# 6. Ultrasound equipment

Ultrasound is used in medicine for both diagnostic and therapeutic procedures, but the equipment differs. For diagnosis, ultrasound echography is commonly used to produce cross-sectional images of the body. The Doppler technique is used mainly for blood flow measurement. For therapy, ultrasound is used in ophthalmology for lens treatment, as well as for lithotripsy of kidney stones and gallstones.

Modern ultrasound scanners are very reliable. They are also technologically sophisticated; the physician can only maintain the instrument as explained in the section on regular preventive maintenance (page 118). The hospital engineer should be able to rectify about 50% of all the common problems, as these tend to be fairly simple, and involve the transducer (probe) cable or power supply.

## *Physical principles*

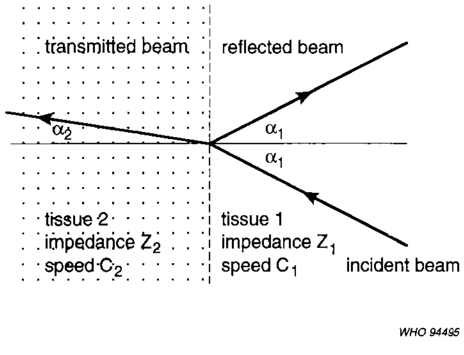
Ultrasound waves can pass through most body tissues. In the soft tissues, only longitudinal waves can propagate to any appreciable distance. Other modes (transversal, shear, etc.) are very strongly attenuated and can be ignored for all practical considerations, as regards image formation. The other modes of vibration can propagate in the bones, but cannot be used in echography. The main parameters of the ultrasound wave are its frequency ($f$), the propagation speed ($c$), the wavelength ($l$), pressure ($P$), and the intensity (energy per unit area per unit time, measured in $W/m^2$ or $W/cm^2$).

The relation of frequency ($f$) to wavelength ($l$) and propagation speed ($c$) is:

$$l = \frac{c}{f}$$

Body tissues can be considered to consist of particles, which oscillate about their equilibrium position when ultrasound passes through. Each tissue under investigation has a characteristic acoustic impedance, which equals the ratio of acoustic pressure to the particle velocity caused by the pressure, and a characteristic propagation speed, which is the same for all frequencies at the intensities used in echography. If the boundary between two media with different characteristic acoustic impedances is much larger than the wavelength, the incident wave is partly reflected while the rest is transmitted across the boundary and, in principle, refracted (Fig. 6.1).

**Fig. 6.1. Geometry of reflectance and transmission of an ultrasound beam at an interface of two media with different densities.**



In the situation shown in Fig. 6.1, the amount of reflection depends on both the ratio of the characteristic acoustic impedances, and the propagation speeds in the respective media. The most important case is the case of normal (at 90°) incidence. In such a case, the ratio of the intensity of the reflected wave ($I_r$) to the intensity of the incident wave ($I_i$) is:

$$\frac{I_r}{I_i} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

where $Z_1$ and $Z_2$ are the characteristic acoustic impedances of the first and the second medium, respectively.

The angle of refraction depends on the ratio of the propagation speeds: the larger the ratio, the larger the refraction.

The impedance of soft tissue is much lower than that of bone and much higher than that of gases. Relative values are approximately 1.5 ± 10% for soft tissues, 0.0004 for gases, and 7–8 for bones.

Ultrasound is attenuated by about two orders of magnitude more in bones and gases than in soft tissues. Attenuation is approximately proportional to the frequency in soft tissues, and to the square of the frequency in water.

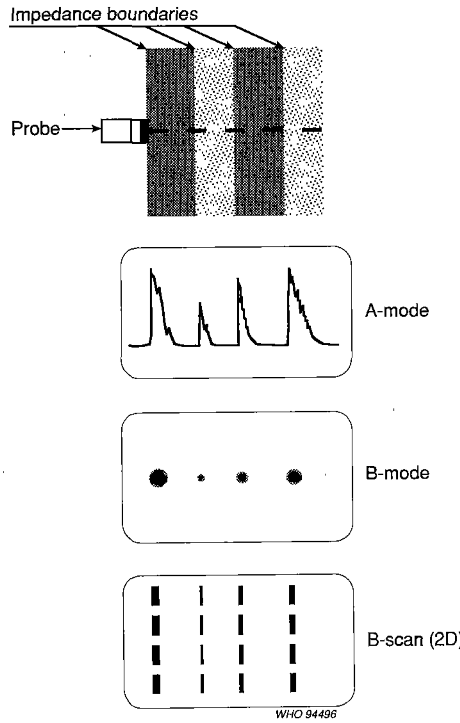
The average propagation speed in the tissues is 1540 m/s, in body gases approximately 330 m/s, and in the bones almost 4000 m/s. Using the above equations, it can be seen that virtually all the ultrasound radiation will be reflected at a soft tissue/gas boundary, and that very little (about 6%) will be returned from behind bone. The angle of refraction at these boundaries is also high.

For these reasons it is not possible to examine the lungs, or the interior of bones, by ultrasound and there are many problems in examining the abdomen when there is a lot of gas in the bowel. Two-dimensional imaging of the brain is impaired by refraction at the bone/soft tissue boundary. The operator must be aware of potential artefacts in order to distinguish them from the symptoms of equipment breakdown. One particular phenomenon appears when the boundary between two media is wider than the wavelength of the ultrasound. Such boundaries act like a mirror and are called specular reflectors. The diaphragm, urinary bladder and gallbladder walls, blood vessel walls, connective tissue capsules, and ventricles are all specular reflectors.

An ultrasound scanner (echograph) transmits short ( < 1 microsecond) ultrasound pulses into the body from a scanning probe, approximately 1000 times per second. Ultrasound pulses are reflected by different reflectors and scatterers in the body, and these echoes (reflected pulses) return to the probe, which serves as a receiver for the ultrasound. From the data, a two-dimensional map of the reflectors can be established. The relative positions of the reflectors are stored in a computer and displayed on a video monitor. Echoes of high intensity are shown as brighter dots on the screen. The image is of a section formed by scanning the body with the ultrasound beam. The echoes can be displayed in different ways (modes), as explained below.

The echoes along the beam may be shown in the form of peaks on the screen, allowing the distance between known structures in the body to be measured. This is called the "A" mode (Fig. 6.2). The "B" mode image shows the echoes as bright dots, with the brightness proportional to the strength of the echo. The B scan is obtained by moving the transducer along the body surface and displaying the B-mode images as a two-dimensional "map". In the "M" mode, the beam is aimed at a moving structure, and the system displays the changing depth of the reflectors. The M mode is often used in cardiology.

**Fig. 6.2. Different ways of displaying ultrasound signals.**

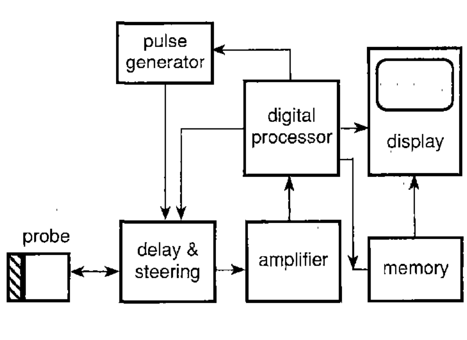



## *The scanner*

Fig. 6.3 shows the various components of an ultrasound scanner.

The system consists of the scanning probe, the electronic scanning apparatus, and the video monitor. The scanner operates as follows: short, fast-rise-time pulses are generated in the pulse generator and taken to the scanning probe, which transforms them into short ultrasound pulses of central frequency determined by the probe resonant frequency. The frequencies used in general practice are between 3 and 8 MHz. The pulses are several cycles long. The probe contains one or more transducers which transmit and collect the ultrasound waves along a number of "lines-of-sight", by automatic movement of the beam in a section plane. The transmitted pulse crosses the body, and is reflected from media interfaces. The reflections return to the probe, where they are transformed into electrical signals. The ultrasound beam can be focused with fixed devices (lenses, mirrors) and by the use of phase-delays in composite probe transducer activation. The echo signals are

**Fig. 6.3. Ultrasound scanner.**



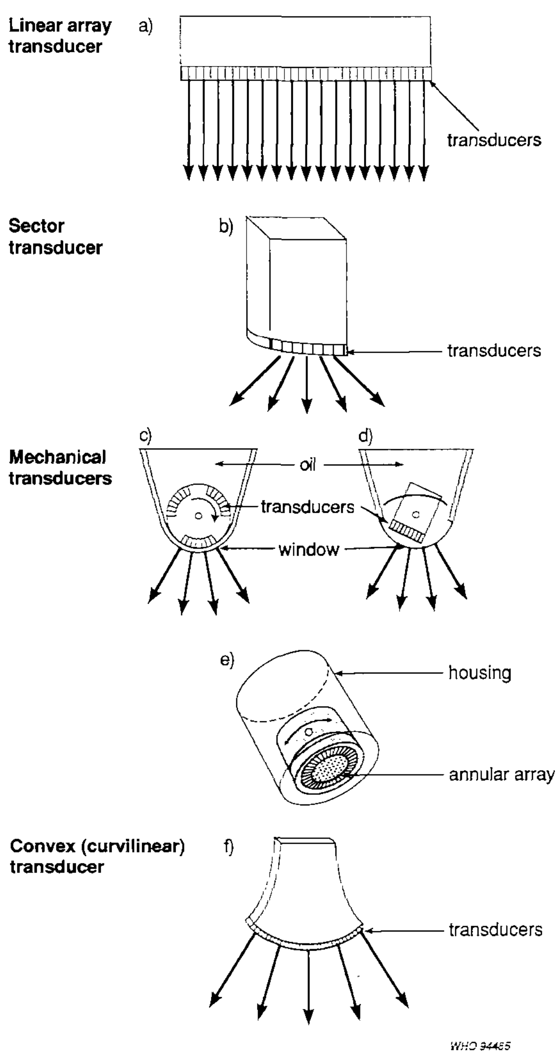
taken to the demodulator and a time-varying amplifier (the TGC—time-gain-compensation—amplifier) which compensates for the attenuation of the ultrasound signal in the body, by amplifying the echoes from deeper structures more than those coming from tissues near the surface. The amplifier has variable gain controls for echoes from different depths. The smallest number of TGC controls is three, i.e., the "near gain", the "far gain", and the slope (of the difference between the near and far gain). Modern scanners have internal preset TGC curves so that the controls serve only for additional adjustment or modification. The signal from the TGC amplifier is digitized and then stored in the computer memory, from where it is taken to the video compression amplifier and the monitor.

## *Scanning probes*

A scanner probe contains one or more piezoelectric transducers. Each transducer is focused to a particular depth and can be classified according to the transducer arrangement as a linear array probe, a sector probe, or a curvilinear (convex) probe.

A linear array probe (Fig. 6.4a) scans in a rectangular format and is used in obstetrics, and in scanning the breast and thyroid. The probe contains between 64 and 120 narrow transducers mounted side-by-side in a 5–10 cm long array. On the

**Fig. 6.4. Scanning probes with different geometry.**



face of the transducers, there is a matching layer and an acoustic lens. Each of the transducers is separately connected to the electronic circuits, thus the connecting cable contains many thin cables, and is easily damaged.

A sector probe (Fig. 6.4b) "looks" into the body through a small acoustic window, forming a nearly triangular image. It is used mainly in the upper abdomen, and for gynaecological and cardiological scanning. A sector probe can be built with up to five transducers, which are moved mechanically with a motor for scanning (Fig. 6.4c and d). Alternatively, scanning can be achieved without mechanically moving parts by appropriately activating a very narrow array of transducers to achieve (phase-controlled) steering.

A sector probe may have an annular array transducer (Fig. 6.4e) which consists of multiple concentric transducer rings. If these are activated at different times, a circular focus can be achieved at any desired depth.

A convex probe (Fig. 6.4f) has an image format between the linear and the sector probes, and is useful for all parts of the body, except for echocardiography. It is built like a linear array, but the transducers are mounted on a curved surface.

The probe is connected to the scanner by an expensive, high-quality multiple cable. This cable is a common cause of malfunction.

## Artefacts

Artefacts are those features in the image that do not conform to the real image for the part being examined. They cause confusion and often lead to incorrect diagnosis. Some examples are given below:

- A space filled with clear liquid appears as an echo-free area on the display screen. There is enhancement of echoes from behind such a space or cyst, while there may be shadows behind the edges of the cyst. This happens because the attenuation of ultrasound is much lower in clear liquid than in other tissues (e.g., the gallbladder has such characteristics).
- Intestinal gases obscure the structures behind them and can introduce multiple reflections (reverberation), which appear as uninterpretable echoes.
- Bones and calcified structures cast shadows on the structures behind them.
- Parallel structures can introduce reverberation (multiple reflections back and forth). This results in multiple parallel lines in the image.

## The Doppler effect

If ultrasound waves of a given frequency are transmitted to a stationary reflector, the reflected waves are of the same frequency as those transmitted. If the reflector is moving towards the transmitter-receiver, the reflected frequency will be higher than the transmitted frequency; if it is moving away, the reflected frequency will be lower than the transmitted frequency. The difference between the transmitted and the received frequency is proportional to the speed with which the reflector moves relative to the transceiver. This effect is called the "Doppler effect", and the frequency difference the "Doppler shift". If the movement of the detector and the ultrasound beam are at an angle, only the component along the direction of the beam gives rise to the Doppler effect. This implies that there is no Doppler effect for plane waves at an angle of 90° to the direction of propagation.

At present, Doppler systems are used only in specialized departments, except for the simplest Doppler instruments, which can be used for the analysis of fetal heart beats. The latter can be easily used in any obstetrics clinic, provided the interpreter has been properly trained.

The general purpose ultrasound unit recommended by the World Health Organization does not have Doppler capabilities.

## Recording

Ultrasound images can be recorded on photographic film, thermal paper, X-ray film, or video tape. Photographs from the video screen can be made with a standard 35-mm camera on ordinary black and white film. Such photographs are of good quality, but are not immediately available. Instant photography has the advantage of giving a print immediately. However, the film is expensive and a special camera and close-up lens are required.

Thermal printers give prints of a fair quality on special paper. The printer itself is relatively expensive, but the price per print is lower than with instant photography, if many images are recorded. Thermal prints tend to fade, if exposed to light, and in hot climates. X-ray printing equipment is expensive, but gives a high quality image. Processing facilities for X-ray film are required.

Video tape recorders are only useful in echocardiography. Digital or laser printers are expensive and only useful in large departments.

## Maintenance and repair

The scanner has the following parts (see Fig. 6.3):

- probe (transducer),
- electronic processing block (amplifiers, TGC system, video amplifiers, digital data processors, digital memory),
- keyboard and other outside controls,
- monitor (display screen),
- power unit,
- hard-copy unit (printer or other recorder).

The probe is the most sensitive part of the scanner, in terms of malfunction. It consists of the transducer assembly, the cable, and a multi-pin fixable connector. The cable contains between 5 and 80 separate conductors.

The transducer assembly can be an electronically activated multi-transducer array (up to 120 transducers), or a mechanically driven transducer system (with up to 6 separate transducers).

### Loss of part of the image or flickering

The most frequent malfunction occurs as a result of a break in one or more of the cable conductors. This may result in interruption of the rotation of the motor that moves the transducers, or cause intermittent rotation, flickering of the image, or drop-out of a part of the image. Such malfunctions are usually the result of mishandling of the cable[1] or of soaking it with gel. The cable can often be mended,

[1] It is important when scanning not to turn the probe always in the same direction, as this will cause the cable to knot and eventually break.

but if it is in a bad state, it should be replaced. The position of the break can often be detected by bending or gently pulling on the cable, while scanning, to see if this affects the image.

If the broken lead is close to the connector (which is less likely) it can be repaired by resoldering the conductors to the connector. If the breakage is close to the transducer, it can only be repaired by dismantling the probe housing, which should be done by a specialized service engineer. If the probe is dropped and the crystals break, any local repair will yield a probe of inferior quality. In such a case, a new probe must be purchased.

In composite probes (linear and convex), the failure of some transducers, or some of the cable conductors, can be detected by putting a pen or pencil on the face of the transducer and moving it from side to side. The reflection from the pen should not disappear in any position on the face of the probe.

## Excess noise

The motor and the bearing in a mechanical probe can fail. Bearing failure is usually preceded by a prolonged period of noisy operation. Listen to the scanner during routine maintenance. In some mechanical probes, the bearing can easily be exchanged, but this requires care and should preferably be carried out by the manufacturer. If the motor fails, it usually requires replacement by the service engineer.

## Gross image deterioration

The oil in the dome of the transducer must be air-free. The presence of air bubbles causes gross deterioration of the image quality. In some probes, the dome is transparent so that any air bubbles are visible. In the case of image deterioration (fuzzy images or moving defect in the image), first inspect the dome of the transducer for air bubbles. If air bubbles are detected, the oil must be replaced.[1] Although in some probes a good quality baby oil may be good enough, it is preferable to use the manufacturer's recommended oil. In well designed probes, refilling is a simple operation, possibly requiring the use of a syringe and a hypodermic needle.

In multiple-transducer mechanical probes, the transducers may have different sensitivities, or may not have been properly adjusted. This can be detected by putting a hypodermic needle obliquely into a beaker or glass filled with water, and scanning it with the probe. The needle image should not oscillate or change its intensity on the screen while being scanned.

## Care of the probe

The face of the probe is usually an acoustic lens. It must be handled with care. Do not drop the probe, and avoid scratching the face with sharp objects.

Keep the probe assembly clean of oil and gel. Always clean the probe and cable with a tissue or damp cloth, after finishing work.

[1] Do not change, connect, or disconnect probes when the machine is running, especially if the image is not "frozen".

## The electronics block

This part of the scanner is a complex electronic system located in the main box of the scanner. Because of its complexity, nonspecialized repair should be limited to changing a blown fuse, or repairing the high-tension circuit that supplies the pulse generator. Disconnect the scanner from the power supply before attempting any repair.

## Change in image quality

A sudden drop in the sensitivity of the scanner can be a sign of preamplifier malfunction. A change in the grey-scale quality can be a sign of malfunctioning of the preprocessing unit, or a monitor problem. An inability to make measurements, or to change programmes, may be due to a digital processor breakdown. If only a part of the image is shown and the probe assembly is intact, it is most likely that the digital memory or the microprocessor is not working properly. Wavy movement of the image may be due to a power supply filter failure, or mains voltage fluctuations outside the working range.

When these faults occur proceed as follows:

1. Switch the unit off.
2. Measure the mains voltage; check that it is within the specified values (see below).
3. Check that the probe is firmly connected.
4. Switch the unit on.
5. Allow two minutes for warm-up.
6. Adjust the electronically generated grey wedge on the monitor screen, using the contrast and brightness controls.
7. Adjust all the controls to their middle positions.
8. Try to scan.

If the scanner still does not work, repeat the same procedure after 10 minutes. If the scanner still does not work, call the specialized service engineer, describing the symptoms of the malfunction.

If the scanner does not operate at all (the lights are not on, the fan cannot be heard), first check the mains voltage and the plug, then check the fuse at the rear of the scanner.

## Mains voltage fluctuation

If the mains voltage varies beyond the specifications, repeat the voltage checks early in the morning or in mid-afternoon, when the voltage is likely to be the best available in the network. The scanner may operate properly when the voltage is correct. It may be necessary to acquire an appropriate voltage stabilizer from the manufacturer.

## Recorded data

Specific hospital data (logo, preset adjustments, etc.) may have been entered in the scanner memory at the time of installation. Such data are retained, even when the scanner is switched off, because the unit has an internal battery. When the battery is exhausted, the scanner may lose some of the stored data. Replace the battery at the recommended intervals, before it is exhausted. Follow the instructions in the manual to avoid losing the memory during the change.

The following rules relate to use of the ultrasound scanner and should be followed by all users:

- Do not switch the scanner off and on in quick sequence. Leave an interval of 2 minutes or more before turning on again.
- Leave the machine running for at least 15 minutes.
- Always save the image after scanning.

Use the grey wedge on the screen to adjust the monitor, but if you need to change the grey scale during working, use the scanner dynamic controls, **not** the monitor controls.

## Keyboard and front panel

All scanners have knobs and buttons that actuate potentiometers, which change the scanner settings. Some scanners have computer-style keyboards, and a few have touch-screen or light-pen controls. The measurement calipers are controlled by joy-sticks, trackball, or multiway buttons. Some scanners have slow digital processors; in such scanners, the computer may block if information is typed in too quickly. If this happens, switch the scanner off and restart after a pause of at least 2 minutes.

## Controls

The controls are normally protected from the casual transfer of oil or gel from the operator's fingers, but may be damaged when liquid is spilled.[1] They will not stand rough handling. Even if used carefully, the potentiometers may respond intermittently after prolonged use, owing to poor electrical contact. Similarly, the trackball blocks may not operate smoothly, and will give a jittery response. Such problems can be temporarily alleviated by spraying the potentiometers with an anti-corrosive contact spray, but it is better to change the potentiometer. It is essential that the correct replacement part is used and checked after installation.

## Power system

The power system for the equipment is installed inside the housing and is usually mounted at the rear of the scanner. During operation, this part of the scanner heats up; it is normally cooled by a fan. The power circuits can accommodate some variation of the mains voltage (usually $\pm$ 10%). The normal protection is a fuse (or two), located at the rear of the scanner, possibly under the cover. The power circuits are the first parts to suffer from surges on the mains network. The most common malfunction is a blown fuse, followed by a blown diode or thyristor. These can usually be repaired by the hospital engineer, provided spares are available.

The following precautions should always be observed:

- If the mains voltage is less stable than recommended by the manufacturer, a voltage stabilizer should be used.
- The fuses may be of a type that is not readily available. Spare fuses should therefore be obtained when the equipment is ordered.

[1] The keyboard and controls must be kept clean. Clean with a tissue or damp cloth after every working day. Do not spill any liquid over the controls. Do not hang anything on or from the controls. Turn them gently and smoothly.

- The ventilation holes in the scanner must not be covered with papers, forms, tissue, etc.
- The ventilator often has a dust filter. This must be changed every 3 or 6 months in dusty climates. If the original filter tissue is not available, a piece of double gauze can be used.

## Monitor

The monitor is usually a commercial or domestic television monitor, and is seldom specific to the scanner. Other monitors can be used in parallel or instead of the original. This may not be easy if the manufacturer uses non-standard connectors, but a hospital electronics engineer should be able to change these. The scanner usually generates a grey or coloured wedge on the monitor, and this is used for adjustment. The monitor should be adjusted after the instrument has warmed up for a few minutes. Once the monitor has been adjusted for good visibility of the grey wedge, it should not be readjusted to change the ultrasound image. Further image adjustment should be made using the scanner controls.

The ventilation holes of the monitor should not be covered or clogged. Greasy fingerprints should be cleaned from the screen with soft tissue or a damp cloth.

### Small or wavy image

If the image on the screen is smaller than normal, or if it is wavy or greyish and cannot be adjusted to its normal size, measure the mains voltage. The monitor cannot operate properly when the voltage is too low. On some monitors, the controls for horizontal and vertical synchronization are on the rear panel. If the image runs vertically, adjust the vertical synchronization; and if the image "collapses", try adjusting the horizontal synchronization.

## The hard-copy unit

There are many different hard-copy units, e.g., a multiformat camera using X-ray films, instant camera, thermal paper printer, or a standard reflex camera. Each type requires different maintenance and supplies.

## Acceptance tests

It is important that the whole unit operates well at the time of purchase. If it does not perform well, it is unlikely that it will work well at any later time. Carry out the following checks on receipt of the unit:

1. Inspect the packing crate and look for external damage that may have occurred while the unit was in transit.
2. Make sure that an operator's manual is supplied. A servicing manual is also essential for the hospital engineer.
3. Be present at the time of unpacking and installation. Check against the manuals to be sure that all accessory parts are present and not broken.
4. Make sure that the unit supplied matches the mains voltage available.
5. Carry out the initial tests when the mains voltage is at its worst, i.e., at a time of the day when the voltage is lowest and least stable. Do not forget that specifying your mains stability to the vendor is your responsibility.
6. Look for any damage on the probe face (the part that comes into contact with the patient) before using it.

7. Look for any traces of oil or contact gel on the cables, the probe, the keyboard and the front panel. When a new scanner is delivered, there should be no traces of oil anywhere on the scanner. When buying a used scanner, inspect the controls and transducer for evidence of oil or misuse.
8. If there is a phantom (i.e., a device with the same range of densities as body tissues, used for testing and calibrating ultrasound equipment), make photographs of several phantom scans. Write down the settings at which these were obtained and the resolution number, as measured with the phantom. Put them into a file for future reference.
9. Check all the probes by scanning your own liver. It should be possible to see the superior mesenteric artery. (This is a test of the resolution.) The dynamics of the grey-scale imaging can be tested by showing that the parenchyma of the kidney is slightly darker grey than the liver.
10. Check all the controls to ensure that they operate correctly and smoothly.
11. Check the electronic caliper system carefully. It must be possible to measure distances between two points on the screen. Check that the biometric tables are in the scanner memory, if they have been specified for the scanner.
12. Make sure that the presetting procedure for scanner settings is explained. Make notes in the operator's manual. These may be useful later if the memory battery fails.
13. Document the quality tests. Record your own superior mesenteric artery and liver/kidney; record a fetal head at 30 weeks of gestation with cavum septi pellucidi visible. Record all test images. Keep the records on file.

## Preventive maintenance

The preventive maintenance that should be carried out by medical or technical staff can be summarized as follows:

- After each day's work clean the scanner, the probe, and the monitor with a tissue or a damp (not wet) cloth. Remove any oil or contact gel.
- Every 6 months (more often if necessary), clean the fan filter.
- Keep the ventilation holes open, do not cover with paper, even if the surface looks like a shelf. Do not put anything on any part of the scanner.
- Take care of the probe cable. Do not allow it to kink. Do not twist it always in the same direction.
- Do not switch the scanner on and off at short intervals; always wait for at least 15 minutes.
- If you are using a mechanical sector probe, listen to the noise from the probe. If it becomes excessive, call the service engineer to check the bearing.
- Save all the images whenever the instrument is apparently malfunctioning.
- Keep all the lids and covers on the scanner closed when not using the controls behind them. Switch the unit off and disconnect from the mains before opening any cover.

## Routine testing

The scanner should be tested occasionally with a grey-scale phantom; if a phantom is not available, test by demonstrating that the cavum septi pellucidi can be seen in the head of a fetus at 30 weeks of gestation, or that veins of about 3 mm in diameter in the liver are seen at 45° to the ultrasound beam. A very good test of resolution is the ability to image the superior mesenteric artery in a normal adult. The superior mesenteric artery should be imaged transversally at the level of the pancreas, where it is seen as a roundish hollow structure. This test takes about 20 seconds to carry out, and should be repeated about once a month. If the scanner fails in this test, it must not be used in clinical practice; it should be repaired at the factory or by a specialized service engineer.

## Necessary equipment

Ultrasound phantoms are commercially available for less than US$ 1000. One phantom is sufficient for many scanners, and the cost can therefore be shared among several institutions. Any large hospital or main health department should have an ultrasound phantom.

## *Specification of the scanner*

A wide variety of scanners is available on the market. Therefore, before ordering, a specification must be agreed upon for an instrument that will allow the physician or sonographer to obtain useful and appropriate clinical data. The criteria must include price and quality. It is better to have no scanner than to have a scanner that does not provide useful data, since poor quality scans will lead to misdiagnosis.

Sector scanners are used for the upper abdomen, as well as in gynaecological and cardiological examinations. Linear scanners are used in obstetrics, and for scanning the breast and thyroid. A combined linear and sector scanner can cover all areas; convex scanners are also useful in the majority of body areas. A good generally applicable compromise frequency is 3.5 MHz, while 5 MHz is useful for scanning children and superficial organs. The original specifications for a general purpose ultrasound scanner were defined in 1984 by a WHO Scientific Group.[1] These have since been reviewed and updated.[2] Units of this type are now commercially available. Careful thought should be given before accepting any unit that does not meet these specifications even if it is less expensive.

The specifications for a general purpose ultrasound scanner are listed below.

1. The transducer design should be curvilinear (convex), or a combination of linear and sector.
2. The standard transducer should have a central frequency of 3.5 MHz, with accurate focusing. An optional transducer of 5 MHz is desirable if it can be afforded. The 3.5 MHz probe is a fair compromise between penetration and resolution, but the 5 MHz is very helpful in scanning children, thin adults and superficial organs. It is a worthwhile addition but should not replace the 3.5 MHz transducer.
3. The sector angle should be 40° or more and the linear array should be 5–8 cm long.
4. The controls should be simple and easy to use. Overall sensitivity (gain or transmitter power) and time-gain-compensation must be an integral part of the circuit. It should be possible to vary the time-gain-compensation from a preset level. However, this is not essential because if the time-gain-compensation is at the correct level for obstetrics, with a preset alternative for the upper abdomen, more than 80% of patients can be satisfactorily examined by varying the overall gain only.
5. The frame rate should be 15–30 Hz for the linear array and at least 5–10 Hz for the sector array.

[1] WHO Technical Report Series, No. 723, 1985 (*Future use of new imaging technologies in developing countries*: report of a WHO Scientific Group).
[2] Palmer PES, ed. *Manual of diagnostic ultrasound.* Geneva, World Health Organization (in press).

6. The frame freeze should have a density of 512 × 512 × 4 bits (to provide 16 grey levels).
7. At least one pair of electronic omnidirectional calipers with quantitative readout is required.
8. It must be possible to add patient identification data (hospital number, date of the examination, etc.) to the screen and the final record.
9. It should be possible to obtain a permanent record (hard copy) of the scan. The hard copy unit must work satisfactorily in the same environment as the scanner.
10. There should be 2 or 3 imaging dynamics ranges available for post-processing. It is unnecessary to have a wider range of options.
11. The screen of the video monitor should measure at least 10 cm × 10 cm, preferably larger.
12. The equipment must be portable, so that an average adult can move it over at least 100 metres; if on wheels, these must be suitable for rough irregular surfaces, but a unit that can be moved without wheels is preferable.
13. The equipment must be suitable for the local climate, and be protected against dust, damp, extremes of temperature, tropical environments, etc. It should be possible to use the scanner continuously within a temperature range of 10–40 °C and 90% relative humidity.
14. It must be possible to transport and store the unit safely under adverse conditions. It should not be affected by air transport or being moved across rough country in any vehicle. A specially designed case for transport may be necessary.
15. It is essential that the scanner can operate from the local power supply and is compatible with the voltage, frequency and stability of the local current. The equipment should be able to stabilize a voltage variation of ±10%. If there is greater fluctuation in the local supply (and this should be tested before the unit is purchased), an additional voltage stabilizer should be obtained. These tests must be carried out before the scanner is accepted.
16. Many ultrasound scanners incorporate biometric tables in the microprocessor memory. These are useful, but care should be taken to ensure that measurements are made in exactly the same way as was used to provide the tables. Biometrics tables may not be universally applicable and should be adjusted for local conditions.
17. It is essential to ensure that servicing is available locally. No ultrasound unit should be purchased unless there are trained service engineers available in the vicinity. When in doubt, ask other local users of ultrasound equipment about the quality of the service and maintenance provided. This may well be the deciding factor when choosing between different scanners.
18. Service manuals and operating instructions should be provided at the time of purchase, especially if local servicing is not readily available.
19. Accessories for ultrasound-guided puncture or biopsy must be easy to sterilize.