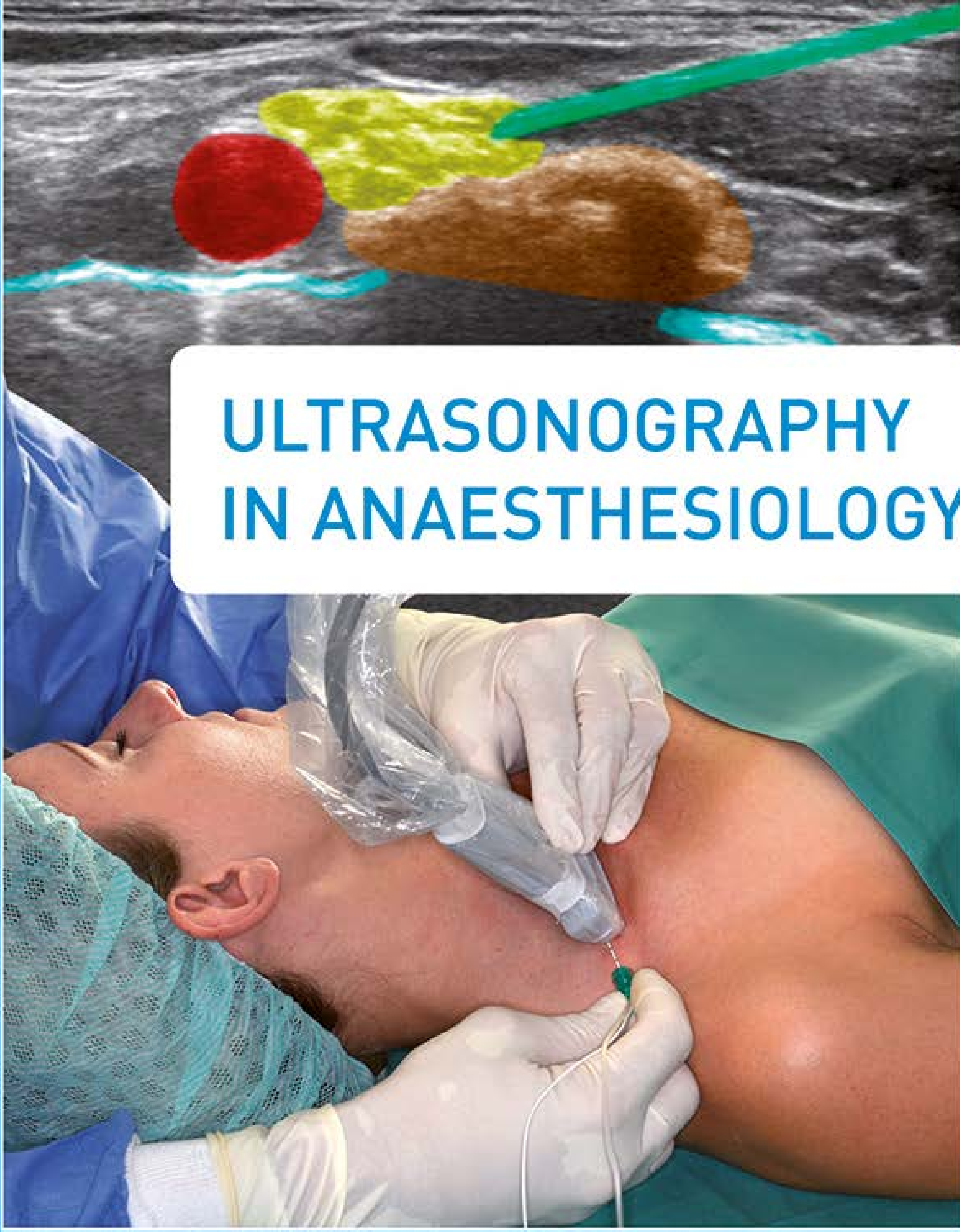
ULTRASONOGRAPHY IN ANAESTHESIOLOGY



BASIC PRINCIPLES – NEEDLE NAVIGATION
VASCULAR ACCESS NERVE BLOCKS
DIAGNOSIS OF DYSPNOEA

AEN

Armbruster Eichholz Notheisen

In cooperation with
Vincent Chan

ULTRASONOGRAPHY IN ANAESTHESIOLOGY

BASIC PRINCIPLES – NEEDLE NAVIGATION
VASCULAR ACCESS NERVE BLOCKS
DIAGNOSIS OF DYSPNOEA

AEN
Armbruster   Eichholz   Notheisen

In cooperation with
Vincent Chan

SCANNING PROCEDURES

Vascular access

Neurosonography

Diagnosis of dyspnoea

TABLE OF CONTENTS

AUTHORS

Dr. med. Wolf Armbruster (born in 1962)

Study: Essen and Heidelberg Clinical activities: Essen University Hospital, Evangelical Hospital of Unna Qualifications: Specialist in anaesthesiology, emergency medicine, special anaesthesia and intensive care, medical quality management, level 2 DEGUM instructor, Anaesthesiology Unit. Current work: Head of the Department of Anaesthesiology, Intensive Care, Pain Therapy at the Evangelical Hospital of Unna

Dr. med. Rüdiger Eichholz (born in 1970)

Study: Marburg and Witten/Herdecke Clinical activities: Filderklinik in Filderstadt, Tübingen University Hospital, Trauma Hospital of Tübingen, many years of experience in aviation and assistance medicine, Senior Consultant of the Department of Anaesthesia, Intensive Care and Pain Therapy at the Trauma Hospital of Tübingen Qualifications: Specialist in anaesthesiology, emergency medicine, level 2 DEGUM instructor, Anaesthesiology Unit Current work: Senior Consultant of medizi., private practice for anaesthesiology in Stuttgart

Dr. med. Thomas Notheisen (born in 1966)

Study: Tübingen Clinical activities: Tübingen University Hospital, Trauma Hospital of Tübingen Qualifications: Specialist in anaesthesiology, emergency medicine, special anaesthesia and intensive care, special pain therapy, palliative medicine, medical quality management, level 2 DEGUM instructor, Anaesthesiology Unit Current work: Senior Consultant of the Department of Anaesthesia, Intensive Care and Pain Therapy at the Trauma Hospital of Tübingen

1 BASIC ULTRASOUND PRINCIPLES

- This section provides a brief overview of the basic principles of physics and basic concepts in sonography
- Understanding the fundamentals will facilitate the application of ultrasonography in daily practice

1.1 From the sound to the image

1.1.1 Compact physics of sound

- Sound propagates spherically as a pressure wave from an acoustic source
- The sound propagation speed inside a homogeneous medium is constant
- In air, sound travels at a speed of 330 m/s
- In human tissue, sound propagates on average at a speed of 1540 m/s, in other words about five times as fast as in air
- The frequency of consecutive sound pressure waves is indicated in 'oscillations per second' and is measured in Hertz (Hz)
- The frequency range of audible sound is roughly between 16 and 20,000 Hz
- The frequency range of diagnostic ultrasound is usually between 1 and 20 MHz
- The wavelength is calculated based on sound velocity and frequency
- At 16 Hz, the wavelength in the air is about 20.5 m, and at 20,000 Hz it is 1.65 cm
- At 3 Megahertz, a wavelength of 0.5 mm is measurable, while at 18 MHz it is 0.08 mm
- Sound can be reflected at interfaces, bounced back to the acoustic source and received as an echo

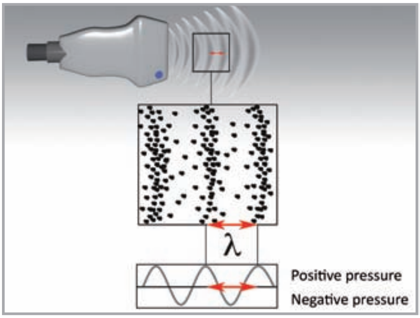


Fig. 1: Visualisation of the pulse wave emitted by the ultrasound probe: areas of higher molecular density (positive pressure) alternate with areas of lower molecular density (negative pressure). The wavelength is shown between the maximum pressure points (red arrows)

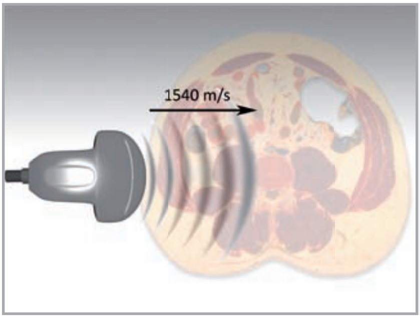


Fig. 2: Illustration of the mean sound velocity in tissue: 1540 m/s

1.1.2 Piezoelectric effect

- Characteristically, piezo crystals become deformed and undergo conformational change when an electrical current passes through them
- This generates a pulse wave, which forms the basis of the inverse piezoelectric effect
- After travelling through the body tissue and after being reflected back to the probe, the returning sound wave causes a conformational change to the piezo crystals and generates an electrical signal that can be displayed as pixels of an image: this is the basis of the piezoelectric effect

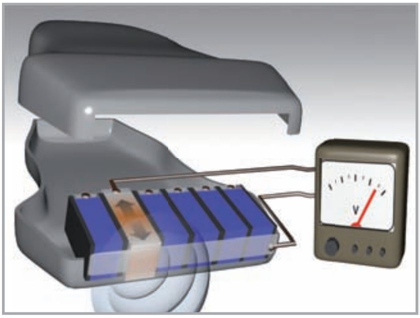


Fig. 3: Inverse piezoelectric effect: electricity causes a change in the conformation of the crystal, thereby creating sound

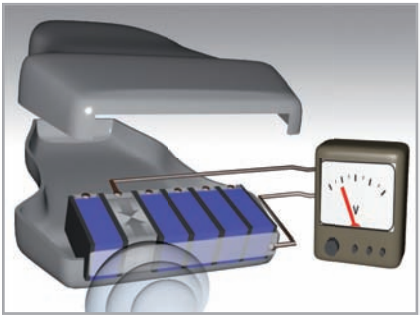


Fig. 4: Piezoelectric effect: sound energy causes a change in the conformation of the crystal, thereby generating electricity

1.4.2 Procedure planes

The terms *in-plane* and *out-of-plane* always refer to the puncture method and not to the visualisation of an anatomical structure

1.4.2.1 Out-of-plane

- To explain this term we will assume that an ultrasound-guided puncture of the internal jugular vein is planned
- The scanning plane crosses the vein in the short axis
- The puncture needle is usually inserted from cranial and is thus advanced into the scanning plane from outside
- This method of guiding the needle is known as out-of-plane (transversely to the scanning plane)
- The needle signal (tip and shaft) is depicted as a hyperechoic dot
- Only very experienced practitioners are able to distinguish the tip and the shaft from one another: when optimally visualised, the needle tip appears as a small double signal that is more hyperechoic than the needle shaft

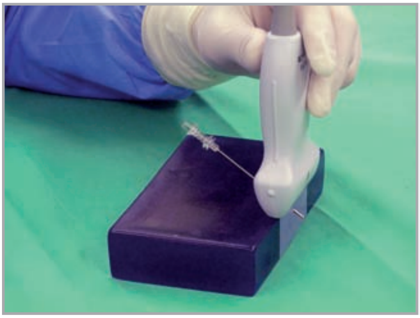


Fig. 34: Demonstration of an out-of-plane puncture using a gel cushion: here, the needle tip is already behind the scanning plane!

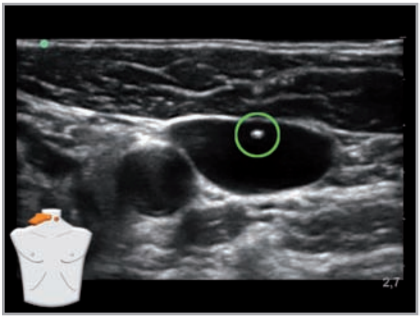


Fig. 35: Visualisation of a out-of-plane puncture of the right internal jugular vein in the short axis: needle tip signal inside the vessel

TIPS AND TRICKS

- Advantage of the method: well suited for beginners
- Disadvantage of the method: the trajectory of the needle in the tissue cannot be visualised
- The needle tip can easily be pushed beyond the scanning plane unnoticed

1.4.2.2 In-plane

- If the probe is positioned along the vessel on the side of the neck, the internal jugular vein is visualised in the long axis
- If the needle is then introduced at one end of the probe, the needle can be guided in-plane entirely through the roughly 1 mm scanning plane (longitudinally through the imaging plane)
- The entire needle is visualised as a hyperechoic sound reflector

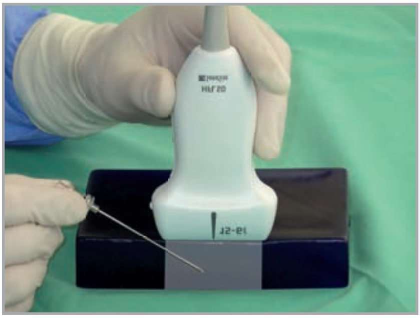


Fig. 36: Demonstration of an in-plane puncture using a gel cushion

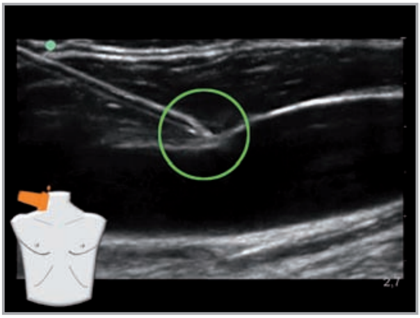


Fig. 37: Visualisation of an in-plane puncture of the right internal jugular vein in the long axis: complete visualisation of the needle

TIPS AND TRICKS

- When introduced flat (i.e. at a shallower angle to the footprint) the needle is easier to recognise
- Advantage of the method: the entire trajectory of the needle in the tissue can be visualised
- Disadvantage of the method: method for advanced practitioners, as the scanning plane and the trajectory of the needle have to be perfectly in line with one another

1.4.2.3 Combinations of puncture techniques and scanning planes

- Short axis and out-of-plane: frequently used for vascular approaches and in regional anaesthesia
- Long axis and in-plane: safe technique for most vascular approaches, but requires a great deal of practice
- Short axis and in-plane: technique used in regional anaesthesia
- Long axis and out-of-plane: not a commonly used technique

2.2.3 Subclavian vein (axillary vein)

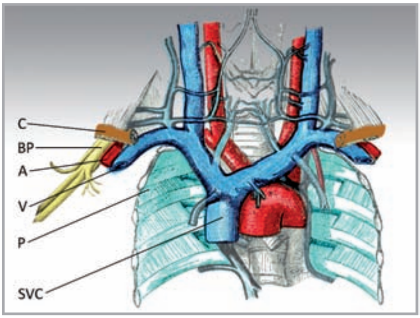


Fig. 136: Subclavian vein, overview:
A: Subclavian artery
C: Clavicle
P: Pleura
BP: Brachial plexus
SVC: Superior vena cava
V: Subclavian vein

Indications:

- Catheter placements into the subclavian vein are a routine access route in intensive care
- If it should prove impossible to puncture the internal jugular vein or the brachiocephalic vein, access via the subclavian vein may be a useful alternative
- The puncture is very sophisticated even with ultrasound guidance
- Due to the proximity to the pleura and the resulting risk of pneumothorax, access via the subclavian vein should only be performed by experienced practitioners preoperatively
- As the vessel is punctured further laterally in the ultrasound-guided than in the landmark-guided method, strictly speaking it is considered to be an access route in the axillary vein or in the junction of the two vessels

Level of difficulty:

- Procedure for very experienced practitioners

Probe selection and image depth setting:

- Linear
- 2-4 cm

Position of the patient:

- Supine position
- If possible, abduct the arm of the side to be punctured

Position of the anaesthesiologist and of the ultrasound device:

- Near the thorax on the puncture side
- The device is positioned on the side to be punctured, close to the head

Clinical anatomy:

- The part of the vessel that runs from the lower edge of the first rib to the confluence with the internal jugular vein is referred to as the subclavian vein
- By definition, the axillary vein commences distal to the first rib (i.e. below the clavicle), so that strictly speaking it is often the axillary vein and not the subclavian vein that is punctured – however, this distinction is irrelevant for the placement of the catheter
- The subclavian vein lies close to the pleura, while the axillary vein runs progressively away from it
- The anterior wall of the vein is united with the clavipectoral fascia: by abducting the arm, the lumen usually becomes larger and the vein lies more superficially below the skin

Scanning procedure:

Preparing an out-of-plane puncture:

- Position the probe parallel to the clavicle below the clavicle
- Locate and centre the artery and vein and identify the rib and pleura using transverse alignment
- In this view, the following structures appear from medial to lateral: pleura, rib, vein, artery and brachial plexus
- To optimally visualise the structures in the sonogram you may have to additionally tilt the probe until the scanning plane points below the clavicle
- Owing to the close proximity to the pleura it is often useful to move the probe 1-2 cm away from the clavicle, as this generates more space between the vein and the pleura, but moves the puncture site further laterally at the same time

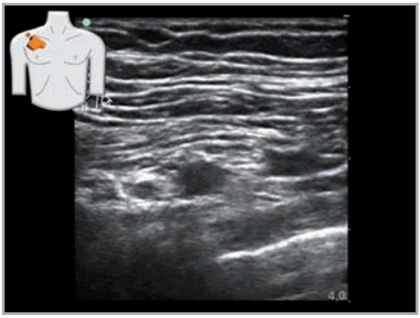


Fig. 137: Subclavian vein and surrounding landmarks, visualisation in the short axis

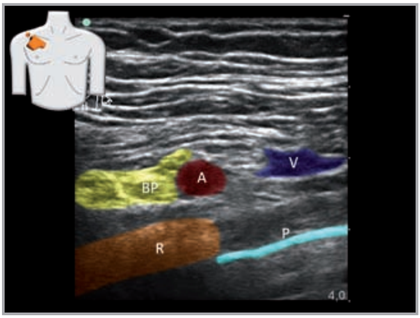


Fig. 138: Identical image with colouring and labelling:
A: Subclavian artery
BP: Brachial plexus
P: Pleura
R: Rib
V: Subclavian vein

Preparing an in-plane puncture:

- Position the probe parallel to the clavicle
- Centre the artery and vein by means of transverse alignment
- Rotate the probe to visualise the vein in the long axis: the probe marker points in the cranial direction
- In addition, push the probe proximally about 1-2 cm onto the clavicle, as the shadow cast by the bone offers excellent guidance as a sonographic landmark and the puncture site is moved closer to the clavicle
- Identify the first and second rib as well as the pleura as additional sonographic landmarks
- Use parallel alignment to the side to visualise the artery, which is always located slightly deeper than the vein

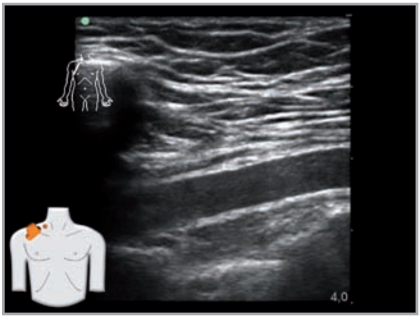


Fig. 139: Visualisation of the subclavian vein in the long axis

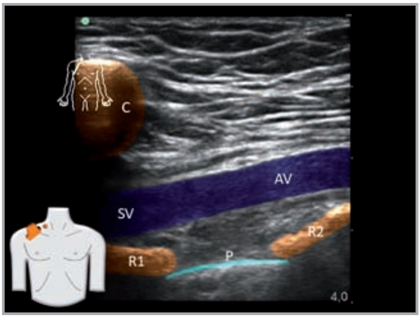


Fig. 140: Identical image with colouring and labelling:
AV: Axillary vein
C: Clavicle
P: Pleura
R1: First rib
R2: Second rib
SV: Subclavian vein

Puncture:

Out-of-plane:

- Due to the proximity to the pleura, the puncture requires secure needle tip control
- Start the needle approach only after the pleura has been identified
- Using a walk-down technique with angle adjustment, gradually advance the tip of the needle to the 12 o'clock position of the vessel
- The walk-down technique with angle adjustment may be more difficult to perform, as the scanning plane is not perpendicular to the skin, but is often tilted to the cranial side
- Target the 12 o'clock position of the vein with the needle tip
- The vascular lumen is often reduced or the vessel collapses owing to the pressure of the needle on the vascular wall
- After the catheter is inserted, pneumothorax is routinely excluded by means of ultrasound (see p. 293 and p. 311)

Fig. 141: Puncture of the subclavian (axillary) vein: short axis, out-of-plane

In-plane:

- Experienced practitioners can carry out the puncture primarily in-plane without a preceding walk-down manoeuvre with visualisation of the long axis
- As outlined in the scanning procedure, intentionally position the probe 1-2 cm on the clavicle
- After visualising the vein in the long axis, move the probe laterally and medially by way of trial to find the position in which the diameter of the vein is greatest
- After penetrating the skin, first identify the needle so that you can carry out both the approximation to the vein and its puncture under complete visualisation of the needle
- If possible, the puncture angle should be selected such that the first rib is located behind the vein and in continuation of the puncture direction
- After the catheter is inserted, pneumothorax is routinely excluded by means of ultrasound (see p. 293 and p. 311)

Fig. 142: Puncture of the subclavian (axillary) vein: long axis, in-plane

Note: in this example, the probe is not positioned on the clavicle, resulting in a very far lateral puncture and absence of the clavicular shadow as a sonographic landmark

See also Fig. 143 and 144
on the following page >

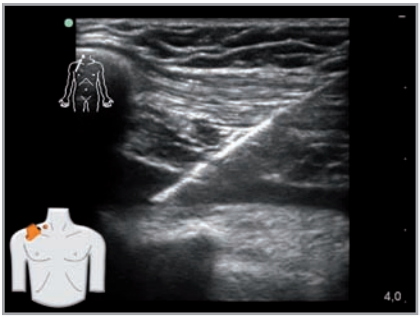


Fig. 143: In-plane puncture of the subclavian vein in the long axis

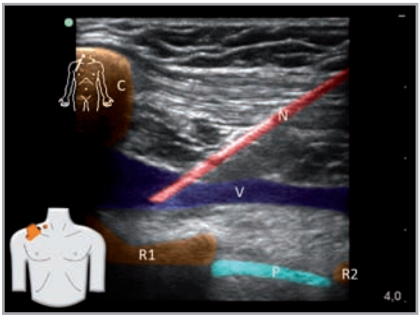


Fig. 144: Identical image with colouring and labelling:
C: Clavicle
N: Needle (echogenic needle)
P: Pleura
R1: First rib
R2: Second rib
V: Subclavian (axillary) vein

TIPS AND TRICKS

- The pleura may be punctured if the needle angle is too steep or the puncture is too medial
- The subclavian artery may be punctured if the needle puncture is too lateral
- When using ultrasound guidance, the puncture angle is significantly steeper and the puncture site lies further lateral than with the landmark technique
- In extremely obese patients it may be necessary to use a convex probe, as the penetration depth of the linear probe may not suffice: the penetration depth has to be adjusted and is usually between 4 and 7 cm
- By abducting the arm, the vessels are moved closer to the surface inside the clavipectoral fossa – however, this also markedly decreases the angle in relation to the clavicle

Out-of-plane:

- If a rib bone can be visualised beneath the vein by means of probe tilting during visualisation of the vessels in the short axis, there is no need to move the probe peripherally, as the bone protects the pleura from injury

In-plane:

- Using an echogenic needle is particularly advisable in obese patients, as it remains visible even at steep puncture angles
- Positioning the probe on the clavicle prevents the puncture site from being too far lateral
- If coupling proves to be difficult, sterile gel is used: particularly in very slender patients there is no contact between the probe and the skin immediately below the clavicle

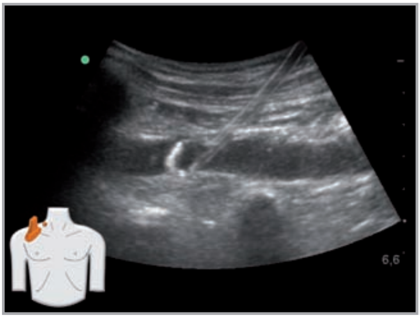


Fig. 145: In-plane puncture of the subclavian vein in the long axis with a convex probe

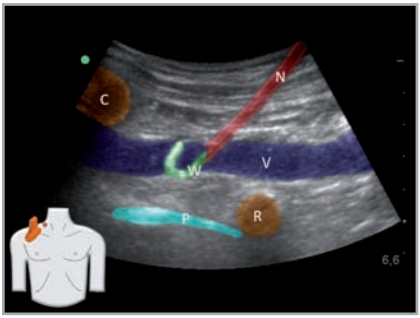


Fig. 146: Identical image with colouring and labelling:
C: Clavicle
N: Needle
P: Pleura
R: Rib
V: Subclavian (axillary) vein
W: Guidewire

Note: due to the convex probe, the needle might appear slightly bent

3.7 Brachial plexus

3.7.1 Interscalene brachial plexus

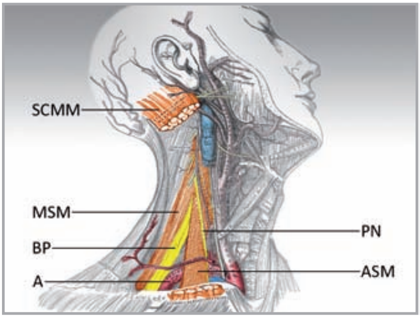


Fig. 285: Interscalene brachial plexus, overview of the anatomy:
A: Subclavian artery
ASM: Anterior scalene muscle
BP: Brachial plexus
MSM: Middle scalene muscle
PN: Phrenic nerve
SCMM: Sternocleidomastoid muscle, resected

Indications:

- Analgesia for surgical procedures in the shoulder and the upper arm
- Analgesic therapy with sensory innervation from C5, C6 and C7
- Interscalene block provides surgical anaesthesia of the shoulder and upper arm in regional anaesthesia with sedation, thus circumventing the need for general anaesthesia in suitable patients

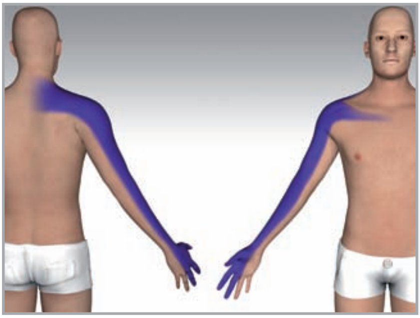


Fig. 286: Interscalene brachial plexus, extent of the block

Level of difficulty:

- Procedure for advanced practitioners
- The method can be modified for beginners

Probe selection and image depth setting:

- Linear, high frequency

Position of the patient:

- Supine position
- The head is rotated slightly to the contralateral side

Position of the anaesthesiologist and of the ultrasound device:

- The anaesthesiologist stands behind the patient
- The ultrasound device is positioned next to the patient's upper body on the side of the procedure

Clinical anatomy:

- Spinal nerves C5-C7 exit the spinal canal via the respective transverse processes: from here, the plexus-forming ventral branches are visible on the ultrasound image (see Spinal nerves of the cervical spine, p. 124 et seq.)
- They emerge from the transverse processes between the anterior and posterior tubercles
- The C5-C7 nerve roots are arranged like a string of pearls in the interscalene groove between the anterior scalene muscle and the middle scalene muscle: the C5 and C6 roots form the superior trunk, the C7 root forms the middle trunk, the C8 and Th1 roots merge to form the inferior trunk, which cannot be visualised sonographically
- As the trunks course distally, they are found lateral to the subclavian artery in close proximity to the pleura
- The phrenic nerve is found in close proximity to C5 (see p. 146 et seq.)
- The pleura can be visualised with a probe position a few centimetres above the clavicle, because the pleural dome reaches very far cranially

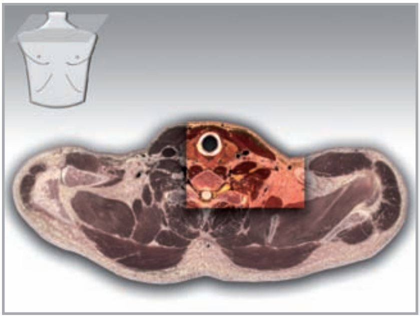


Fig. 287: Interscalene brachial plexus, cross-sectional anatomy: illustrated axial cryo-section at Th1, cranial view of the right side

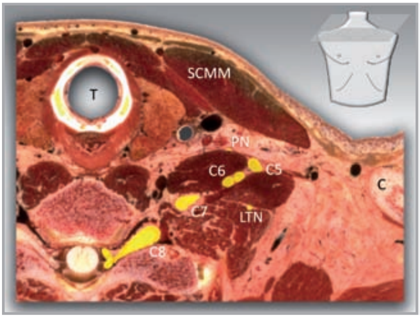


Fig. 288: Cross-sectional anatomy, excerpt from Fig. 287:
C5, C6, C7, C8: Spinal nerves 5, 6, 7 and 8
C: Clavicle
SCMM: Sternocleidomastoid muscle
PN: Phrenic nerve
LTN: Long thoracic nerve
T: Trachea

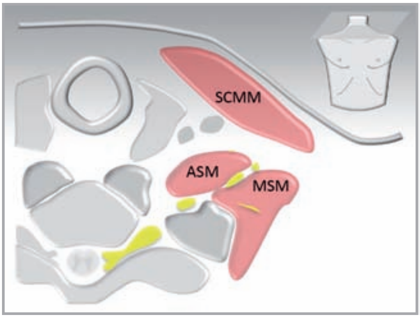


Fig. 289: Interscalene brachial plexus, muscular landmarks, excerpt from Fig. 287:
ASM: Anterior scalene muscle
MSM: Middle scalene muscle
SCMM: Sternocleidomastoid muscle

Scanning procedure:

- Identify the interscalene groove using a trace-back manoeuvre from the supraclavicular fossa: see Spinal nerves of the cervical spine, p. 124 et seq.
- The spinal nerves and the trunks of the brachial plexus are aligned like a pearl of strings inside the interscalene groove
- In practice, it is not necessary to identify and count individual nerve roots for interscalene block especially for beginners, however, it is mandatory to clearly visualise the nerve structures in the interscalene groove and if no pleura is visible at the height of the puncture
- If the probe is moved further cranially, the nerve roots disappear under the bony shadow of the transverse processes
- More advanced practitioners are able to allocate the spinal nerves to their respective transverse processes: the spinal nerve roots can be clearly identified by the characteristic shape of the bony acoustic shadows cast by the transverse processes
- The needle is inserted slightly below the transverse processes of the seventh cervical vertebra: in this position, the segments of the spinal nerves of C5, C6 and C7 lie superficially inside the interscalene groove and can be easily accessed
- Colour Doppler and, if necessary, Colour Power Doppler should be part of the preliminary examination to allow the practitioner to distinguish vessels from nerve structures

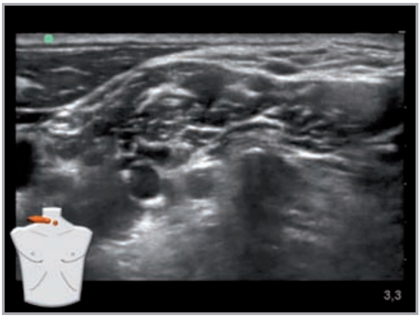


Fig. 290: Interscalene brachial plexus, sonoanatomy: at C7, cranial view of the right side

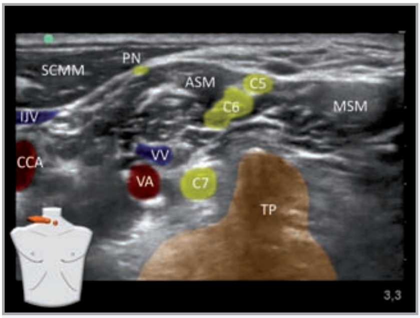


Fig. 291: Identical image with colouring and labelling:
ASM: Anterior scalene muscle
C5, C6, C7: Spinal nerves 5, 6 and 7
CCA: Common carotid artery
IJV: Internal jugular vein
MSM: Middle scalene muscle
PN: Phrenic nerve
SCMM: Sternocleidomastoid muscle
TP: Transverse process
VA: Vertebral artery
VV: Vertebral vein

Puncture:

Short axis, out-of-plane: method for novice practitioners

- Position the needle tip dorsal to the plexus structures out-of-plane by means of a walk-down technique with angle adjustment, i.e. between the middle scalene muscle and the plexus
- Hydrodissection is recommended to separate the brachial plexus from the middle scalene muscle
- It is not necessary to achieve a donut sign with interscalene block, because needle tip corrections harbour the risk of unintentional nerve damage and as a unilateral spread of the local anaesthetic around the nerves also results in a complete block
- Exercise extreme caution to avoid direct needle-nerve contact and accidental intraneural needle puncture, as the nerves are very vulnerable in this area

Short axis, out-of-plane: method for advanced practitioners

- Advanced practitioners are able to selectively block spinal nerves and the trunks of the brachial plexus, which allows them to match the block to the surgical site
- Also in this method, the puncture should be performed below the C7 vertebra: local anaesthetic injection near the transverse process increases the risk of high spinal anaesthesia and should therefore be avoided at all costs
- Aim to deposit approximately 1-3 ml of local anaesthetic per nerve root and trunk between the scalene muscles and the respective part of the plexus: this volume is sufficient to achieve an effective block

Fig. 292: Interscalene brachial plexus, puncture: demonstration of an out-of-plane needle insertion approach

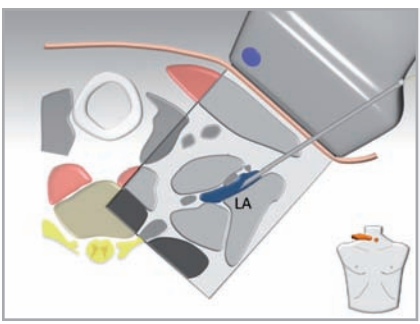


Fig. 293: Interscalene brachial plexus, puncture: schematic illustration of the injection, cranial view of the right side, targeted block of C7, C6 and C5 nerve roots
LA: Local anaesthetic, located between the nerve roots and the middle scalene muscle

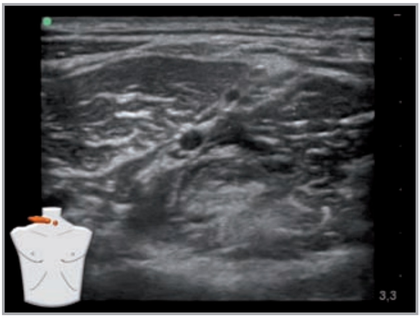


Fig. 294: Interscalene brachial plexus, out-of-plane puncture: cranial view of the right side
Local anaesthetic spread between C5 and C6

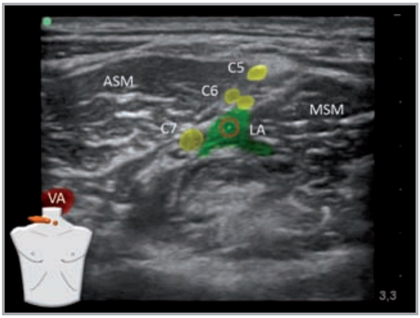


Fig. 295: Identical image with colouring and labelling:
ASM: Anterior scalene muscle
C5, C6, C7: Spinal nerves 5, 6 and 7
LA: Local anaesthetic, needle tip circled
MSM: Middle scalene muscle
VA: Vertebral artery

Recommended injection volume:

- 3-8 ml

TIPS AND TRICKS

- Local anaesthetic should also be administered under sonographic control, as the phrenic nerve is located just a few millimetres below the skin: without sonographic control, the phrenic nerve may be blocked unintentionally
- In-plane needle insertion through the middle scalene muscle may injure the dorsal scapular and the long thoracic nerves because these two nerves run through the belly of the middle scalene muscle: injury may compromise the innervation of the levator scapulae and rhomboid muscles (dorsal scapular nerve) and of the serratus anterior muscles (long thoracic nerve)
- Unintentional phrenic nerve block resulting in unilateral hemi-diaphragmatic paresis occurs frequently especially with a high-volume injection (20 ml cause an incidence of nearly 100%): fortunately, this does not cause signs of respiratory distress in healthy patients
- There are three effective ways of reducing the risk of inadvertent diaphragmatic paresis in high-risk patients:
  1. Low volume injection is the most important factor, e.g. 5 ml
  2. The interscalene puncture should be performed at a deeper caudal site on the neck than outlined above in order to increase the distance to the course of the phrenic nerve (deep interscalene or high supraclavicular puncture site)
  3. Access between the middle scalene muscle and the interscalene nerves: also here, the distance to the phrenic nerve is somewhat greater than with an injection between the anterior scalene muscle and the plexus (see Fig. 293)

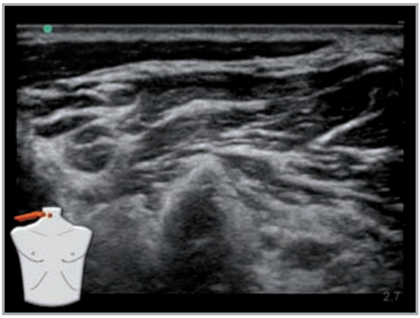


Fig. 296: Interscalene brachial plexus, special features: cranial view of the right side, visualisation of the intramuscular course of the long thoracic nerve and dorsal scapular nerve

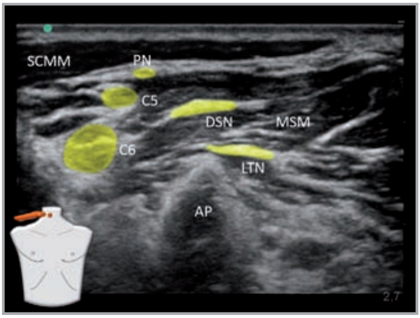


Fig. 297: Identical image with colouring and labelling:
C5, C6: Spinal nerves 5 and 6
AP: Articular process
DSN: Dorsal scapular nerve
LTN: Long thoracic nerve
MSM: Middle scalene muscle
PN: Phrenic nerve
SCMM: Sternocleidomastoid muscle

4 DIAGNOSIS OF DYSPNOEA IN THE OPERATING THEATRE AND IN THE RECOVERY ROOM

4.1 Introduction

- Mobile sonography devices are used in the operating theatre and in the recovery room not only for ultrasound-guided punctures, but also for diagnostic investigations
- Ultrasound examination is a quick and reliable bedside tool for diagnosis of respiratory distress, such as pneumothorax, unilateral endobronchial intubation or unwanted diaphragmatic paresis following an interscalene plexus block

4.2 Diagnostic pleural imaging

Indications:

- Exclusion of pneumothorax as a routine examination after any intervention in the vicinity of the pleura
- Suspected unilateral endobronchial intubation
- Bedside diagnostics in the context of respiratory failure in the operating theatre or in the recovery room

Level of difficulty:

- Examination for beginners
- However, the appraisal of pathological findings demands experience, so that advanced practitioners should be involved

Probe selection and image depth setting:

- Linear or convex probe
- 3-6 cm

Position of the patient:

- The patient's position does not have to be changed after a puncture
- The supine position is particularly suited for diagnosing pneumothorax, because air accumulates at the highest point in the pleural space below the anterior thoracic wall

Position of the anaesthesiologist and of the ultrasound device:

- Variable, usually the examination can be continued in the position that was used for the intervention

Clinical anatomy:

- The anterior thoracic wall is structured as follows from superficial to deep:
  - Skin
  - Subcutaneous adipose tissue
  - External thoracic fascia
  - Pectoralis major muscle
  - Ribs, with external and internal intercostal muscles in-between
  - Endothoracic fascia
  - Parietal pleura which adheres firmly to the thoracic wall
  - Visceral pleura which covers the surface of the lungs
- During the respiratory cycle, the visceral pleura slides across the parietal pleura which adheres firmly to the thoracic wall
- The sliding movement is more pronounced closer to the diaphragm, and weaker at the apex of the lung
- In the case of pneumothorax or pleural effusion, the parietal pleura and the visceral pleura may no longer adhere to one another; the extent of dehiscence is variable

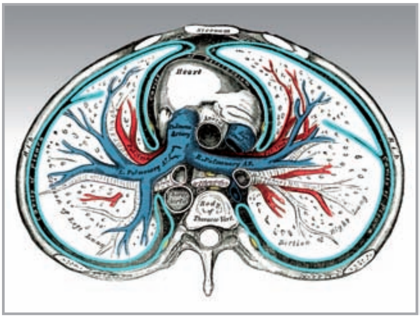


Fig. 583: Overview of the pleural anatomy: cranial view, pleura highlighted

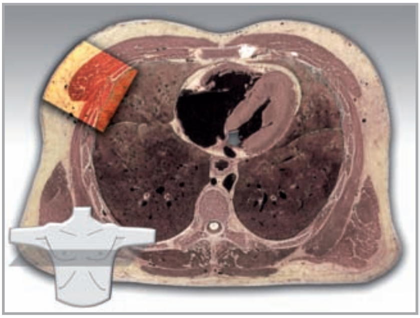


Fig. 584: Pleura, cross-sectional anatomy: illustrated axial cryo-section, caudal view

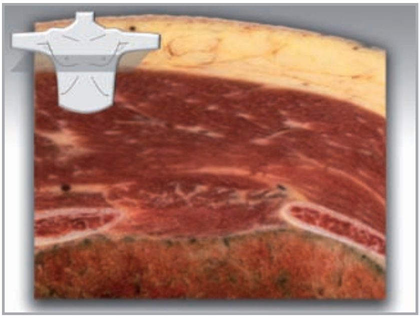


Fig. 585: Excerpt from Fig. 584: the excerpt was graphically modified to improve clarity

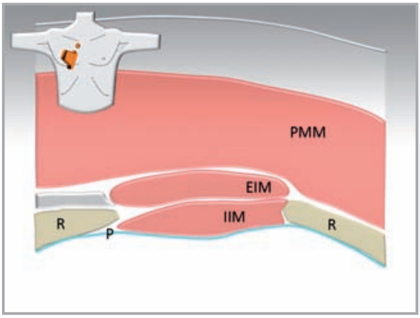


Fig. 586: Landmarks, from Fig. 585, adjusted to a longitudinal acoustic window:
EIM: External intercostal muscle
IIM: Internal intercostal muscle
P: Pleura
PMM: Pectoralis major muscle
R: Rib

Scanning procedure:

- Position the probe on the thoracic wall in a longitudinal sagittal direction adjacent to the sternum and between two ribs (see Fig. 588), usually this is done between the second and third or between the third and fourth rib
- As is common in diagnostic ultrasound (see p. 36), the probe marker points cranially: the upper rib appears on the left, the lower rib on the right side of the monitor
- Immediately adjacent to the sternum, the ribs are cartilaginous, which allows the pleura to be visualised below the ribs: however, the exact position of the probe is not important, only that the pleura is visualised clearly
- Since the heart adheres to the thoracic wall in the left hemithorax, the area between the third and sixth intercostal spaces is not suitable for parasternal pleural sonography

Fig. 587: Pleural sonography, scanning procedure: parasternal scanning direction

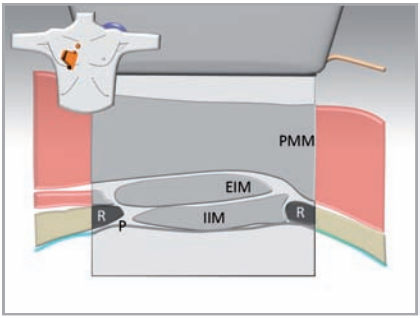


Fig. 588: Pleural sonography, illustration of a typical acoustic window from Fig. 587:
EIM: External intercostal muscle
IIM: Internal intercostal muscle
P: Pleura
PMM: Pectoralis major muscle
R: Rib

4.2.1 Physiological pleural findings

- On the B-mode image, the parietal pleura and the visceral pleura are depicted as a mutual hyperechoic line
- Owing to the large difference in impedance between sound conduction in the tissue (1540 m/s on average) and sound conduction in the air (330 m/s), the intrapulmonary air below the pleura results in total reflection of the ultrasound waves:
  - this results in the pleura acting as a mirror
  - below the pleural line, the mirror artifact of the thoracic muscles, of the subcutaneous tissue and of the skin becomes visible
  - however, this mirror artifact is only easy to identify if the scanning plane is orthograde to the pleura

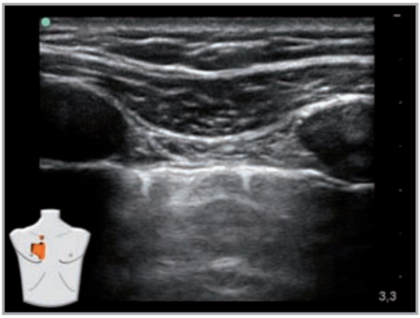


Fig. 589: Physiological pleural findings in the B-mode image, parasternal acoustic window

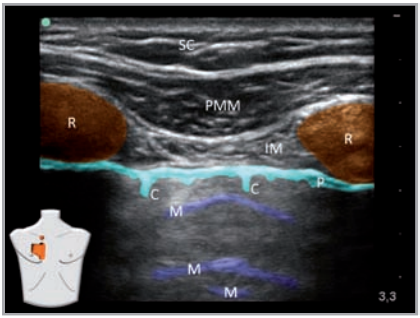


Fig. 590: Identical image with colouring and labelling:
C: Comet tail artifact, only suggested here
IM: Intercostal muscle
M: Mirror artifacts
P: Pleura
PMM: Pectoralis major muscle
R: Rib, cartilaginous
SC: Subcutis

4.2.2.3 Pulmonary oedema

- The presence of individual, briefly appearing comet tail artifacts and B-lines is physiological
- The number of B-line artifacts present correlates with the level of extravascular lung water
- In the event of increasing interstitial oedema, liquid also travels to the pleural space, so that many B-lines can occur here that are visible on the image for a prolonged period or permanently
- If numerous B-lines (more than three) appear in multiple regions being examined or on both sides of the thorax, this is indicative of pulmonary oedema (in the presence of corresponding clinical signs)
- In the event of clinically pronounced pulmonary oedema, the B-lines become wider or coalesce
- The number and size of the B-lines correlates with the severity of the disease, and therapeutic success can be established by a decrease in the number of B-line artifacts
- In the presence of numerous B-lines, interstitial pneumonia or lung fibrosis have to be considered in the differential diagnosis; these conditions are associated with chronic changes of the pleural surface
- Locally delimited, increased B-lines can occur in pneumonia, atelectasis, lung contusion, pleural disease, neoplasia or pulmonary infarction

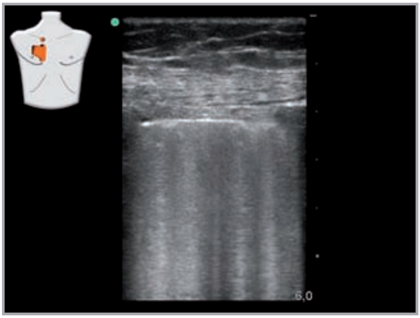


Fig. 609: Pulmonary oedema, visualisation of the increased occurrence of B-line artifacts with a linear probe

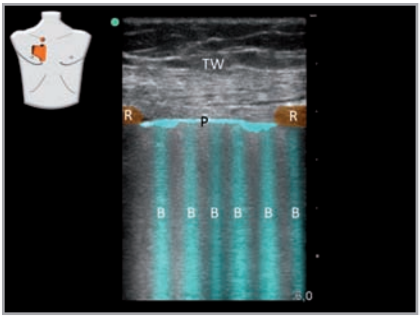


Fig. 610: Identical image with colouring and labelling:
B: B-lines
P: Pleura
R: Ribs
TW: Thoracic wall

4.2.2.4 Pleural effusion

- Effusion is easiest to diagnose in the FAST 1 and FAST 3 position with a convex probe (for the scanning procedure see Diagnostics for diaphragmatic function, p. 303)
- Two important findings are visualised as physiological findings above the diaphragm:
  - during inhalation the so-called dirty curtain appears, which occurs because the air-filled lung forces itself partially or completely under the probe, thus generating poor acoustic conditions
  - the mirror artifact of the liver or of the spleen appears near the spine
- When smaller pleural effusions are present, a hypoechoic or anechoic area caused by fluid appears near the spine, or a small border of fluid surrounding the lung in this area is visualised near the probe
- With a large effusion, the interfering curtain sign due to lung expansion is no longer seen, because the fluid is located below the probe and is not displaced by the ventilated lung during inhalation: the entire area above the diaphragm appears hypoechoic owing to fluid
- In the context of large pleural effusions, the lung is often visualised as hydrostatic atelectasis
- A serous effusion cannot be distinguished from blood on the ultrasound image

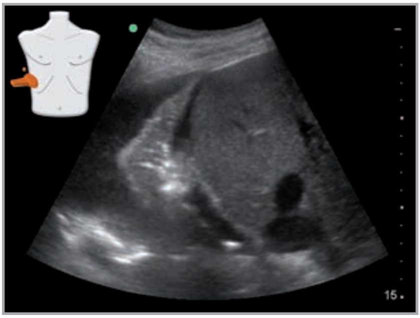


Fig. 611: Right-sided pleural effusion, visualisation in the FAST 1 position

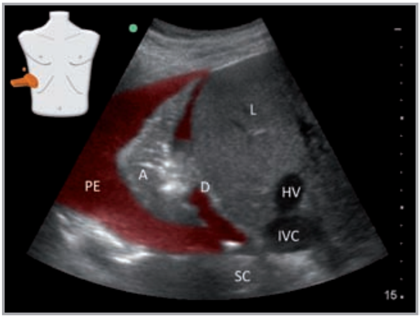


Fig. 612: Identical image with colouring and labelling:
A: Atelectasis
D: Diaphragm
HV: Hepatic vein
IVC: Inferior vena cava
L: Liver
PE: Pleural effusion
SC: Spinal column

Fig. 616: Scanning procedure, probe position in the FAST 1 position

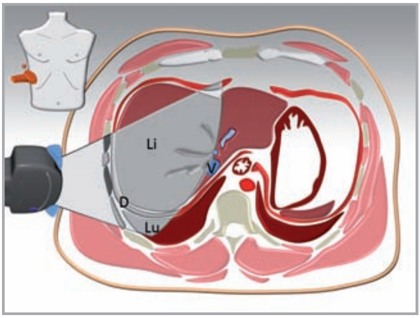


Fig. 617: Sonoanatomy, illustration from Fig. 614:
D: Diaphragm
Li: Liver
Lu: Lung
V: Inferior vena cava

Fig. 618: Scanning procedure, probe position in the FAST 3 position

4 Diagnosis of dyspnoea

4.3.1 Physiological findings

- The diaphragm covers the liver and the spleen as a hyperechoic border
- In the respiratory rest position, i.e. when respiratory cycles are small, the diaphragmatic excursions are easy to identify on the ultrasound image
- Deeper inhalations cause the air-filled lung to force itself under the probe, with the consequence that parts of the liver and spleen are obscured by the artifact image of the lung
- Very deep inhalations result in complete artifact superimposition
- The breathing-related lung artifact that appears as blurred and grey on the B-mode image is known as the curtain sign (dirty curtain) that obsures all anatomical structures below the pleura
- The M-mode visualisation is suitable for documenting the diaphragmatic excursion
- For this, the active aperture line is positioned in a spot in which the diaphragm is visualised clearly, preferably close to the spine
- The mobility of the diaphragm can be visualised as a hyperechoic curve in the M-mode recording: during inhalation the curve moves up towards the probe, while during exhalation it returns to the starting position
- Deep inhalation causes the air curtain to move into the active scan line: the curve is interrupted and only becomes visible again during exhalation
- For the sniff test the patient is asked to make a short and strong inspiratory effort through the nose while the mouth is closed (inhale strongly): this results in a strong contraction of the diaphragm and thus to a steep spike in the M-mode, which is not disturbed by the air curtain owing to the only small volume of air that is moved

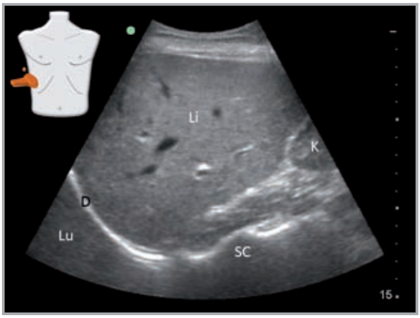


Fig. 619: Visualisation of the diaphragm in the B-mode image: physiological findings of the right side during exhalation
D: Diaphragm
K: Kidney
Li: Liver
Lu: Lung, here a mirror artifact of the liver
SC: Spinal column

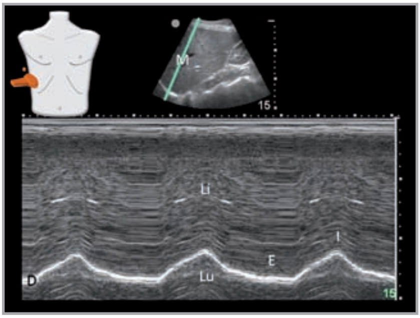


Fig. 620: Visualisation of the diaphragm in the M-mode: corresponding image to Fig. 619 in the respiratory rest position
D: Diaphragm
E: Exhalation
I: Inhalation
Li: Liver
Lu: Lung, here a mirror artifact of the liver
M: M-mode aperture

See also Fig. 621 to 626 on the following pages >

WINNERS OF THE DGAI THIEME TEACHING AWARD 2015

Wolf Armbruster Rüdiger Eichholz Thomas Notheisen

This pocket-sized book "from clinicians for clinicians" is meant to support beginners and advanced practitioners in their practical work in the operating theatre and in the ICU. Each chapter presents scientific information in an easily understandable structured format that is supplemented with multiple illustrations. The brief anatomy section provides the clinical basis of sonoanatomy. The scanning and procedure sections focus on sonographic landmarks that guide diagnostic procedure and intervention safety. The Tips and Tricks section includes practical experience to complement many subject areas.

632 illustrations
39 scanning procedures

ISBN 978-3-00-054523-8

www.aen-sono.de

9 783000 545238

AEN