Ultrasound Basics

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Basics of Ultrasound

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1.1 Physical and Technical Principals

Ultrasound is the term applied to mechanical pressure waves with frequencies above 20,000 Hz (beyond the audible range).

A medium must be present for ultrasound propagation to occur. In biological tissues, ultrasonic energy is propagated mainly in the form of longitudinal waves, as it is in fluid.

The ultrasound wave can be both emitted and received by a piezoelectric transducer. The piezoelectric transducer is able to change electrical signals into mechanical waves, that is, transmitting ultrasound (= reverse piezoelectric effect), and vice versa to change mechanical pressure (reflected ultrasound waves, "echoes") into electrical signals (= direct piezoelectric effect).

Ultrasound in the MHz range (high-frequency) can be emitted as a directional beam, comparable to a light beam, from transducers of practical size.

Ultrasound waves propagate in biological tissue at an average speed of 1540 meters (m) per second, with the exception of bones, where the waves move at more than 3000 m per second.

Ultrasound waves interact with biological tissue in various ways; they are partially absorbed by the tissue, which means that their energy is converted into heat. This is important for safety reasons (see Sect. 1.5 below). Ultrasound waves can also be reflected (interference > beam diameter) or (back-) scattered on their way through the tissue. Whether reflected or back-scattered, echoes are received by the transducer. These echoes are the source of the diagnostic information.

The echoes are analyzed first with regard to their site of origin (time–distance principle), and secondly with regard to their intensity. This information is used for example to construct an image (two-dimensional

B-scan technique). One of the preconditions is that only a small part of the ultrasound is reflected at each interface, and most of the ultrasound is transmitted to deeper levels. Only bones, gas, and foreign bodies (metallic or nonmetallic) cause a very strong reflection (acoustic shadow); thus no information is obtainable from regions behind such obstacles.

Absorption, reflection, and scattering cause a permanent attenuation of ultrasound energy of approx. 1 decibel per cm of propagation in the tissue traversed per 1 MHz of frequency. The ultrasound attenuation must be corrected by amplifying echoes as a function of distance from the transducer (TGC), in order to get a homogeneous display of the echoes (Fig. 1.1a–d). Nevertheless this attenuation can seriously limit the depth

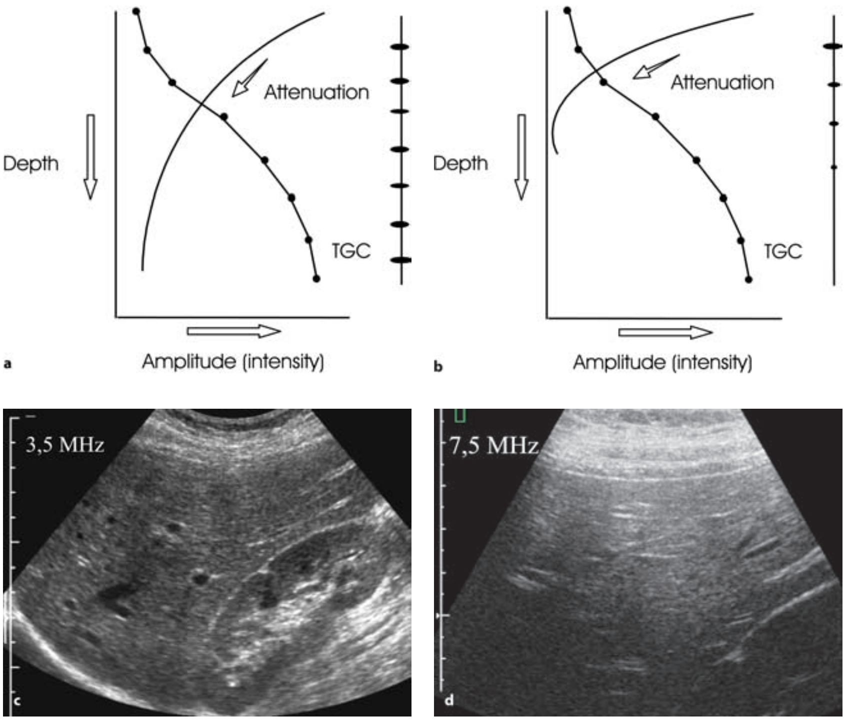


Fig. 1.1a–d. Ultrasound attenuation in the tissue and its correction by the TGC. With 3.5 MHz, a homogeneous image is possible (**a**,**c**), whereas a frequency of 7.5 MHz (**b**,**d**) is too high for the examination of the abdomen. On the other side, the resolution close to the 7.5-MHz transducer is better (small-part transducer)

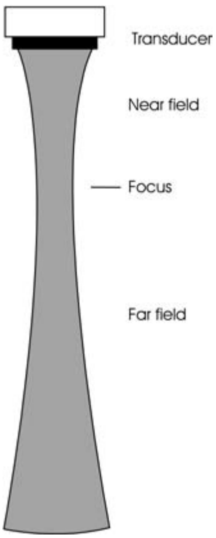
of penetration of higher frequencies (the so-called small part transducers are suitable for small *and superficial* organs only!).

The *ultrasonic field* is a geometric description of the region encompassed by the ultrasound beam. There are two main sectors, the near field (interference field), located between the ultrasound transducer and the (natural) focus, and the far field. The lateral boundary of the ultrasound field is not sharp, because the beam intensity falls off continuously with distance from the center (Fig. 1.2).

The *lateral resolution* depends on the diameter of the ultrasound beam: the smaller the diameter, the better the resolution. The resolution therefore is best in the focal area. The ultrasound beams are focused (mainly electronically by modern techniques), enabling the clinician to always focus on the region of interest (Fig. 1.3).

The *axial resolution* depends on the length of the emitted ultrasound pulses and finally on the wave length, i.e., the frequency.

These basic physical principles are still important in regard to the quality of ultrasound equipment despite the advances in electronic techniques:



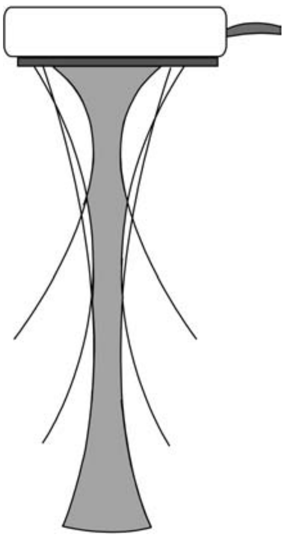


Fig. 1.2. The ultrasonic field of a flat transducer

Fig. 1.3. Schematic representation of electronic focusing of a linear array transducer

the higher the frequency, the better the resolution on the one hand, but the higher the attenuation in the tissue on the other hand, which means a limited penetration depth. For small and superficial parts, therefore, high-frequency transducers (5 – 10 MHz) should be used, whereas for the abdomen or in late pregnancy, transducers with lower frequencies (2 – 5 MHz) are necessary.

1.2 Imaging Techniques

The echo principle forms the basis of all of the commonly used diagnostic ultrasound techniques. These are:

- A-scan
- M-scan
- B-scan
- Doppler techniques

A-scan (*a*mplitude modulation) is a one-dimensional technique. The echoes received are displayed on a screen as vertical deflections. This technique is rarely used today except for measurements.

B-scan (*b*rightness modulation) is a technique in which the echo amplitude is depicted as dots of different brightness (gray scale). It is mostly used as a two-dimensional B-scan to form a two-dimensional ultrasound image by multiple ultrasound beams, arranged successively in one plane. The images are built up by mechanically or electronically regulated scanning in a fraction of a second. The image rate of more than 15 per second enables an impression of "permanent" imaging during the examination (real time).

M-scan (also sometimes referred to as TM-scan) is a way to display motion, e.g. of parts of the heart. The echoes produced by a stationary ultrasound beam are recorded over time, continuously (Fig. 1.4a,b).

Doppler techniques use the Doppler effect as a further source of information: if the ultrasound waves are reflected by an interface moving towards the transducer or away from it, the reflected frequency will be higher or lower respectively than the transmitted frequency. The difference between the emitted and received frequencies is proportional to the speed of the moving reflector. This phenomenon is called the Doppler effect, and the difference is called the Doppler frequency or Doppler shift.

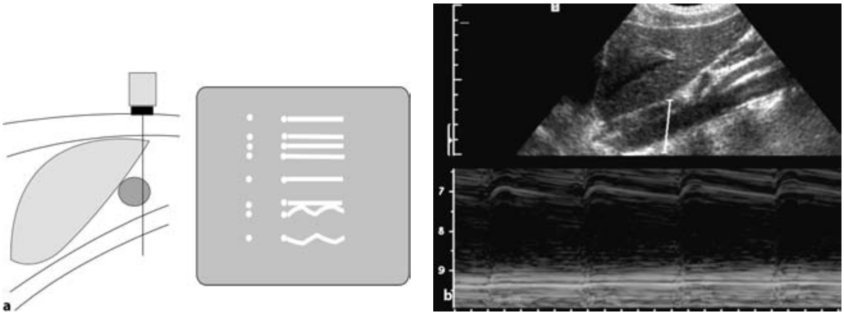


Fig. 1.4. M-scan. Schematic representation (**a**) and original image (**b**). Note the movement of the wall of the aorta. The *line* in the B-scan image marks the area of the M-scan

The Doppler shift depends on the ultrasonic frequency (f), the velocity of the reflector (v), and the angle between the ultrasound beam and the blood stream. Information can only achieved if the angle is less than 60°. An angle of 90° has the cosine $\alpha = 0$, which means no Doppler shift = no signal.

Doppler Formula: $\Delta f = 2f/c \cdot v \cdot \cos\ \alpha$.

There are various Doppler techniques:

– *Continuous wave Doppler* (cw Doppler): the transducer is divided in two parts: one crystal transmits ultrasound permanently, the other crystal receives all the echoes. There is no information about the distance of

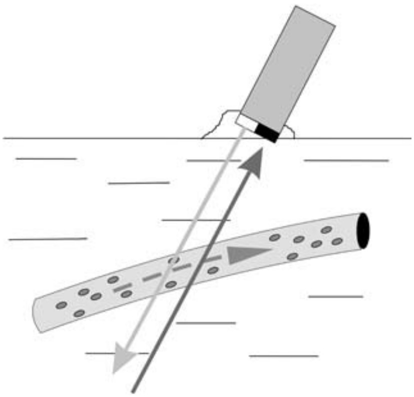
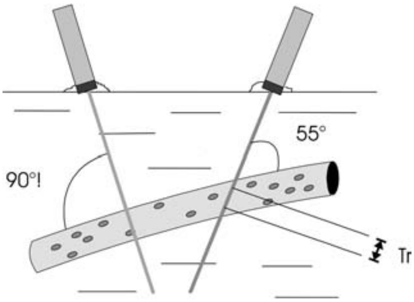


Fig. 1.5. Diagram of the cw Doppler technique. Note the two crystals

the reflector(s), but only about the velocity, at which the reflector (the blood stream) moves (Fig. 1.5).

– *Pulsed Doppler*: Ultrasound is emitted in very short pulses (as in the A-,B-, and M-scan techniques). Between the pulses the echoes reaching the transducer in a certain time interval are received and analyzed. In this way, the movement of the reflectors in a particular distance (gate, selected by the operator) can be displayed (Fig. 1.6) and analyzed (spectral Doppler, Fig. 1.7), or displayed in the B-scan image (duplex techniques, Figs. 1.8–1.10).



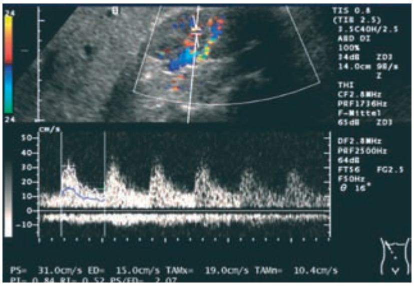
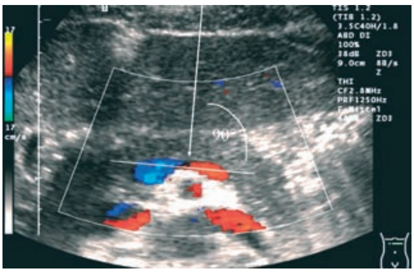


Fig. 1.6. Pulsed Doppler. The echoes, received in a definite time distance (so-called sample volume), are analyzed (in this example marked with "Tr"). The ultrasound beam of the left transducer crosses the vessel at a 90° angle; this means no Doppler signal, as is demonstrated in Fig. 1.8

Fig. 1.7. Spectral Doppler analysis of a segmental artery in the left kidney



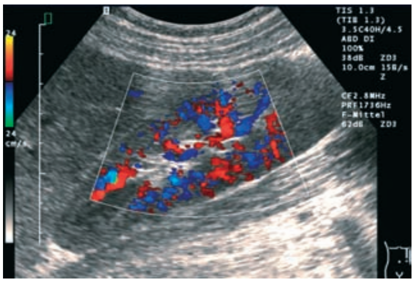


Fig. 1.8. Color-Doppler image of the splenic vein. Flow towards the transducer in the distal part, *red-coded*; away from the transducer in the proximal part, *blue*. Note the gap of Doppler signals (90°!)

Fig. 1.9. Color-Doppler image of the left kidney. The *color-coded* information about the flow direction enables the differentiation between veins and arteries

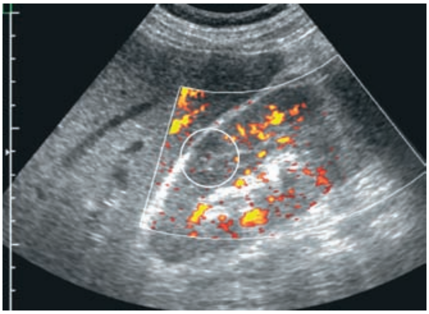


Fig. 1.10. Power-Doppler image of the right kidney. This technique is more sensitive. In this case it enables the diagnosis of a renal infarction (O)

- *Color-Doppler* and *power-Doppler* techniques are used as duplex techniques integrated in the B-scan image. The echoes arising from stationary reflectors (tissue) are displayed as bright spots (gray-scale technique).The echoes from moving reflectors are analyzed by the Doppler technique separately, but displayed in the same image "color-coded". Color-Doppler imaging is based on the mean Doppler frequency shift of the scatterers. The different colors indicate the direction of the blood flow (color-Doppler, CD) (Figs. 1.8, 1.9). Disadvantages of this technique are the angle dependency, especially in the abdomen, and the aliasing artifact.
- The power Doppler technique (synonyms: color Doppler energy or, not as suitable, "ultrasound angiography") is based on the total integrated power of the Doppler signal. This Doppler technique is more sensitive for the detection of small vessels and slow flow and is angle-independent, but does not give information about the direction of the flow (Fig. 1.10).

Contrast agents were originally developed and used to obtain a stronger signal from blood flows. So-called microbubbles, more or less stabilized encapsulated gas bubbles, somewhat smaller than erythrocytes, are used for this purpose. The use of these contrast agents considerably improves the visibility of small vessels with slow flow. However, the real advantage is the possibility to get more detailed information about the static and especially the dynamic vascularity of tissues and tumors. Special software programs and efficient equipment are necessary to use this interesting technique, including, for example, contrast harmonic imaging. With this technique the nonlinear interaction of the microbubbles with ultrasound power is used, to improve the Doppler signals. This new technique improves the quality of ultrasound in a way similar to that seen with the tissue harmonic imaging technique used for the B-mode (see Fig. 2.16).

1.3 General Remarks and Recommendations on Examination Technique

1.3.1 Applications

All body regions which are not situated behind bones or gas-containing tissues (lung!) are accessible to ultrasonic examination. However, even the periosteum and the surface of bones can be demonstrated, e.g. to diagnose fractured ribs or periosteal abscesses and tumors if the integrity of the bone is compromised.

1.3.2 Preparation

Preparations for ultrasound examinations depend on the organ or the region to be examined. No special preparation is needed in many situations, an important advantage of ultrasound compared to other imaging modalities.

Overlying bowel gas may be an obstacle for scanning the abdomen by causing a total reflection of the ultrasound. Parts of the pancreas and other dorsally situated structures cannot be visualized, because they are located in the acoustic shadow of the gas-containing bowel. To avoid this problem the following preparations and tricks are recommended:

- examining the patient in a fasting state
- imposing dietary restrictions (avoidance of gas-producing foods)
- physical exercise (walking for 30 min before the examination)
- water contrast (fill up the stomach as an acoustic window to the pancreas or the urinary bladder for examination of the small pelvis)
- the water contrast method is also very suitable for demonstrating the wall of hollow organs such as the bladder, gall bladder, and stomach.
- Special positioning (see below)

Precaution:
When carrying out ultrasound examinations one must pay attention to the possibility of transmitting infectious material with the transducer or the jelly on the instruments from one patient to another. The transducer and other parts having direct contact with the patient must therefore be cleaned after each examination. The minimum requirements are to wipe off the transducer after each examination and to clean it with a suitable disinfectant agent each day and after the examination of an obviously infectious patient.

A suitable method in infectious patients, and especially in patients with open wounds or other skin lesions, is to slip a disposable glove over the transducer with some jelly on the active surface. The same method with a sterile glove is suitable for ultrasonically guided punctures.

1.3.3
Positioning

Usually the examination is carried out with the patient in supine position. Additional scans in the lateral decubitus and prone positions may be necessary and useful in some situations, especially in obese patients or patients with skeletal deformations. The following positions may be helpful for special examinations:

- hyperextension of the neck for scanning the thyroid gland
- upright position for the evaluation of the pancreas
- prone position for the kidneys, especially the left one
- turning 45° to the left to evaluate the hilus of the liver, the common bile duct, and the head of the pancreas
- pelvic elevation to scan the small pelvis.

1.3.4
Coupling Agents

A coupling agent is necessary to ensure good acoustic contact between the transducer and the skin. Water is not ideal and is useful only for very short examinations. Disinfectant fluids can be used for short contact with the transducer, especially for guided punctures. Oil has the disadvantage of dissolving rubber or plastic parts of the transducer.

Table 1.1. A commonly used formula for a coupling agent for ultrasound

Carbomer 10.0 g
EDTA 0.25 g
Propylene glycol 75.0 g
Trolamine 12.5 g
Demineralized water up to 500 ml

Preparation: first combine the EDTA with 400 ml of water. When the EDTA has dissolved, add the propylene glycol. Then add the carbomer to the solution and stir, if possible with a high-speed stirrer, until the mixture forms a gel without bubbles. Add water up to 500 g of gel. Stir carefully to avoid air bubbles.

The best coupling agent is a water-soluble gel, available commercially or homemade (Table 1.1).

1.3.5 General Recommendations and Guidelines for Ultrasound Examinations (Twelve Golden Rules)

Ultrasound examinations must be done by trained people! In addition, the following 12 'Golden Rules' should be respected:

- know the history and the problems of the patient
- make sure that the settings of the equipment are correct
- conduct a systematic examination of the body region of interest, even with obvious palpable mass or circumscribed pain
- always proceed from the known to the unknown, e.g. from the anatomically constant area to a more variable area (e.g. abdomen: start with the liver and proceed to the region of the pancreas or the intestine)
- move the transducer in a slow constant pattern while maintaining the defined scanning plane, and hold the transducer motionless during movements of the patient (respiration)
- use anatomically constant and easily visualized structures for orientation (e.g. liver, aorta, fluid-filled bladder) and use normal structures for comparison (right and left kidney, liver parenchyma and kidney)
- demonstrate each organ or mass in at least two planes
- never overlook the possibility of false positive or negative results due to artifacts
- utilize palpation to displace fluid- or gas filled-bowel, to test the consistency of tumors and organs, and to localize points of pain

- continue the entire examination even if pathologies are found early in the exam
- check equipment settings again if findings are questionable
- repeat the examination within a short time in clinically difficult situations

1.4 Interventional Ultrasound

In principle, all percutaneous punctures in body regions accessible to ultrasound examination can be performed using ultrasound guidance. This method is used for the safe puncture of fluid in the various cavities, as for pleural or pericardial effusion or ascites as well as for biopsy of organs such as the liver or kidney or for amniocentesis.

The fine-needle aspiration biopsy in the strict sense was developed for the puncture of suspected tumors in parenchymatous organs and other suspicious masses. The same technique is suitable for the diagnostic puncture of fluid collections in organs or body cavities. These techniques were developed for the treatment of those lesions as well: emptying fluid collections, especially abscesses (if necessary repeatedly), insertion of drains, and application of drugs into parasitic cysts (PAIR) or tumors. Ultrasound has proven to be a nearly ideal puncture guide that has made "classic" percutaneous puncture procedures safer and enabled the development of new diagnostic and therapeutic puncture procedures.

Precautions:
Interventional procedures should be carried out only by well trained and experienced doctors!

The ultrasonic-guided punctures are invasive techniques. The puncture must therefore be carried out only if it is clearly indicated. The patient must be informed about this intervention. The puncture must be performed carefully and under strictly sterile conditions.

Coagulation parameters should be checked, at least if any suspicion of hypocoagulability is apparent from the case history.

Fine needles with a diameters less than 1 mm should be used for the diagnostic puncture of (suspected) tumors. It must be remembered that cutting needles are more traumatic than the needles with the same diameter used for aspiration cytology.

The puncture of pheochromocytomas and aneurysms must be avoided.

The puncture of hydatid cysts requires a special technique that must be taken into consideration whenever a cystic lesion should be punctured (see Chap. 3, Sect. 3.3.7.1).

The best needle route is selected by ultrasound, and the puncture tract should be free of large vessels and other problematic structures. However, it is not a problem to puncture through the gastrointestinal tract or the bladder with thin needles, since the walls of these organs contain muscular fibers.

The transpulmonary route should be avoided when puncturing the abdomen.

When puncturing superficial lymph nodes, and especially if tuberculosis is suspected, it is useful to shift the skin over the lymph node, to avoid the development of fistulas.

1.4.1 Technique

The technique described here pertains to fine-needle aspiration but is conceptually valid for other types of percutaneous puncture as well.

The skin is cleaned carefully with a disinfecting solution and infiltrated with a local anesthetic.

The exact procedure depends on the type of ultrasound system used, especially whether or not special biopsy transducers are used.

Special biopsy transducers combined with a suitable software program make the puncture easier. They are necessary if small and distant targets should be punctured. The disadvantages of these convenient techniques are the higher expenses. Not only is a special transducer needed in the beginning, but also more expensive special (disposable) needles must be used. Furthermore, the biopsy transducer must be sterilized or enveloped in a sterile cover.

The so-called free-hand puncture is a more primitive method, but needs less "infrastructure". No special needles are necessary, and the normal transducer used need not be sterilized.

In this technique, the most favorable puncture site is first marked on the skin in two planes during the ultrasound examination. The distance between the surface of the skin and the target can be measured on the screen and marked on the needle, if necessary. The direction of the needle insertion corresponds to the direction of the scan. The transducer will

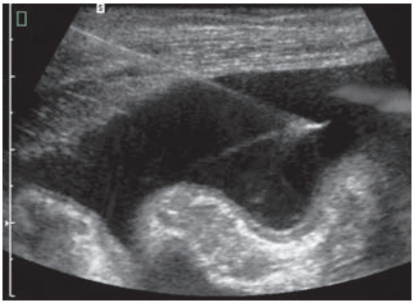


Fig. 1.11. Free-hand puncture of ascites. The position of the needle is demonstrated by the transducer placed at the side

be removed and the puncture will be carried out after having the skin disinfected. The correct position of the needle tip in the target can be controlled with the transducer from the side (Fig. 1.11).

For the diagnostic puncture of fluid collections and for the fine-needle aspiration cytology of suspected tumors, no special needles are necessary. Only if the puncture of a suspected tumor is being performed to get histological samples are special (and much more expensive) needle systems required.

1.4.2 Evaluation of the Aspirated Material

1.4.2.1 Fluid (Cystic Lesions)

The evaluation of the aspirated fluid is based on its appearance, some simple laboratory tests, and on bacteriological examinations if an infectious disease is suspected (Tables 1.2, 1.3). In this case, aerobic and anaerobic cultures are ideal, but for a first orientation, staining methods are suitable (e.g. methylene blue or Gram's staining method).

If a microscopic examination of cells in the aspirated fluid is necessary, the material should be centrifuged and prepared immediately to avoid destruction of the cells.

1.4.2.2 Solid Lesion

For cytological examination, the lesion should be punctured in a fan-like pattern in order to obtain representative material. Drops of the aspirated

Table 1.2. Appearance of fluid

Clear, transparent, light-yellow	Serous exudate
Clear like water	Hydatid cyst
Opaque, fine clots	Fibrinous exudate
cloudy-purulent (smell)	Exudate with leukocytes, empyema, abscess
Milky	Chylous fluid
Homogeneous bright–dark red	Sanguinolent, fresh – old blood
Bright red veils	Fresh blood admixture caused by the puncture procedure
Dark green–brown	Amoebic (liver) abscess

Table 1.3. Simple laboratory tests for the differentiation of aspirated fluid

Specific gravity > 1015	Exudate
Protein elevated	Exudate
Moritz-Rivalta-probe (acetic acid) positive	Exudate
Creatine elevated	Urine
Amylase	Pancreatic ascites or pseudocyst
Bilirubin	Biloma
Cholesterol elevated (> 50 mg/dl)	Malignant

material in the syringe are brought on microscopic slides and spread in a thin film with a second glass placed over the first slide or with the needle itself. The specimens are air-dried or wet-fixed or a spray fixative is used, following the recommendations of the person who will analyze the material. To obtain histological specimens, special fine "cutting" needles are used.

The puncture should not be aimed at the center of (larger) lesions, in order to avoid the biopsy of necrotic material.

1.4.2.3 Therapeutic Puncture of Fluid Collections

If with a diagnostic puncture purulent fluid is aspirated – which means that the diagnosis of an abscess or an empyema, respectively, is established – the procedure can be expanded as an appropriate treatment. In a first step, the abscess is emptied as far as possible. Sometimes a thicker needle (1.2 mm) is needed. Irrigation with saline is helpful for this purpose.

The success of the treatment is controlled with ultrasound over the next few days. Often a single puncture with emptying of at least 80% of the abscess is sufficient, and the abscess heals under continued antibiotic therapy. In other cases, the procedure must be repeated after 2–3 days. Alternatively, a catheter of suitable caliber (depending on the viscosity of the pus) is introduced under ultrasonic guidance, using, for example, the Seldinger technique. The correct position of the catheter is normally controlled by ultrasound. The catheter is irrigated each day and can also be used for the local instillation of antibiotics until the abscess disappears and the cavity has collapsed.

1.4.3 Hazards

Percutaneous punctures are contraindicated by coagulation disorders. If the coagulation is normal, the fine-needle puncture of tumors has a very low risk of serious hemorrhage. The risk becomes much higher if thicker needles are used (Fig. 1.12.).

The danger of introducing tumor cells into the needle track has been studied by many authors. Single cases of inoculation metastases have been described. However, based on extensive experience and many studies, this risk seems to be so small that generally it does not represent a contraindication. Much more so, this technique seems to be the less risky method to establish a final diagnosis in many cases.

The risk of spreading infectious material has also been extensively discussed and studied. The method has proven to be very useful for the treatment of abscesses and other pyogenic lesions. Nevertheless, in some special parasitic diseases, the risk of spreading a living organism must be

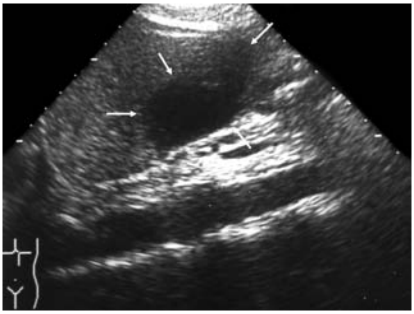


Fig. 1.12. Hemorrhage after fine-needle puncture of the liver. The hemorrhage of around 70 ml (measured with ultrasound) in this case was unusual, but did not need any treatment

considered carefully. A typical example of this problem is echinococcosis (see Chap. 3, Sect. 3.3.7.1).

1.5 Safety

(by Hassen A. Gharbi, Heykel Ben Romdhane, Azza Hammou, Férid Ben Chehida, Ibtissem Bellagha)

Physicians have used ultrasound to make images of the inside of the human body for nearly half a century. Around the world, with the exception of some areas affected by poverty, most of the infants born within recent times were exposed to ultrasound before birth. In some countries, all pregnant women are screened with ultrasound. To date, researchers around the world have not identified any adverse biological effects clearly caused by ultrasound used in medical fields. This is an enviable safety record.

However, all of the experts around the world advocate continued study of ultrasound safety, improvements in the safety features of ultrasound, and more safety education for ultrasound system operators. In light of the sheer numbers of people exposed to ultrasound, any possibility of a harmful effect must be investigated thoroughly.

1.5.1 Ultrasound Effects

While it remains unclear whether there are any long-term effects of the diagnostic ultrasound in use today, scientists do know from laboratory studies and from industrial use of ultrasound that ultrasound at high intensities does create immediate effects at the time of exposure. From studies in test tubes, animals, and human beings, we know that ultrasound causes heating, referred to as ultrasound's thermal effect. Ultrasound also creates nonthermal effects, also known as mechanical effects.

1.5.1.1 Thermal Effects

As ultrasound waves pass through the body, their energy is partially absorbed and converted into heat, heat absorbed by the tissues of the body.

In general, the more dense the tissue, the more heat is absorbed, as the ultrasound waves cannot pass through dense tissue as easily. Thus fluid does not heat up very much, soft tissues heat up somewhat more, and bone heats up the most.

This thermal effect is used in industries and in laboratories but must be avoided in medical use.

1.5.1.2
Nonthermal Effects

Ultrasound's nonthermal effects include audible sounds, the movement of cells in liquid, electrical changes in cell membranes, shrinking and expansion of bubbles in liquid, and pressure changes. Researching these thermal and nonthermal effects in the laboratory should help scientists to determine which long-term effects to check for in the human population.

In addition to heat, scientists have begun to learn more about the various types of mechanical effects that ultrasound can have on the body. They divide these effects into two categories.

The first category is called acoustic cavitation. Cavitation can occur when sound passes through an area that contains a cavity, such as a gas bubble or other air pocket. Some tissues, most notably adult lung and intestine, do contain air bubbles, and are therefore more vulnerable to these cavitation effects. The fetal lung and intestine do not contain obvious air bubbles, because the fetus does not breath air yet, getting oxygen from the mother's blood stream. However, researchers believe that tiny bubbles could potentially form in parts of the body other than the lung and intestine. More research is needed in this area.

In cavitation, the sound waves can cause the bubbles or air pockets to expand and contract rhythmically; in other words, to pulsate, or resonate. When they pulsate, the bubbles send secondary sound waves off in all directions. These secondary sound waves can actually improve ultrasound images because the secondary waves also reflect back to the transducer, and provide more information. Thus, doctors now sometimes inject artificial bubbles known as ultrasound contrast agents into the body before taking ultrasound images, for instance, for the circulatory system. However, these contrast agents are not used to image the fetus.

Other effects: If the bubbles contract towards the point of collapsing, they can build up very high temperatures and pressures for a few tens of nanoseconds. These high temperatures and high pressures can produce highly reactive chemicals called free radicals and other potentially toxic compounds that, although considered unlikely, could theoretically cause genetic damage. The rapid contraction of bubbles in cavitation can also cause microjets of liquid that can damage cells. When diagnostic ultrasound is focused on the lung or intestine of laboratory animals, which contain gas bubbles, these cavitation effects can cause ruptures in very small blood vessels.

When ultrasound passes through liquid, it causes a type of stirring action called acoustic streaming. As the acoustic pressure of the ultrasound increases, the flow of liquid speeds up. This stirring action, in theory, could occur in fluid-filled parts of a patient's body, such as blood vessels, the bladder, or amniotic sac. In experiments with animals, when streaming of the liquid comes near a solid object, shearing can occur, and this can damage platelets and lead to abnormal blood clotting (thrombosis). It is not clear to what extent this effect occurs in humans exposed to diagnostic ultrasound.

1.5.1.3 Healing with Ultrasound

It should be noted that even before ultrasound became a widespread diagnostic tool, doctors were using it as a therapeutic tool. The fact that ultrasound does have biological effects on the body is clear from its use to promote healing and even to operate on human beings. Ultrasound speeds the healing of bone, although it is not clear why this occurs. Surgeons are also using highly focused ultrasound beams to operate in delicate areas such as the eyes. The focused beam heats up and selectively destroys a minute portion of the tissue. Studying the therapeutic effects of ultrasound could also yield clues to any possible harmful effects of diagnostic ultrasound.

In conclusion, according to researchers, the relevant literature, and the safety committee conclusions of the World Federation of Ultrasound in Medicine and Biology, the use of ultrasound for medical diagnosis does not produce any adverse biological effects. Ultrasound examination is safe and accurate.

However the doctor or technician must respect the following golden rules:

1. Ultrasound examinations must be done only by well-trained clinicians
2. Ultrasound examinations must respect the maximum of energy allowed
3. An ultrasound examinations must be done only when the patient's situation indicates its need. All-over use of ultrasound must be avoided.