) is discussed later in the section on adnexal pathology, the uterus is frequently involved though the ultrasonic findings are more subtle. PID. is described as inflammation due to infection of the genito-urinary system and consists of all or some of the following; endometritis, salpingitis, perioophoritis and tubo-ovarian abscess. These are Often associated with non-specific urethritis and chlamydial organisms are the commonest pathogens. The clinical picture of PID. is of pelvic pain plus any of the following; cervical excitation, fever, discharge and a pelvic mass. Because the infection is ascending, endometritis and

Figure 1—
a) Transverse TVS through uterus 2 years prior to this presentation showing hypoechoic fibroid.
b,c, Transverse and longitudinal TVS through uterus on day of admission. The fibroid has increased in size and
has undergone cystic degeneration. There was localised tenderness elicited during examination.
Diagnosis: *Cystic degeneration of a fibroid causing acute pelvic pain.*

Age	:	35 Years.
LMP	:	Day 14.
Presenting Complaint	:	Acute pelvic pain 2 days duration.
Pregnancy test	:	Negative.
Previous obstetric/ gynaecological history	:	Menorrhagia. Previous ultrasound 2 years ago showed small fibroid.
Clinical examination	:	Enlarged tender uterus.

Figure 2—
a) Transverse TAS showing indistinct uterine outline and indistinct endometrium. Some free fluid containing echoes is seen around the uterus.
b,c) Transverse and longitudinal TVS images of dilated Fallopian tube with thickened endosalpingeal folds. The transverse image suggests a `cog-wheel' appearance.
Diagnosis: *PID with mild endometritis/myometritis and acute salpingitis. Patient settled with antibiotic therapy alone.*

Age	:	21 Years
LMP	:	Day 20
Presenting Complaint	:	Acute pelvic pain with some pv discharge for 48 hours. General malaise.
Pregnancy test	:	Negative.
Previous obstetric/ gynaecological history	:	None.
Clinical examination	:	Pyrexial. PV examination limited by severe tenderness. No masses palpable.

myometritis nearly always accompany the salpingitis and oophoritis which, as mentioned above, are usually more obvious on ultrasound. The ultrasound signs of endometritis and myometritis include mild uterine enlargement, endometrial fluid, and decreased echogenicity of the endometrial cavity which may become indistinct. [1] Sometimes there is associated free fluid containing echoes, with an indistinct uterine outline due to exudative adhesions, (Figure 2).

Adnexae

The adnexae are considered in anatomical terms to include the fallopian tubes and ovaries. Acute pain originating from the ovary itself is common and in order to understand the ultrasound appearances it is essential to understand the normal ovarian cycle. Follicles are commonly seen within the ovary and several follicles may become quite large, up to 2 cm, prior to ovulation. Following ovulation the follicle should collapse or disappear and this may be preceeded by some haemorrhage within it, the so-called corpus haemorrhagica or haemorrhagic functional cyst. Pain in the middle of the cycle or `Mittleschmerz', which means literally middle pain, is said to be due to follicular rupture. This pain is usually mild and not severe enough to warrant hospital admission. At this stage, pelvic free fluid is often seen directly as a result of follicular rupture. The amount of free fluid
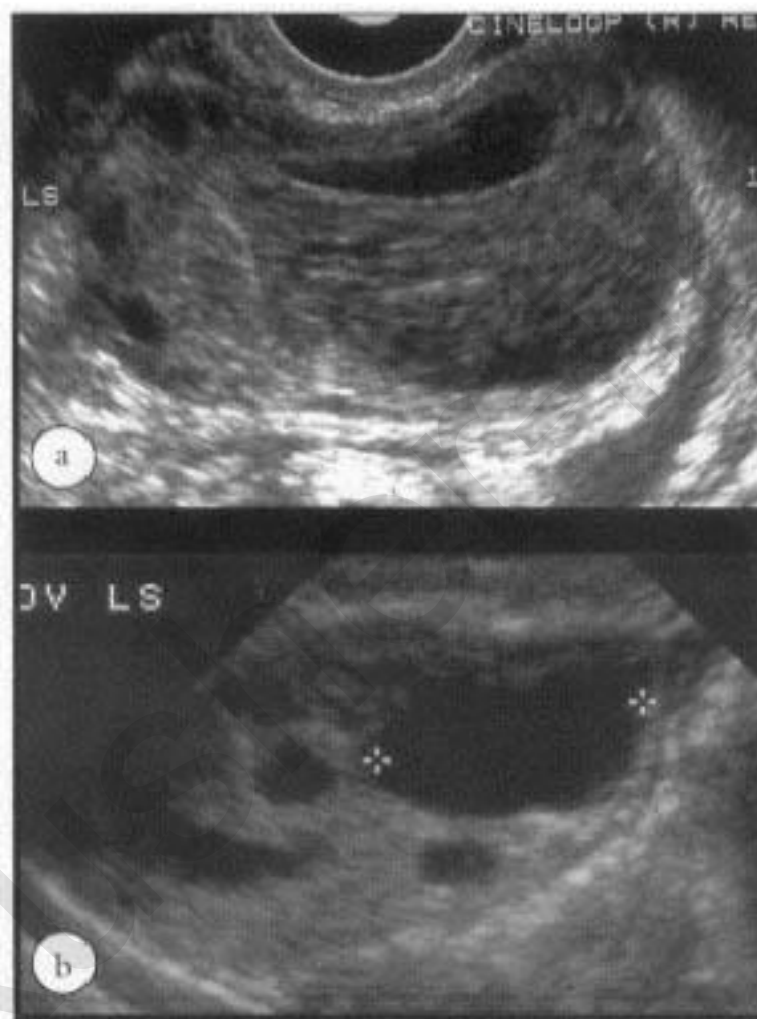
Figure 3—
a) TVS of 5 cm cyst showing internal echoes and a
clear fluid/debris level consistent with haemorrhage into
a right ovarian cyst.
b) Scan for comparison from 4 weeks previously. Simple

Figure 3—
a) TVS of 5 cm cyst showing internal echoes and a
clear fluid/debris level consistent with haemorrhage into
a right ovarian cyst.
b) Scan for comparison from 4 weeks previously. Simple
functional cyst demonstrated in right ovary.
Diagnosis: *Haemorrhage into functional cyst.*
Patient reviewed 4 weeks later and was completely well.

Age	:	32 Years.
LMP	:	Day 7.
Presenting Complaint	:	Acute on chronic pelvic pain.
Pregnancy test	:	Negative.
Previous obstetric/ gynaecological history	:	Chronic mild right sided pelvic pain for 4 weeks. Ultrasound examination 4 weeks ago showed functional cyst. 24 hour history of more severe right sided pain warranting admission.
Clinical examination	:	Acute tenderness right fornix ? mass.

seen in a normal pelvis is variable but as a rule of thumb normal free fluid is always clear and freely mobile. [2] Some functional cysts fail to resolve and may even increase in size and present with acute pain due to stretching of the capsule or to secondary haemorrhage. Initially, the haemorrhage will appear echogenic in first 24 hours. After this the appearances are variable; most commonly low level echos throughout the cyst, but internal septations and a fluid/debris interface can also be seen.[3] Such cysts rarely exceed 5 cm in diameter and will usually resolve within two months.[4] Although haemorrhagic cysts are frequently seen in asymptomatic women during routine transvaginal ultrasound they are also seen in the symptomatic patients. If local tenderness is elicited on transvaginal ultrasound, as in the assessment of fibroid degeneration, it can be presumed that the haemorrhagic cyst is the cause of the pain, (Figure 3). Endometriosis is another pathological cause of haemorrhagic cysts. Endometriosis is defined as the presence of functioning endometrial tissue in an ectopic location. This usually presents with chronic or acute on chronic pain. The ultrasound appearances are of a cystic pelvic mass with homogeneous low level echoes within it which is seen in 82% of patients but, unlike functional haemorrhagic cysts, they tend to persist without resolution and indeed may increase in size.[5]

Normal ovaries may tort, but torsion is commoner in the presence of a cyst. The likelihood of torsion increases with the size of the cyst and also torsion is more common on the right, since the sigmoid colon supports the adnexae on the left.[6] In addition, it is said that malignant ovarian cysts tort less frequently than benign cysts due to local tumour infiltration fixing the ovary to adjacent structures.[7] Pain can refer to the inner aspect of the thigh as the ovary lies on and compresses the obturator nerve which innervates this area. Ultrasound appearances of the torted ovary are of an odematous enlarged ovary which is increased in echogenicity, and can be solid, cystic or complex. Torsion is unlikely if the whole ovary measures less than 5 cm.[8] If colour flow Doppler is available, absence of blood flow may be demonstrated, however, this is not diagnostic since torsion may be intermittent or partial, (Figures 4, and 5). Oophoritis causes enlargement and increased echogenicity of the ovary with prominent cysts secondary to oedema and in this instance colour flow Doppler usually shows increased blood flow. Isolated oophoritis is uncommon and is usually associated with signs of inflammation elsewhere, usually in association with PID, but occasionally, in acute appendicitis. In oophoritis the
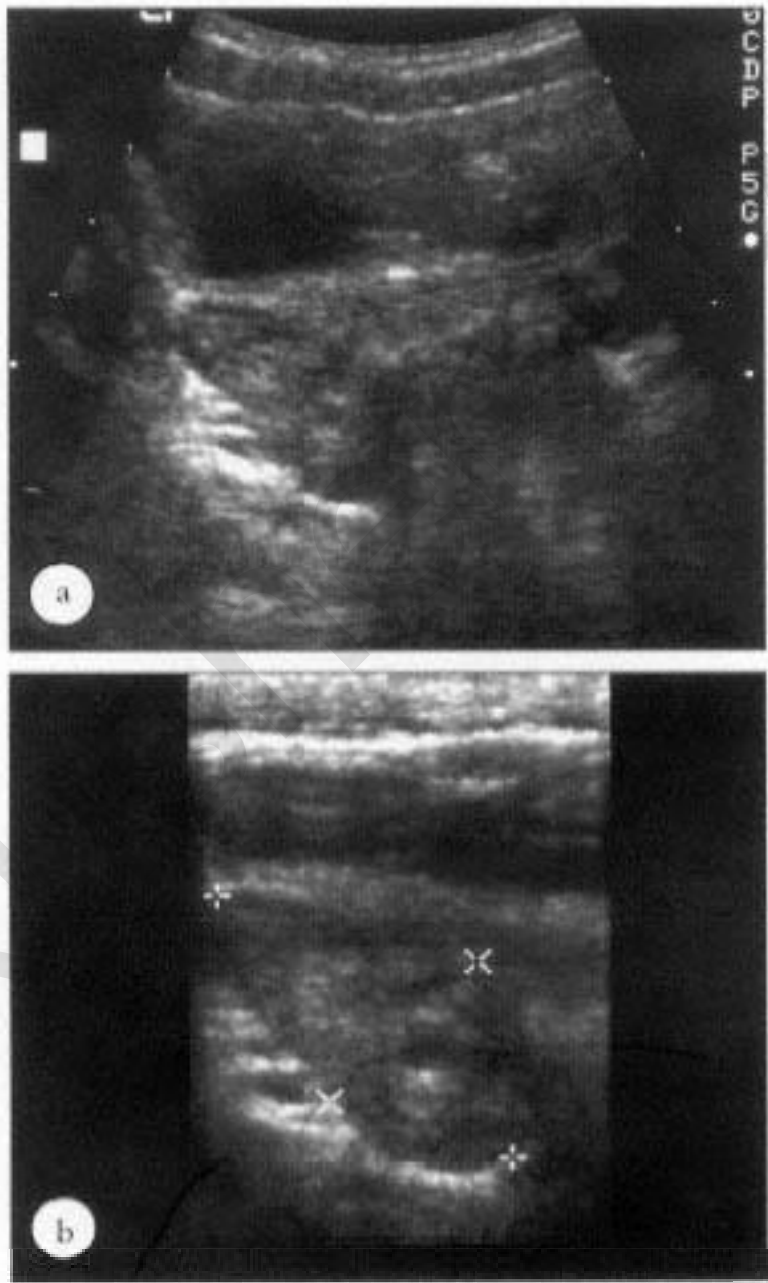
Figure 4—
a) Transverse scan through pelvis. Right ovary significantly larger than left, which is of normal size for premenarchal patient, measuring $2.5\,cm^3$ volume.
b) Magnified view of right ovary showing increased size ($12\,cm^3$) and echogenicity.
During ultrasound examination patient developed very severe pelvic pain. Colour flow Doppler was not helpful due to patient movement.
Diagnosis: *Torsion of normal ovary. At surgery the ovarian pedicle twisted three times; however, the ovary was viable and conserved.*

Age	:	10 Years.
LMP	:	Premenarchal.
Presenting Complaint	:	Severe intermittent acute pelvic pain.
Pregnancy test	:	Not applicable.
Previous obstetric/ gynaecological history	:	None.
Clinical examination	:	Slight pelvic tenderness on right. Notes comment patient well and not in acute pain at time of clinical examination.

previously described findings of endometritis or myometritis are usually seen but the changes of acute salpingitis predominate. Normal fallopian tubes are not reliably seen on ultrasound though this has been disputed. [9] When acutely inflamed, the Fallopian tube is seen as a dilated tube with echogenic fluid within it and exaggerated endo-salpingeal folds, due to the thickening, presenting a `cog-wheel' appearance.[10] This dilated tubal appearance can be misinterpreted as a large parametrial vein but colour flow Doppler can be used to avoid this misdiagnosis. Due to the inflammatory exudate, fluid levels within the tube may be visualised and there may be loss of the `sliding organ' sign, in which normal, uninflamed organs are seen to be freely mobile with reference to each other.[11] In the presence of inflammation the bowel is seen to be adherent to the Fallopian tube, uterus and ovaries and there is free fluid. The most severe form of PID results in a tubo-ovarian abscess which is acutely tender to the extent that it may even limit the TVS. In these cases it is often difficult to decide what is ovarian and what is tubal in origin as there is often a large multi-cystic complex mass with again free pelvic fluid and loss of definition of the uterine

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Figure 5—
Transverse TVS showing complex ovarian cyst.
Colour flow identified within cyst. No obvious free
fluid. Normal uterus and left adnexae visualised
during scanning.
Diagnosis: *On ultrasound, the cyst has typical
appearances of a dermoid cyst. With the history of
acute pain, torsion should be considered. Surgery
revealed a teratodermoid with no evidence of torsion.
What caused the acute pain in this patient, in
whom the cyst had presumably been present for
some time, is not clear. No other pathology was seen
at surgery.*

Age	:	18 Years.
LMP	:	Day 24.
Presenting Complaint	:	Sudden onset pelvic pain over 36 hours.
Pregnancy test	:	Not available.

Pregnancy test	:	Not available.
Previous obstetric/ gynaecological history	:	Denied previous pain.
Clinical examination	:	Tender in pouch of Douglas. No mass felt.
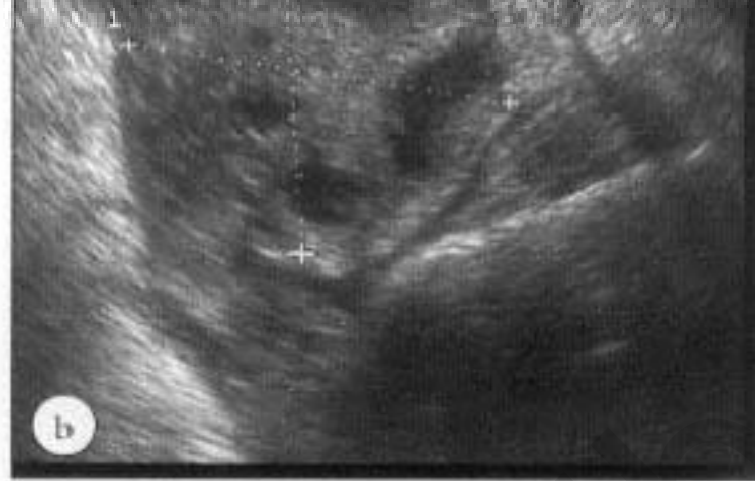
Figure 6—
a) TVS left fallopian tube dilated and serpiginous with echogenic fluid within.
b) TVS right adnexae. Complex mass where fallopian tube and ovary cannot be differentiated.
Diagnosis: *PID with pyosalpinx on left and tubo-ovarian abscess on right. This was treated conservatively with antibiotics but later required surgical drainage.*

Age	:	27 Years.
LMP	:	Day 28.
Presenting Complaint	:	Wide spread pelvic pain gradually increasing in severity over 48 hours.
Pregnancy test	:	Negative.
Previous obstetric/ gynaecological history	:	None.
Clinical examination	:	Severe pv tenderness. Pyrexial.
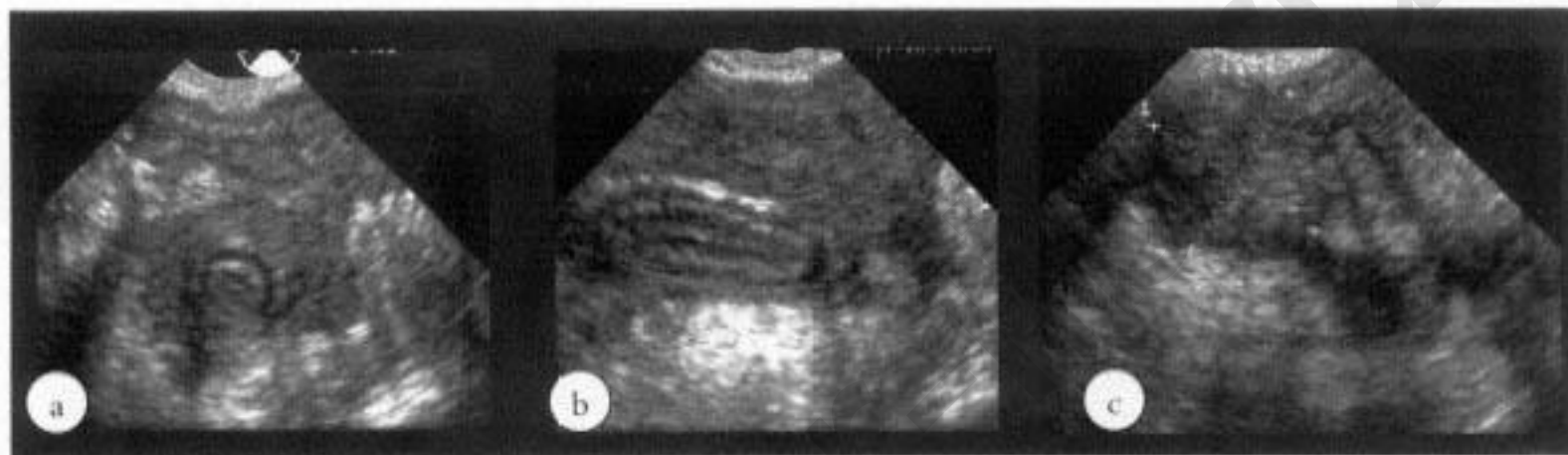
Figure 7—
a, b) Initial TAS suggested an ill defined right sided mass. The TVS shown revealed an oedematous thick walled appendix with loss of sliding organ sign, seen here in transverse and longitudinal section.
c, TVS shows enlarged (18 cm³) right ovary which was increased in echogenicity and adherent to appendix.
Diagnosis: *Acute appendicitis with secondary oophoritis was confirmed at surgery*.

Age	:	20 Years.
LMP	:	Day 14.
Presenting Complaint	:	Severe right sided pain for three days becoming progressively more severe. Small PV bleed two days ago.
Pregnancy test	:	Negative.
Previous obstetric/ gynaecological history	:	None.
Clinical examination	:	Thickening noted in the right fornix with tenderness.

Gastro-Intestinal Tract

Transvaginal ultrasound shows the close proximity of peristalsing small bowel and the relatively adynamic sigmoid colon to the uterus and adnexae and it is,

Transvaginal ultrasound shows the close proximity of peristalsing small bowel and the relatively adynamic sigmoid colon to the uterus and adnexae and it is, therefore, not surprising that bowel disease can cause pelvic pain masquerading as a gynaecological problem.

Appendicitis

In the younger patient appendicitis should be considered as a possible diagnosis. Appendicitis, particularly in the late presenting, case can cause acute inflammation of the adjacent tubo-ovarian structures, and it may then be impossible to decide where the inflammation began. In young girls the diagnosis of acute appendicitis should be made as early as possible before this secondary inflammation occurs, causing late problems of infertility due to adhesions damaging the Fallopian tubes. The ultrasound appearances may include an oedematous enlarged appendix, periappendiceal fluid/abscess, appendicolith and adjacent aperistaltic fluid filled small bowel loops, [13] (Figure 7).

Diverticular Disease

In the older patient acute diverticular disease of the sigmoid colon can cause acute pelvic pain. Although the majority of these patients will also have gastro-intestinal symptoms, such as diarrhoea with blood and mucus in the faeces, some patients present to the gynaecologist with atypical features. The more severe forms of acute diverticular disease can be associated with peri-colic abscess formation which, as discussed above, may be mistaken for primary tubo-ovarian disease. Diverticular disease can also cause complications within the genito-urinary tract, such as utero-colic fistulae, and vagino-colic fistulae which will lead to secondary gynaecological disease with symptoms of a urinary tract infection or vaginal discharge respectively. Ultrasound reveals hypoechoic mural thickening, echogenic inflamed diverticula and pericolic fat. In addition peridiverticular abscesses and linear echogenic foci suggestive of fistulous tracts may be seen.[13]

Inflammatory Bowel Disease

Patients with Crohns disease (an inflammatory bowel disease) can cause diagnostic difficulties. Crohns tends to occur in the younger patient and usually presents with pain, sub-acute obstruction and peri-colic abscess formation. Crohns disease is renowned for fistula formation and this can lead to secondary gynaecological and urinary symptoms. Ultrasound shows sections of thickened
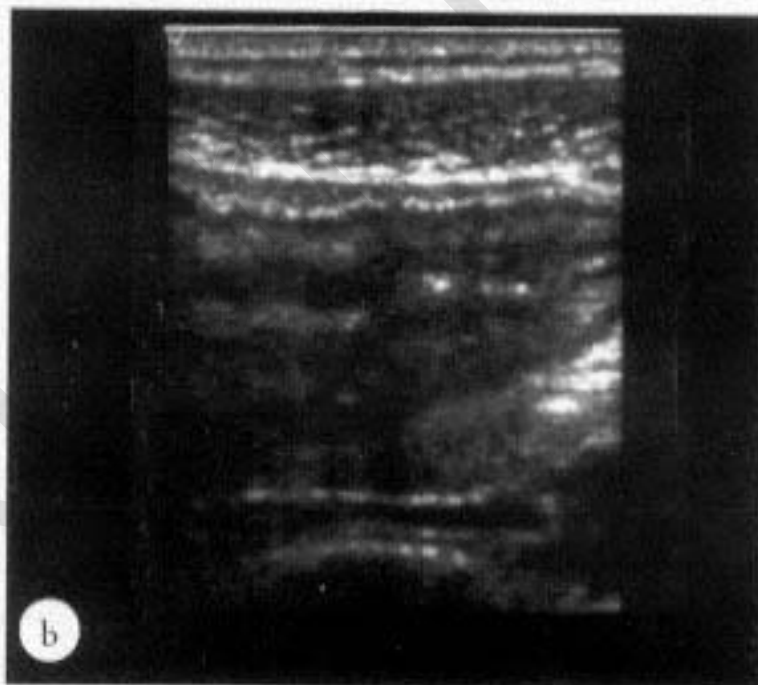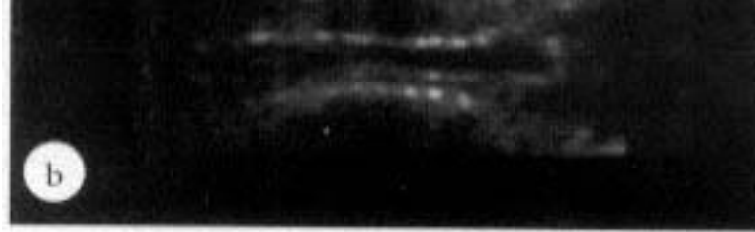
Figure 8—
TAS revealed a viable intrauterine pregnancy of
12 week size.
In the right iliac fossa a thickened loop of bowel was
identified which was tender. The mucosal line is
irregular, consistent with ulceration. From its
position it was considered to be terminal ileum.
No free fluid or associated collections seen.
Diagnosis: *Terminal ileitis presumed due to Crohns
disease. Patients pain settled conservatively.
Following delivery at term, intermittent
pain occurred, though the patient never
suffered from diarrhoea. Small bowel
meal confirmed Crohns disease of terminal ileum.*

Age	: 28 Years.
LMP	: 12 weeks ago.
Presenting Complaint	: Known to be pregnant. Three day history of right sided pelvic pain continuous ache.
Pregnancy test	: Positive.
Previous obstetric/ gynaecological history	: None.
Clinical examination	: Tenderness only.

bowel and, in later stages, features of abscess/fistula formation as described above.

The above discussion underlines how important it is to extend the examination beyond the uterus and ovaries. TV ultrasound visualises the sigmoid colon and adjacent small bowel and, on some occasions, the appendix. However, more importantly, and as discussed earlier, the transabdominal scan may well yield additional vital information, (Figure 8).

Urinary Tract

Patients with cystitis, pyelonephritis and ureteric calculi can all present with pelvic pain. This emphasises how important it is to include the urinary tract in a pelvic examination. Most patients with urinary tract infection or pathology will present with frequency, urgency, dysuria, haematuria and fever. However, many of these features of cystitis can also be present with unrelated primary uterine and ovarian pathology. Ultrasound of the kidneys to assess for normal parenchymal echogenicity, pelvicalyceal distension or tell-tale signs of the scarring of chronic disease may detect underlying renal pathology. If the ureters are followed toward the pelvis, calculi in the lower ureters may be visualised. Assessment with colour flow Doppler of the urinary jets into the bladder can be helpful to exclude ureteric obstruction, (Figure 9). Cystitis itself can cause thickening of the bladder wall which may be visualised on transvaginal ultrasound, and infective "debris" may be found in the urine. These are non-specific, findings and the definitive diagnosis of a urinary tract infection is on direct

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Post-Operative Patient

Acute pelvic pain following pelvic surgery is common. The normal pain of recent surgery needs to be differentiated from the persisting pain of a complication.
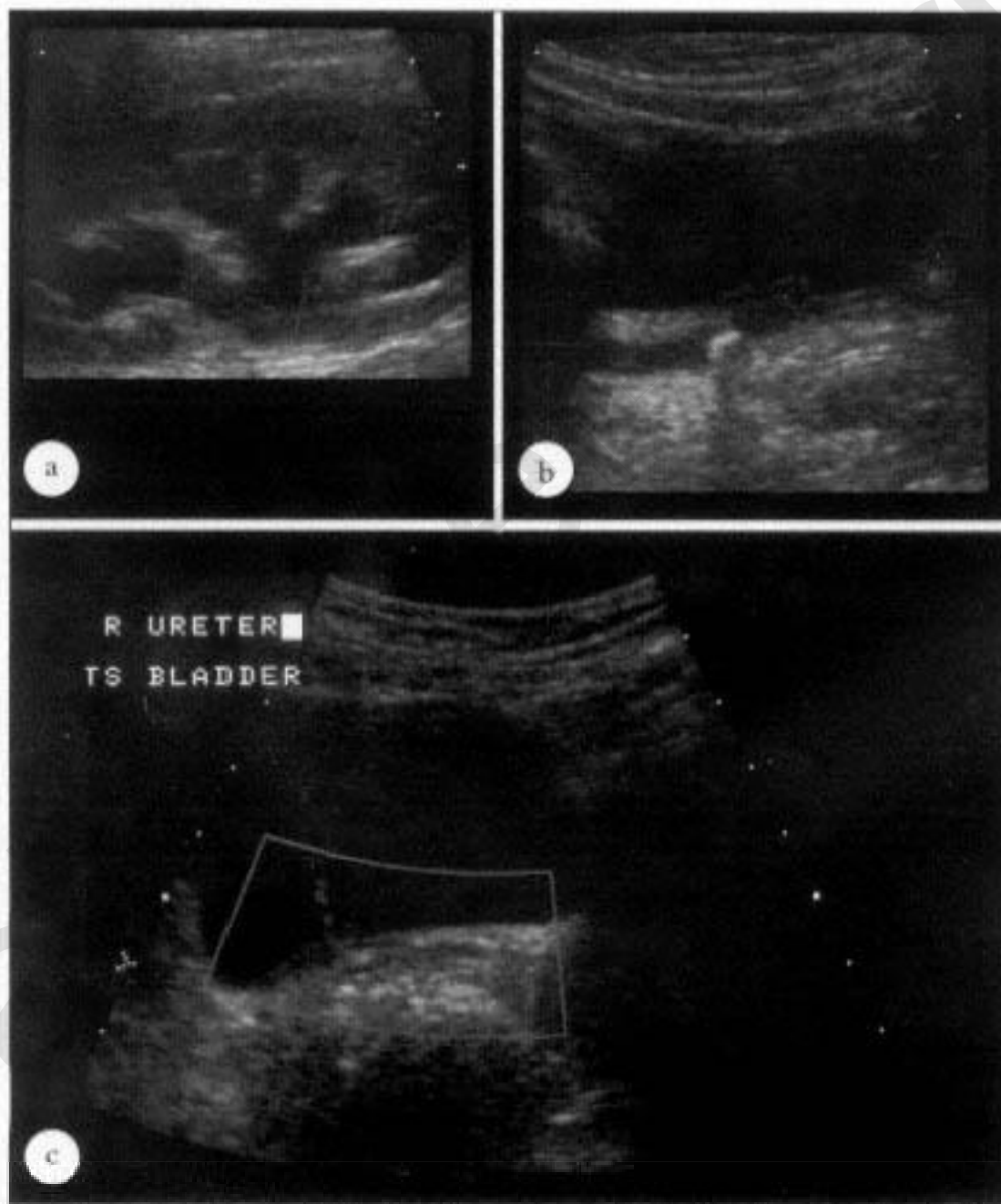
R URETER
TS BLADDER

Figure 9—
a) Right kidney shows pelvicalyceal and upper ureteric distension.
b) Calculus seen in the lower right ureter.
c, Colour flow Doppler showing reduced urinary jet, suggesting partial
obstruction only.
Diagnosis: *Partial obstruction by lower ureteric calculus. The calculus
was passed spontaneously in the next 48 hours.*

Age   : 15 Years.

LMP   : 4 weeks
                                                     ago.

Presenting Complaint   : Localised right sided pelvic pain. Worse on micturition.

Pregnancy test   : Negative.

**Previous obstetric/ gynaecological
history**   : None.

Clinical examination   : NAD.
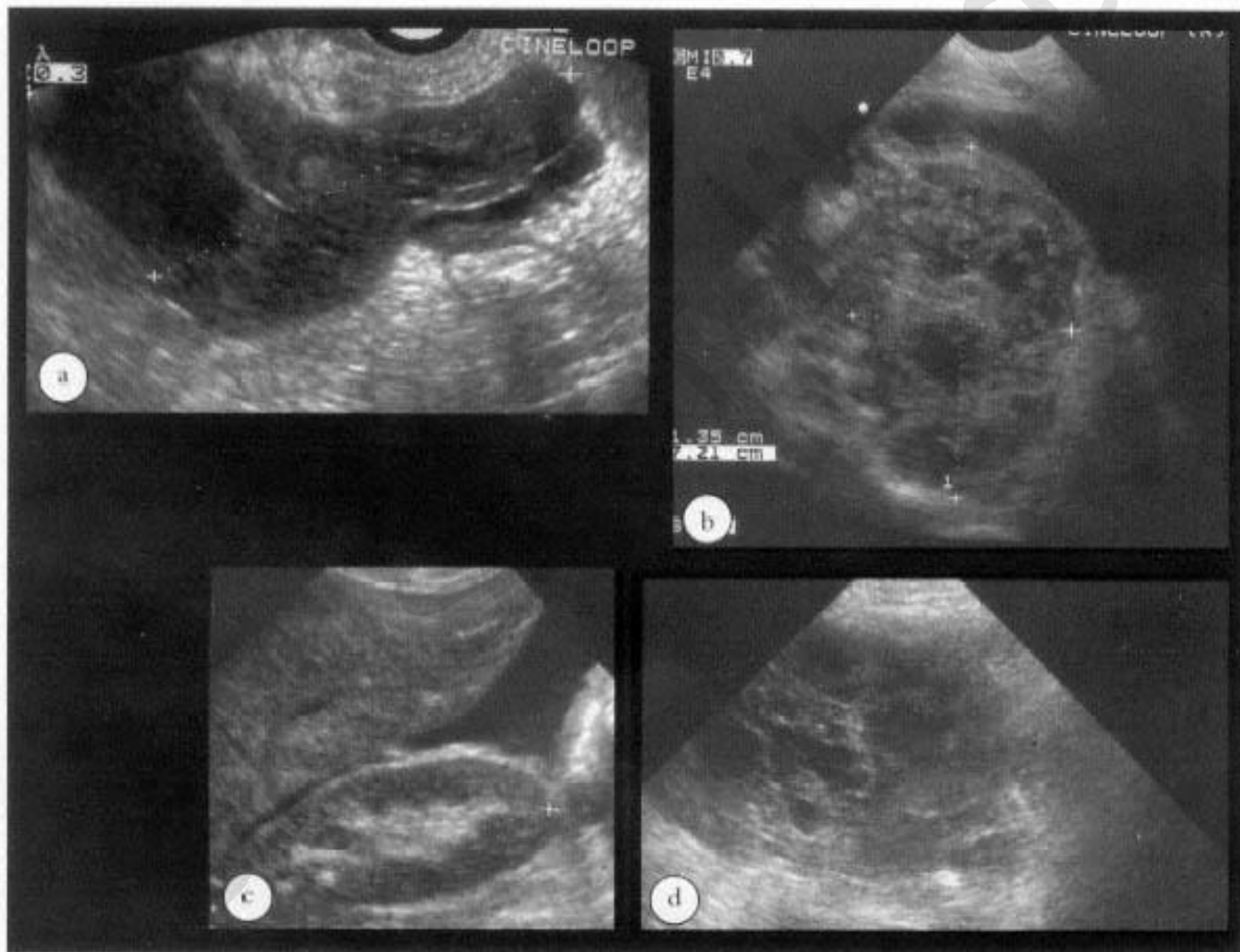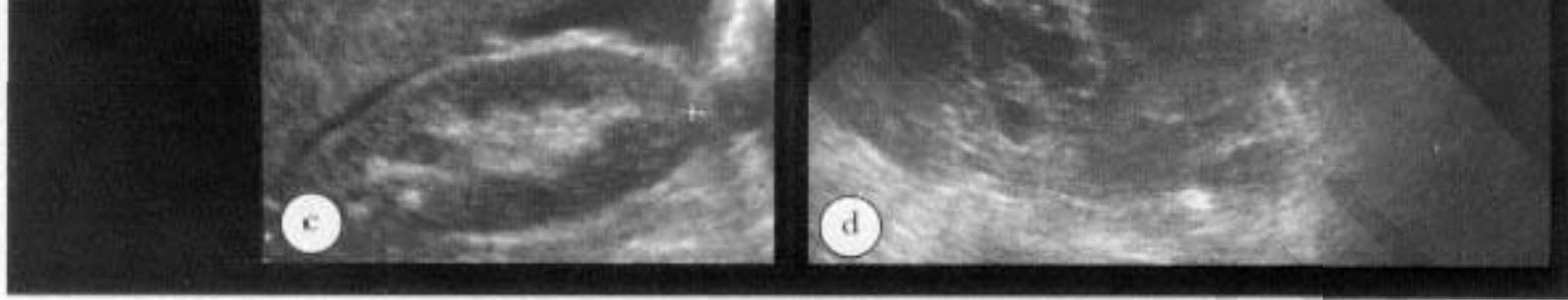
Figure 10

— *a)* TVS showing complex mass adjacent to vault consistent with a vault haematoma involving both ovaries which cannot be clearly distinguished.

b) 4 days later patient's condition deteriorating. Transabdominal pelvic ultrasound shows large complex mass. Pain prevented TVS.

c) Ultrasound left upper quadrant revealed free fluid containing echoes.

d) Ultrasound of the left loin showing a complex cystic mass.

Diagnosis: *Initial post-operative ultrasound shows vault haematoma. However, the patient became septic. Later scans show a large pelvic abscess, left loin abscess and pus in left upper quadrant. This patient required surgical intervention to drain these collections.*

Age	: 42 Years.
LMP	: 14 days.
Presenting Complaint	: Generalised pelvic pain for 3 days. Now acutely unwell.
Pregnancy test	: N/A
Previous obstetric/ gynaecological history	: Hysterectomy 5 days ago patient pyrexial and becoming less ambulatory due to increasing pain.
Clinical examination	: Tender pv? slight fullness.

Wherever surgery has been performed there is a risk of haematoma and abscess formation. For example, following hysterectomy, vaginal vault haematomas and abscesses are relatively common. They are most often found in direct continuity with the vaginal vault and the ovaries, if still present, are often part of the inflammatory mass. In the more severe forms of post-operative infection, paracolic and even sub-diaphragmatic collections can occur and again the importance of examination of the whole abdomen is emphasized. Such patients are often very unwell, (Figure 10).

Acute Pelvic Pain in the Pregnant Patient

Pain Directly Related to Pregnancy

This section deals with the group of patients who suffer pain in the first trimester of pregnancy as a direct result of their pregnancy. The majority of these patients will have prior knowledge of the pregnancy and may also have vaginal bleeding at the time of scanning. However, the differential diagnosis is wider than the request card details `threatened abortion? viability', implies.

Threatened/Inevitable Abortion

A threatened abortion is described as a pregnancy less than 20 weeks with potentially viable fetus and evidence of vaginal bleeding. Pelvic pain is often present. Up to 25% of women have a threatened abortion, [14] and it has been estimated that up to 78% of all human conceptions are lost, often as "late periods". Ultrasound can confirm viability and an obvious subchorionic or retroplacental haemorrhage may be seen, (Figure 11). An incomplete abortion, where there is a non-viable fetus, or evidence of retained products of conception may also be demonstrated. Recent publicity about misdiagnosis of early pregnancy loss has led to guidelines being issued by the Royal Colleges of Radiologists and of Obstetricians and Gynaecologists.[15] Although many believe these guidelines err too much on the side of caution to be of practical clinical help, most radiology departments in the country are now adhering to them for medicolegal reasons.

Ectopic Pregnancy

Ectopic pregnancy is a diagnosis that should be considered in all women of child-bearing age. The risk of death in women with ectopic pregnancies is 1:1000.[16] It is also generally acknowledged that the rate of ectopic pregnancy is increasing and this is thought to be due to a number of factors, not least infertility treatment.[17] Other

Figure 11—
TAS of the uterus confirming viable intrauterine pregnancy of 8 weeks gestation. A moderate subchorionic haemorrhagic is identified.
Diagnosis: *Acute sub chorionic haemorrhage.*
Pregnancy still ongoing at recent routine dating scan.

Age	: 22 Years.
LMP	: 8 weeks.
Presenting Complaint	: Pelvic pain, cramping of 24 hours duration.
Pregnancy test	: Positive.
Previous obstetric/ gynaecological history	: 2 previous miscarriages at 8 and 12 weeks respectively.
Clinical examination	: Uterus correct size for dates. No blood pv. Os closed.

risk factors for ectopic pregnancy include intra-uterine contraceptive device, PID, previous ectopic, tubal surgery, Ashermans syndrome and smoking.

The commonest symptom of ectopic pregnancy is pelvic pain, present in 97% of cases.[18] 95% of ectopic pregnancies are tubal and rarely the pregnancy is ovarian, cervical or interstitial.

The most important fact available to a sonographer at the time of scanning for a possible ectopic is a pregnancy test result. The use of the discriminatory level of serum b

Human Chorionic Gonadotrophin (bHCG) has become widely accepted. This is described as the serum level of the hormone above which an intrauterine pregnancy should be visualised. If this level is reached and an intrauterine pregnancy is not seen, it must be assumed that there is an ectopic pregnancy, a recent abortion or, uncommonly, a molar pregnancy. This level has most recently been quoted at 750 IU/l (Second International Standard). [19] It is presumed this level will decrease as TVS resolution continues to improve.[20]

The classic ultrasound findings of ectopic pregnancy are the the triad of firstly, and most importantly, the lack of an intra-uterine pregnancy, secondly, an adnexal mass, and thirdly, free intraperitoneal fluid (Figure 12). Since the introduction of TVS there has been a decrease in the number of false positive diagnoses as very early intra-uterine pregnancies can now be detected in over 80% of cases. Beware that a `normal' ultrasound of the uterus and ovaries does not exclude an ectopic pregnancy.[20],[21] This emphasizes the importance of obtaining the result of a recent pregnancy test and in assessing the uterus, adnexae and the cul-de-sac; this latter area in particular is often omitted. The pseudo-gestation sac is a major source of confusion in assessment of the uterine cavity (Figure 13). In contrast to the true gestation sac the pseudo-gestation sac, is irregular and contains low level echoes and conforms to the uterine cavity rather than to a well-defined spherical shape. The pseudo-gestation sac contains neither yolk sac nor an embryo, and the decidual reaction `double ring sign' is not usually visualised.[20] Colour flow Doppler may provide additional information in a limited number of patients but it should not be considered a necessity.[20] An adnexal mass seen separate

Figure 12—
a) TAS transverse section showing echogenic adnexal mass adjacent to left ovary.
b, Upper abdominal scan showing free echogenic fluid in right upper quadrant.
Diagnosis: *Ectopic pregnancy with haemoperitoneum. The patient was severely hypotensive on arrival in the ultrasound department. An ectopic pregnancy had not been considered by the paediatricians under whom she had been admitted. The patient was taken straight to theatre from the ultrasound department and had a ruptured ectopic.*

Age	: 14 Years.
LMP	: Not known.
Presenting Complaint	: Intermittent pelvic pain for 1 week 8 hour history of severe abdo pain radiating to right shoulder.
Pregnancy test	: Not known.
Previous obstetric/ gynaecological history	: None.
Clinical examination	: Generalised pelvic and abdominal tenderness.

Clinical examination : Generalised pelvic and abdominal tenderness.
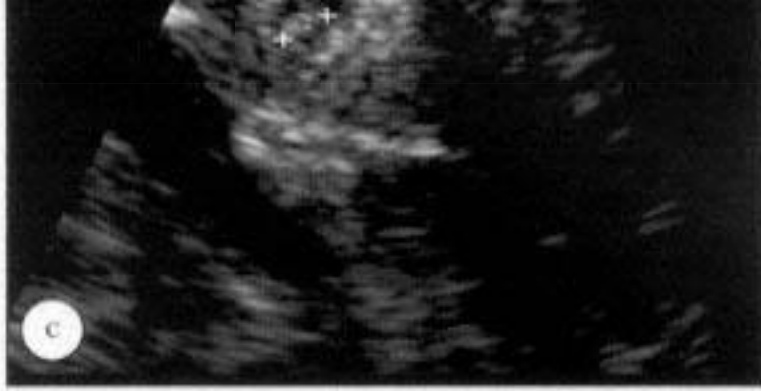
Figure 13—
a) Transverse TVS through uterus. A bicornuate uterus is seen with endometrial reaction in the left horn and an irregular pseudo-sac in the right horn.
b) Transverse section of right adnexal region. An echogenic rimmed mass is seen adjacent to the ovary.
c, A viable fetal pole is seen within this gestation sac.
Diagnosis: *Viable right sided ectopic pregnancy confirmed at laparoscopy where a salpingostomy was performed with removal of the ectopic.*

Age	: 19 Years
LMP	: Unknown. Irregular periods
Presenting Complaint	: Diffuse pelvic pain of 10 hours duration
Pregnancy test	: Positive
Previous obstetric/ gynaecological history	: Episode of PID one year ago.
Clinical examination	: General tenderness.

from the ovaries is also a very strong indicator of an ectopic pregnancy. 60% of ectopic pregnancies will have abnormal free fluid within the pelvis. This is not due to rupture of an ectopic pregnancy but due to the invading trophoblast causing haemato-salpinx, which then flows retrogradely into the peritoneal cavity causing a haemo peritoneum. Indeed, there are no diagnostic findings of tubal rupture on ultrasound. [21]

Ovarian ectopics are uncommon, and not only is their diagnosis extremely difficult on ultrasound, but they are also often misdiagnosed even at surgery. This is because on ultrasound the corpus luteum can often show significant thick echogenic wall, and will also show considerable increased blood flow on colour flow Doppler.

The finding of a normal intra-uterine pregnancy should not lead to complacency; remember the additional
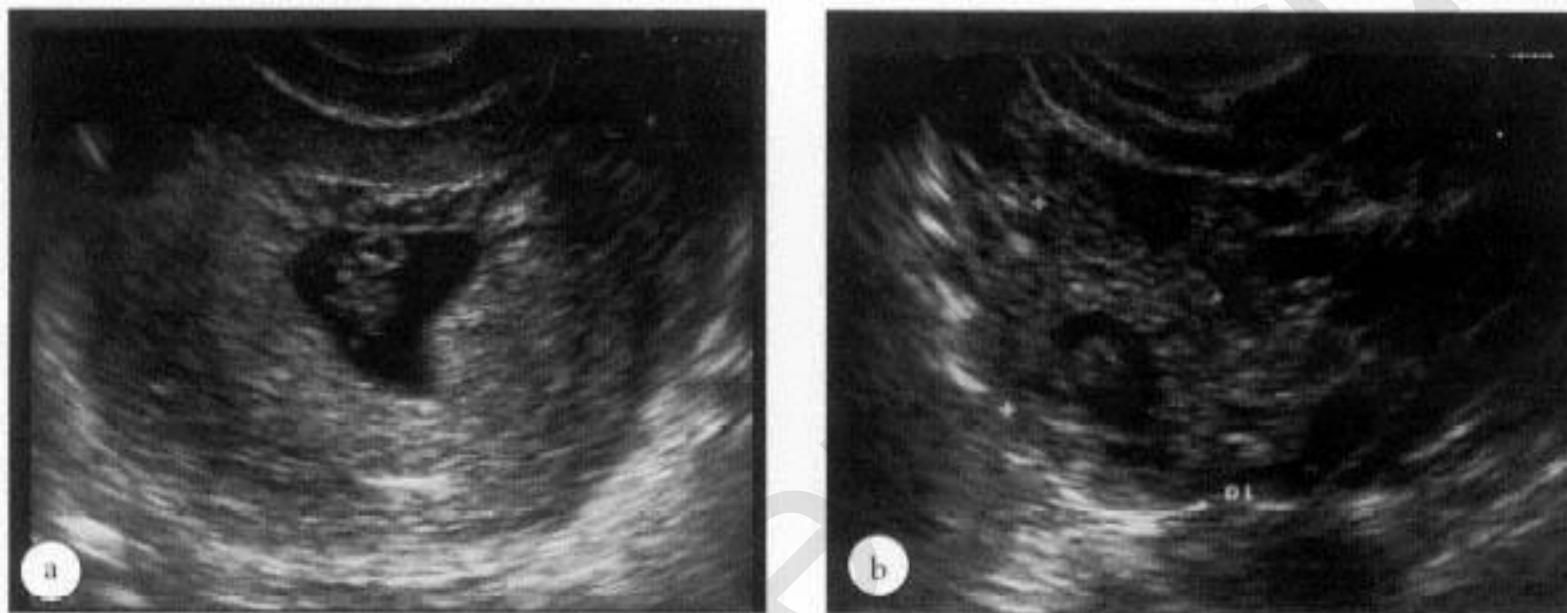
Figure 14—
a) Viable intrauterine of seven weeks gestation.
b) Viable ectopic pregnancy of seven weeks gestation in right adnexae.
Diagnosis: *Heterotopic pregnancy in a women with no pre-disposing factors. This would have been missed if full examination of adenexae and cul de sac had not been performed in order to find a cause for pain in this patient with a viable intrauterine pregnancy.*

Age	: 32 Years.
LMP	: 7 weeks ago.
Presenting Complaint	: Dull aching pelvic pain of 4 days duration becoming increasingly severe over 24 hours.
Pregnancy test	: Positive.
Previous obstetric/ gynaecological history	: None.

Clinical examination : Enlarged uterus consistent with dates. Os closed.

Figure 15—
TVS longitudinal section through retroverted
uterus. A gestation sac with a viable pregnancy is
seen in the cervix. No myometrial `rim' is seen
around the sac, which bulges from the cervix.
Diagnosis: *Cervical ectopic. This was initially
thought to represent an inevitable abortion.*

Age : 30 Years

LMP : Uncertain

Presenting Complaint : Dull aching pain in perineum and pelvis

Pregnancy test : Positive

**Previous obstetric/ gynaecological
history** : T.O.P. 1 year previously.

Clinical examination   : Fullness in pouch of Douglas.

second ectopic, the so-called heterotopic pregnancy. Although rare, about 1 in 30,000 natural pregnancies, infertility treatment can increase this rate to 1 in 8000, [22] (Figure 14).

Cervical ectopics are exceptionally rare, but can result in life-threatening haemorrhage and require abdominal hysterectomy.[23] This is a devastating operation for the woman planning a family. An additional predisposition to this form of ectopic is Asherman's syndrome, where intrauterine adhesions occur following zealous dilatation and curettage. In many reported cases, inevitable abortion is the initial diagnosis. An early rescan will confirm cervical implantation, and prominent blood flow seen around the gestation sac on colour flow imaging may give additional support to the diagnosis, (Figure 15).

Recent figures indicate the incidence of ectopic pregnancy is now 19.7/1000 of all reported pregnancies, and represents 9% of all pregnancy related deaths.[24] There has been a decline in the in-patient treatment, as many are now treated as out-patients by salpingectomy, salpingostomy or methrotrexate orally, or injected via the transvaginal route. Because previous history of ectopic is a strong risk factor for recurrence, all patients with this history should be examined early in subsequent pregnancies (as early as six weeks) to ensure an intrauterine pregnancy.

Trophoblastic Disease

The usual clinical presentation of hydatidiform mole is intractable vomiting or threatened abortion which is due to the high level of Human Chorionic Gonadotrophin (HCG). A further effect of this hormone is ovarian hyper-stimulation, as can occur when HCG is used in infertility treatment. The overstimulation of the ovaries produces an excessive number of large functional cysts (often termed theca lutein cysts in this disease process) in 50% of women.[25] These rapidly expanding cysts produce acute pelvic pain, due to stretching of the ovarian capsule.

A complete hydatidiform mole is the commonest form of trophoblastic disease and is an abnormal conceptus, without an embryo, and characterized by abnormal proliferation of the trophoblast. Although the appearances are usually typical in the second trimester, ultrasonically they are indistinguishable from the appearances of retained products of conception in the first trimester abortion. The differential diagnosis of a hydatidiform mole includes hydropic degeneration of the placenta and haemorrhage or cystic degeneration of a leiomyoma. A past medical history of hydatidiform mole is associated with an approximately 30-fold increase risk of hydatidiform mole in subsequent pregnancies. The previously described theca-lutein cysts can take up to eight weeks to regress and are a cause of continuing pelvic pain following surgical removal of the molar pregnancy.

In extreme examples of ovarian hyper-stimulation syndrome, whether iatrogenic, or related to hydatidiform mole, excessive amounts of pelvic free fluid, abdominal ascites and pleural effusions can be seen, (Figure 16).

Pain not Related Directly to Pregnancy

Whilst it is natural tendency to focus on pregnancy as the cause of a patient's pain, it should be remembered that the simple fact of pregnancy does not render the woman immune from the disease processes and causes of pain that have been previously discussed in other sections. A pregnant patient with pain can be doubly difficult to assess, firstly, on account of distortion of normal anatomy by the gravid uterus and, secondly, because of the anxiety generated through fear that pain experienced really is due to fetal compromise. This section will concentrate on the most frequent and relevant causes of non-pregnancy related pain in the pregnant patient.

Uterine

Although fibroids have previously been discussed, in pregnancy the rate of growth tends to be particularly rapid in the second trimester, which can precipitate degeneration and haemorrhage. If previous ultrasound scans exist, for example from a dating scan, it is often helpful to compare directly and assess for cystic change or size of the leiomyoma. The development of cystic/anechoic areas within the fibroid represents significant degeneration.[26] Again localised tenderness is a very important ultrasound finding in these cases. Multiple fibroids are also associated with a high rate of premature contractions.

Ovarian Cysts in Pregnancy

In pregnancy, ovarian cysts are usually an incidental finding on routine pregnancy scanning. In approximately half they are asymptomatic and are followed up by serial ultrasound. The patient may become symptomatic if the ovarian cyst increases in size, ruptures or torts. Given the risk of surgery in the pregnant

In pregnancy, ovarian cysts are usually an incidental finding on routine pregnancy scanning. In approximately half they are asymptomatic and are followed up by serial ultrasound. The patient may become symptomatic if the ovarian cyst increases in size, ruptures or torts. Given the risk of surgery in the pregnant patient, all attempts are made to treat the cysts conservatively unless there is evidence of torsion or rupture. The majority, about 75%, of cysts are less than 10 cm in size.[27] If the cyst increases to a size greater than 10 cm the risk of the above complications is higher and surgery is usually advised. Rarely, the cyst appears complex and large, (greater than 5 cm), on ultrasound and in these circumstances malignancy, although rare, must be suspected and, again, surgical treatment is often advised.[28] (Figure 17).
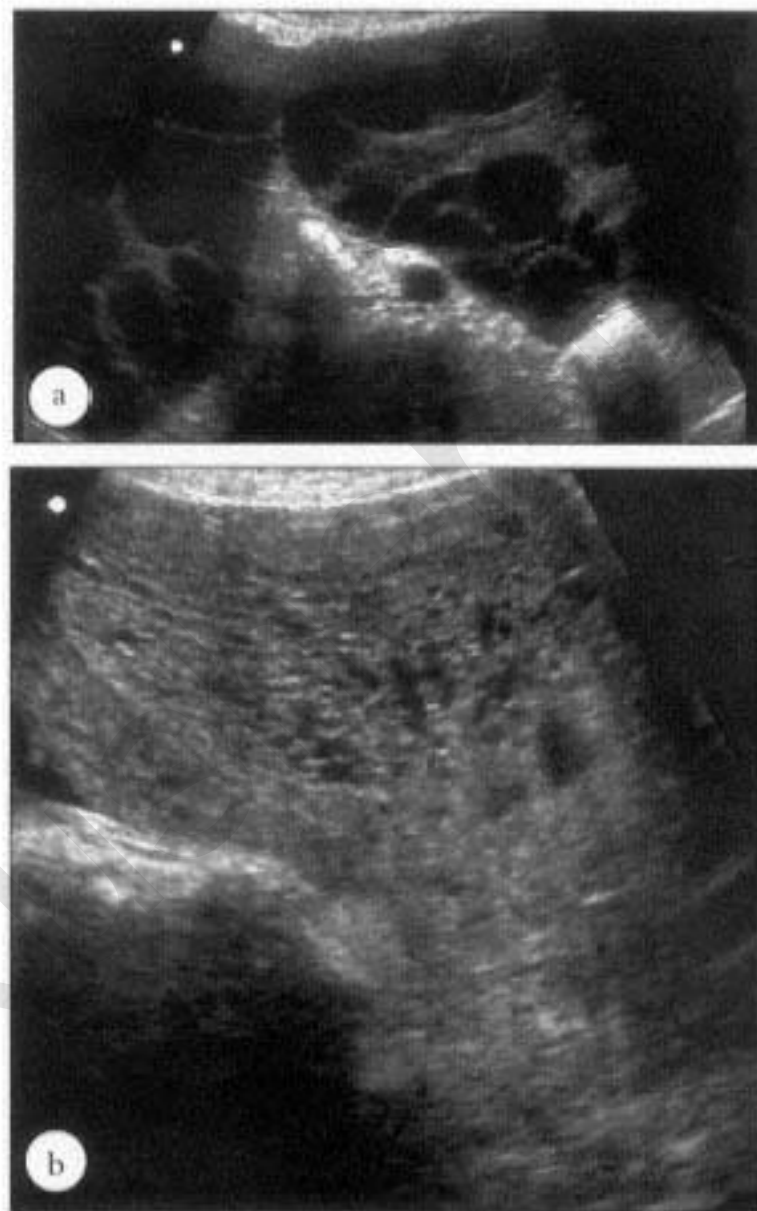
Figure 16—
a) TAS shows bilateral multiple ovarian cysts.
Maximum diameter of ovaries was 10 cm.
b) TAS of uterus revealed a prominent endometrial
thickening which was cystic and showed increased
blood flow on colour flow Doppler.
Diagnosis: *Bilateral theca lutein cysts associated
with a molar pregnancy confirmed at dilatation
and curettage and HCG levels were high. The
cysts took 9 weeks to resolve.*

Age : 19 Years.

LMP : Day 14.

Presenting Complaint : Bilateral groin pain of 24 hours duration.

Pregnancy test : Result not available at time of scanning.

Previous obstetric/ gynaecological history : None.

Clinical examination : Pelvic mass.
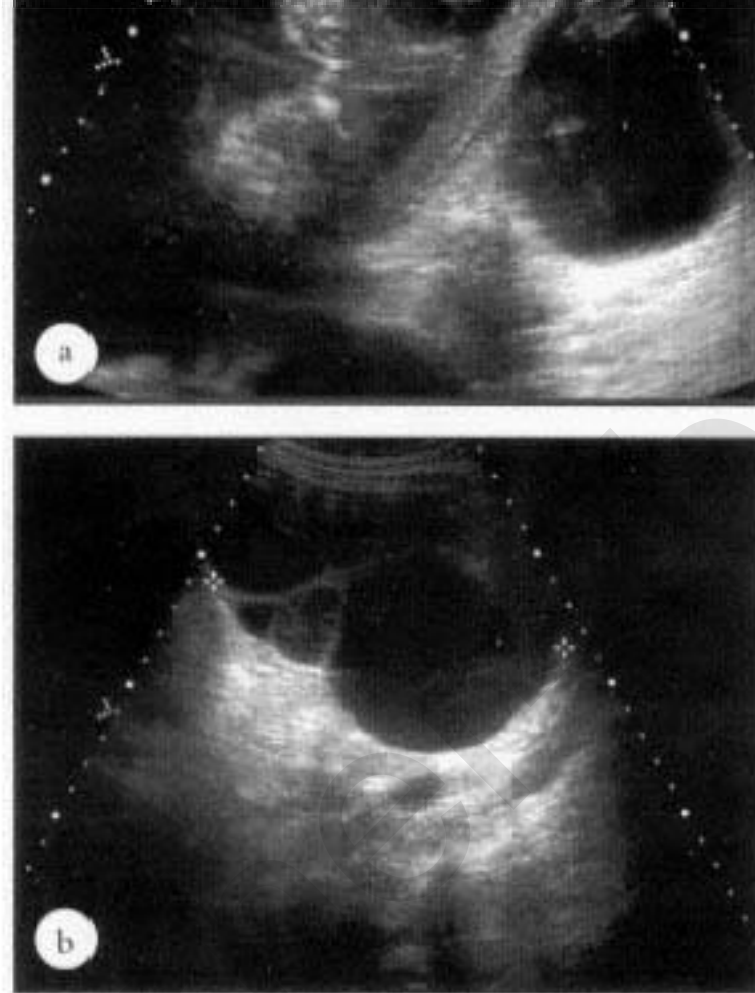
Figure 17—
a) Viable 24 week intrauterine pregnancy ovarian cyst seen on left.
b) Complex left ovarian cyst measuring 11 cm diameter.
Diagnosis: *Complex left ovarian cyst, - size sufficient to cause concern of torsion/rupture. However, there is poly-hydramnios. Because of this surgery must be avoided in order to prevent premature labour. Patient at present under regular observation Now six months pregnant. No change in the appearances of the cyst.*

Age : 22 Years.

LMP	: 5 months ago.
Presenting Complaint	: Pain left side pelvis for 3 days.
Pregnancy test	: Known to be 24 weeks pregnant.
Previous obstetric/ gynaecological history	: No abnormality detected.
Clinical examination	: No abnormality detected.

Figure 18—
Right renal ultrasound shows a dilated
pelvicalycealBsystem, but in addition an obvious
renal calculus. The ureter could not be identified
in the pelvis.
Diagnosis: *Right ureteric calculus, confirmed
on passage of calculus. Although the renal
dilatation could be considered within
physiological limits of pregnancy and was no
more than on the asymptomatic left side, the
renal calculus gave supporting evidence
that an additional ureteric calculus was the*

Diagnosis: *Right ureteric calculus, confirmed on passage of calculus. Although the renal dilatation could be considered within physiological limits of pregnancy and was no more than on the asymptomatic left side, the renal calculus gave supporting evidence that an additional ureteric calculus was the likely cause of pain.*

Age	: 37 Years.
LMP	: 28 weeks ago.
Presenting Complaint	: Severe right iliac fossa pain intermittent and associated with vomiting. Fetal movements normal.
Pregnancy test	: Not applicable.
Previous obstetric/ gynaecological history	: Two normal full term deliveries.
Clinical examination	: No abnormal findings.

Urinary Tract in Pregnancy

The two commonest urinary tract diseases in pregnancy are pyelonephritis and renal colic. For reasons that are not clear, renal colic tends to present in the second and third trimester as opposed to the first trimester and, though infrequent, it is a significant management problem. [28] Ultrasound assessment is difficult as varying degrees of pelvicalyceal and ureteric distension are part of the normal physiology of pregnancy and it is often not possible to decide when this becomes pathological. The pelvicalyceal system will be distended which will mimic pressure distension due to a distal calculous obstruction, (Figure 18). This is confirmed by research which suggests that the ultrasound scan will be considered `normal' in 56% of cases of ureteric calculi in pregnancy.[29] The classic symptoms of loin pain radiating to the pelvis are not as clear cut in pregnancy and again pregnancy related causes of pain, such as placental abruption must be considered. The other main differential diagnosis is pyelonephritis which will give a similar range of appearances on ultrasound and may also show haematuria on urine testing. Ultimately, microbiological analysis is necessary to make the diagnosis. Most patients with urinary tract disease will settle with conservative treatment, very few requiring intervention such as nephrostomy or cystoscopic calculus retrieval. (Figure 18).

Conclusion

Ultrasound is a quick, risk-free, first-line investigation in women with pelvic pain. The approach should be holistic so that the relevant history is obtained and a complete appropriate examination can be performed in each patient. The main drawback is that ultrasound is so highly operator dependent. In my experience, ultrasound can be relied on to answer the clinical question in the vast majority of women with acute pelvic pain, although recourse to other investigations, such as CT and MRI will be needed in a selected few.

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8—

Ultrasound in Infertility

Jeanette Clewes

Josephine Swallow

Introduction

Historical development of ultrasound in infertility

The normal spontaneous menstrual cycle

The sub-fertile couple

Ultrasound in the diagnosis of infertility

Ovulation disorders

Ultrasound in the treatment of infertility

Assisted conception techniques

Problems arising from assisted conception

Guidelines and legislation

Introduction

Infertility is defined as a failure to conceive a desired pregnancy after twelve months of unprotected intercourse. With appropriate evaluation and therapy approximately 50% of these couples will subsequently achieve a pregnancy.

Infertility causes a form of grief similar to that of bereavement. It is deeply painful and deserves help from a caring and dedicated team of professionals who possess good communication and counselling skills. It is now mandatory to offer proper counselling to couples seeking fertility treatment.

Historical Development of Ultrasound in Infertility

The demonstration of ovarian follicles in the female pelvis by ultrasound became recognised and published in the mid 1970's. Hackelöer and Hansmann in 1976 [1] were some of the first workers to indicate that it was possible to demonstrate ovarian follicles, to measure their size and to monitor their growth by ultrasound. Their results were confirmed in 1978[2] and in 1981[3] in women with normal menstrual cycles. From 1980, these and many other authors described and published their results.[4],[5]

In the UK, the very first symposium on the role of ultrasound in the management of infertility was held at the Walton Hospital in Liverpool in 1981, the proceedings of which were published,[6] and formed the basis of established practice in the UK at that time. This publication included the observation that successful imaging of ovarian follicles will always depend upon two fundamental factors: the quality of the imaging equipment and the experience of the ultrasound operator. These two factors are, of course, still very relevant today.

In the early 1980's the technique of ultrasound imaging of the ovaries was performed transabdominally with static `B' scanners, real time linear array and sector scanners. Many of the characteristics of the serial monitoring of the female menstrual cycle by ultrasound, reported in the late 70's and early 80's, have basically not changed and are summarised in Table 1.

The introduction of transvaginal ultrasound probes in the late 80's and 90's has dramatically improved the image quality obtained, and provided for greater patient examination acceptability by obviating the requirement of a full bladder. The characteristics reported in 1981, (Table 1), still currently apply. With transvaginal ultrasound the failure rate is unchanged, some 2% of patients will have ovaries which are out of the focal range of the tranducer and will require an abdominal examination. The serial monitoring of the cyclical development of ovarian follicles with ultrasound is unchanged, except that the dramatic improvement in image quality now allows for endometrial thickness measurements and changes in the texture to be observed. These vary according to the cyclical changes and the effects of modern day hormonal preparations used in ovarian stimulation regimes. Improved image quality has also resulted in the improved diagnosis of gynaecological pathology associated with reduced fertility in women

Table 1. (After Christie 1981[6])

Characteristics of ultrasound imaging and monitoring observed in 1981

- The failure rate of imaging the ovaries is 2%.

- Ovarian follicles greater than 4mm can be identified.

- The Graafian follicle can be distinguished from a follicular cyst by identifying the cumulus oophorus as the follicle reaches maturity.

- Ovulation generally occurs when Graafian follicles are 18-22mm in diameter.

- The corpus luteum can be identified following follicular monitoring.

- In certain cases ovulation may be predicted.

In certain cases ovulation may be predicted.

- Ovulation may be confirmed by uterine endometrial characteristics.

which has contributed greatly to the improved management of these women in the 1990's.

The Normal Spontaneous Menstrual Cycle

Before considering the various treatment regimes available, the reader is advised to review the normal menstrual cycle of events in Chapter 3, and the related ultrasound features.

The three phases of the menstrual cycle related to the ovaries are revistited in Figure 1.

The Follicular Phase

After recruitment and selection of the dominant follicle, growth and development can be monitored by demonstrating the linear increase of mean follicular diameter at a rate of 2-3mm per day, with maturity at around 18-20mm mean diameter just prior to ovulation. Growth and maturation of dominant follicles can be correlated with the serum assay of associated elevations in oestrogen concentration.

The ultrasound appearance of a follicle is that of a thin walled, spherical transonic structure within the ovary, demonstrating a progressive increase in size. The measurement given should represent the mean follicular diameter, which, with increasing experience and competency may be estimated as demonstrated, (Figure 2). The endometrium is measured by scanning through the longitudinal axis of the uterus in the midline, with the calipers positioned across the double layers of the endometrium, perpendicular to the centre line, which represents the double interface of the two layers of the cavity wall in close apposition. The hyperechoic rim around the outside edge of the endometrium which represents its interface with the myometrium, should not be included, (Figure 3). The normal endometrial thickness increases from 4 mm on day six of the menstrual cycle, to approximately 8mm just prior to ovulation in spontaneous cycles, 9-10 mm in clomiphene citrate stimulated cycles, and approximately 12 mm in cycles stimulated with gonadotrophins. [8]

The Ovulatory Phase

Following the oestrogen evoked LH surge, rupture of the dominant follicle can be observed upon ultrasound as a significant reduction in size or the complete disappearance of the follicle. The irregular outline of the thickened oedematous wall of a recently ruptured follicle can be demonstrated, (Figure 4). All of these findings may be accompanied by the appearance of, or an increase in the amount of, free fluid in the pouch of Douglas, (Figure 5).

The Post Ovulatory or Luteal Phase

This phase of the menstrual cycle has previously not been subjected to detailed ultrasound evaluation. There is an increasing amount of evidence supporting the role of ultrasound in the evaluation of the normal and abnormal sequence of events of this phase both in the presence and in the absence of fertilisation and conception.

The Sub-Fertile Couple

An estimated one in every six couples in the UK are affected by reduced fertility. In the general total population, 80% of women will become pregnant by the end of the first year of regular, unprotected intercourse and 90% after 18 months, with the chances of conception decreasing with time after this two year period.[9] Therefore 10% of this population will present to their GP initially and will need some form of assistance to achieve a pregnancy. It must also be remembered that all human fertility declines with age and this decline starts well before the menopause. On average biological infertility commences ten years prior to the menopause in British women.

It is important, therefore, that a couple be referred by their GP to a specialist fertility clinic as soon as possible after the first year period when there is a reasonable chance that one or more problems causing a couples reduced fertitlity may be treated. Prompt recognition of the factors which may be causing their reduced fertility leads to ordered and logical attempts at treatment. This is particularly important in view of the availability of new techologies which now offer real hope to couples whose prognosis would have been hopeless just a few years ago.

Today, male infertility, failure to ovulate effectively and tubal disease are by far the commonest causes of reduced fertility in the UK, (Table 2). In as many as 20% of infertile couples, both partners will contribute to the problem and in some couples there may be three or more factors present all working to prevent conception.

The importance of rigorous and thorough initial investigations can not be stressed enough, in order to determine the most efficacous and cost effective treatment regime for each couple. Traditionally, the female was investigated primarily, male partners being often unamenable to investigation. Treatments are now becoming more sucessful, however, and men are more amenable to allowing investigations into their fertility, thus accepting more responsibility for their role in an infertile relationship.

FSH ml IU/ml   LH ml IU/ml

Ovulation

Follicular Phase   Luteal Phase

(Recruitment)

Rescue

Selection   Nidation

Growth & Development

Estrogen pg/ml   Progesterone ng/ml
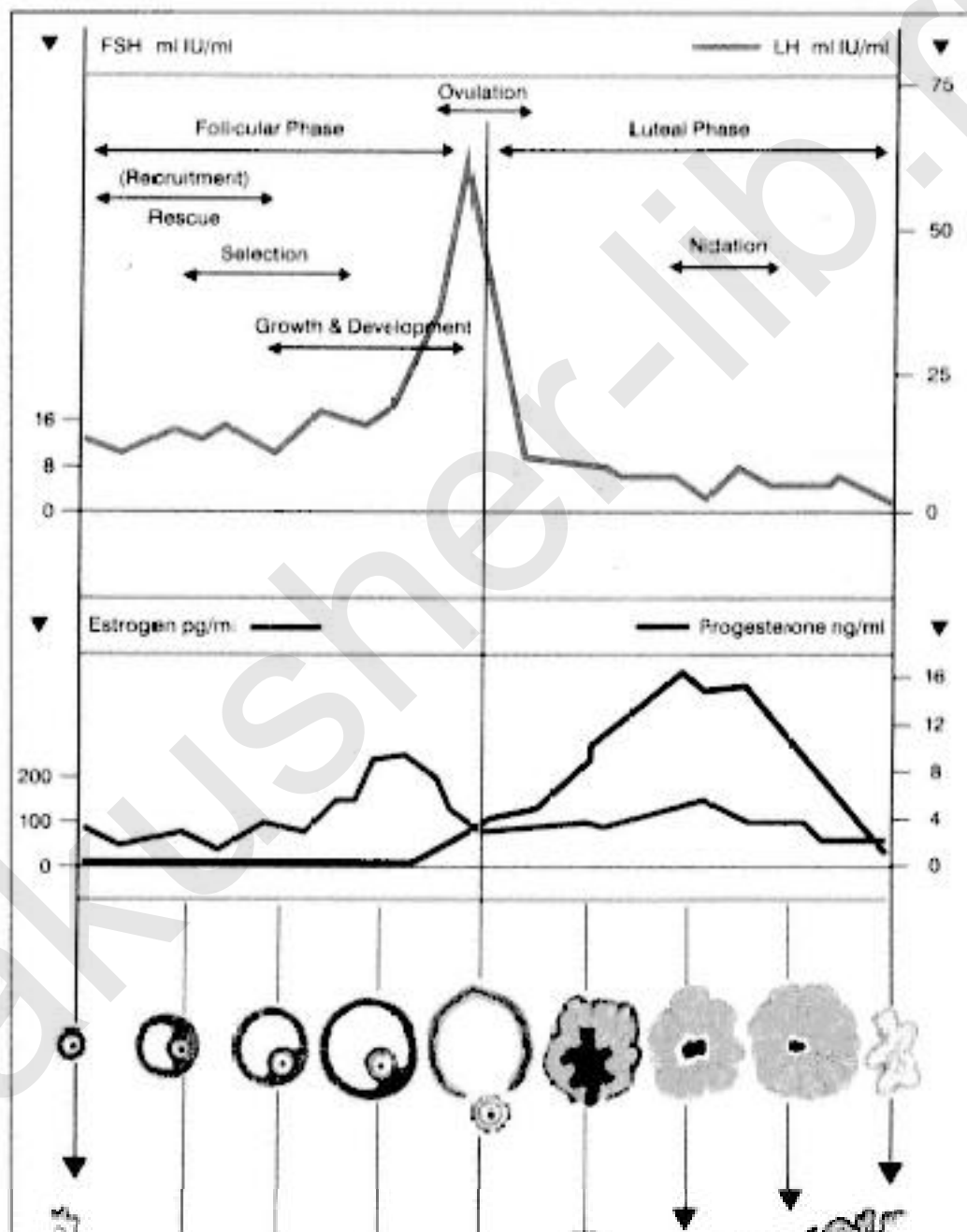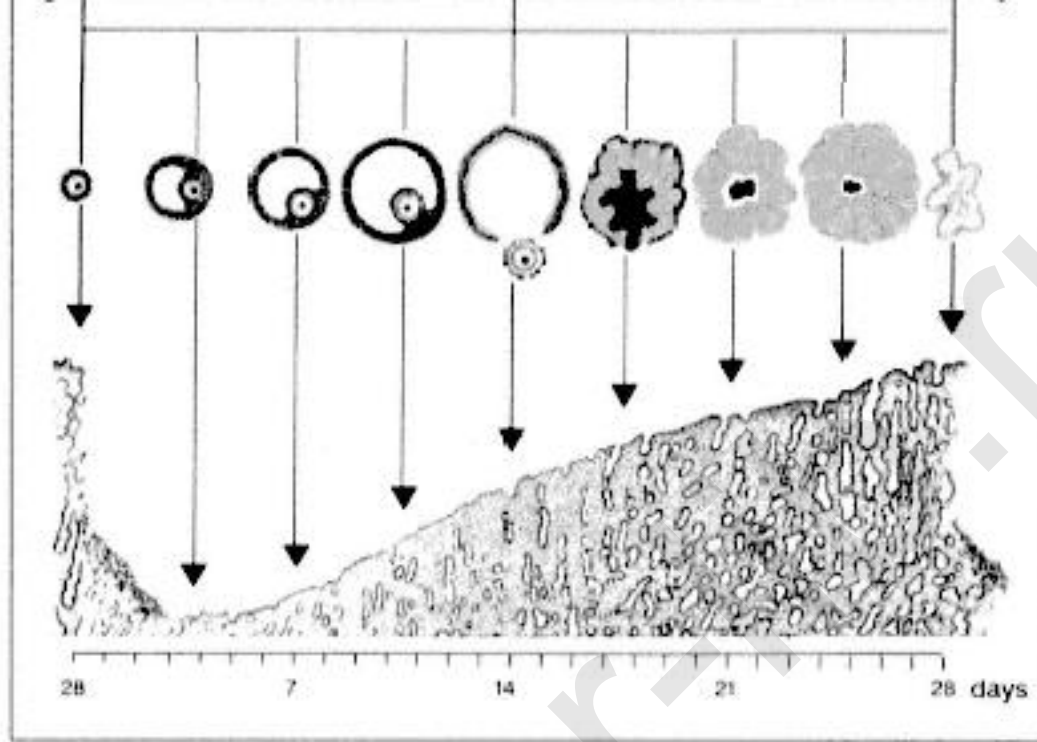
Figure 1—
The Menstrual Cycle. Schematic presentation of hormonal profiles
and endometrial events, after Lunfield et al. [7]
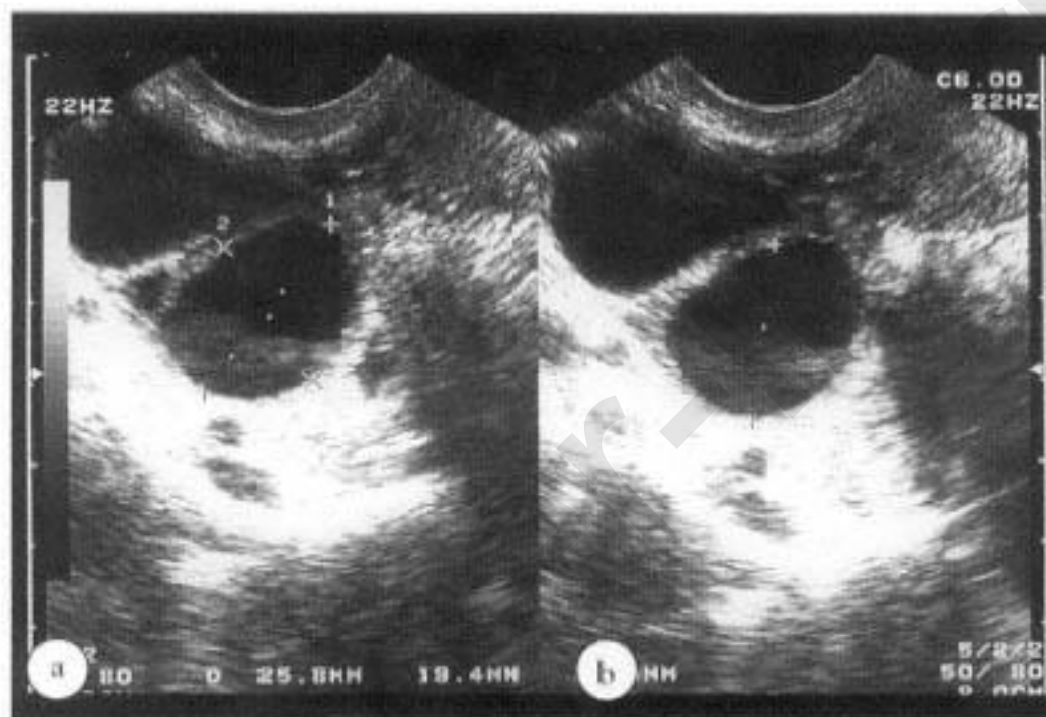
Figure 2—
A mature follicle.
a) shows distance 1 = 26mm.
Distance 2 = 19mm. Representing the maximum and the minimum
diameters.
b) shows the estimated mean diameter of 22mm.

Figure 3—
Endometrial thickness measuring 12mm.
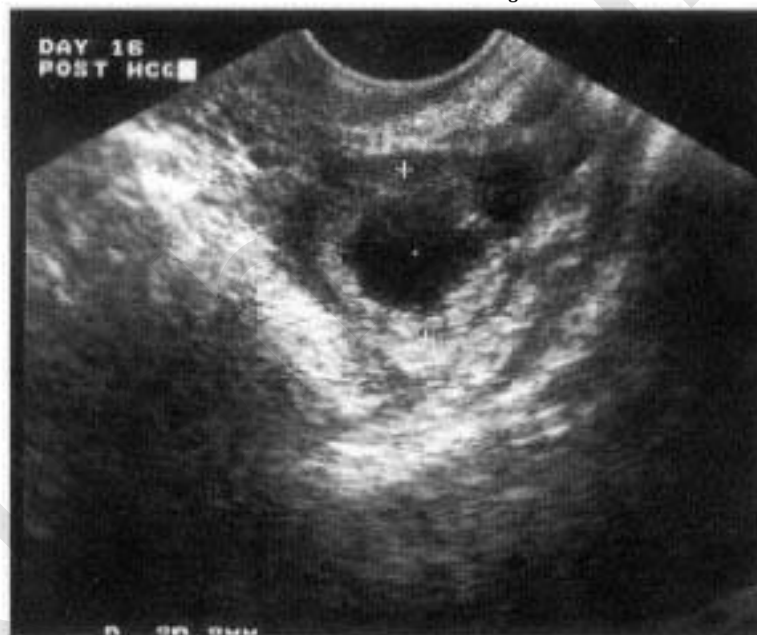
Figure 4—
A ruptured follicle. Demonstrating thick,
oedematous, irregular walls.

Figure 5—
Fluid in the pouch of Douglas post ovulation.

SUBFERTILITY - KEY POINTS

• Approximately 10% of women of reproductive age experience problems in conceiving.

• 20% of infertile couples have more than one causetive factor, involving both partners.

• Prompt referral and investigation into the possible causes are essential as fertility declines with age.

• Access to treatment may be currently restricted by the application of criteria relating to age and medical and/or social background.

Table 2

Causes of infertility

Causes of infertility

Male factors	32%
Hormonal abnormalities	28%
Tubal factors	22%
Uterine abnormalities	11%
Unknown cases	4%
Cervical	3%

Source: *Infertility - Postgraduate Update Series* 1995 Edition.
Pub: Reed Healthcare Communications

Unfortunately, following a possible diagnosis of a problem, a couple is then faced with a lack of national uniformity in the availability of infertility treatment. In the light of current financial restraints, infertility treatment is often the first to suffer when cutbacks are made, with many NHS units unable to offer treatment of any kind. Infertility is often not considered to be an illness, but medical intervention is essential to assist these couples and, perhaps, fertility should be considered to be a natural right. When available, treatment is subject to strict rationing, particularly in the case of IVF, access to which in this country is subjected to several, often highly controversial criteria, for example, age limits for treatment, the requirement of marriage or the definition of a stable relationship (with limited or no access to single women), the existence of children from a previous relationship, (some clinics will not offer IVF to couples who already have a child), the `suitability' for parenthood, (treatment may be withheld to couples from very poor economic circumstances or unemployed) or the access to treatment for single women.

With increasing financial constraints in NHS funding in the UK, this situation seems unlikely to improve. IVF, for example, is offered in very few districts under the NHS and for many couples the cost of private treatment is the limiting factor in how far they can proceed with a particular line of treatment.

Ultrasound in the Diagnosis of Infertility

There are a whole host of standard diagnostic tests to be performed on couples presenting with reduced fertility in order to investigate all the functional requirements for conception. Some are performed by the GP prior to referral to a specialist hospital based fertility unit for further evaluation. These intial tests include female bi-manual pelvic examination and examination of the male external genitalia. A history is taken with regard to genital infections of both partners, semen analysis in the male, and in the female, previous obstetric history, operations, rubella anti-body screening, menstrual irregularities, ovulation disorders and biochemical analysis of hormonal.

Diagnostic ultrasound plays an essential role in the assessment of the female partner, both in the initial diagnosis and in the monitoring of any subsequent treatment regimes initiated. Couples seeking help for infertility need careful and sympathetic support Many are extremely anxious and emotional. It is extremely important that a room is set aside, away from the ante-natal clinic, for the ultrasound examination. The room should be private and couples treated with great respect and discretion. A calm, unhurried approach is necessary, as many patients may take the opportunity to seek advice and support during their ultrasound examination. They must feel comfortable that everything is treated with the utmost confidentiality. Indeed, the governing body of fertility treatment, the HFEA (Human Fertilisation & Embryology Authority) now makes it mandatory for all treatment and monitoring to be performed within the clinic setting.

One very important initial investigation is tubal patency status in the female partner. This usually requires referral to a gynaecologist and/or radiology services, and may be investigated by laparoscopy, hystersalpingography or, more recently, by ultrasound based contrast medium examination, *HyCoSy.* Tubal patency should be an early investigation, ovulation induction being obviated in the presence of tubal occlusion and therefore requiring referral for IVF.

HyCoSy (hysterosalpingo-contrast sonography) has benefits over traditional HSg (hysterosalpingography) techniques, being a cost-effective method of determining tubal patency without using ionising radiation, and also providing initial information of adnexal and ovarian pathology, therefore comparing favourably with the gold standard diagnostic test of laparoscopy and dye hydrotubation. Ultrasound based contrast media are either positive or negative based. A negative contrast medium, such as sterile saline, is used to assess the uterine cavity in cases of endometrial adhesions, polyps or fibroids. An example of a positive contast medium is Echovist R, which consists of sugar coated micro-bubbles of air which act as an acoustic scatter medium upon transcervical injection into the uterus, and is solely used to detrmine tubal patency, (Figure 6). HyCoSy is a relatively simple, quick, out-patient, procedure for the determination of tubal patency, necessary before embarking upon costly ovarian stimulation and induction treatment.

Figure 6—
Patent right Fallopian tube demonstrated by
ECHO-VIST during HyCoSy examination. This image
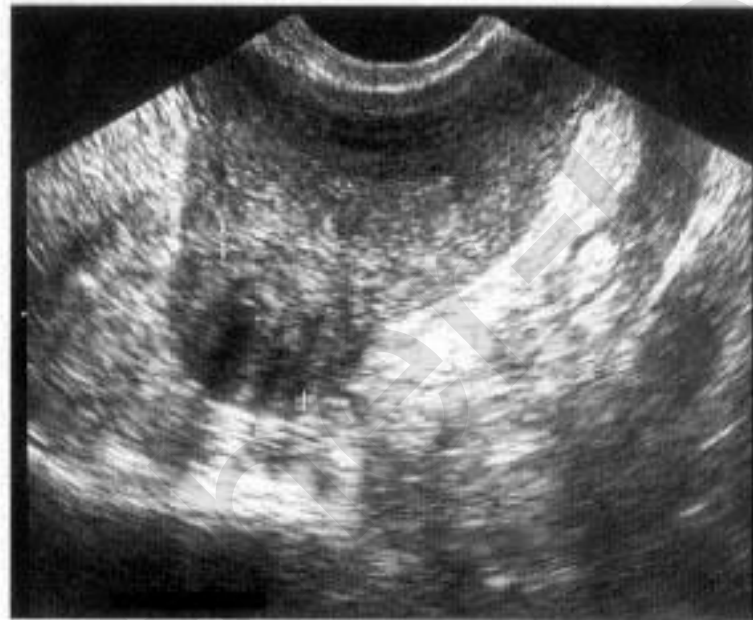is taken from a real time examination on a VCR.

Figure 7—
A fibroid in the posterior myometrium of the
uterus measuring 22mm.

Figure 8—
A fibroid within the endometrial cavity
measuring 12mm.

Transvaginal ultrasound assessment of the female pelvis is an early, mandatory requirement, to establish the possible presence of congenital or acquired pelvic abnormalities which may contribute to subfertility. Examples of these include bicornuate or septated uterus, fibroids, endometrial polyps, endometriosis, pelvic inflammatory disease and ovulation disorders. The sizes and positions of fibroids should be evaluated as distortion of the uterine cavity is associated with implantation problems, (Figures 7 and 8. Uterine polyps can cause similar problems, (Figure 9).

Further information on the ultrasound appearances of uterine and ovarian pathology are found in Chapters 4 and 5.

Endometriosis

Endometriosis is the most common cause of infertility. It is the development of secretory endometrium outside the uterine cavity which is disseminated via vascular or lymphatic routes into the peritoneal cavity with menstrual flow. The most common sites of ectopic endometrium are the utero-sacral ligaments, sigmoid colon, recto-vaginal septum, round ligaments, pelvic peritoneum, ovaries, pouch of Douglas and the urinary bladder. Ectopic endometrial tissue responds to hormonal variations in the menstrual cycle. It may therefore proliferate and bleed throughout the mentrsual cycle, causing pelvic pain. `Chocolate' cysts are a common characteristic of endometriosis and result from encapsulated old blood from ovarian endometriosis. It is a progressive, chronic disease, not always symptomatic. Approximately 20-25%
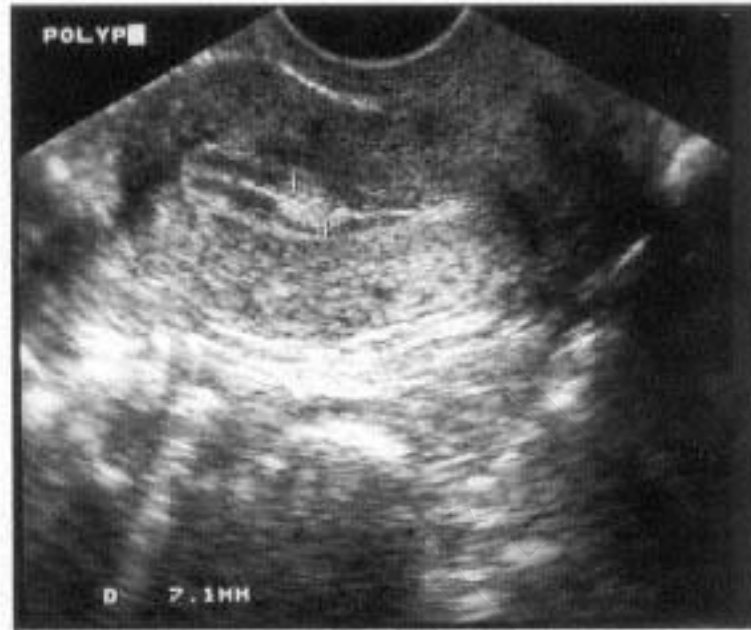
Figure 9—
A polyp in the endometrial cavity measuring 7mm.

of women may have endometriosis at some time in their lives. It is most common during the reproductive years and rare in women over 50 years of age.

Endometriosis is diagnosed laparoscopically in 30-60% of infertile women. [10]

The role of transvaginal ultrasound is that of the differentiation of resultant endometriotic cysts from simple functional ovarian cysts which contain clear fluid. Endometriotic cysts have well defined, smooth margins containing homogeneous, low level echoes from the blood, (Figure 10).

Figure 10—
A `chocolate' or endometriotic cyst measuring
45 × 33mm.

Pelvic Inflammatory Disease (PID)

Infection and diseases may be acquired by sexual transmission or may be associated with an intra-uterine contraceptive device, urinary tract infection, septic abortion or opportunistic infection in women with immunological disorders. Infection in the female pelvis causes adhesions and may damage and/or occlude Fallopian tubes.

Transvaginal pelvic ultrasound will demonstrate fluid in the POD, tubo-ovarian abscess formation, hydro/pyosalpinx in acute infective processes and the characteristic ultrasound appearance of hydrosalpinx in chronic disease, (Figures 11 and 12). Acute processes are not usually seen in women attending for ovarian stimulation, especially on assisted reproduction treatment cycles such as IVF. The disease process has usually progressed to the chronic stage, before women present for such therapy. The differentiation of chronic hydrosalpinx from ovarian cysts or free fluid may be difficult, but should be possible with high resolution transvaginal ultrasound by a careful evaluation of outline, shape and
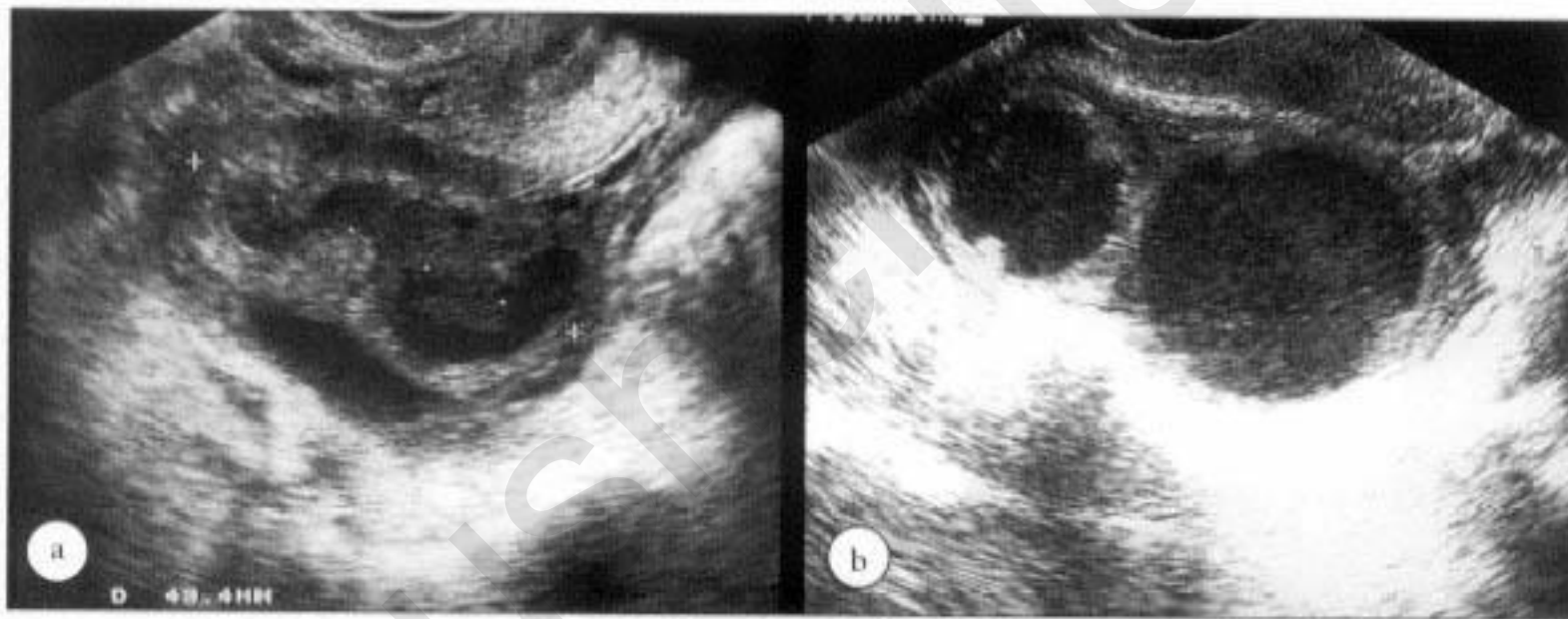
Figure 11—
Acute hydro/pyosalpinx. Dilated Fallopian tube filled with echogenic material, the walls are thickened and hyperechoic.
a) TVS longitudinal section.
b) TVS transverse section.
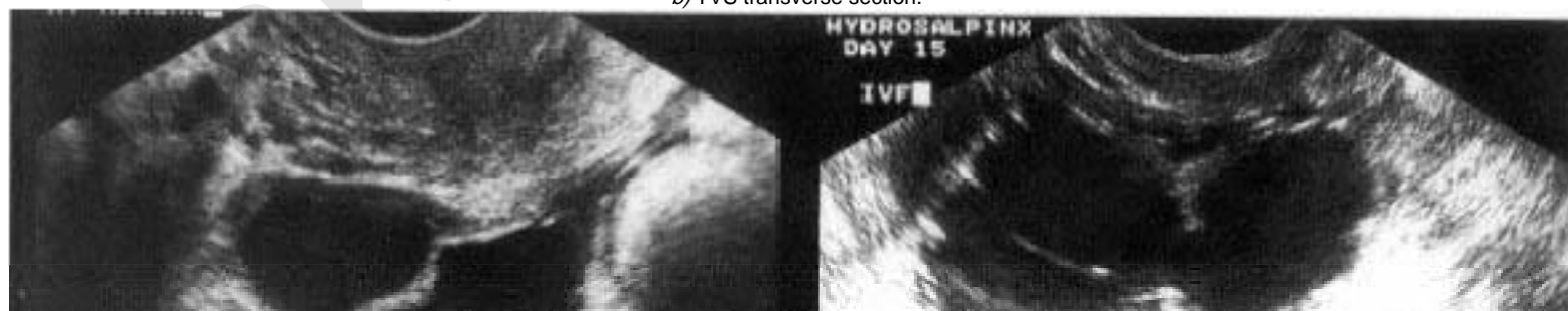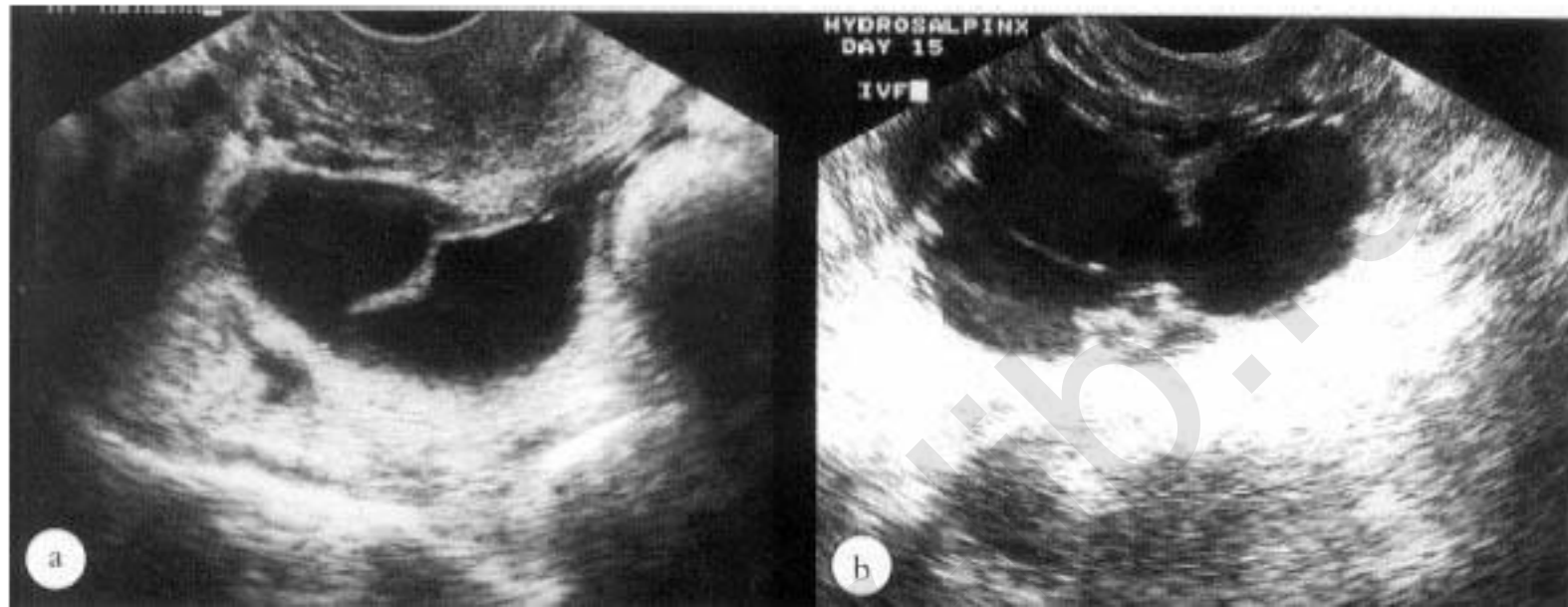
Figure 12—
Chronic hydro/pyosalpinx. Dilated Fallopian tube filled with echopoor material, the walls are thin and
hypoechoic.
a) TVS longitudinal section.
b) TVS transverse section.

Figure 13—
Complex combination of pathology and stimulated
follicles encountered during IVF treatment.

position of the structures relative to the ovaries, (Figures 11 and 12). Combinations of pelvic pathology encountered during treatment cycles also cause problems of differentiation for the sonographer, (Figure 13).

Ovulation Disorders

Polycystic Ovaries

Another major cause of infertility where ultrasound is a very useful tool is in disorders of ovulation. The most common disorder of ovulation (20% of cases) is attributable to polycystic ovarian syndrome (PCOS). The ultrasound appearances are of a collection of ten or more cysts, 2-8 mm in diameter, arranged around a dense stroma or scattered throughout an increased amount of stroma. The ovaries appear somewhat enlarged compared with the normal range (6-12 ccs) (Figure 14). These ovaries are unable to produce hormones in the correct proportions and may result in either irregular cycles (oligomennorhoea), or no ovulation at all (anovulation). It is important to remember that not all women with the classic appearances have clinically manifest PCOS, and that approximately one third of women with clinical PCOS have normal ovaries on ultrasound.

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Luteinised Unruptured Follicle Syndrome

The normal physiological development of the corpus luteum from the ruptured follicle after expulsion of the ovum is that of a rapid refill of the collapsed follicle. This can cause problems of ultrasonic differentiation in cases of luteinised unruptured follicle syndrome (LUF) where follicles fail to rupture or to release the ovum. Both LUF
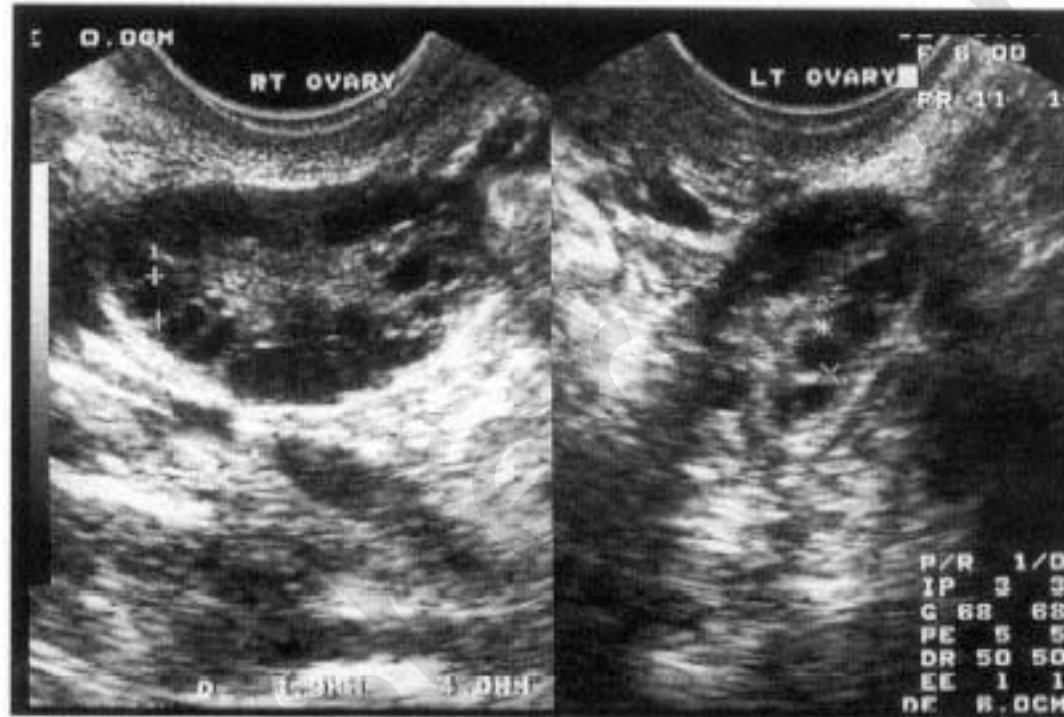

Figure 14—
Polycystic ovaries prior to stimulation.

and corpus luteae can appear haemorrhagic on ultrasound, (Figure 15). LUF is defined as continued growth up to three days after the dominant follicle has reached a mean diameter of 30 mm, or until no further growth occurs for three consecutive days. Reliable documentation of LUF requires daily scans, 24 hours apart, and this should be demonstrated to occur repetitively in the same woman in a majority of cycles. It can be confirmed laparoscopically after ultrasound demonstration. Despite the many publications describing this phenomenon, the diagnosis of LUF is still controversial and optimal treatments have not been determined. [11], [12]

Other Causes of Anovulation

Premature ovarian failure may present as primary or secondary amennorhoea, both of which have a variey of causes including Turner's syndrome and damage by infection or irradiation of the ovaries. The only treatment for either congenital or acquired ovarian failure is egg donation. Anovulation may also be caused by hypopituiterism, either congenital hypogonadotrophic hypogonadism or aquired hyperprolactinaemia, both of which result in the pituitary gland not secreting the gonadotrophins LH and FSH in sufficient amounts to stimulate the gonad (the ovary). A prolactinoma is a benign tumour of the pituitary gland which causes hyperprolactinaemia (raised prolactin levels) and is

ULTRASOUND IN THE DIAGNOSIS OF INFERTILITY - KEY POINTS

• TVS is a primary line of investigation to establish the presence or absence of congenital abnormalities or pelvic pathology.

• Possible findings include -

Bicornuate uterus

Fibroids

Endometrial polyp

Endometriosis

Pelvic inflammatory disease

Ovulation disorders such as Polycystic ovaries,

Luteinised unruptured follicle

• HyCoSy can establish tubal patency. It is cost effective, safe and accurate when compared to conventional techniques of X-Ray hysterosalpingography or laparoscopy and dye hydrotubation.

Figure 15—
A haemorrhagic follicle or LUF.

effectively treated with bromocriptine tablets over a few weeks, restoring ovulatory menstrual cycles and returning the patient's chances of pregnancy to normal.

Ultrasound in the Treatment of Infertility

The aim of treatment is to improve a woman's chances of conception by stimulating the ovaries to produce mature follicles of optimum size, and to assist ovulation at the apporopriate time. The main goals of ultrasound monitoring are to avoid the occurrance of large-order multiple pregnancies, and to prevent ovarian hyperstimulation syndrome, which is a potentially lethal condition if allowed to develop to its extreme. The various hormonal preparations used for ovarian stimulation have side-effects. They commonly result, to varying degrees, in abdominal discomfort and distension, caused by ovarian enlargement. It is useful to monitor two cycles ultrasonically before treatment commences to assess spontaneous ovulation, often in conjunction with Clomid, which is the usual first line therapy to assist follicle maturation.

Clomiphene Citrate (Clomid)

The first clinical trials of Clomid were performed in 1961. It is an oral preparation of 50 mg tablets, usually taken for days 2-6 of the menstrual cycle. When Clomid is ingested, the brain takes up Clomid instead of oestrogen, causing low oestrogen levels which then leads

to the release of FSH by the pituitary gland, thereby stimulating the ovaries to produce follicles. (It has been shown that four out five women taking Clomid will subsequently ovulate). The reaction of any patient to Clomid is unpredictable and, therefore, its use should begin with the lowest dose, 50 mg daily, and then to increase it gradually in subsequent cycles. Ovarian cysts developing after Clomid treatment usually resolve spontaneously within a few weeks, during which period Clomid should not be administered. Clomid may cause mild visual distrubances, (1.6%) hot flushes, (10%) nausea, vomiting and breast discomfort, (2%). The incidence of multiple follicular development varies from 20% to 60% per cycle, with a multiple pregnancy rate of about 5%. The incidence of hyperstimulation with a short course therapy of Clomid, (not exceeding 7 days) is approximately 5%, the length of therapy being more important than the dose. Doses of up to 200mg per day, confined to four to six days, keep the incidence of hyper-stimulation within reasonable limits.

After taking Clomid from days 2-6, monitoring of follicular development includes an ultrasound scan performed on day 10-12 of the cycle. As well as measuring follicular size/sizes, the endometrial response must be assessed. In Clomid stimulated cycles, some women have a poor endometrial response of only 4-6 mm mid cycle, although pre-ovulatory follicles of 22-30 mm mean diameter are present. This is due to the anti-oestrogenic activity of Clomid, which has an adverse effect on the endometrium, the cervix and its mucus. This is claimed to be one factor responsible for the reported discrepancy between an ovulation rate of 70% but a pregnancy rate of 32% with Clomid. It results in an endometrium out-of-phase to receive and support the fertilised ovum, unsuitable for implantation, and also produces hostile cervical mucus. Clomid can also result in premature luteinisation of follicles due to an untimely LH surge and, in some women, it can cause abnormally high LH levels during the follicular phase, which interferes with follicular development and maturation of the oocyte. The ultrasound appearances in some women may also show that follicles of Clomid stimulated cycles do not ovulate until they attain a mean diameter of 30-35mm or, alternatively, do not ovulate and subsequently regress.

If spontaneous ovulation does not occur hcG (human chorionic gonadotrophin) can be given to induce ovulation upon demonstration of follicular size of 18-22mm mean diameter. An intra-muscular injection of 10,000 units will induce ovulation approximately 36-48 hours later and will contribute to follicular maturation within this time, (it's action is identical to that of the mid cycle LH surge). The ultrasound appearance of ovulation is the same as previously described for the spontaneous cycle. Patients who do not successfully ovulate during clomid therapy should be offered gonadotrophins and hcG therapy.

Gonadotrophin Therapy

Pergonal and Metrodin ovarian stimulation therapy consists of intra-muscular injections. Pergonal consists of human menopausal gonadotrophin (hMG), which contains human FSH plus LH, whilst Metrodin is pure FSH. Both are used when the pituitary fails to produce the hormones. Direct side effects have not been reported, apart from local reactions at injection sites. The main complications of gonadotrophin therapy are ovarian hyperstimulation, high incidence of multiple pregnancy and an abortion rate higher than in spontaneous conceptions.

Both treatment regimes require a baseline ultrasound usually on day 5 or 6 of the cycle to exclude any pre-existing ovarian pathology or retained follicles from previous normal or stimulated cycles. The treatment then consists of daily intra-muscular injections followed by an ultrasound 5 or 6 days later to assess the response, which then determines the subsequent dosage. Plasma oestrogen levels may also be performed in conjunction with daily or alternate daily ultrasound monitoring to assess the amount of stimulation and to allow the dosage to be increased or decreased as required.

A single pre-ovulatory follicle is usually spherical; however, when several follicles are present during ovulation stimulation, they are usually deformed because of pressure from adjacent follicles or from the constraints imposed by the ovarian capsule. The follicular growth pattern is linear (as with spontaneous cycles), but there is a slightly more rapid growth rate. Ovulation induction with hcG may then be administered when a dominant follicle of at least 17mm is reached. Only follicles of 15mm or more may produce pregnancies; therefore a maximum of two additional follicles of 15-17mm is acceptable to prevent large-order multiples pregnancies. Small follicles of 5-15mm play an important role in the development of ovarian hyperstimulation; consequently, it has been suggested that no more than six of these small follicles should be present in the ovaries before hcG administration. HcG should be withheld to avoid multiple pregnancies, ovarian hyperstimulation and ovarian hyperstimulation syndrome.

Ultrasound enables maximum treatment efficacy and signals impending hyperstimulation, providing similar information to that of serum oestrogen monitoring but not totally replacing it. Only ultrasound will reveal the number and sizes of these small follicles which contribute to the oestrogen levels. A combination of both methods

Ultrasound enables maximum treatment efficacy and signals impending hyperstimulation, providing similar information to that of serum oestrogen monitoring but not totally replacing it. Only ultrasound will reveal the number and sizes of these small follicles which contribute to the oestrogen levels. A combination of both methods

will enable ovulation stimulation with Pergonal or Metrodin and ovulation induction with hcG to take place in a reliable and successful way.

Following successful stimulation and ovulation, couples can be advised about intercourse timing or offered assisted conception techniques such as AID (artificial insemination with donor sperm) or IUI (intra-uterine insemination with husband or donor sperm) if they are known to have a poor sperm count or if the couple have sperm/mucus antibody problems demonstrated by a PCT (post coital test).

"NON-INVASIVE" TREATMENT OF INFERTILITY - KEY POINTS

- • Ultrasound monitoring helps to avoid large-order multiple pregnancies and prevents hyperstimulation of the ovaries.
- • Pre-treatment monitoring of two cycles is recommended to asses spontaneous ovulation.
- • Clomid stimulates follicle production.

    Ultrasound is used to monitor follicle development and establish if ovulation is about to take place, (usually when the follicle reaches 30 - 35 mm diameter)
    HcG is given if spontaneous ovulation does not occur.
    Ultrasound also assesses the endometrial response, which may be poor due to the antioestrogenic effect of Clomid.
- • Gonadotrophin Therapy

    Contains FSH (Pergonal) or FSH + LH(Metrodin)
    Used when the hormones are not produced by the pituitary gland.
    HcG is given to induce ovulation when a follicle of at least 17mm is present.
    A maximum of 3 follicles of 15-17 mm prevents large-order multiple pregnancies.
    A maximum of 6 follicles of 5-15 mm prevents ovarian hyperstimulation.
    - • After successful stimulation and ovulation induction, couples are advised about intercourse timing or are offered assisted conception.

Assisted Conception Techniques
In Vitro Fertilisation (IVF).

This was the original `test tube' technique first performed in 1978. It must be remembered that the aims of stimulation in IVF treatment protocols are very different to those detailed previously. The same hormone preparations are used but the aim is to produce multiple, optimum sized follicles for aspiration and fertilisation in the laboratory under controlled circumstances, (the technique is often referred to as super-ovulation). Successfully fertilised gametes are selected for embryo transfer (no more than three in the UK) and/or cryo-preservation for implantation at a later stage.
Treatment by IVF requires careful initial preparation:

Starting from day 21 of the previous cycle, the hormones from the pituitary gland are suppressed - a process known as `down regulation'. This is achieved by the administration of buserelin, a gonadotropin releasing hormone (GnRH analogue), as either a nasal spray or by sub-cutaneous injection.
The ultrasound examination on day 7 (14 days later) should show a thin endometrium with tiny follicles in the ovaries (Figures 16 and 17). If this is the case, daily injections of hmG are given from day 8 to stimulate follicle growth. This is administered in conjunction with continuing GnRH analogue to suppress the late follicular phase LH rise, thereby preventing ovulation.
If on day 7 the endometrium is thicker than 6mm on the down regulation scan, buserelin is continued for a further 7 days after which a further scan and blood test are performed.

If on day 7 the endometrium is thicker than 6mm on the down regulation scan, buserelin is continued for a further 7 days after which a further scan and blood test are performed.

Figure 16—
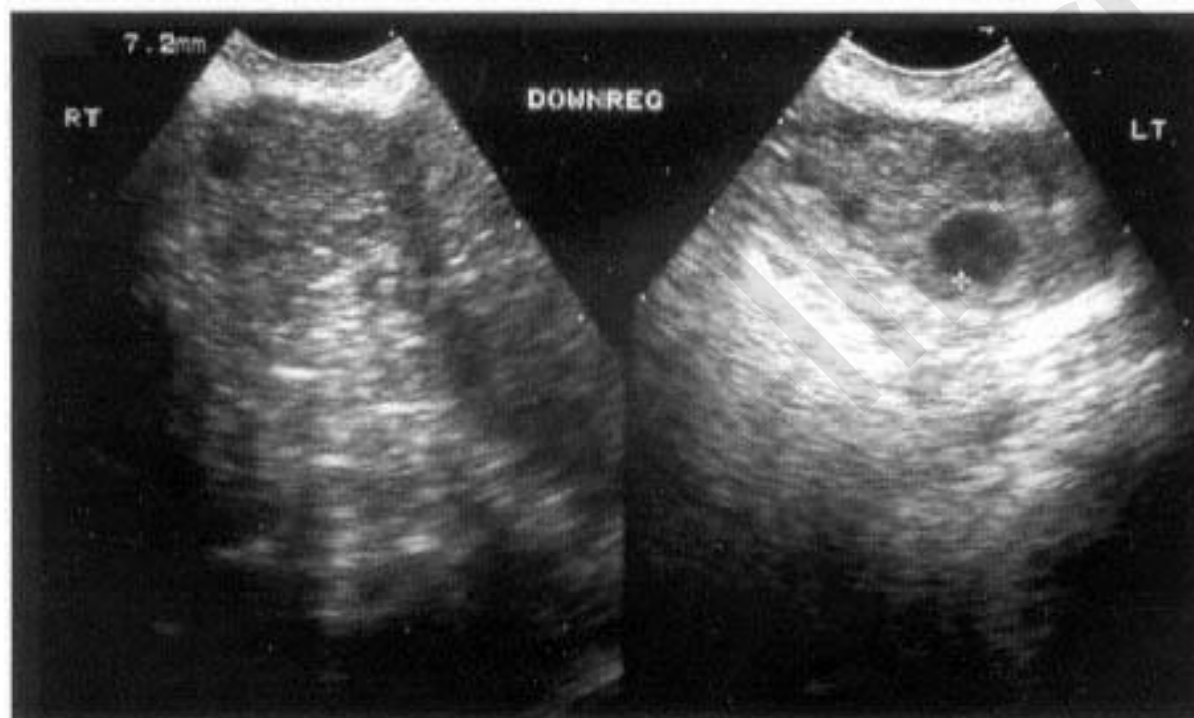Successfully downregulated endometrium
measuring 2.9mm.

Figure 17—
Successfully down regulated ovaries.

After successful down regulation, plasma oestrodiol should be less than 200 picomols/L before follicular stimulation with hmG can commence. If the `down reg' scan demonstrates an ovarian cyst of over 3 cms, the serum progesterone level is also checked, and if raised, more buserelin and a further `down reg' check is performed 7 days later. If the serum progesterone level is under 4 nanomols/L, the cyst is probably inactive and stimulation with hmG may commence.

When the "down reg" ultrasound scan appearances are suitable, intensive monitoring begins on day 8 and continues daily until until the oocytes are ready for retrieval, (Figure 18.) The endometrium should achieve a thickness of 8-12 mm. The aim of stimulation is to acquire 8-12 oocytes of 18-22 mm prior to oocyte retrieval with a plasma oestrodiol level of around 11000 pmols/L to 15000 pmols/L and an endometrium greater than 10 mm.

When this is achieved the woman is given 1 litre of albumin to calm the ovaries down prior to oocyte retrieval along with an injection of hcG. (This is not to promote ovululation, which will occur at around 42 hours after injection, but to assist in the final maturation of the oocyte. The intra-follicular fluid subsequently becomes less viscous thereby allowing the oocyte to be released from the follicle wall and become freely floating, facilitating the aspiration process which is timed to occur 36 hours after hcG injection.)

transvaginal oocyte retrieval is performed under local or general anasthetic. Successfully recovered oocytes are then mixed with the partner's or donor's

transvaginal oocyte retrieval is performed under local or general anasthetic. Successfully recovered oocytes are then mixed with the partner's or donor's sperm. One day later, after incubation, two pro nuclei should have developed. By day 2, the four cell embryo has developed, at which
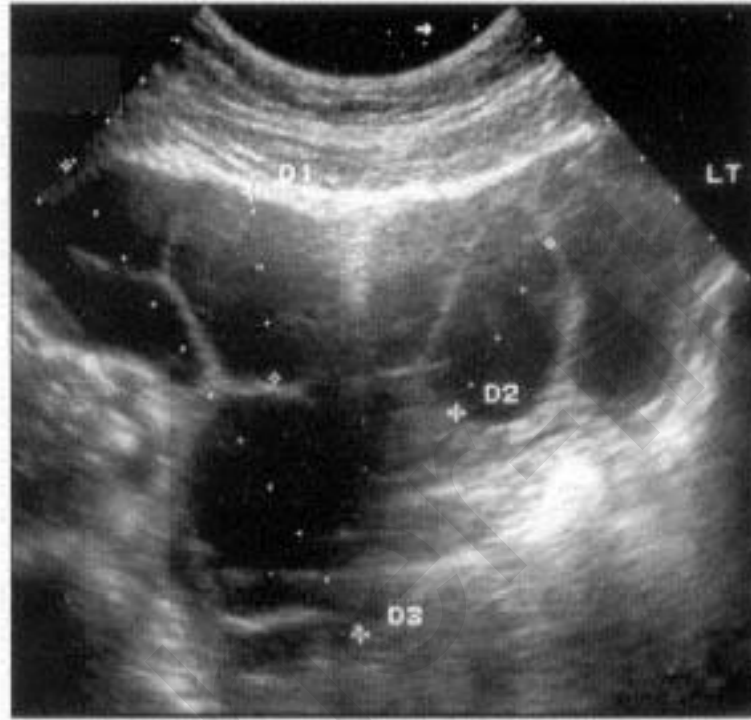

Figure 18—
Severe hyperstimulation. TAS. D3 measurement
represents the length of the right ovary, measuring
10.1 mm.
D1 = a follicle in the right ovary measuring 33.5 mm.
D2 = a follicle in the left ovary measuring 35.8 mm.

stage 3, 2 or 1 of the best quality embryos are selected for transfer into the uterine cavity.

At day 18 post oocyte retrieval a bHcg is performed; if positive, daily gestone injections are prescribed until 7 weeks post embryo transfer. An ultrasound is performed at 6 weeks post transfer.

IVF was developed primarily as a treatment for female factors such as blocked or absent fallopian tubes. However, it is commonly performed today for male factor infertility; following oocyte recovery with micro-assisted fertilisation techniques of SUZI and ICSI.

Sub Zonal Insemination (SUZI)

This was originally pioneered at NURTURE (Nottingham University Research & Treatment Unit in Reproduction) in Nottingham and resulted in Britain's first birth from this technique in August 1992. The technique consists of the injection of fertile sperm via a microneedle into the perivitelline space, past the zona pellucida (outer shell), into the space between the zona and the oocyte, sperm being put into direct contact with the oocyte. This technique has recently been enhanced by the introduction of CISS.

Computer Image Sperm Selection (CISS)

CISS is used to identify `fertile' sperm by their movement characteristics. The world's first baby was delivered after conception with this procedure in 1994 at NURTURE.

Intra-Cytoplasmic Sperm Injection (ICSI)

ICSI, also known as Direct Injection of Sperm into the Cytoplasm of the Oocyte (DISCO), consists of directly depositing the sperm into the cytoplasm of the oocyte bypassing all the natural barriers that the sperm encounters and is the most invasive mico-injection technique. The technique is used where fertilisation is unlikely (or has already failed with conventional IVF), either because of low sperm numbers or sperm dysfunction. As a result of this technique, fertilisation rates per mature oocyte have lept from 20% to 70%. 95% of couples who have an oocyte recovery now have embryo transfer and the pregnancy rate has risen from 5% per treatment cycle to 25% per treatment cycle (from which there should be an estimated delivery rate of 23% and live birth rate of 26% per cycle).

An exciting area currently under study is that of evaluating whether CISS can enhance ICSI fertilisation and pregnancy rates with the same dramatic effect as was shown when combined with SUZI.

Due to it's invasiveness, licensing regulations in Britain have led to a gradual and cautious introduction of ICSI. Over 300 babies worldwide have now been born with no increased risk of abnormality as a result of the procedure. However, no long term follow-up data is available and extensive international evaluation is in progress, and until it is available the long term risks of ICSI remain unquantified.

There are other treatment protocols which may be offered to couples:

Frozen Embryo Replacement (FER)

Following successful fertilisation of more than 3 oocytes during a treatment cycle, embryos at the four cell stage of development may be frozen (cryopreservation) for use in subsequent treatment cycles. For FER the woman does not have to undergo ovarian stimulation. However, she has to undergo endometrial preparation, which involves the downreg procedure as described previously but discontinuing the GnRH analogue after acceptable ultrasound and serum assay results. This is followed by HRT for 14 days to build up the endometrium to a minimum of 8 mm prior to embryo transfer (ET). She will then receive gestone injections from ET+4 until 7 weeks, with an ultrasound scan as before, after a positive bHcG.

EGG Donation Programme

For oocyte donation, a donor plus two recipients have to be timed to undergo all procedures together. The recipients require endometrial preparation to coincide with the donor being ready for oocyte retrieval. The donor undergoes ovarian stimulation as previously described for IVF and the two recipients undergo preparation as described for FER. After oocyte retrieval from the donor, oocytes are shared by both recipients, who undergo fertilisation by IVF, with or without microfertilisation by SUZI or ICSI as required.

Gamete Intra-Fallopian Transfer (GIFT)

Gamete Intra-Fallopian Transfer (GIFT)

This is only suitable for patients who have healthy patent fallopian tubes. The oocytes collected from the ovary are transfered back to the fallopian tubes almost immediately after collection, together with a small amount of sperm. This technique is less commonly used now, due to the requirement of laparoscopic techniques under general anasthetic, and to the fact that the newer micro manipulation techniques of SUZI and ICSI are now much more successful.

Problems Arising from Assisted Conception

There is a higher risk of miscarriage with all assisted conception techniques. There is also a higher risk of ectopic

ASSISTED CONCEPTION TECHNIQUES - KEY POINTS

• IVF (in vitro fertilisation): stimulation of the ovaries to produce multiple optimum-sized follicles for aspiration.
Fertilisation in the laboratory with the transfer of a maximum of 3 gametes to the uterus.

• "Down regulation" with Buserelin inhibits pituitary activity causing the endometrium to remain thin and the ovarian follicles to remain small. Then daily hmG to stimulate follicular development.
When ripe, the follicles are aspirated and the eggs retrieved and mixed with sperm.
They are replaced at the 4-cell stage into the uterine cavity.

• SUZI (sub zonal insemination): injects fertile sperm into the ovum between the zona pellucida and the oocyte, It may be dramatically enhanced by CISS (computer image sperm selection) which identifies fertile sperm by their movement characteristics.

• ICSI or DISCO (direct injection of sperm into the cytoplasm of the oocyte): injects sperm into the cytoplasm next to the oocyte. Used when other methods, such as IVF, have failed, it improves fertility rates up to 70%.

• FER (frozen embryo replacement): the endometrium is prepared prior to the transfer of frozen, 4-cell stage embryos from previous retrieval procedures.

• Egg Donation: must synchronise the endometrial preparation of two recipients with donor oocyte retrieval.

• GIFT (Gamete intra-fallopian transfer): transfers both oocyte and sperm to a healthy tube, using laparoscopy techniques under general anaesthetic. It is being replaced by the newer, more successful techniques of SUZI and ICSI.

pregnancy especially with IVF treatment, mainly due to the presence of underlying pelvic disease such as blocked tubes. A very careful ultrasound examination is essential if the patient has a positive pregnancy test and no intrauterine pregnancy can be demonstrated. There is no increased risk of malformations in successful pregnancies.

Ovarian Hyperstimulation Syndrome (OHSS)

This is the most serious complication of ovulation induction therapy. It occurs when ovulation inducing treatment results in the growth of multiple large follicles followed by the development of follicular and luteal cysts. Women with polycystic ovaries have the highest risk of deveolping OHSS; caused by excessive oestrogen secretion, with symptoms usually appearing 3-6 days after hcG administation or spontaneous ovulation. It is defined as mild, moderate or severe.

Grade 1 — (mild); characterised by ovarian enlargement with cysts measuring up to 5cms in diameter. It is usually accompanied by some mild abdominal swelling and pain. Therapy consists of rest, careful observation and symtomatic relief.

Grade 2 — (moderate); characterised by ovarian enlargment up to 12cms in diameter, accompanied by more pronounced symptomatology, including abdominal distension and pain, nausea, vomiting and occaisonal diarrhoea. Therapy includes bed rest and close observation to detect any progression to severe hyperstimulation in cases where conception has occured. In the majority of cases, the syptoms should subside spontaneously within 2-3 weeks. Moderate hyperstimulation has an incidence of 3.4%.

Grade 3 — (severe hyperstimulation); a rare but serious complication characterised by ovarian enlargement in excess of 12cms in diameter. The symptoms include pronounced abdominal distension and pain, ascites, pleural effusion, haemoconcentration, reduced urine output, electrolyte imbalance and, sometimes, shock. Hospitalisation is mandatory and treatment should include concentration on restoring fluid balance and preventing shock. The acute symptoms should subside over several days and the ovaries should return to their normal size within 20-40 days if conception does not occur. The symptoms

Grade 3 — (severe hyperstimulation); a rare but serious complication characterised by ovarian enlargement in excess of 12cms in diameter. The symptoms include pronounced abdominal distension and pain, ascites, pleural effusion, haemoconcentration, reduced urine output, electrolyte imbalance and, sometimes, shock. Hospitalisation is mandatory and treatment should include concentration on restoring fluid balance and preventing shock. The acute symptoms should subside over several days and the ovaries should return to their normal size within 20-40 days if conception does not occur. The symptoms may, however, be prolonged if conception occurs. Severe hyperstimulation has an incidence of 0.84%.

Indeed OHSS is rarely seen with present modern treatment protocols, mainly due to the use of buserilin and intensive monitoring with serum assays and ultrasound, and is only usually seen to occur post embryo

transfer. When performing an ultrasound examination in this case, it must be remembered that it is necessary to perform a transabdominal, as well as transvaginal examination to assess the full extent of hyperstimulation, Figure 18. Moderate and severe hyperstimulation may be accompanied by considerable abdominal ascites. It is difficult to quantify the amount of fluid present, although serial monitoring is helpful. Free fluid may be present both with a normal intra-uterine and with ectopic pregnancy (although pregnancy will not be demonstrable at such an early stage), which can make interpretation of the 7 - 14 day post-IVF ultrasound scan difficult.

Guidelines and Legislation

Guidelines of infertility treatment practices have been published by the Royal College of Obstetricians & Gynaecologists. [13]

All NHS fertility units are required to be licensed and regularly inspected by the Human Fertilisation & Embryology Authority. A Code of Practice is published by the authority, which came into being after the Human Fertilisation & Embryology Act was passed by parliament in 1990,[14] and can bring the full weight of criminal law into being if the code of practice is not adhered to. The act should eliminate poorly run clinics and therefore protect patients from inefficiently run units and ensure confidentiality of treatment. The confidentiality clauses are very strict and the act established access to `proper counselling' as mandatory. Success rates of all UK units are regularly published by the HFEA.

Several very active pressure groups regularly debate and publicise issues surrounding infertility treatment.

The high-profile publicity given to new high-technology treatments may often raise unrealistic expectations in the general public. Success rates in the best units average around 25%, which means a failure rate of 75%. There are very few medical programmes where the failure rate consistently exceeds the success rate and providers of treatment need to be careful not to transfer their perception of failure onto their patients. Sonographers have an important role to play within the team in providing support to couples undergoing any treatment and it is essential that they are adequately trained and experienced. Follicular scanning cannot be performed in isolation without adequate training in all aspects of gynaecological ultrasound.

Acknowledgements

The authors would like to aknowledge the assistance of Simon Fishel, Simon Thornton and Sue Sargeant of NURTURE in the preparation of this chapter.

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9—

Paediatric Gynaecological Ultrasound

David RM Lindsell

Introduction

Ultrasound is clearly established as the imaging modality of choice for the evaluation of paediatric gynaecological conditions. In certain circumstances Magnetic Resonance Imaging (MRI) will also have a role, as will specialised techniques such as genitography. Computed Tomography (CT) has a very limited place and should be avoided, if possible, because of the significant dose of ionising radiation to the ovaries.

Ultrasound Technique

As with all examinations on children, a safe, warm, non threatening environment should be provided for the examination. Reassurance and an explanation of what is about to be done should be given. A couch in a darkened room with a big machine can be a frightening experience for a young child. It is often helpful to demonstrate on oneself or on a child's arm or leg that the transducer does not cause any discomfort.

As scans have to be carried out transabdominally, a full bladder is necessary, which most girls over the age of three or four years can readily achieve. In younger children and babies it is pure chance as to whether the bladder is full or not. If it is not, then the infant should be given a drink and rescanned at half hourly intervals until the bladder is full enough for an adequate examination.

Small faced, higher frequency (7.5MHz) transducers are preferred in babies, with 5 MHz and 3.5 MHz transducers reserved for older children.

Normal Anatomy

The uterus and ovaries undergo significant changes between birth and puberty and these must be appreciated in order to avoid misinterpreting normal changes as pathological processes. At birth both the uterus and ovaries are affected by maternal and placental gonadotrophins and, as this stimulus disappears, so their appearances change over the first few months. Further significant changes take place at the time of puberty.

Neonates and Young Infants

At birth the fundal region of the uterus is proportionately larger than at a slightly older age. The length of the uterus is between 2.3 and 4 cm and the width between 0.8 and 2.2 cm. The endometrium may be visualised as an echogenic stripe and there may be a little fluid within the endometrial cavity, (Figure 1).

Figure 1—
Uterus at one month showing a prominent fundal
region and clear endometrial stripe.

By birth the ovaries have usually descended to lie at the superior margin of the broad ligament, although rarely they may be as high as the lower pole of the

By birth the ovaries have usually descended to lie at the superior margin of the broad ligament, although rarely they may be as high as the lower pole of the kidneys. On ultrasound they appear homogeneous apart from the frequent presence of small microcysts. (Figure 2). Mean ovarian volume has been shown to be 1.06 cm^3 (range 0.7 to 3.6 cm^3) up to three months of age: 1.05 cm^3 (range 0.2 to 2.7 cm^3) in girls aged 4 to 12 months: and 0.67 cm^3 (range 0.1 to 1.7 cm^3) in girls between 13 and 24 months old. [1]

Premenarchal Girls

Beyond the neonatal period the uterus assumes a more tubular or `teardrop' shape with the cervix accounting for two thirds of the total length, (Figure 3). The length of the uterus and the size of the ovaries change very little in the first six years of life but after that they gradually increase, (Table 1). Throughout this time small microcysts within the ovaries may be seen on ultrasound scanning, (Figure 4).
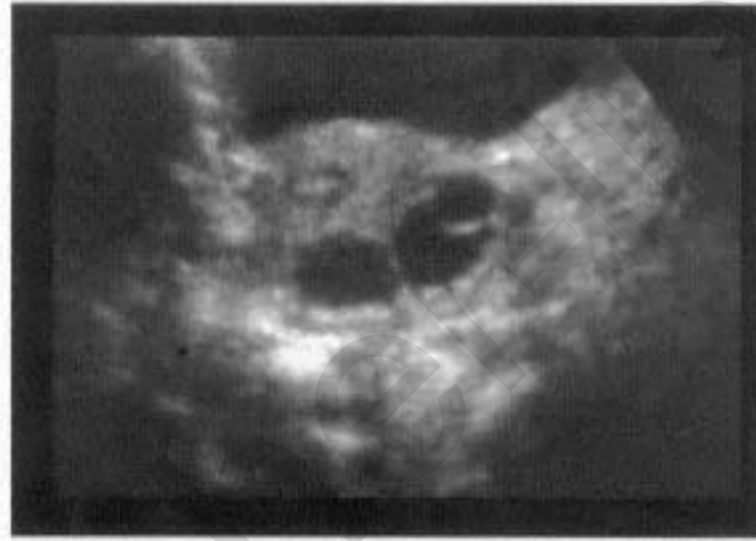

Figure 2—
Normal ovary at one month with volume of 0.9
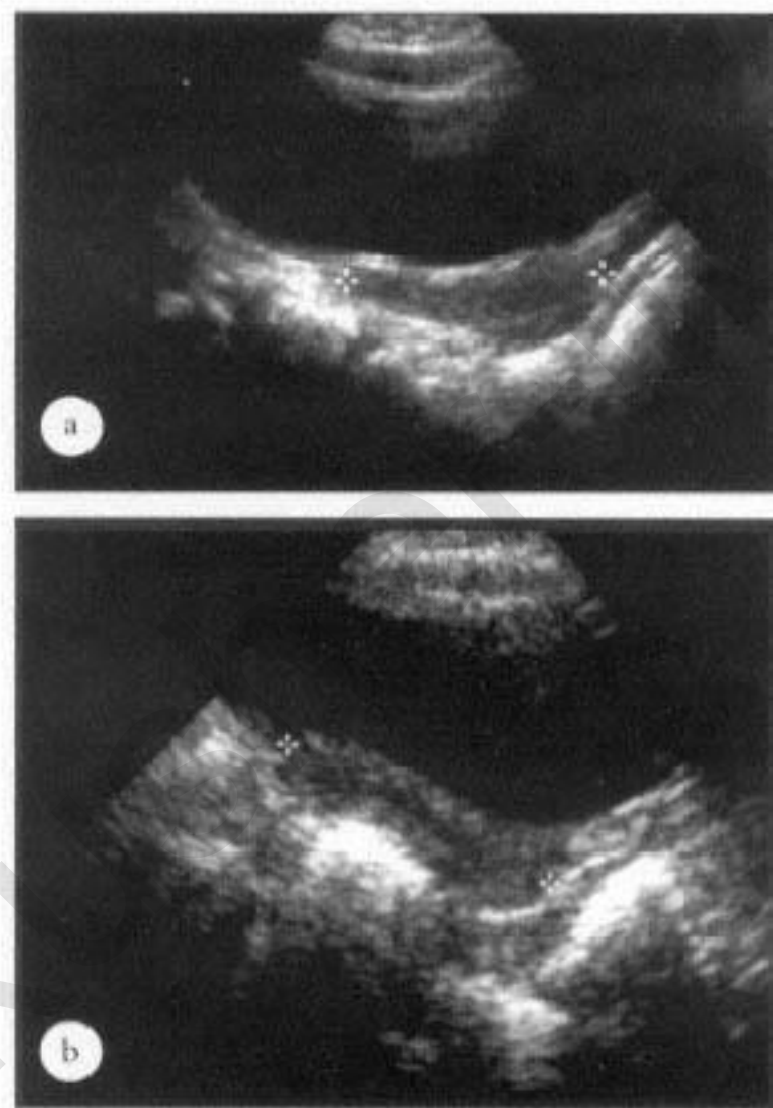cm^3 and small microcysts.

Figure 3—

Figure 3—
a) At six months the cervix is more prominent than the fundus and body of the uterus. *b)* By one year the uterus has assumed a more tubular appearance.

Puberty

The uterus increases in size and changes shape at the time of puberty, (Table 1). It assumes a pear shape and starts to undergo cyclical endometrial changes as in the adult. With gonadotrophin stimulus the ovaries enlarge and lie more deeply in the pelvis, either laterally or posterolaterally to the uterus.

Follicular Development

Small (less than 0.9 mm) microcysts or follicles are frequently seen in the ovaries at any time between birth and puberty. They have been shown to occur in 84% of ovaries between birth and two years of age. [1] In the same study, larger macrocysts (1 cm to 1.4 cm) were noted in 18% of normal ovaries. From six or seven years onwards, the number and size of cysts increases, although it is unusual for the cysts to be larger than 1.5 cm in diameter. In girls aged between two and ten years cysts up to 1.7 cm in diameter have been identified in 68%.[2]
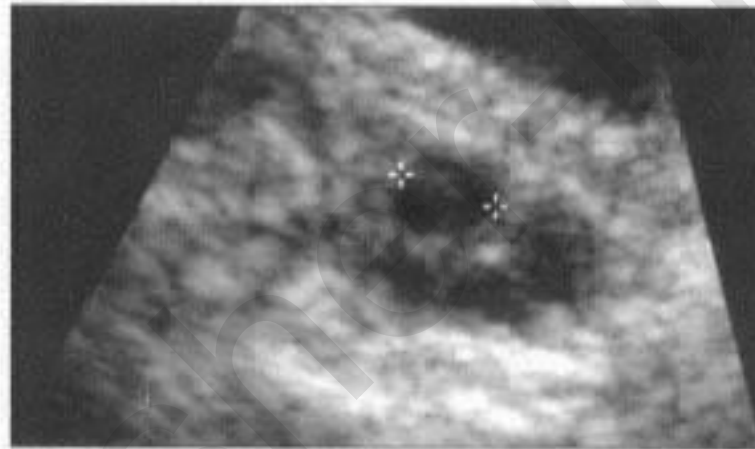

Figure 4—
Normal ovary containing microcysts in a 3.5 year old.

At the time of puberty cyclical follicular development begins with a number of small primordial follicles being present early in the cycle. Between days 8 and 12 of the cycle a dominant follicle becomes apparent with ovulation, occurring at mid cycle when the follicle is between 1.7 and 2.7 cm in size. With follicular rupture the follicle decreases in size and a corpus luteum forms. This appears as a 1.6 to 2.4 cm cystic structure with internal echoes. If fertilisation does not occur this degenerates at the end of the cycle.

Neonatal Ovarian Cysts

With the widespread use of both antenatal and postnatal ultrasound scanning ovarian cysts of greater than 1.5 cm in diameter have been diagnosed with increasing frequency. Occasionally, larger cysts present as abdominal masses or as bowel obstruction or respiratory embarrassment (Figure 5). In these cases absolute differentiation

Table 1.

Table 1.

Paediatric Uterine and Ovarian Growth

Age	Uterine Length (mm)[*]			Ovarian Volume (cm^3)		
	Mean		SD	Mean		SD
2	33.1	±	4.4	0.75	±	0.41
4	32.9	±	3.3	0.82	±	0.36
6	33.2	±	4.1	1.19	±	0.36
8	35.8	±	7.3	1.05	±	0.50
10	40.3	±	6.4	2.22	±	0.69
12	54.3	±	8.4	3.80	±	1.40
13	53.8	±	11.4	4.18	±	2.30

[*] Total uterine length from fundus to cervix.

Data from Orsini *et al.*[18]

Figure 5—
Plain abdominal radiograph in a newborn showing
a huge right sided abdominal mass which was seen
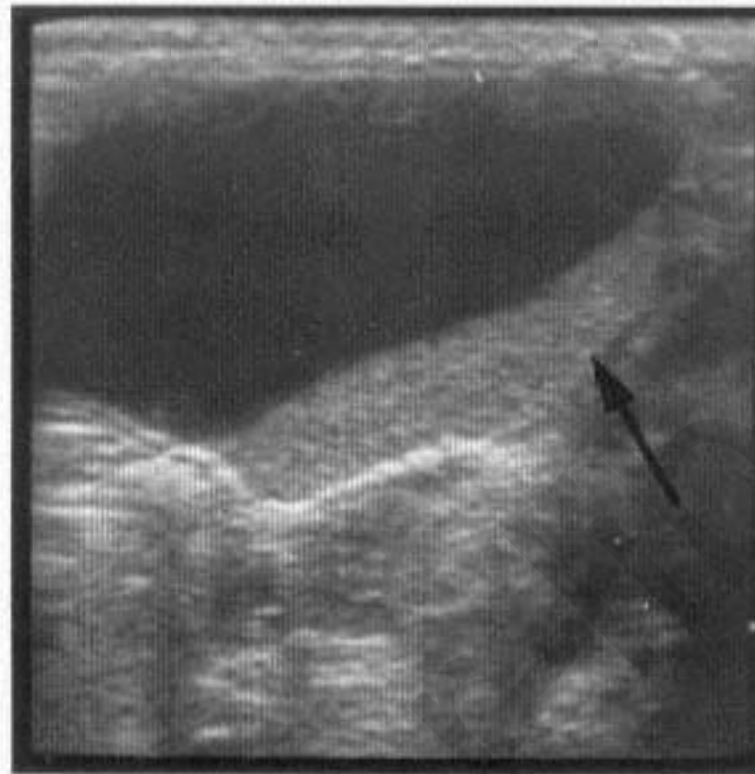on ultrasound to be a unilocular cyst.
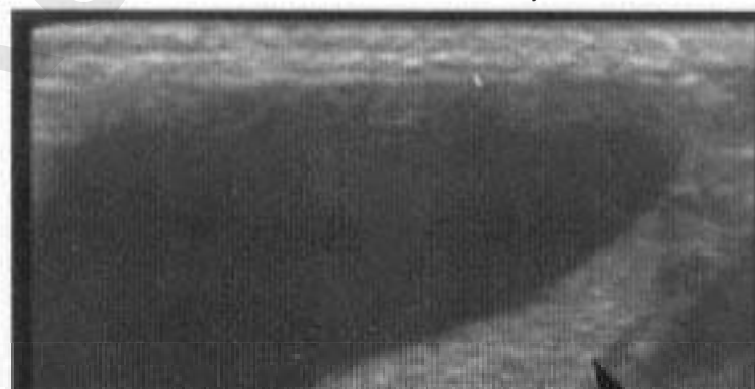
Figure 6—
5 cm unilocular neonatal ovarian cyst with debris
(arrow) in its base.

from other cystic structures such as mesenteric, duplication or urachal cysts can be impossible. All ovarian cysts can, theoretically, undergo torsion or cyst rupture.

Most neonatal ovarian cysts are of germinal or Graafian epithelial origin, although occasionally cystadenomas are found. The stimulus to cyst formation is thought to be maternal gonadotrophins leading to aberrant follicular development. It is, therefore, reasonable to assume that after birth when this stimulus is removed at least some of these cysts will resolve. As a result of this, a conservative approach to their management has been advocated. Early studies suggested that only uncomplicated cysts which were totally anechoic and thin walled should be managed in this way and that other complicated cysts should be removed. More recent studies have shown that most asymptomatic cysts can be managed conservatively with serial ultrasound monitoring. [3] Symptomatic cysts can be treated by percutaneous aspiration or surgery. The ultrasound appearances of complicated cysts include the presence of fluid/debris levels, retracting clot, septae or calcification in the cyst wall, but neither these features nor the size reliably predict the clinical outcome, (Figure 6).

Other Neonatal Abnormalities

Hydro or Hydrometrocolpos

Vaginal obstruction in the neonate may lead to fluid secretions distending the vagina (hydrocolpos) or the vagina and uterus (hydrometrocolpos).[4] Two forms of vaginal obstruction may occur. The first type includes imperforate hymen, complete vaginal membrane, vaginal stenosis or atresia. In the second type a urogenital sinus or cloacal malformation is seen in association with vaginal obstruction. Urogenital sinus is a condition in which there is a single opening for the bladder and vagina, whereas with a cloacal malformation there is a single perineal opening for the bladder, vagina and rectum. These types of abnormality are often also associated with other congenital anomalies such as bicornuate uterus, imperforate anus, oesophageal or duodenal atresia, congenital heart disease or renal abnormalities.

The fluid distension of the vagina and/or uterus leads to a predominantly cystic, tubular, mid line mass lying between the bladder and rectum. The fluid within

The fluid distension of the vagina and/or uterus leads to a predominantly cystic, tubular, mid line mass lying between the bladder and rectum. The fluid within this mass is often echogenic due to the presence of debris. Occasionally, the mass may be very large, containing up to one litre of fluid and, if very large, may displace the bladder and cause ureteric obstruction.

Ambiguous Genitalia

Rapid and accurate assessment of a newborn with ambiguous genitalia is required so that a decision can be made as to whether the child should be brought up as a boy or a girl. The main role of ultrasound is to determine whether a uterus is present. As the uterus is most easily seen in the neonatal period, the examination should be undertaken as soon as possible after birth. As well as ultrasound, genitography (the introduction of a contrast medium into the presumed vagina) is often also required to define the presence or absence of a vagina or urogenital sinus. Sex assignment is based on the results of chromosomal analysis, gonadal biopsy and the knowledge of genital anatomy.

Ambiguous genitalia may be classified into four main groups: Female intersex (female pseudohermaphroditism), true hermaphroditism, mixed gonadal dysgenesis and male intersex (male pseudohermaphroditism). [5]

Female intersex is seen in females with normal chromosomes (46 XX). These babies have masculinised external genitalia with an enlarged clitoris, prominent fused labia and an elongated male type urethra. The usual cause is excessive androgenic stimulus and this is often the result of congenital adrenal hyperplasia. These babies have normal female internal genital anatomy.

True hermaphrodites usually have an ovary on one side and a testis on the other side or the gonads may be fused as ovotestes. A uterus is often present but may be hypoplastic.

In mixed gonadal dysgenesis there is asymmetric gonadal differentiation, often with both a testis and a streak gonad. A uterus is usually present.

In male intersex (male pseudohermaphroditism) there are testes with feminisation or ambiguous external genitalia with an XY karyotype. Ultrasound is required to evaluate the presence or absence of gonads and a uterus.

Abnormalities in Premenarchal Girls

Precocious Puberty

Precocious puberty is the appearance of gonadal maturation or secondary sexual characteristics before eight years of age in girls and nine and a half years in boys. Isosexual precocious puberty refers to pubertal manifestations which are appropriate to the sex of the child. For example, premature breast development in a female is considered isosexual. If the pubertal manifestation is inappropriate for the child's sex, e.g., virilisation occurring in a girl, then this is considered a heterosexual disorder.

The role of ultrasound in the investigation of precocious puberty is to determine the size and degree of development of the uterus and ovaries, as well as assessing the presence of ovarian cysts or masses. It may also be appropriate to evaluate the adrenal glands by either ultrasound, CT or MRI, and in true precocious puberty MRI of the brain is necessary. [6]

True precocious puberty is seen in association with increased oestrogen and gonadotrophin levels. There is enlargement of the uterus and ovaries with ovulation before the age of eight years and the development of secondary sexual characteristics. 60 to 80% are due to idiopathic activation of the hypothalamic-pituitary-gonadal axis, but in the others there may be a demonstrable abnormality of the central nervous system, and hence the need for MRI scanning.

In incomplete precocious puberty there is early development of secondary sexual characteristics but immature gonads and absent ovulation. The hormonal profile is variable but there are usually elevated levels of oestrogens or androgens, but low gonadotrophins. There are many causes for incomplete precocious puberty but amongst these, and of relevance to ultrasound scanning, are ovarian tumours or cysts or adrenal tumours.

The two other forms of precocious puberty are isolated premature thelarche (early breast development) which may occur with a normal endocrine profile, and isolated adrenarche (early pubic or axillary hair development) which may be seen in association with increased adrenal androgens.

A recent study looking at the usefulness of assessing ovarian volume and the presence of cysts in female isosexual precocious puberty has provided some helpful guidelines. [7] Bilateral ovarian enlargement (mean ovarian volume 4.6 cm^3) appears to be a reliable indicator of true precocious puberty, (Figure 7), whereas unilateral ovarian enlargement (mean volume 4.1 cm^3) in combination with macrocysts (greater than 9mm in size) is suggestive of incomplete precocious puberty. In the same study looking at girls under the age of eight years, mean ovarian volume in the control group and in a small group with

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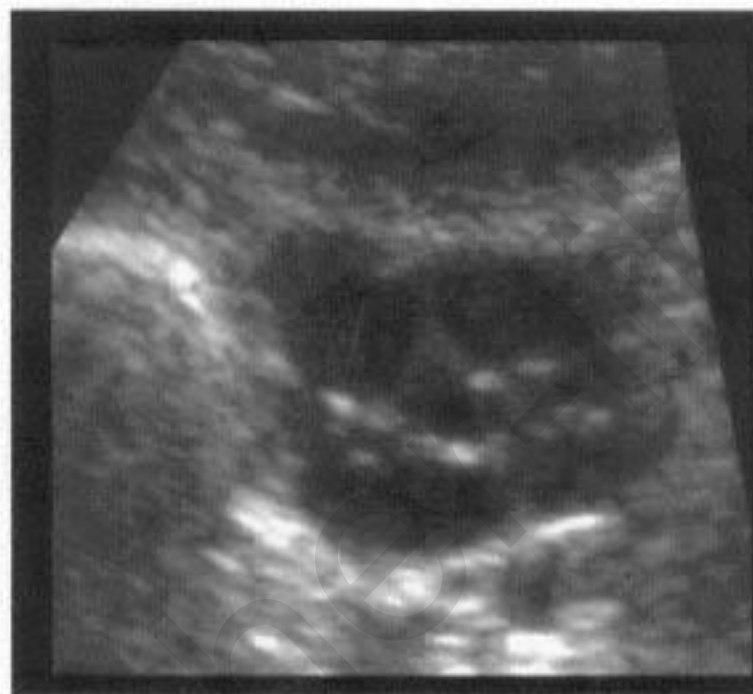
Figure 7—
Enlarged (5.5 cm^3) microcystic ovary in a seven
year old with precocious puberty. Both ovaries
were of similar appearance.

Gynaecological Pelvic Masses in Premenarchal Girls

These account for 3 to 4% of all abdominopelvic masses in children. Many are simple benign ovarian cysts which fulfil the ultrasound criteria for a cyst, usually being unilocular, thin walled and totally anechoic. Occasionally, haemorrhage within a simple cyst may alter the appearances so that they are difficult to differentiate from solid ovarian masses. Rarely, serous cystadenomas or cystadenocarcinomas occur in the ovaries, but usually in adolescents, and these are rare before puberty. In the investigation of solid pelvic masses the primary role of ultrasound is to identify the organ of origin. Many of the solid masses that can occur in the pelvis have similar appearances and can be very difficult to differentiate. Although many of the masses will arise from the ovaries, it is important to remember that others such as neuroblastoma, sacrococcygeal teratoma, lymphadenopathy, bowel related lesions, abscesses and pelvic inflammatory disease may occur, (Figure 8). Some of these may mimic cystic ovarian masses, (Figure 9). Other imaging modalities such as MRI and CT may aid differentiation.

Ovarian Tumours

About a third of these are malignant. The most common ovarian tumour is a teratoma, with the most common malignant tumour being a dysgerminoma,

About a third of these are malignant. The most common ovarian tumour is a teratoma, with the most common malignant tumour being a dysgerminoma, (Figure 10). The most common tumour to be seen in association with precocious puberty is a granulosa thecal cell tumour
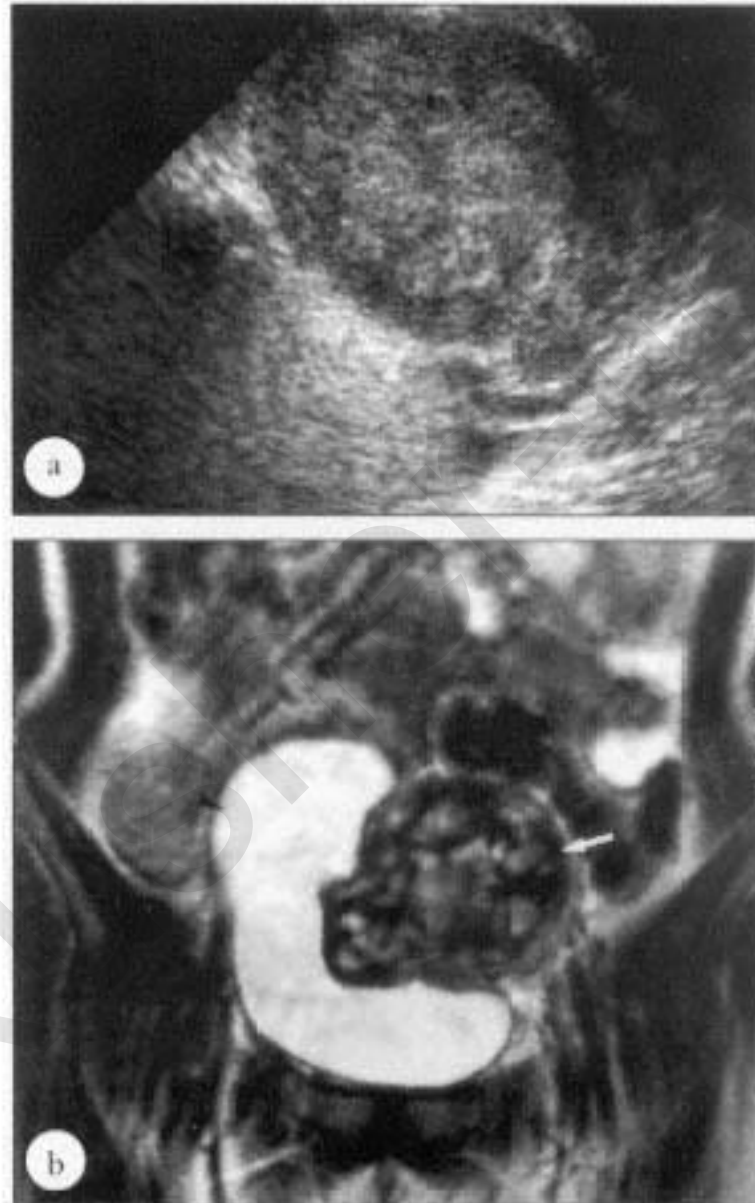
Figure 8—
a) Ultrasound demonstrates a solid non-specific pelvic mass in a ten year old girl with haematuria.
b) A T2 weighted coronal fast spin echo image clearly shows the mass (white arrow) arising from the bladder wall (arrow head). Histological diagnosis was a very rare pseudosarcomatous myofibroblastic proliferation.

(Figure 11). Other rare causes of ovarian masses are fibromas and leukaemic infiltration. [9],[10]

Teratomas can occur in both pre or postpubertal girls but are more common after puberty. They may present due to the presence of a mass or as a result of torsion. They have many and varied appearances. They often have solid and cystic elements and may contain sebum, fat, hair and teeth. If the fat content is significant, then they may be overlooked on ultrasound, as the echogenicity of the fat may be misinterpreted as adjacent bowel. The most characteristic findings are the presence of mural nodules and acoustic shadowing from teeth or calcification within a semisolid semicystic mass, (Figure 12).[11]
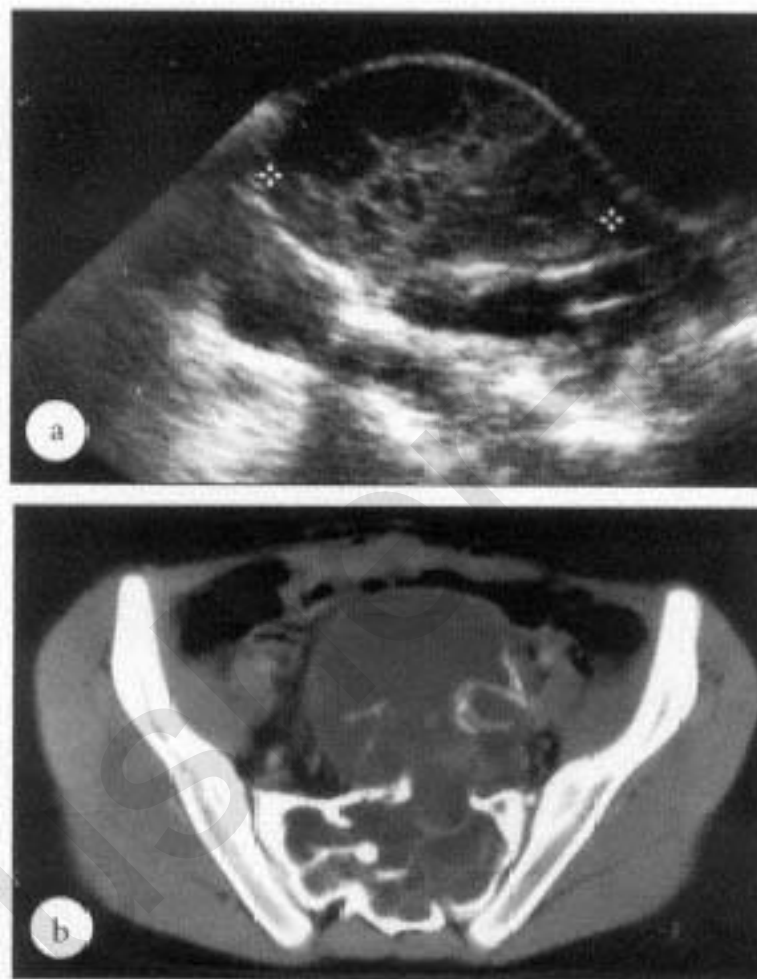
Figure 9—
a) Ultrasound shows a multiloculated semi-solid
semi-cystic pelvic mass in a twelve year old girl with
low back pain. *b)* CT examination of the pelvis shows
that this soft tissue cystic mass arises from the
sacrum and a diagnosis of aneurysmal bone cyst

Figure 9—
a) Ultrasound shows a multiloculated semi-solid semi-cystic pelvic mass in a twelve year old girl with low back pain. *b)* CT examination of the pelvis shows that this soft tissue cystic mass arises from the sacrum and a diagnosis of aneurysmal bone cyst was made.
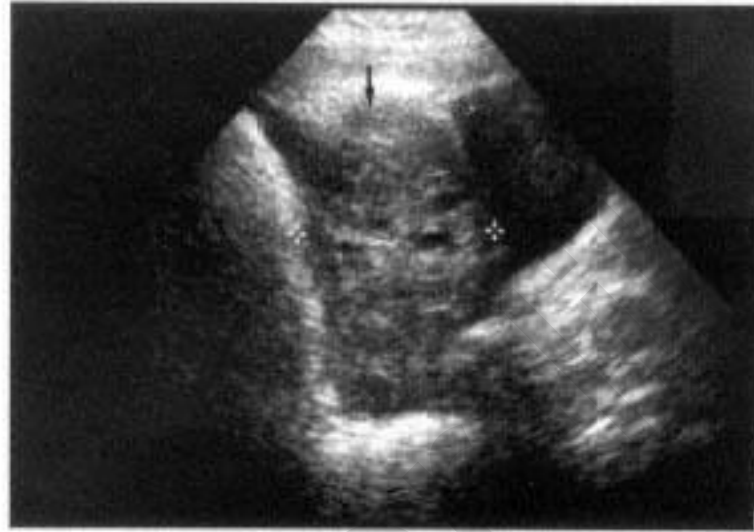

Figure 10—
Predominantly solid ovarian dysgerminoma (arrow) lying in the midline of the pelvis in a ten year old girl.
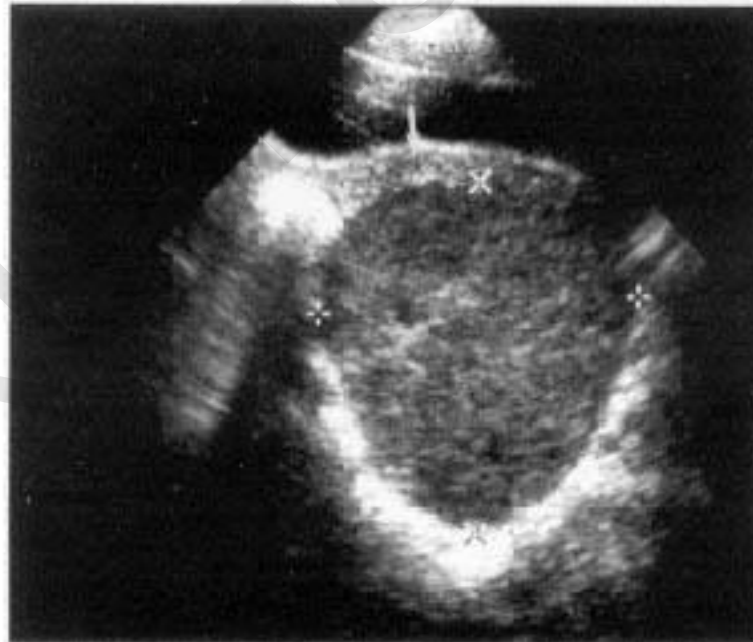
Figure 11—
6.5 cm solid, fairly homogeneous mass lying behind the uterus (arrow) in a six year old and shown at surgery to be an ovarian juvenile granulosa cell tumour.
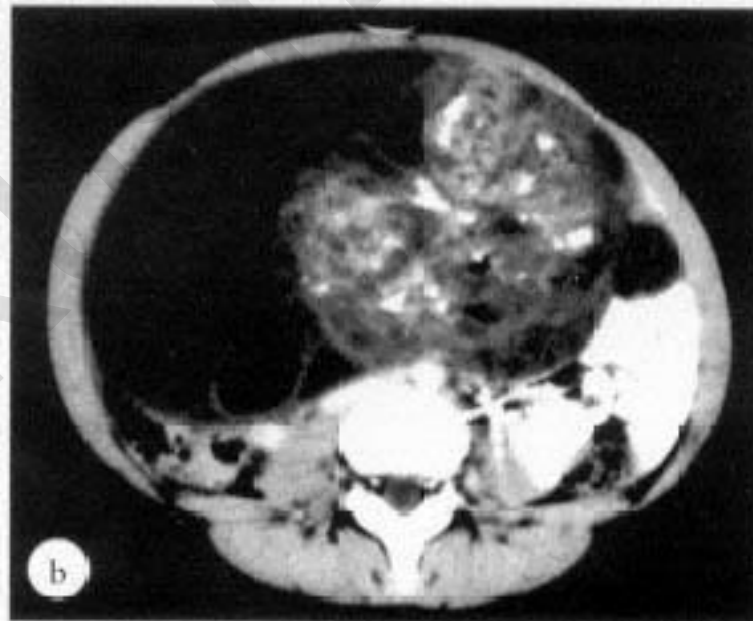
Figure 12—
a) Eleven year old girl with a huge
abdomino-pelvic teratoma shown on ultrasound
to be a combination of cystic and solid areas
with focal areas of calcification. *b)* CT confirms the
semisolid semicystic nature of the tumour as
well as showing the extensive focal
calcification within.

Figure 13—
Vaginal rhabdomyosarcoma (arrow) abutting the
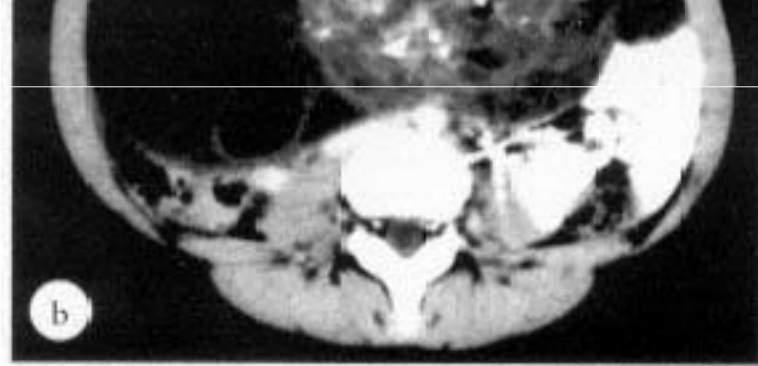uterus (arrowhead) in a five month old girl with
vaginal bleeding.

Vaginal/Uterine Tumours

The most common tumour is a rhabdomyosarcoma, which usually arises from the anterior vaginal wall adjacent to the cervix. It can occasionally infiltrate the uterus or arise primarily from within the uterus itself. These tumours appear on ultrasound as inhomogenous solid masses lying behind the bladder in the region of the vagina and cervix, (Figure 13). They usually present in children under the age of five with vaginal bleeding or polypoid prolapse of the tumour through the vagina. They need to be differentiated from vaginal adenocarcinoma which is extremely rare.
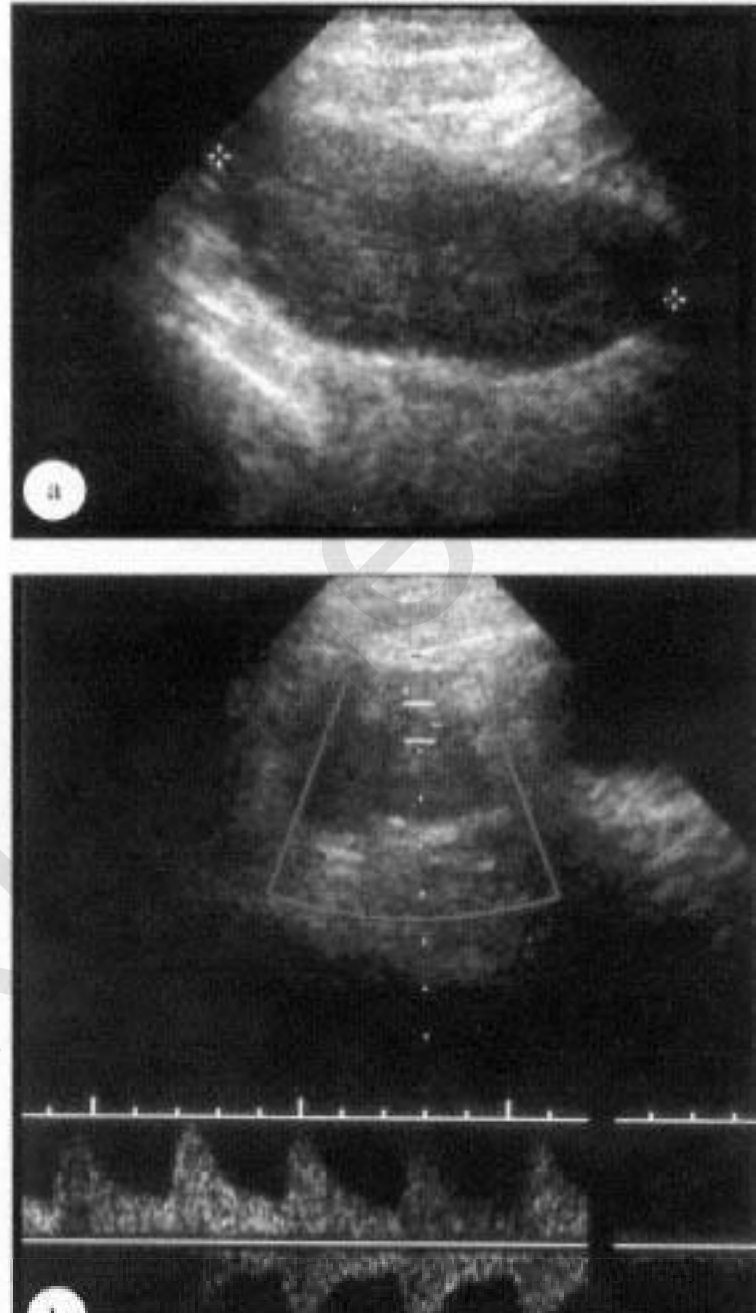
Ovarian Torsion

Adnexal torsion presents with acute or intermittent abdominal pain which may be confused with conditions such as appendicitis or intussusception. Normal adnexal structures, which in young girls are unusually mobile, may undergo torsion or there may be torsion of an ovarian mass. The degree of torsion is variable ranging from lymphatic obstruction through venous obstruction to arterial occlusion. This leads to a markedly enlarged and oedematous ovary which if completely infarcted will show no blood flow on colour Doppler. The appearances may be misinterpreted as those of an ovarian tumour, (Figure 14). Occasionally, a characteristic appearance of distended follicles on the surface of an abnormally enlarged ovary may give the clue to the diagnosis. A study of 20 girls, 11 of whom were prepubertal, showed a variety of appearances. [12] Neonates and young children with torsion were more likely to have extra pelvic cystic or complex cystic masses, whereas pubertal girls had predominantly solid masses in an adnexal location. Colour Doppler signals were frequently detected in the torted ovaries, with absent flow in about a third of cases.

Vaginal Discharge

Vaginal discharges can be clear, cloudy or blood stained. Causes include infection, foreign bodies, tumours or precocious puberty. Foreign bodies and

Vaginal discharges can be clear, cloudy or blood stained. Causes include infection, foreign bodies, tumours or precocious puberty. Foreign bodies and tumours are more likely to cause foul smelling, bloody discharges. The detection of foreign bodies within the vagina by ultrasound is dependent on the nature of the foreign body. Even quite solid foreign bodies may be difficult to detect because of the natural linear echogenicity of the opposed walls of the vagina.
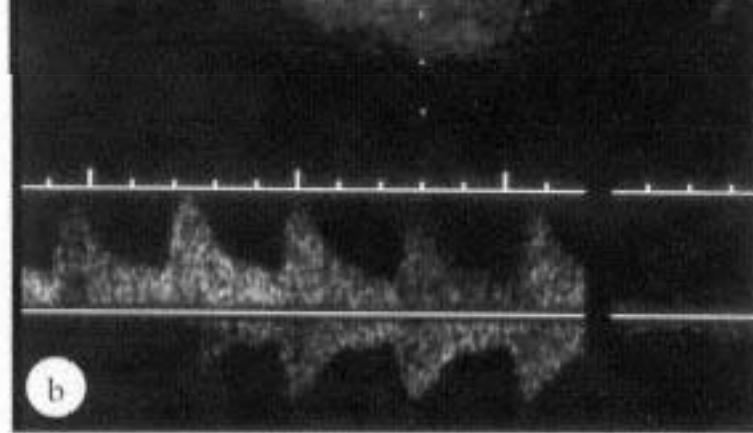
Figure 14—
a) 5 cm × 2.2 cm solid right adnexal mass
resembling an ovarian tumour in a seven year old
with severe intermittent lower abdominal
pain, later found to be due to right ovarian
torsion. b) Clearly demonstrable blood flow on
spectral Doppler in the lower part of this mass
did not exclude the diagnosis of torsion.

Ultrasound Imaging of Adolescent Gynaecological Problems

Delayed Puberty

Primary amenorrhoea is defined as the failure to menstruate by the age of 16. Gonadotrophin hormones (luteinizing and follicular stimulating hormone) stimulate the Graafian follicle within the ovary, which leads to ovulation. Following ovulation the corpus luteum produces oestrogen and progesterone which prepares the endometrium for implantation. If fertilisation does not occur the blood levels of oestrogen and progesterone fall and the endometrium breaks down and menstruation ensues. Any interruption in this pathway may cause delayed puberty. Abnormalities in the region of the pituitary or hypothalamus may be detected by MRI and rarely the cause may relate to androgen producing tumours of the adrenal gland, which may be visualised with ultrasound or CT. Genital causes of primary amenorrhoea may be idiopathic or due to genital tract obstruction, gonadal dysgenesis, uterine agenesis or testicular feminisation. The role of ultrasound is to evaluate the presence of the uterus, ovaries and vagina, and to assess whether they appear prepubertal or pubertal in size and shape, as well as to detect genital tract obstruction. [6]

Genital Tract Obstruction

Uterovaginal obstruction usually becomes apparent at puberty when the onset of menstruation leads to an accumulation of menstrual blood and secondary distension of the vagina (haematocolpos), (Figure 15). In addition, the uterus may also be distended (haematometrocolpos), (Figure 16) or rarely the uterus alone is distended (haematometra). This distension may lead to cyclical lower abdominal pain without menstruation occurring.

Three main types of uterovaginal abnormalities have been described,[13] and the corresponding ultrasound findings documented.[14]

1. Agenesis of the uterus and vagina (Mayer - Rokitansky - Küster - Hauser Syndrome).

An active Müllerian duct remnant with functioning endometrial tissue may lead to unilateral haematometra.

2. Disorders of vertical fusion, e.g., imperforate hymen, transverse vaginal septum and agenesis of the cervix

3. Disorders of lateral fusion usually leading to unilateral obstruction.
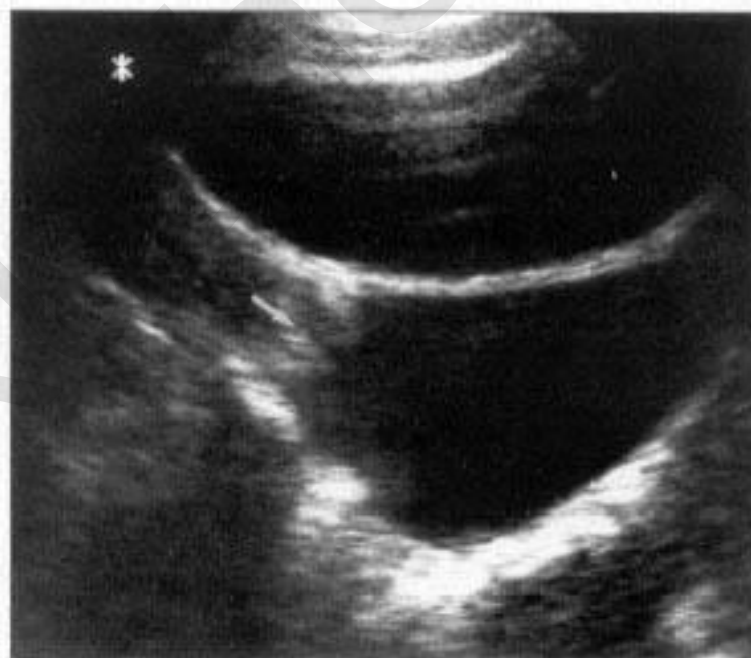
Figure 15—
Fluid filled vagina in a twelve year old girl with
haematocolpos. Cervix can be seen (arrow)
protruding into this.

The ultrasound appearances of haematocolpos and haematometrocolpos are of a tubular, semifluid collection lying in the mid line of the pelvis behind the bladder. The degree of internal echogenicity is variable and on occasions the mass may appear solid.

Confusion can arise with other pelvic fluid collections such as abscesses, (Figure 17). Infrequently, a single horn of a bicornuate uterus or one part of a duplicated vagina
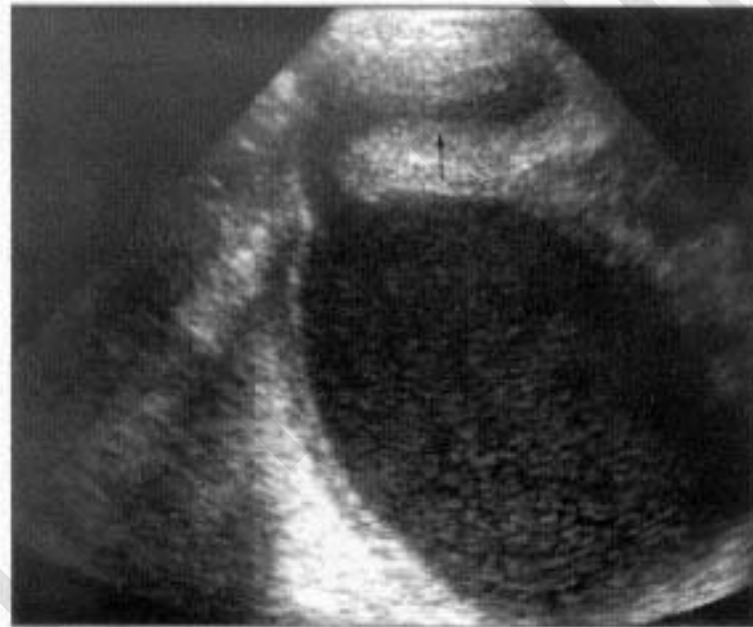
Figure 16—
Echogenic fluid distension of the vagina with less
distension of the uterus (arrow) in a thirteen year old
girl with haematometrocolpos.

Figure 17—
A pelvic abscess from a perforated appendix
lying behind the bladder (arrow) in an eleven year
old girl mimicking haematometrocolpos

may become obstructed and in this situation a similar pelvic mass is present but with normal menstruation, (Figure 18).

Gonadal Dysgenesis

The most common form of gonadal dysgenesis is Turner's syndrome. In Turner's syndrome the uterus is normal, although it may remain prepubertal in size and

Figure 18—
Unilateral haematocolpos (arrow) in a duplicated
genital tract in a teenage girl with lower abdominal
pain but normal menstruation. The normal right
moiety of the genital tract can also be seen
(arrowhead).

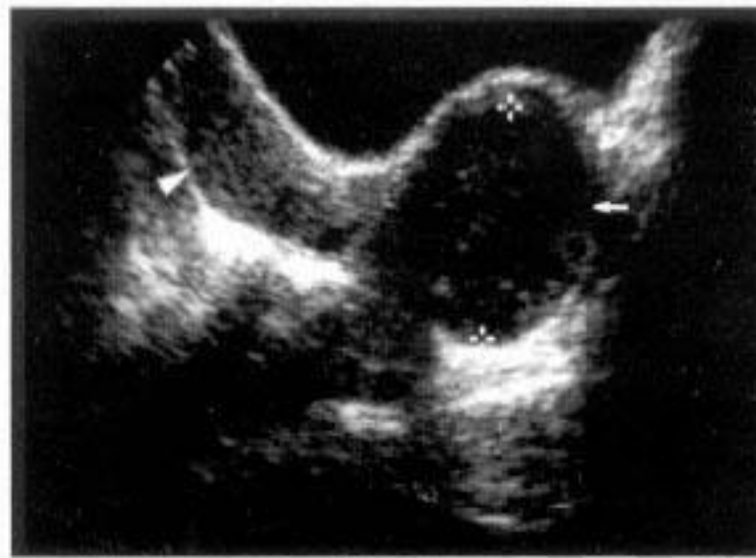shape. About two thirds of patients will have no visible ovarian tissue or simply `streak' ovaries. On ultrasound `streak' ovaries are visualised as very small confluent streaks of tissue in the expected region of the ovaries. One third of patients will have `non-streak' ovaries which have variable appearances on ultrasound. These range from small ovaries, sometimes containing minute cysts, to normal looking ovaries. [15] The importance of this differentiation is that `non-streak' ovaries may retain a degree of function and in some cases spontaneous breast development and uterine enlargement may occur.

Testicular Feminisation

These patients have no uterus, a rudimentary vagina and testes lying somewhere between the retroperitoneum and the labia. They have a male karyotype and female phenotype due to end organ insensitivity to testosterone.

Polycystic Ovaries in Childhood

Polycystic ovaries are probably the most common cause of delayed puberty, or menarche, or heavy irregular periods in teenage girls. They are also a cause of secondary amenorrhoea. On ultrasound scanning these ovaries must be differentiated from the normally appearing multicystic ovaries that are seen before or during puberty. Multicystic ovaries are normal sized ovaries containing more than six cysts measuring greater than 4 mm in diameter, but with a normal stromal pattern. Polycystic ovaries may be of normal or increased size and tend to have an excessive number of small peripherally based cysts and an increased stromal pattern, (Figure 19). However, not all girls with polycystic ovaries

Figure 19—
Enlarged (18 cm^3) polycystic ovary showing
numerous small cysts (arrow).

will have polycystic ovary syndrome, and indeed studies have shown that 25% of normal volunteers have polycystic ovaries. Even in the absence of manifestations of the polycystic ovary syndrome there does appear to be an association between polycystic ovaries and obesity and a later reduction in fertility. [16]

Secondary Amenorrhoea

In teenage girls the most common causes of secondary amenorrhoea are pregnancy, functional cysts, or polycystic ovary syndrome. Much rarer causes would be ovarian tumours or central nervous system lesions.

Congenital Abnormalities of the Uterus

It may only be possible to detect these with ultrasound at, or after, puberty when the uterus has enlarged. Even then some of the minor abnormalities, such as uterine and vaginal septae, may be impossible to visualise.

The most common congenital abnormality is a bicornuate uterus, where there is fusion which is confined to the caudal end of the Müllerian duct system. This leads to two uterine bodies joined at variable levels above the cervix. On ultrasound examination the uterus may be slightly wider than usual with two endometrial echoes from each cornual region which converge in the lower uterine body. [17]

Much less common is the finding of uterus didelphys, where there is failure of fusion of the dual Müllerian duct system leading to two uteri, two cervices and two vaginas. Unilateral failure of Müllerian duct development is slightly more common giving a uterus unicornis unicollis which on ultrasound appears as a smaller than normal uterine body with a single cervix and vagina.

Figure 20—
Dilated fluid filled Fallopian tube (arrow) in a
teenage girl with pelvic inflammatory disease.

Pelvic Masses in Adolescent Girls

Pelvic Masses in Adolescent Girls

Many of these have been described in the section on premenarchal girls. With the onset of puberty the incidence of functional ovarian cysts, which may vary in size from 2 to 10 cm, increases greatly. These functional cysts may present as palpable masses or give pain due to torsion or rupture. They may be follicular, corpus luteal or theca lutein cysts. The latter cysts may be multiloculated and therefore confused with cystadenoma or even cystadenocarcinoma.

Pelvic Pain

Gynaecological causes of pelvic pain include mid cycle mittelschmerz pain, torsion or rupture of ovarian cysts, torsion of normal ovaries or ovarian masses, endometriosis, ectopic pregnancy and pelvic inflammatory disease, (Figure 20). The risk of pelvic inflammatory disease is increased in the young, sexually active adolescent. The ultrasound findings of these conditions have either been described elsewhere in this chapter or are identical to those that have been well described in the adult population. Non gynaecological causes, such as appendicitis, need to be borne in mind and looked for when carrying out ultrasound examinations for acute lower abdominal pain.

Associated Renal Tract Abnormalities

It should be remembered that a number of congenital abnormalities of the genital tract are also associated with abnormalities of the renal tract, and these should be looked for at the time of the ultrasound scan. These include renal agenesis, renal ectopia and horseshoe kidneys. When scanning the pelvis, abnormalities of the renal tract may cause confusion. Dilated tubular structures behind the bladder may be due to dilated ureters. Cyst like structures within the bladder may be due to ureterocoeles and both of these findings should lead to an examination of the kidneys to look for hydronephrosis and the presence of duplex collecting system, (Figure 21). A bladder diverticulum may be misinterpreted as an adnexal cyst, and a close look for a communication with the bladder should be made.

Conclusion

Ultrasound examination of the paediatric female pelvis requires a thorough knowledge of the developmental changes that take place in the uterus and ovaries between birth and puberty. It also requires knowledge of the vari-
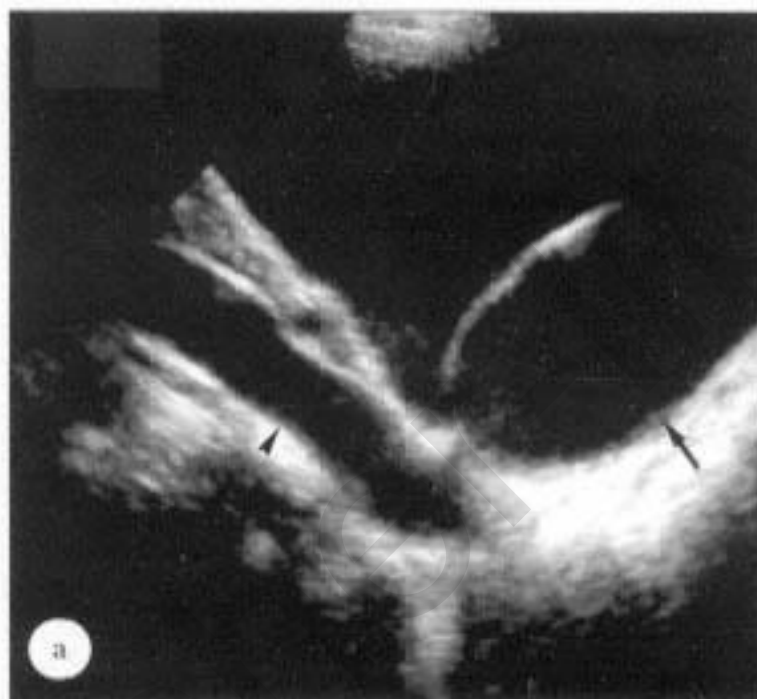
Figure 21—
a) Ureterocoele (arrow) within the bladder and associated hydroureter (arrow head) in a newborn girl. *b)* Further examination reveals an obstructed upper pole moiety of a duplex kidney.

ous congenital abnormalities that may occur and their associations with abnormalities elsewhere within the abdomen. The main role of ultrasound in the evaluation of a pelvic mass is to define whether the mass is cystic or solid and its organ of origin. Many of the solid pelvic masses have similar ultrasound appearances and a specific pathological diagnosis cannot be made until the time of surgery or biopsy.

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Management of Patients:
The Gynaecologist's Perspective
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Introduction

Gynaecology, like any other speciality in medicine, has its roots in the assessment of patients' symptoms, placed in context with the given physical findings, from which management or treatment is chosen. Largely, treatment has evolved from empirical studies, but increasingly the principles of treatment have become based on researched fact. Ultrasound has played a pivotal role in both obstetrics and gynaecology ever since its first use by Professor Donald in the 1950's and has rapidly ensured its place in clinical practice.

The key benefit of ultrasound imaging, over the traditional method of bimanual palpation of the pelvis, is the ability to see with the transducer what the examining hand cannot always feel. Therefore, its first role in gynaecology has been that of a screening tool. However, with increasing technological advances, the evolution of ultrasound has been from a screening role to a diagnostic and therapeutic one.

The use of ultrasound, from a clinical viewpoint can be roughly divided into that related to pregnancy and that not related to pregnancy. In gynaecology, pregnancy related topics usually refer to miscarriage (more properly referred to as early pregnancy loss) and ectopic pregnancy. Non-pregnancy related clinical conditions range from dysfunctional uterine bleeding to postmenopausal bleeding. This chapter will concentrate on non-pregnancy related clinical situations and helps to put into a clinical context the use of ultrasound in daily practice.

Figure 1—
Ultrasound image of a fibroid uterus. A
submucosal fibroid (arrows) is displacing the
endometrium.

Non-Pregnancy Related Gynaecological Conditions

It is perhaps easier to consider the need and practical use of ultrasound in gynaecology when one considers the symptom groups that one encounters. In

It is perhaps easier to consider the need and practical use of ultrasound in gynaecology when one considers the symptom groups that one encounters. In broad terms, gynaecological patients requiring ultrasound fall into four main categories: those with symptoms relating to abnormal uterine bleeding; symptoms relating to infertility; symptoms or signs relating to a pelvic mass; and acute symptoms (pain or bleeding). By far the commonest condition seen by gynaecologists is menstrual disorders.

Abnormal Uterine Bleeding

Pre-Menopausal Patients

Abnormal uterine bleeding, occurring before the menopause, accounts for nearly a third of referrals to a gynaecologist. The pattern of bleeding maybe excessive heaviness with clot formation each month, or total chaos (in other words, no clear pattern with bleeding occurring without warning at any stage of the menstrual cycle). In pre-menopausal women the need to investigate the uterus is because of the likelihood of finding significant intra-uterine pathology, like fibroids, (Figure 1), that may be the cause of the bleeding. Once found, fibroids and polyps can be treated in the hope of resolving the symptoms. Women who do not have an organic cause for the bleeding, that is no pathological basis, are classified as having dysfunctional uterine bleeding. The remaining patients are deemed as having a pathological reason, for example, fibroids.

The traditional method of investigating such women was by dilatation and curettage (D&C), a blind sampling technique. Hysteroscopy, the direct visualisation of the uterine cavity with an endoscope, has superseded D & C,[1] and will identify intra-uterine pathologies in approximately 45% of this group of women. In other words, 55% of women investigated by hysteroscopy will have an apparently normal uterus. This has led to the recent interest in transvaginal ultrasound as a screening tool for the diagnosis of normality in such women. The advantages of this are of a non-invasive procedure and more realistic use of resources. A recent study has indicated that ultrasound was very accurate in screening out "normal cases" where there was no intra-uterine pathology.[2]

If normality can be used as the basis for screening with ultrasound, why can ultrasound not be used for all cases of abnormal uterine bleeding in pre-menopausal women? The limitation of ultrasound in the presence of pathology

is its inability to reliably define the presence, location and character of any given abnormality. The sensitivity of transvaginal ultrasound in this situation is at best 75%.[3,4] Studies that have assessed the role of ultrasound in such a group of women have failed to justify its place in clinical practice because of the need for the clinician to be able to accurately map the abnormality, so that appropriate treatment may be provided.[5]

At present, therefore, ultrasound has a potential role in acting as a triage mechanism in women with dysfunctional uterine bleeding by screening out those patients that do not require subsequent hysteroscopy. There may be additional benefit in the use of ultrasound in this group of women because of the ability to visualise the ovaries. Whether additional information on ovarian pathology, gathered during the ultrasound, is a bonus, has yet to be clarified (vide infra).

Management of Dysfunctional Uterine Bleeding

The management of patients in whom no intra-uterine pathology is discovered at investigation can be either through medical or surgical therapy. Medical therapy consists of hormonal based or non-hormonally based drugs. If the menstrual cycle is chaotic, a progesterone is often used to stabilise the menstrual loss. Alternatively, if there are no contraindications, the combined oral contraceptive pill is excellent in controlling menstrual loss. In a non-smoking patient the pill can be used beyond the age of 35. Non hormonal therapy acts by controlling the haemostatic mechanisms in the endometrium, for example, cyclokapron, or the prostaglandin production in the uterus, for example, mefenamic acid. The latter are used in women who have a regular, but heavy, menstrual loss.

The alternative to medical treatment is surgical treatment. Hysterectomy is the most traditional surgical method but less invasive alternatives are now available. Hysterectomy can be performed by the abdominal route (usually with a transverse scar in the lower abdomen) or by the vaginal route. The reason for using the abdominal route as opposed to the vaginal route was often because of operator preference, uterine size, or the presence of other pelvic pathology, such as adhesions and ovarian cysts. With the recent introduction of laparoscopic assisted vaginal hysterectomy (LAVH), the ability to perform a vaginal hysterectomy in all cases is now possible.

Surgical treatment by hysteroscopic endometrial ablation has become popular in the belief that ablation is a less complicated operation with an acceptable success rate for the patient's symptoms. Randomised trials have demonstrated the benefits of operations such as endometrial resection and laser ablation over hysterectomy with significant

ABNORMAL UTERINE BLEEDING - KEY POINTS

The Premenopausal patient:
- Hysteroscopy identifies pathology in about 45% of women.
- 55% have dysfunctional uterine bleeding with no evident pathology.
- Ultrasound:
  - is a useful screening tool, identifying pathology such as polyps or fibroids.
  - accurately screens out those with normal uteri who would otherwise have gone on to have hysteroscopy.
  - is limited in its ability to accurately map the location of abnormalities and reliably characterise them.
  - may give useful additional information regarding the ovaries.
- Treatment options for dysfunctional uterine bleeding include:
  - medical therapy,
  - hysterectomy,
  - endometrial resection or laser ablation.

benefits to the patients in terms of recovery time after surgery. Hysteroscopic surgery also opens the opportunity for treatment to be given to the identified

benefits to the patients in terms of recovery time after surgery. Hysteroscopic surgery also opens the opportunity for treatment to be given to the identified pathology, as in the case of fibroids, rather than resorting to hysterectomy.

Post-Menopausal Patients

Women with abnormal bleeding after the menopause are a group more at risk of endometrial cancer than their premenopausal counterparts. The risk of cancer increases with age, therefore, there is a need for more urgent investigation in this group of patients. Once more, the traditional approach to investigation was by performing a D&C but latterly hysteroscopy has taken over as the gold standard. If ultrasound is used as a screening tool in this group it is essential that the accuracy of the technique at least matches that of direct visualisation at hysteroscopy, especially as hysteroscopy, as an outpatient procedure, has become more patient acceptable.[6]
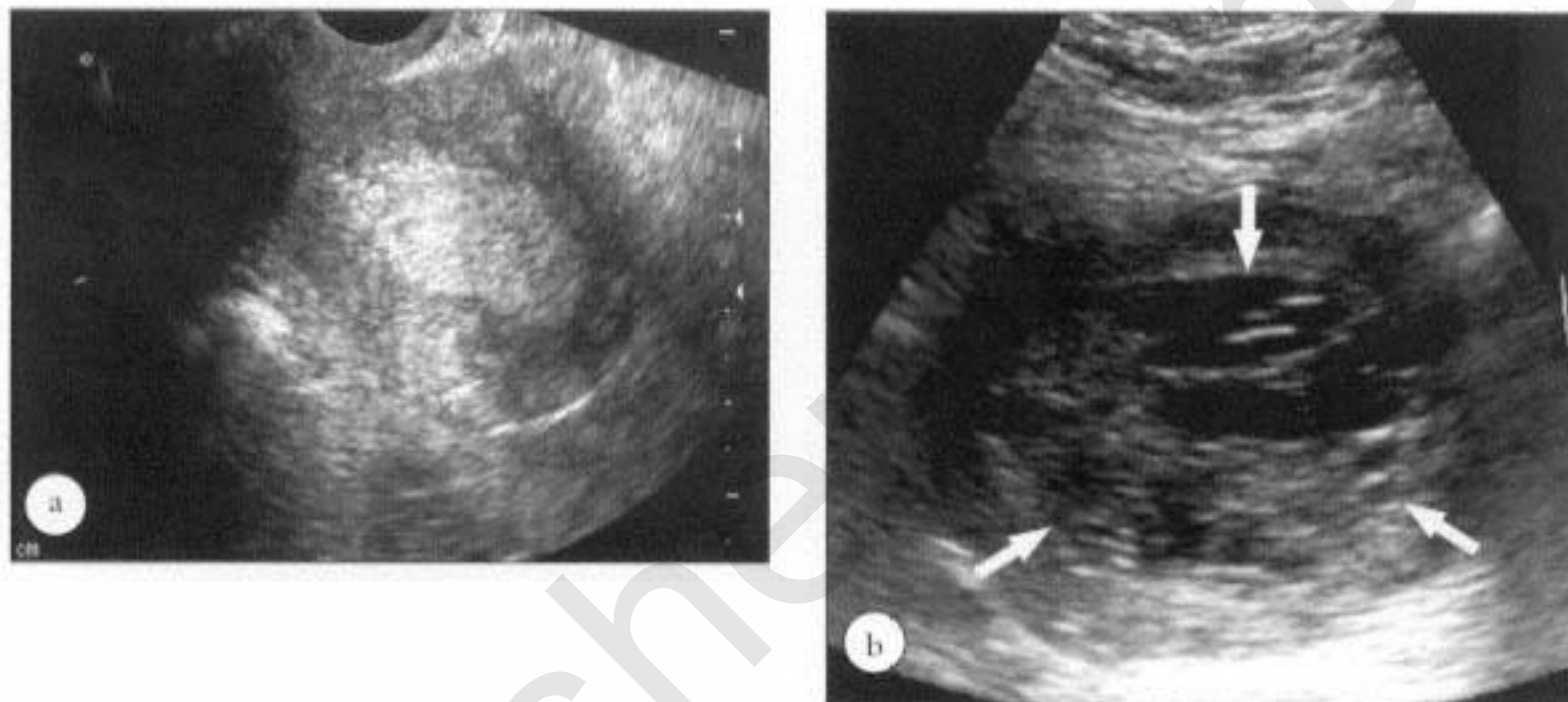
Figure 2—
a) Endometrial thickness seen on ultrasound in a patient with a tamoxifen related polyp. b) A large, tamoxifen related polyp (arrows) showing cystic change.

Attempts at utilising ultrasound in post-menopausal bleeding patients have centred on the measurement of endometrial thickness. It has been suggested that an endometrial thickness of less than 5 mm is a useful screening end point for the determination of normality (Figure 2).[7] Many studies have taken other measurements (< 3 and < 4 mm).[8] There are a number of problems with this approach; firstly, endometrial cancers have been identified in women whose endometrium is less than 5 mm.[9] This may mean that a lower cut-off measurement should be used, but the lower the cut-off for normality the more likely patients are to need hysteroscopy anyway. Secondly, there is considerable intra- and inter-observer variation in ultrasound measurements which will have to be taken into account should universal screening become employed.[10]

The same arguments concerning the identification of abnormalities in pre-menopausal women apply to postmenopausal women. The latter are still likely to have endometrial polyps (22%) and fibroids (15%). In addition, the presence of endometrial hyperplasia (a pathological diagnosis with a risk of coincident endometrial cancer which may be found as a localised area of thickened endometrium) may be missed.

In both these categories of patients there are continuing developments in ultrasound technology that show promise in improving diagnostic accuracy. The use

In both these categories of patients there are continuing developments in ultrasound technology that show promise in improving diagnostic accuracy. The use of contrast media (HyCoSy) appears to enhance the view obtained, allowing accurate visualisation of polyps and fibroids.[5] In addition, the contrast medium may make the definition of a thin endometrium easier. Another advance is the incorporation of Doppler studies to look at the endometrial/myometrial interface and vascular neogenesis.[11]

Post-Menopausal Bleeding and Tamoxifen

A specific group of post-menopausal patients are attracting an increasing number of new referrals to gynaecologists and ultrasonographers. This group consists of patients with breast cancer who are on long term tamoxifen therapy. Tamoxifen, which is a partial oestrogen antagonist, is extremely effective in controlling

ABNORMAL UTERINE BLEEDING - KEY POINTS

The Postmenopausal Patient:

- This group has an increased risk of endometrial carcinoma.
- Hysteroscopy is the gold standard for investigation.
- Ultrasound:
  - can be used as a screening tool.
  - measures the endometrial thickness, which correlates with the presence of pathology.
  - the cut-off point, in mm, is a balance between generating too many hysteroscopies (if set too low) and missing abnormalities (if set too high).
- Tamoxifen may be associated with endometrial proliferation, polyps and endometrial cancer.
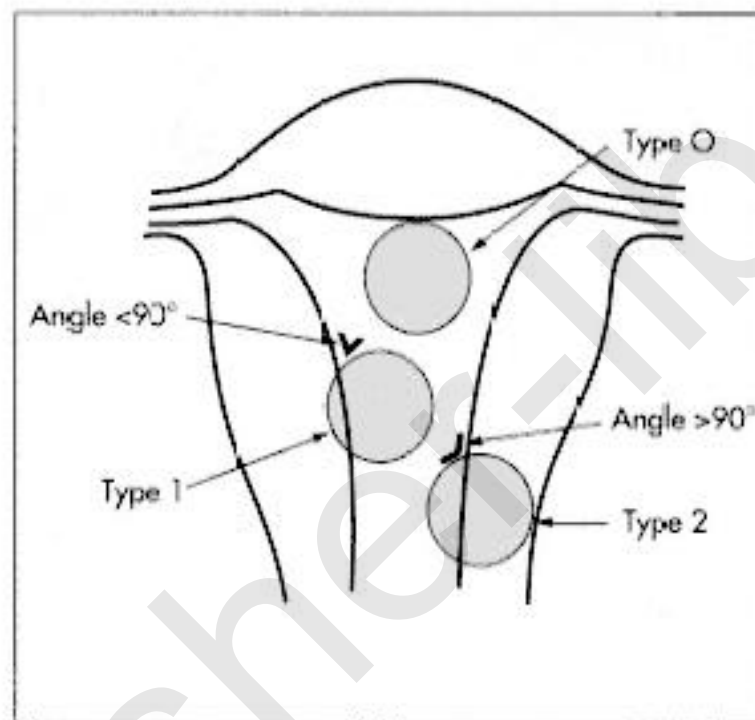
Figure 3—
Classification of submucous fibroids. From the
European Society of Hysteroscopy.

breast disease. Its antagonistic action, however, is in the endometrium. This can lead to excessive oestrogen stimulation in the endometrium and endometrial polyps, endometrial proliferation, and in some cases endometrial cancer. The exact relationship between tamoxifen and its endometrial effects is currently being investigated. Tamoxifen related polyps and endometrial changes are often difficult to detect by ultrasound. Because of the tissue effects of tamoxifen, the endometrium can simply seem thickened, but when subsequent hysteroscopy is carried out the true nature of the lesion is seen. The polyps are often very soft and vascular with stromal thickening and oedema, and their removal is essential.

Fibroids and Polyps

In both groups of patients with abnormal uterine bleeding, fibroids and polyps can be found at hysteroscopy and ultrasound. From the clinical view point, the exact site and character of these lesions is becoming an important issue. There is a growing body of evidence that the removal of the lesion alone, rather than the total removal of the uterus, has a successful chance of improving the patient's symptoms.[12,13] With advances in hysteroscopic surgery it is now possible to remove these lesions with the minimum of trauma and under direct vision.

In both groups of patients with abnormal uterine bleeding, fibroids and polyps can be found at hysteroscopy and ultrasound. From the clinical view point, the exact site and character of these lesions is becoming an important issue. There is a growing body of evidence that the removal of the lesion alone, rather than the total removal of the uterus, has a successful chance of improving the patient's symptoms.[12,13] With advances in hysteroscopic surgery it is now possible to remove these lesions with the minimum of trauma and under direct vision.

Polyps are exuberant endometrial proliferation and, more often than not, are benign in nature. However, they can be the site of endometrial carcinoma and as such should be removed in post-menopausal women.[14] Removal of polyps in symptomatic women is more likely to result in cessation of symptoms in the post-menopausal group than the pre-menopausal group. The difficulty ultrasound has in the detection of polyps is the differentiation between a thick endometrium and that containing a polyp. However, contrast sonography may overcome this problem.

Fibroids can be found in three places in the uterus. They may be sub-serosal, on the outer surface of the uterus, intra-mural, within the myometrial wall, or submucous, impinging on the endometrial cavity. The former is not amenable to hysteroscopic surgery and is also unlikely to be involved in the evolution of the patient's bleeding symptoms. Fibroids in the intra-mural portion of the uterus may be removed by hysteroscopic resection but it is difficult. The final site, impinging on the endometrial cavity, is the site most amenable to hysteroscopic surgery.[12] For the patient and the clinician, it is important to know the exact site of the sub-mucous fibroid, (Figure 3). How much of the fibroid is present in the endometrial cavity as opposed to the wall of the uterus and the size of the fibroid are important pieces of information. Both these issues are taken into account in patient counselling and are indices used to establish the ability to treat. The success rate of the procedure is also determined, pre-operatively, using these indices. Patients need to be warned of the possibility of a two stage procedure to treat the fibroid and this can only be done if the information is available. To date, hysteroscopy is the best way to obtain this information but contrast sonography may prove useful in the future.

FIBROIDS AND POLYPS - KEY POINTS

• Treatment options for fibroids include hysterectomy or hysteroscopic resection.
   • Submucous fibroids are more amenable to hysteroscopic removal than intra-mural. The exact location and size of the lesion is important in treatment planning, counselling and in predicting the success of treatment.
• Polyps may be the site of endometrial carcinoma.
   • Removal of polyps alleviates symptoms in post-menopausal women more successfully than in pre-menopausal women.

Pelvic Masses and Gynaecological Cancer

Patients are often referred specifically to investigate a pelvic mass. The most serious concern is that of ovarian carcinoma, (Figure 4). Other reasons for a pelvic mass are large fibroids, benign ovarian cysts, inflammatory masses and non-gynaecological causes, (such as inflammatory bowel disease, diverticular disease and colonic carcinoma.

Usually, the patient's symptoms are not overt but, occasionally, there are vague symptoms of abdominal bloatedness or pressure symptoms relating to bladder function.

Ultrasound plays a key role in the differentiation of pelvic masses. Large fibroids are usually readily identifiable. If not removed surgically by the clinician the subsequent monitoring of the fibroid is made easy with further ultrasound scans. Ovarian cysts can be easily identified by ultrasound. Features suggestive, but not indicative, of malignancy are solid and cystic components and vascular neogenesis as seen with Doppler examination. [15] Usually, laparotomy is carried out in the presence of a suspicious pelvic mass and the final histology is obtained thereafter. Subsequent follow-up of patients with malignant disease

Figure 5—
Ovarian carcinoma - note the cystic and solid
components.

of the ovary may occasionally be carried out by ultrasound, but CT is superior in its ability to detect and monitor spread of disease.

Malignant Ovarian Lesions

Malignant ovarian cysts all need to be removed at laparotomy. The nature of ovarian cancer is that it tends to present late in the stage of the disease, and this often means that the disease has spread beyond the pelvis. CT is superior to ultrasound in its ability to stage the disease, detecting spread into adjacent organs, omentum and lymphadenopathy. It provides a good baseline for monitoring the results of debulking surgery and the effects of subsequent chemotherapy.

Surgery for ovarian cancer necessitates removal of as much of the malignancy as possible and usually means a hysterectomy, removal of both ovaries and, in addition, removal of the omentum and appendix. The ability of post-operative chemotherapy, as needed in nearly all cases, to be effective, is to some extent determined by the volume of disease remaining after surgery. The smaller the volume of tissue, the better the chance of a response. The prognosis for ovarian cancer also depends on the stage of the disease; the more confined the cancer, the better the outcome. Having said this, because of the late presentation of the disease in many women, the overall survival for ovarian cancer is poor. The cumulative lifetime risk of developing ovarian cancer is 1.5% and the risk of dying from cancer is similar, 1.3%.

Benign Lesions

Ovarian masses that appear benign and are persistent will need to be explored surgically with subsequent removal. If left in place ovarian cysts may bleed or tort and can therefore result in an acute episode with emergency admission. It is better to have the cyst removed electively. Benign ovarian cysts can be removed on their own, but sometimes there is no normal remaining tissue and in these cases the ovary may need to be removed together with the cyst. Benign ovarian cysts are more likely to be unilocular and completely cystic. Physiological benign cysts, such as ovulatory cysts and corpus luteal cysts, are well recognised and can be very simply monitored by serial ultrasounds to ensure resolution. Usually, cysts less than 4 cm in diameter resolve spontaneously. Dermoid cysts are benign cystic teratomas and have solid features within the cyst. As there is the chance of bilateral dermoid cysts in a proportion of patients, screening of the non-affected ovary is important. Occult cysts, seen at ultrasound in the presumed unaffected ovary, would warrant a careful examination at the time of removal of the affected side.

Ovarian Screening

Screening for ovarian cancer by ultrasound has been investigated.[16] Pelvic ultrasound in combination with CA 125 (a tumour marker) has been the method used (See Chapter 6). However, if this screening procedure was introduced in the general population, there would have to be a huge number of people screened to detect a very small number of malignancies. In addition, there would be a substantial number of patients found to have benign cysts that would have to undergo laparotomy for a non-malignant condition. Overall, this strategy for screening has not been pursued because of the above considerations. In high risk families, who have a first degree or close relative with ovarian cancer, limited screening is available. It is important that this screening is done in a facility where genetic counselling is available.

Cervical Cancer

Cervical cancer tends to be diagnosed clinically or as a result of cervical cytology. Ultrasound, however, may be important in the preliminary investigation of patients. If ureteric involvement is suspected identification of ureteric dilatation or pelvicalyceal dilatation would then lead to more extensive investigation using CT.

PELVIC MASSES - KEY POINTS

- May present with abdominal bloatedness and/or bladder symptoms
- Ultrasound is the first line investigation
- Treatment options include:
  - Laparotomy if suspision of malignancy
  - CT for staging of carcinoma and post-operative follow-up.
  - Surgical removal of the mass with possible hysterectomy, bilateral salpingo-oophorectomy, omentectomy and lymphadenectomy
  - Post operative chemotherapy.
  - Monitoring of fibroids or suspected physiological cysts with ultrasound
- Diagnosis of cervical cancer is usually made clinically and with cervical cytology. Ultrasound may identify renal tract involvement.

Infertility

This is comprehensively discussed in Chapter 8.

Investigation of the Infertile Couple

In routine practice the diagnosis of anovulation is made by repeat progesterone assays. Causes of anovulation, such as polycystic ovaries, (Figure 5), and congenital malformations of the genital tract, can be readily identified by ultrasound. Tubal disease may be assessed with high sensitivity and specificity by HyCoSy[17] or by hysterosalpingography, laparoscopy and dye testing, can provide more information than routine ultrasound about the cause, site and extent of tubal damage.

When post-coital tests are required to assess cervical mucus/sperm interaction, precise timing of the test is essential to avoid confusing and inaccurate results. A positive post-coital test offers couples a good prognosis. In women with long menstrual cycles timing by dates may be impossible, and in these cases follicular mapping, performed serially, can be very useful in determining the correct time to carry out the test.

Monitoring of Assisted Conception

Ultrasound monitoring of ovarian and endometrial response to stimulation regimes is now established practice in fertility centres. The ability to time cycles, ovum harvest and to prevent multiple pregnancy has been made possible by the concomitant use of ultrasound and hormonal monitoring, and it is essential

Ultrasound monitoring of ovarian and endometrial response to stimulation regimes is now established practice in fertility centres. The ability to time cycles, ovum harvest and to prevent multiple pregnancy has been made possible by the concomitant use of ultrasound and hormonal monitoring, and it is essential for the guidance of harvest procedures, obviating the need for laparoscopic egg retrieval.[18]

Figure 5—
Polycystic ovarian disease, with a halo of small
follicles surrounding the stroma and tiny cysts
within the stroma.

Ultrasound is also useful in reducing the complications associated with therapy. Ovarian hyperstimulation, following the maturation of a large number of follicles, is one of the most serious complications for women undergoing gonadotrophin therapy, and is responsible for major, maternal morbidity. The underlying problem of capillary leakage from the stimulated ovary can lead to ascites, pleural effusions, hypovolaemia and venous thrombosis. The problem can be avoided or reduced by withholding administration of the ovulation induction agent (human chorionic gonadotrophin) when too many follicles are present.[19]

The Acute Pelvis

Patients admitted via casualty with a history of acute lower abdominal pain are often assessed by gynaecologists The first diagnosis to exclude or consider is ectopic pregnancy, which is discussed under the next heading.

The second most common condition to consider is pelvic inflammatory disease. The symptoms most often described in pelvic infection are bilateral low abdominal pain and a vaginal discharge. Patients are not always pyrexial. Examination usually reveals bilateral iliac fossa tenderness, sometimes with guarding, with both adnexal regions usually tender to palpation. Vaginal examination may reveal a cervical discharge but not always. The diagnosis is based on the clinical symptoms and confirmatory bacterial swabs, however, ultrasound can be used to corroborate the findings and, more usefully, to exclude other

Figure 6—
Fluid seen in the Pouch of Douglas and
surrounding the uterus in pelvic inflammatory
disease. (Longitudinal midline section).

pathology. The finding of fluid in the pouch of Douglas has been used to help confirm a clinical suspicion of pelvic inflammatory disease, (Figure 6),[20] but may also be found in a ruptured ectopic pregnancy. A pelvic abscess has characteristic appearances on ultrasound and the patient is very often quite toxic.

Patients with the suspected diagnosis of pelvic inflammatory disease are usually treated by antibiotics, after bacterial swabs have been taken. Registration with a genito-urinary clinic with contact tracing is also an important part of the patient's management. Occasionally, if the patient's symptoms do not respond to conservative antibiotic therapy, a diagnostic laparoscopy is carried out to ensure there is no pelvic collection or abscess formation. In patients with a pelvic abscess, antibiotics are also important but the abscess should be drained surgically at laparoscopy, or via ultrasound guidance where amenable, in order for the patients symptoms to resolve.

Pain low in the pelvis may also be associated with ovarian cysts. The commonest cyst to cause such symptoms are corpus luteal cysts which have ruptured, usually postcoitally. Ovarian cysts may also become twisted on their pedicle (torted) or bleed internally into the substance of the cyst itself.

Patients who are admitted with a history of acute pelvic pain and who have a cyst diagnosed at subsequent ultrasound need to undergo laparoscopy to assess the nature of the cyst and treat it accordingly. Often a haemorrhagic cyst may require removal, together with the ovary, if it is affected. A torted ovarian cyst will need to be removed

THE ACUTE PELVIS - KEY POINTS

- Be sure to exclude ectopic pregnancy.
- PID is a common cause of lower abdominal pain and may be accompanied by vaginal discharge.
- Diagnosis of PID clinically is confirmed by bacterial swabs and ultrasound scan.
- Treatment with antibiotics and subsequent drainage of abscess if symptoms persist.
- Ovarian cysts are assessed laparoscopically and may be removed if haemorrhagic or torted.

but the ovary may be conserved if it has not been affected by the interruption in its blood supply, in other words, if has not become ischaemic. Laparoscopic treatment, rather than laparotomy, should be possible in the majority of cases.

Pedunculated fibroids on the surface of the uterus can also be a source of pain because of torsion or red degeneration. The latter is most often associated with pregnancy and occurs as a result of the fibroid out growing its blood supply with subsequent haemorrhage into itself.

Pregnancy Related Gynaecological Conditions

Ectopic Pregnancy

The incidence of ectopic pregnancy has shown a consistent increase during the last two to three decades. However, it is difficult to compare the various publications because ectopic pregnancy is seldom described in absolute numbers. Most often it is expressed as an overall rate, such as ectopic pregnancy per 1000 live births. The current incidence rate for ectopic pregnancy in western societies is 12-14 per 1000 live births. In the UK, ectopic pregnancy accounts for about 10 per cent of maternal deaths and is the fourth commonest cause of maternal death. In the western world as a whole, ectopic pregnancy is the major cause of maternal mortality in the first trimester.

The clinical diagnosis of ectopic pregnancy remains a challenge for gynaecologists. The diagnosis is only correct in current practice in less than 50% of cases. Ectopic pregnancy may mimic the symptoms of other gynaecological conditions, such as pelvic inflammatory disease, ruptured corpus luteum, dysfunctional uterine bleeding and incomplete abortion. Abdominal pain is the commonest symptom and is frequently present even before rupture. Amenorrhoea is reported in 75-95% of patients. The last menstrual period is often described as lighter than normal and may occur earlier or later than expected. The most common physical sign is abdominal tenderness, often associated with rebound tenderness.

The role of ultrasonography in suspected ectopic gestation is to attempt to localise the pregnancy. If the pregnancy is found to be intra-uterine, ectopic pregnancy is virtually excluded because the combination of intra-uterine and ectopic pregnancy is extremely rare in normal conceptions (1 in 30,000), although in stimulated IVF pregnancies the heterotopic pregnancy rate is higher. The interpretation of ultrasound findings is dependent on the accurate knowledge of the duration of amenorrhoea. It is well known that more than a third of the patients with ectopic pregnancy do not know the date of their last menstrual period, and in others irregular bleeding may lead to confusion. If no gestational sac or pregnancy is seen on transabdominal ultrasound and a pregnancy test is positive, an ectopic pregnancy is highly likely.

A major advantage of transvaginal sonography is that it can diagnose normal or failed intra-uterine pregnancy at least one week earlier than by transabdominal sonography.[21] In particular, when trying to differentiate between a pseudogestational sac, as occurs with ectopic pregnancy, from a normal early intra-uterine gestational sac, the transvaginal probe is more useful than a transabdominal scan.

Ectopic pregnancy is a potentially dangerous condition that should be managed with the utmost of care. Initial expectant management, with bhCG monitoring is possible in women who are haemodynamically stable and where there is the possibility that the pregnancy is situated in the uterus. There are guidelines for this approach; when a suboptimal rise in the pregnancy hormone occurs the patient should undergo a diagnostic laparoscopy.

At laparoscopy the ectopic pregnancy can be either be removed on its own after opening the Fallopian tube (salpingostomy) or by removal of the ectopic and the Fallopian tube (salpingectomy). Some centres are injecting the ectopic with methotrexate or hyperosmolar glu-

Figure 7—
Left ectopic pregnancy, suggested by the
absence of an intra-uterine pregnancy and a cystic
adnexal mass. Note the IUCD in the endometrial
cavity.

cose to kill the pregnancy, and this may prove to useful in the future. Most surgery can be carried out laparoscopically.

Cystic adnexal masses, (Figure 7), and free fluid in the pouch of Douglas are other sonographic signs which should raise the index of suspicion of the presence of a possible ectopic gestation. However, it is very difficult to differentiate between the other numerous possible underlying conditions such as pelvic inflammatory diseases, ovarian cysts and endometriosis, all of which may mimic an ectopic pregnancy. In addition, it has been reported that the adnexal mass, as seen ultrasonically, can be on the contra-lateral side of the ectopic pregnancy in about 30% of the cases, and normal adnexal findings on ultrasound have been seen in 20% of women with laparoscopically confirmed ectopic pregnancy. Overall, the use of sonography as a diagnostic test in suspected ectopic pregnancy allows an accurate diagnosis as to the presence or absence of an ectopic gestation in approximately 70 to 90% of affected cases.

Miscarriage

Bleeding in early pregnancy is a considerable source of distress to the patient. The concerns regarding the continuing viability or not of a pregnancy are very real and should be allayed as soon as possible. Bleeding, in the past, was often a reason for immediate admission to a gynaecological ward but, with the introduction of Early Pregnancy Assessment Units (EPAU) throughout the UK, the management is now carried out in out-patients. Ultrasound availability has played a critical role in the development of these units. Patients and GPs can now, at short notice, have an assessment of the uterus in the event of bleeding. Ultrasound helps clarify whether a pregnancy is ongoing or not.

Types of miscarriage vary, and can be categorised on history, examination and ultrasound findings. A complete miscarriage means the conception has been lost completely. The patient will often have a history of heavy bleeding with clots followed by crampy abdominal pain with subsequent reduction in the both the vaginal loss and pain. On ultrasound the uterus should be empty. In cases of incomplete miscarriage, ultrasound will identify remaining products of conception. A missed miscarriage, where the pregnancy has stopped developing and only the gestational sac remains, also has a characteristic appearance. Occasionally, a pregnancy which has become complicated by excessive trophoblastic proliferation is picked up at a routine pregnancy scan in the first trimester. These molar pregnancies can be easily treated by evacuation of the uterus and, occasionally, methotrexate therapy. The classical appearances on ultrasound are of an enlarged uterus filled with echogenic material in the early stages, developing easily visible cystic vesicles as the mole progresses, which considerably increases through tramsission of the beam.

Women who miscarry recurrently (defined as more than three times) gain most from early pregnancy ultrasound scanning. The early ultrasound findings of a normally situated and viable pregnancy provides the woman with a 95% chance of an eventual good outcome. The reassurance value of such a non-invasive intervention early in pregnancy is enormous for these women. A randomised trial of early scanning and active reassurance found a significant benefit, in terms of pregnancy outcome, to those women who received the supportive care by scanning and reassurance compared to those who did not.[22]

The Future

The quality and definition of ultrasound technology is improving all the time. The future is likely to be filled with increasing knowledge of Doppler function and variation in differing disease states. As our understanding increases the scope for incorporation into clinical practice will inevitably improve. Contrast sonography is a new concept attracting more and more innovative practice with obvious clinical usefulness. The role of ultrasound, from its humble beginnings, is growing apace.

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```

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JavaScript:doPopup('EndNote','page_128_popup_7.html','width=480,height=384,resizable=yes,scrollbars=yes')
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```

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JavaScript:doPopup('EndNote','page_170_popup_2.html','width=480,height=384,resizable=yes,scrollbars=yes')
JavaScript:doPopup('EndNote','page_170_popup_3.html','width=480,height=384,resizable=yes,scrollbars=yes')
JavaScript:doPopup('EndNote','page_171_popup_1.html','width=480,height=384,resizable=yes,scrollbars=yes')
JavaScript:doPopup('EndNote','page_172_popup_1.html','width=480,height=384,resizable=yes,scrollbars=yes')
JavaScript:doPopup('EndNote','page_172_popup_2.html','width=480,height=384,resizable=yes,scrollbars=yes')
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