BASIC SCHEMES OF ULTRASOUND EXAMINATIONS

Editors

Jan Baron, Joanna Pilch-Kowalczyk

MEDICAL UNIVERSITY OF SILESIA IN KATOWICE

Basic schemes
of ultrasound examinations

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Table of contents

Abbreviations

Ao – aorta
AP – anteroposterior diameter
CBD – common bile duct
CC – craniocaudal diameter
CCA – common carotid artery CD – color doppler
DD – diaphragm dome
ECA – external carotid artery
ECST – European Carotid Surgery Trial
EDV – end diastolic velocity
FNB – fine needle biopsy
GB – gallbladder
ICA – internal carotid artery IMT – intima-media thickness
IVC – inferior vena cava
K – kidney
L – liver
LLT – left lobe of the thyroid
LV – liver veins
NASCET – North American Symptomatic Carotid Endarterectomy Trial
P – pancreas
PD – power doppler
PG – prostate gland
PSV – peak systolic velocity
PV – portal vein
PVC – portal venous confluence
R – rectum
RLT – right lobe of the thyroid
S – spleen
SD – sinister-dexter (or TV – transverse diameter)
SMA – superior mesenteric artery
SV – splenic vein
SVEs – seminal vesicles
TI – thyroid isthmus
TV – transverse diameter (or SD – sinister-dexter)
U – uterus
UB – urinary bladder
VA – vertebral artery
VT – visceral trunk

1. Introduction

Ultrasonography is a diagnostic method that uses ultrasonic waves with a frequency between 2 and 15 MHz [4] (and for abdominal examinations 2.5–5 MHz [8]) to visualize tissues and organs. The frequency of the ultrasonic waves used depends primarily on the scope of the examination and the type of transducer.

The method is completely safe, offers high accuracy of measurements and the possibility to repeat the test frequently if needed. The small dimensions of currently manufactured ultrasound devices ensure great mobility. Together with the low cost of a single examination, these features make ultrasonography a widely available and valued diagnostic method.

As a drawback, the diagnostic value highly depends on the skills of the examiner and the quality of the ultrasound scanner. Insufficient competences of the ultrasonographer may lead to misdiagnosis, a missed diagnosis or the overdetection of abnormalities.

In the text you will find QR codes, which, when scanned, will redirect you to pictures and videos showing the examined organs and structures. We hope you will find them helpful.

1.1. Image formation

The main element of the ultrasound device is the transducer (probe), which works on the principle of the piezoelectric effect [4]. The piezoelectric crystals located under the surface of the transducer convert the kinetic energy (mechanical stress) into an electric signal [8]. The piezoelectric crystal is also subject to the reverse piezoelectric effect [10], making the transducer in ultrasound machines both a wave emitter and receiver.

Acoustic waves which propagate as longitudinal waves can be reflected, absorbed and dispersed [10]. The speed of wave propagation in a material medium depends on the inertial and elastic properties of the given medium. The inertial properties have an impact on the accumulation of kinetic energy, and the elastic properties on the accumulation of potential energy [9]. For the purposes of ultrasound examination, it is assumed that the speed of ultrasonic wave propagation in tissues is constant and equals 1540 m/s [8]. The emitter sends an ultrasonic wave of a certain frequency, which is partially reflected at the border of two media with different densities. The wave reflection coefficient depends on the difference in the acoustic impedance of the media at the border of which it occurs [8]. All these variables determine the depth of wave penetration, and thus the depth at which the examined element is located.

However, the higher the wave frequency, the smaller the range of its penetration. The reflected wave returns to the transducer (receiver), where it is converted into an electric signal. The electric signal is then processed to form an image.

Structures in the image form specific echogenic patterns that correspond to their ability to reflect ultrasonic waves.

Nomenclature [8]:

- Normoechoic structures – structures with an average echo.
- Hypoechoic structures – darker structures with a reduced echo.
- Hyperechoic structures – lighter structures with an increased echo.
- Anechoic structures – uniformly black areas corresponding to a clear fluid.

1.2. Image presentation

There are three basic types of image presentations in ultrasonography [10]:

- A-mode presentation (Amplitude Modulation) – a one-dimensional type of image presentation. The amplitudes of echoes that arise at the border of two media are presented in the form of a function depending on the depth. This type of presentation is mainly used in ophthalmology.
- M-mode presentation (Motion Mode) – a one-dimensional type of image presentation used to analyze moving elements of the body. It can be obtained by analyzing the echo amplitude and the pace of movement. The echo created at the border of two media is presented as an image element, while the brightness of a given point depends on the size of the echo amplitude. This type of presentation is mainly used in cardiology.
- B-mode presentation (Brightness Modulation) – a two-dimensional type of image presentation. Echoes are recorded from each cross-section of the tested object, line by line, depending on the location of the transducer. The brightness of the image depends on the amplitude or size of the echo. This presentation is most widely used.

1.3. Elastography

Elastography is a technique that allows the stiffness of tissues to be assessed. It is possible by measuring the deformation of the tissue in response to an applied force. Depending on the depth at which the examined organs are located, we can use one of three techniques [10]:

- Assessment of the tissue response to direct pressure – for organs located superficially.
- Assessment of tissue movement under the influence of external stimuli, e.g. a vibration impulse – for deeper organs, e.g. the liver, pancreas.
- Assessment of the weakening of wave penetration resulting in a flexible tissue model – also used to study organs located deeper in the abdominal cavity.

1.4. Color Doppler ultrasound

The Doppler effect can be observed wherever the source of the wave is in motion in relation to the receiver [9]. The ultrasonic wave reflecting from the moving blood cells changes its frequency in relation to the blood flow velocity. The echo coming from the flowing blood cells may be coded with a color, the shade of which depends on the direction and velocity of the flow. This means that the image of blood flowing towards the transducer will be coded with a different color than the image of blood flowing away from the probe. The image of the color-coded structures is plotted over a grayscale image of the structures. Thanks to this, it is possible to simultaneously observe the flow image against the background of other anatomical structures in the studied area.

Fig. 1. Visualization of blood flow in blood vessel using color Doppler method.

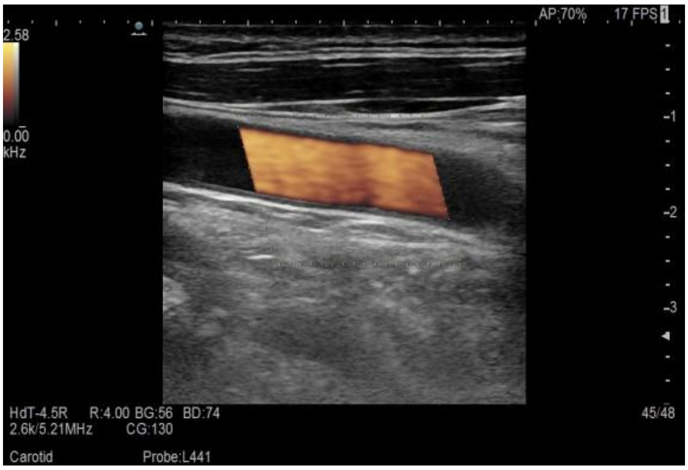

Fig. 2. Visualization of blood flow in blood vessel using power Doppler method.

1.5. Transducers (probes)

Three basic types of transducers are most often used:

Sector transducer – the obtained image has the shape of a sector of a circle with a different value of the opening angle (from 60 to 120 degrees); it is relatively narrow near the transducer surface and widens with increasing depth. With a small surface of contact with the skin, the transducer gives an image with wide cross-sections, enabling a good overview of deeper organs [10].

Fig. 3. Sector transducer.

Convex transducer – a transducer providing wide contact with the patient's skin. The image obtained with a convex transducer is between images from sector and line probes. A convex probe with a frequency of 3.5 MHz is used to examine the abdominal cavity [8].

Fig. 4. Convex transducer.

Linear transducer – the resulting image has a rectangular shape, whose width depends on the width of the transducer adjacent to the skin, not the depth of the impulse penetration. At high frequencies, it is used to examine superficial organs, such as the thyroid gland, breast or testicles [8].

Fig. 5. Linear transducer.

1.6. Settings and parameters

Gain – the gain function is used to control the signal strength (brightness) of the whole image or its chosen layers. Greater gain is used for obese patients. To strengthen a specific layer of the image, potentiometer sliders are used [5].

Freeze – a function that freezes the image during the examination, used for taking measurements, longer evaluation or for documentation.

Measure function – a function that allows you to measure the distance, area or other parameter. It requires placing the starting point and the end point within the examined structure or marking of the area of interest.

Depth – a function for determining the depth of the examination. As the resolution of the obtained image decreases with the penetration depth of the ultrasonic wave, this parameter should be set adequately to the area we wish to visualize [5].

Focus – this function defines the depth of the best lateral resolution. The focus should be set at the depth of the assessed structures [17].

Color Doppler – a function for the color coding of blood vessels based on the Doppler effect. The color informs about the direction of blood flow in relation to the ultrasound transducer (usually red color means the flow is towards the transducer, blue away from it).

1.7. Artifacts

Artifacts are echoes visible during an ultrasound examination that do not correspond to anatomical structures. Some of them can be eliminated by changing the settings of the ultrasound machine. Nonetheless, it is worth remembering that some artifacts may be useful for the diagnostic process.

Acoustic shadow is created when the ultrasonic wave is completely reflected. As a result of the reflection of the wave, an anechoic band is created behind the structures. This artifact may be helpful in recognizing fine, calcified deposits [8].

Dorsal enhancement – areas behind fluid lesions will be hyperechoic to tissues at the same level [8].

Side lobes – arc artifacts which are formed within the lateral regions of fluid-filled spaces such as the urinary bladder. They may be confused with wall structure changes [8].

Reverberations – artifacts resulting from the repeated reflection of an ultrasonic beam. They follow strong parallel echoes such as air.

1.8. Contrast agents

Contrast agents used in ultrasonography are designed to enhance the echogenicity of blood and soft tissues. It is possible by the intravenous (iv) administration of solutions containing microbubbles with a diameter in the range of 3–5 µm. At present, three contrasting agents are in use [8]:

- Leovist – consists of gas bubbles 3 µm in diameter, with walls of palmitic acid. This contrast solution must be used within 8 minutes of preparation; after iv administration it passes through the pulmonary circulation.
- Optison – consists of microbubbles of human albumin and octafluoropropane, 3.7 µm in size. Octafluoropropane is eliminated through the lungs within 10 minutes of iv administration.
- SonoVue – consists of an aqueous solution of sulfur hexafluoride, enclosed in a phospholipid shell. The bubble diameter is 2.9 µm. A prepared solution is stable for 6 hours.

2. Preparing patient for examination of abdominal cavity

In order to obtain the best image parameters and to enable assessment of all the abdominal and pelvic structures, remember to properly prepare the patient:

- The patient comes to the examination after fasting [2].
  For adult patients, this means a period of 6 hours without solid food intake. Patients should also avoid drinking sweet and carbonated drinks and smoking. This allows the assessment of a filled gallbladder and reduces the amount of gas in the stomach and intestines.
- The patient comes to the examination with a full urinary bladder [18].
  The structure of the urinary bladder can only be assessed if it is well filled. In the case of examination through the abdominal wall, the acoustic window formed by a full bladder enables accurate assessment of the pelvic organs.
- Proper hydration of the patient.
  The quality of the ultrasound image strongly depends on the degree of hydration of the tissues. The patient should be properly hydrated.
- Reducing the amount of intestinal gas.
  The gas present in the gut causes the formation of artifacts that obscure deeper structures and make it difficult or even impossible to assess them correctly. In patients predisposed to flatulence, prescribing medications containing simethicone for several days prior to the examination to reduce the amount of intestinal gas is recommended.

3. Examination technique and basic information

An abdominal ultrasound examination is performed in the recumbent supine position. During the examination it is possible to obtain an unlimited number of projections, but it is advisable to use standard projections, which are presented later in this study. Standard projections can help to keep the order of the assessed areas and avoid omitting any of them.

There is a marker on the side of each ultrasound transducer, which facilitates orientation during the examination. In all the schemes of the projections, it is assumed that for longitudinal projections the marker is directed towards the head, while for transverse projections, it is directed towards the right side of the patient.

During the examination, the ultrasound transducer is held in the right hand, while the left hand operates the buttons of the ultrasound machine. Holding the transducer like a pen is suggested, which allows the examiner to rotate it freely during the examination.

In order to start the examination, the operator enters the patient's data into the ultrasound machine, selects the transducer that will be used during the examination (for the abdominal cavity it is usually a convex transducer), and then selects the preset, i.e. pre-programmed device settings to examine a given anatomical area.

To obtain an image, it is necessary to apply a layer of gel to the frontal surface of the transducer, which prevents the formation of a gas layer in which ultrasounds completely disperse, and then the examination can be started.

3.1. Large blood vessels

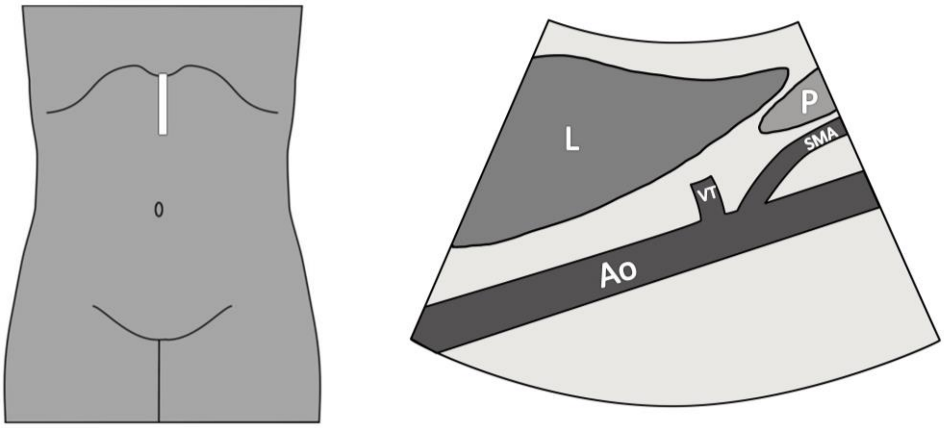

Fig. 6. Diagram of longitudinal section through vessels in epigastric region.

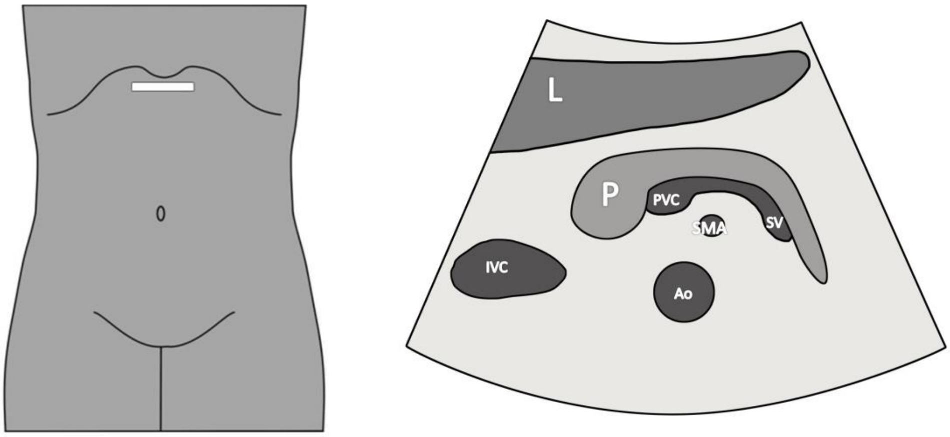

Fig. 7. Diagram of transverse section through vessels in epigastric region.

Table I. Normal dimensions of large blood vessels in abdominal cavity

Normal abdominal aorta	< 25 mm [18]
Abdominal aortic aneurysm	> 30 mm or dilation of vessel lumen by > 50% in relation to normal section (above or below dilation) [12]
Inferior vena cava (IVC)	diameters vary individually and during breathing phases
Portal vein	6–12 mm [14]

Comments:

- The aorta should be assessed over the entire length available for examination. Its diameter is measured in the anterior – posterior (AP) dimension.
- Color Doppler coding is used to assess the direction and nature of the flow in the vessel.

3.2. Liver

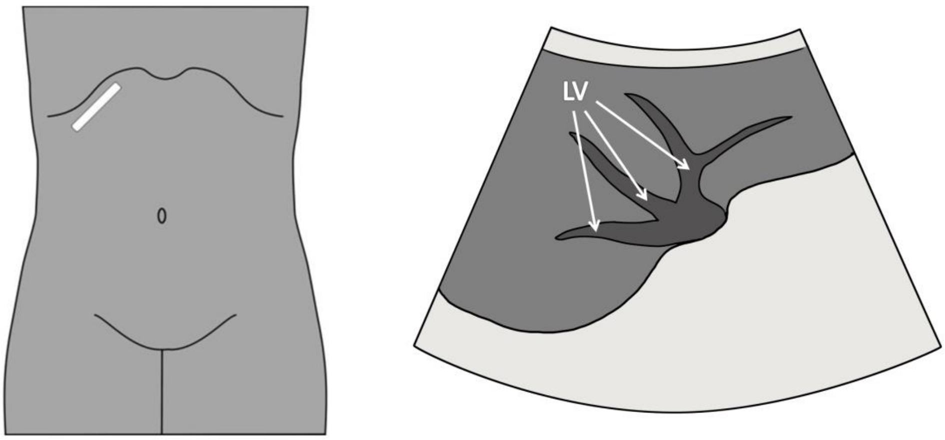

Fig. 8. Diagram of transverse section through hilum of the liver from under right subcostal area.

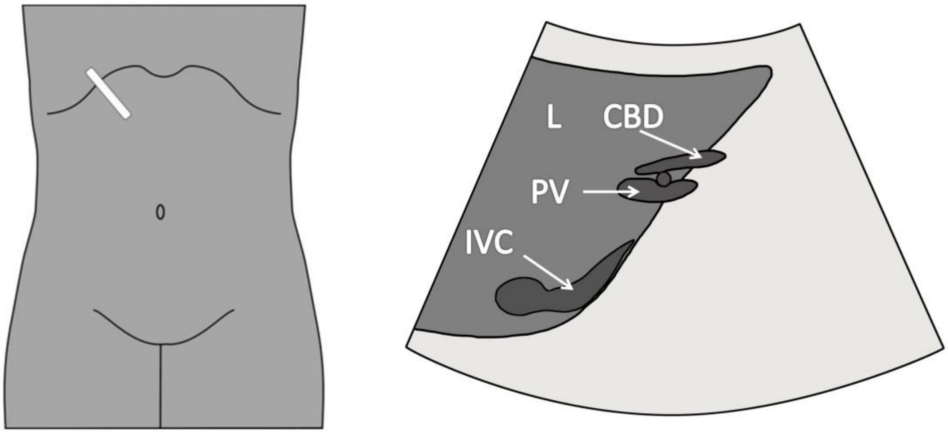

Fig. 9. Diagram of longitudinal section through hilum of the liver from under right subcostal area.

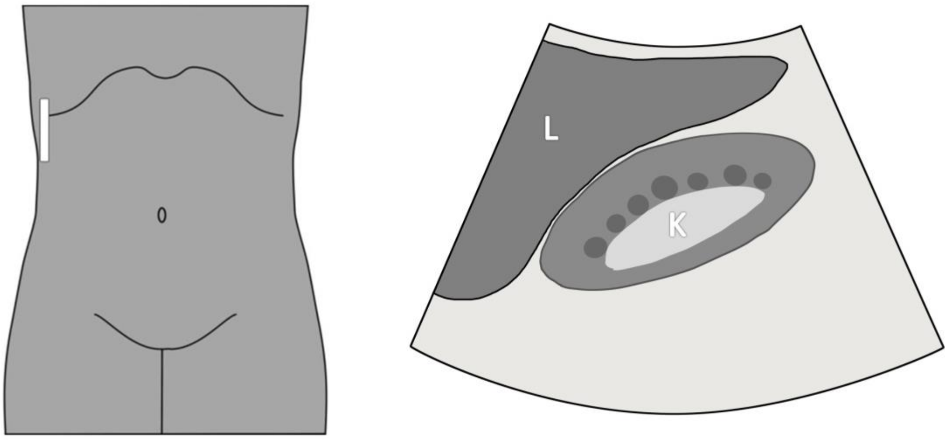

Fig. 10. Diagram of longitudinal section through liver and right kidney from right midaxillary line.

Table II. Normal dimensions of liver and intrahepatic and extrahepatic bile ducts [14]

Liver – right lobe in AP dimension	< 120 mm
Common bile duct (CBD)	< 6 mm
Common bile duct – in patients after cholecystectomy	< 9–10 mm
Intrahepatic bile ducts	< 2 mm, often invisible

Comments:

- During a liver examination, the patient is asked to breathe in fully and hold the breath.
- In the case of a high liver setting, intercostal access is necessary.

3.3. Gallbladder

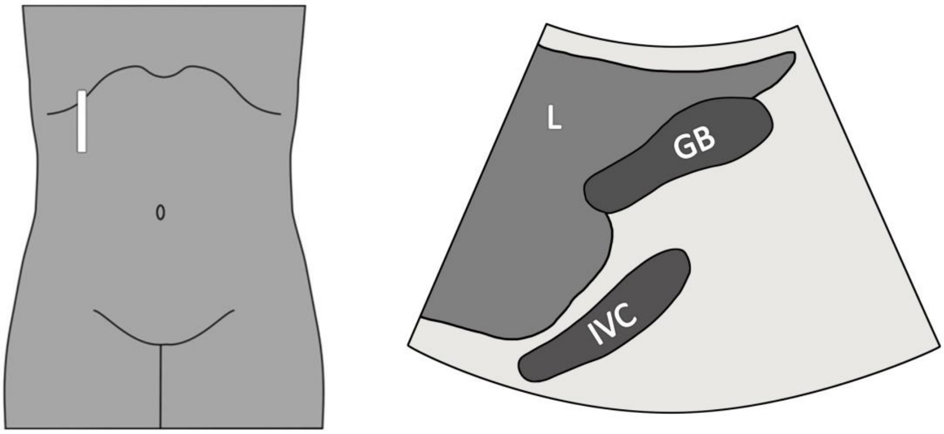

Fig. 11. Diagram of longitudinal section through gallbladder placed under right subcostal area.

Table III. Normal dimensions of gallbladder [14]

Width	< 40 mm
Length	individually variable, less important than width
Wall	Thin, less than 3 mm

Comments:

- In order to evaluate the gallbladder, the patient must report for the examination after fasting.
- The tortuous course of the gallbladder can make it difficult to assess it accurately.

3.4. Pancreas

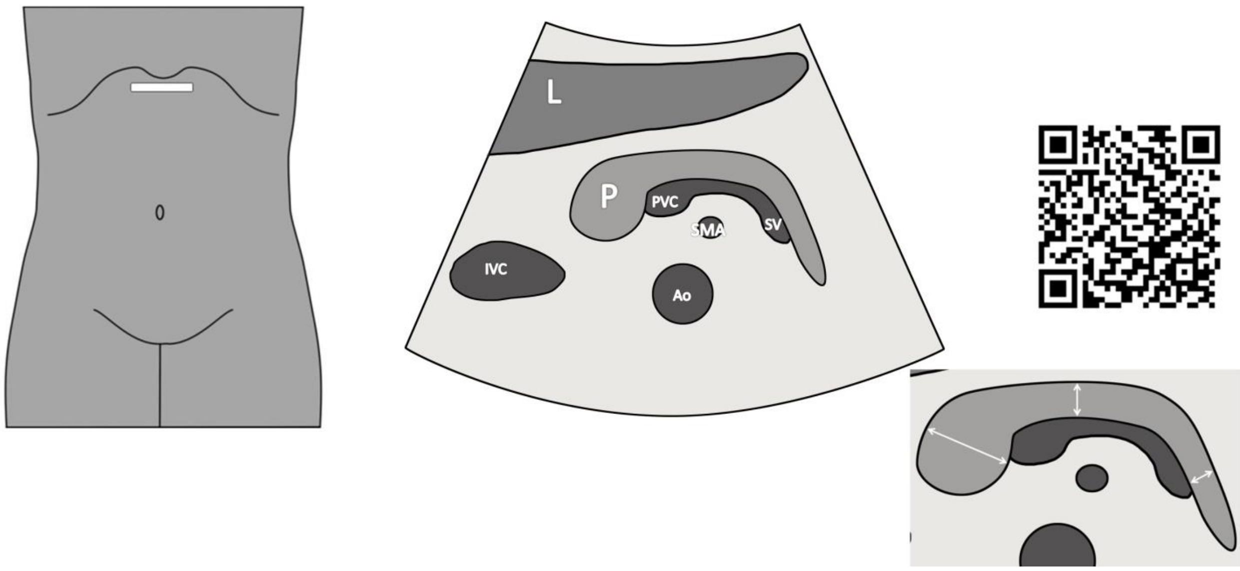

Fig. 12. Diagram of transverse section of pancreas from substernal approach.

Table IV. Normal dimensions of pancreas – values measured in anterior-posterior dimension [2]

Head	< 34 mm
Body	< 29 mm
Tail	< 32 mm
Length of the pancreas	120–200 mm
Pancreatic duct (duct of Wirsung)	< 3 mm

Comments:

- The technique of measuring the pancreas is shown in the diagram above.
- In case of difficulties with visualization of the pancreas, the patient may be asked to push the abdomen forward, this procedure will facilitate the evaluation.

3.5. Kidneys

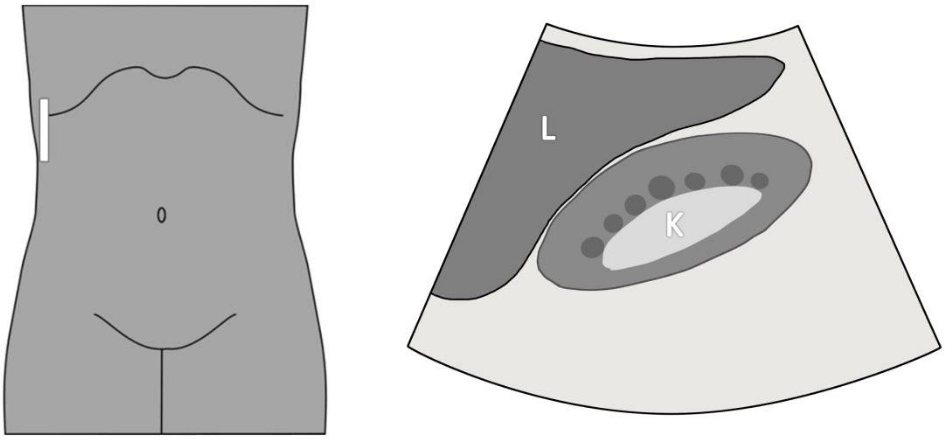

Fig. 13. Diagram of longitudinal section through right kidney from right midaxillary line.

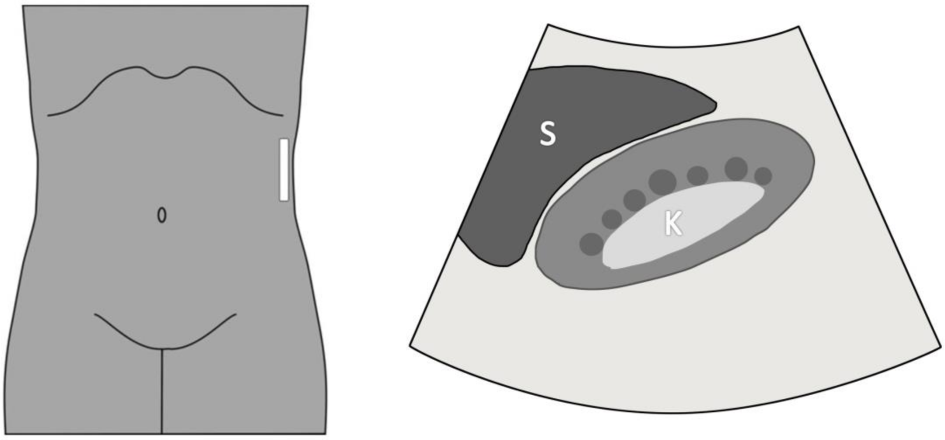

Fig. 14. Diagram of longitudinal section through left kidney from left midaxillary line.

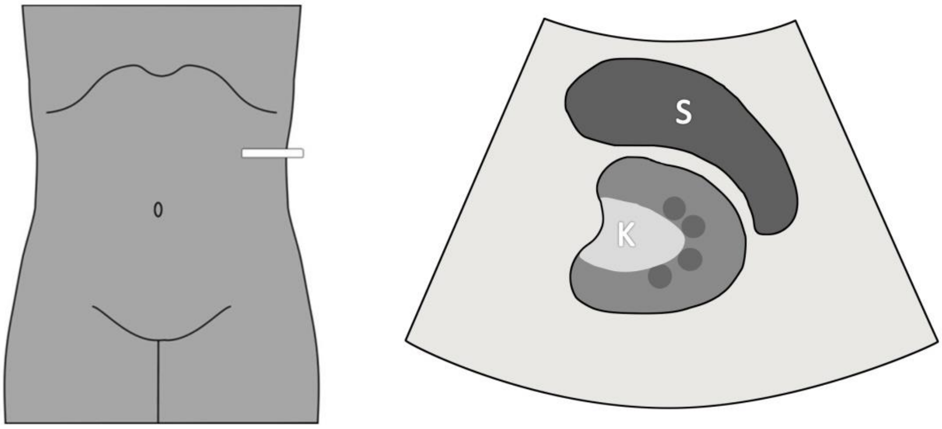

Fig. 15. Diagram of transverse section through left kidney from left midaxillary line.

Table V. Normal dimensions of kidneys [7]

Length	90–130 mm
Width	40–60 mm
Thickness of parenchymal layer (measured from top of pyramid to surface of the kidney)	14–18 mm

Comments:

- Measurements of the kidney should be performed in the long axis of the organ.
- If you have difficulty visualizing the kidneys you can examine the patient in a prone position or on his/her sides.
- The renal pelvis and ureter are only visible when they are dilated.

3.6. Spleen

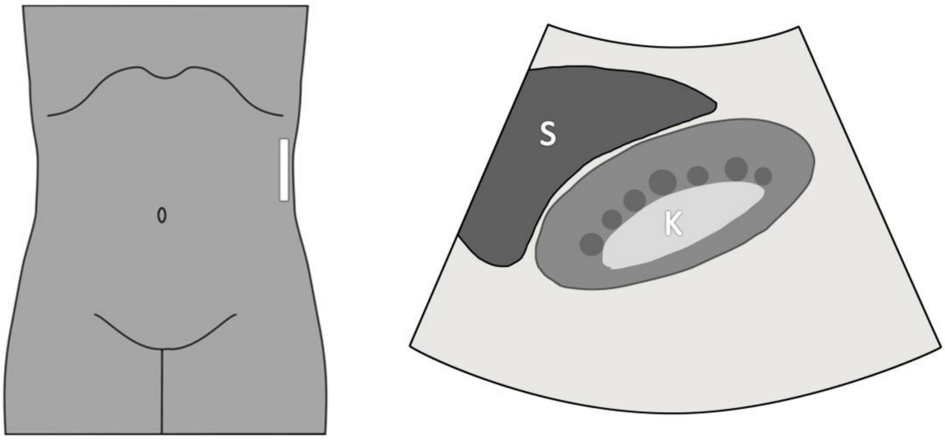

Fig. 16. Diagram of longitudinal section through spleen from left midaxillary line.

Table VI. Normal spleen size [13]

Length (bipolar dimension)	< 120 mm

Comments:

- In case of difficulties with visualization of the spleen, the examination may be performed in the position on the right side and/or from the intercostal approach.
- In order to evaluate the entire organ, examination is performed during different respiratory phases.

3.7. Lower abdomen

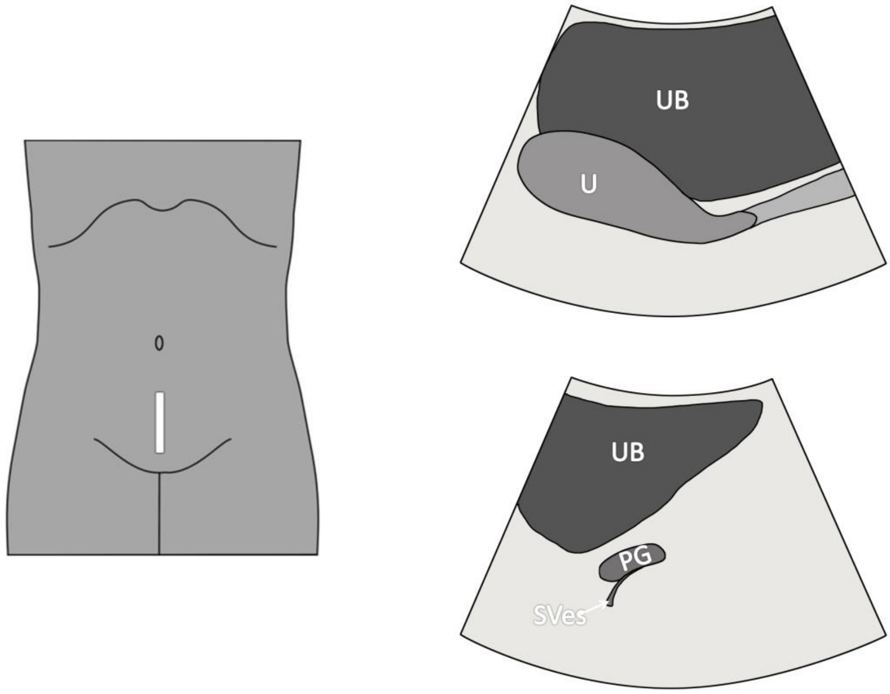

Fig. 17. Diagram of longitudinal section through pelvic organs from midline application.

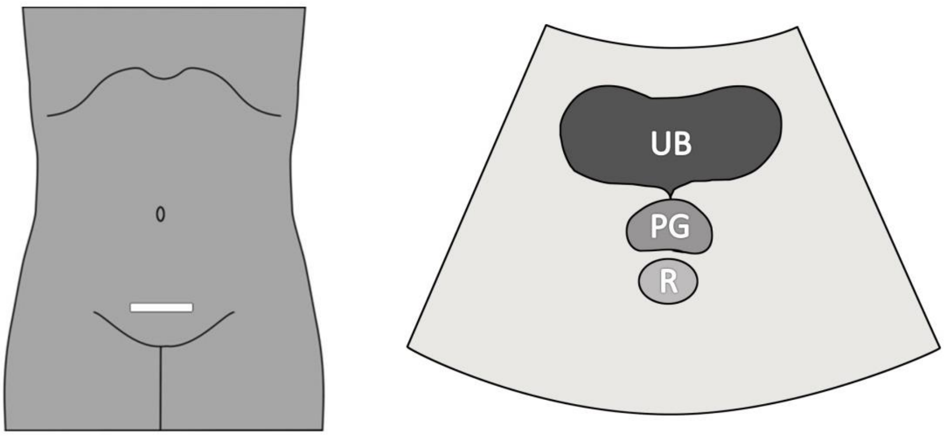

Fig. 18. Diagram of transverse section through pelvic organs in men from midline application.

Table VII. Normal dimensions of lower abdominal organs [18]

Urinary bladder volume in men	750 ml
Urinary bladder volume in women	550 ml
Urinary bladder residual volume	< 50 ml
Full urinary bladder wall thickness	< 3 mm
Prostate gland – maximum dimensions	45 x 35 x 35 mm (AP x SD x CC)
Uterus – maximum dimensions (length x width x thickness)	90 x 40 x 60 mm
Uterus dimensions in multiparous women	100 x 50 x 60 mm
Uterus dimensions after menopause	50 x 20 x 15 mm
Endometrium thickness before menstruation	8–15 mm
Endometrium thickness after menstruation	invisible on ultrasound
Endometrium thickness after menopause	< 8 mm

Comments:

- During assessment of the lower abdomen, the bladder acts as an acoustic window and must therefore be filled.
- The volume of the bladder can be calculated using the formula:

$$width \times length \times depth \times 0.5$$

- There may be a small amount of fluid in the pouch of Douglas, depending on the phase of the patient's menstrual cycle.

3.8. Lymph nodes

Table VIII. Characteristics of normal lymph nodes [18]

Length/width ratio	2
Fatty hilum	visible
Neck lymph nodes – short axis dimension	< 5 mm
Retroperitoneal lymph nodes – short axis dimension	< 10 mm
Iliac lymph nodes – short axis dimension	< 12 mm

Comments:

- Normal lymph nodes have an oval shape and a hyperechoic hilum.
- Most lymph nodes are seen near large vessels.

4. FAST protocol

FAST (Focused Assessment with Sonography in Trauma) is an ultrasound screening protocol used after abdominal and thoracic injuries. It enables the detection of free fluid in the peritoneal, pleural and pericardial cavities.

The main advantage of this test is its speed and non-invasiveness. The availability of portable ultrasound machines makes it possible to conduct an examination at the scene of an accident, in an ambulance, at an emergency department and even on the battlefield.

Performing the FAST protocol helps in making further therapeutic and diagnostic decisions. Depending on the presence of the free fluid and the patient's hemodynamic status, a decision may be made to urgently operate, perform a CT scan or leave the patient for further observation. For this reason, the duration of the test should be as short as possible.

The examination can be performed by using sector and convex probes with low frequency (3–5 MHz).

The FAST protocol is performed by means of 4 touchdowns, enabling the visualization of free fluid, which accumulates most often in the patient lying on his back in:

- Morison's pouch and between the spleen and left kidney
- the recto-bladder or recto-uterine cavity
- the pericardial cavity

The FAST protocol can give false-negative results if performed very shortly after the injury because a small amount of fluid in the peritoneal cavity may go unnoticed, as well as very late after the injury because the blood begins to clot, changing its echogenicity and making the diagnosis of internal bleeding difficult. The main cause of false-positive results is the inexperience of the ultrasound examiner. Additional diagnostic difficulties may be encountered in obese patients with comorbid edema and in pregnant women [6].

4.1. Right upper quadrant (RUQ)

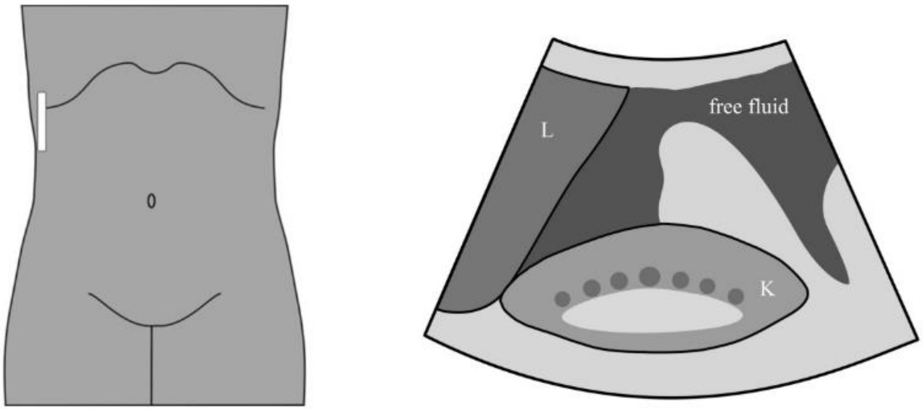

Fig. 19. Diagram of projection through right upper quadrant.

Comments:

- The most sensitive projection to visualize is free fluid.
- A 0.5 cm layer of fluid in Morison's pouch = approximately 500 ml of fluid in the peritoneal cavity.
- Visualizes the diaphragm to assess the presence of fluid in the pleural cavity.

4.2. Left upper quadrant (LUQ)

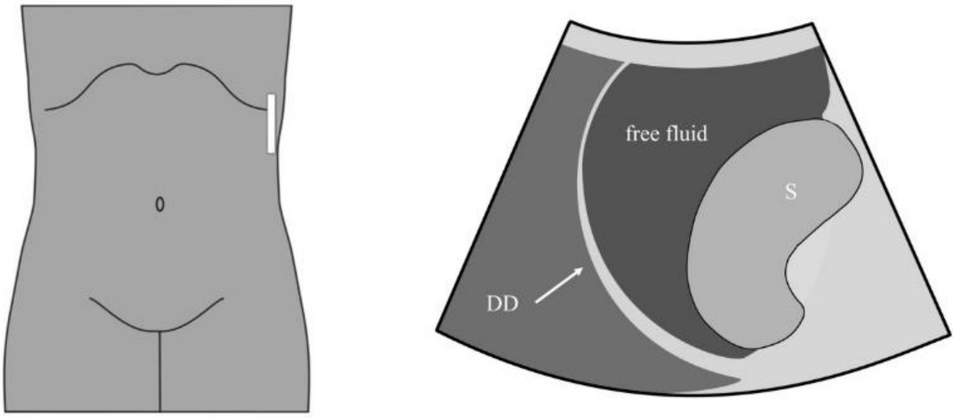

Fig. 20. Diagram of projection through left upper quadrant.

Comments:

- In order to better visualize the examined structures, the transducer can be positioned more headwise and towards the back.

4.3. Substernal projection

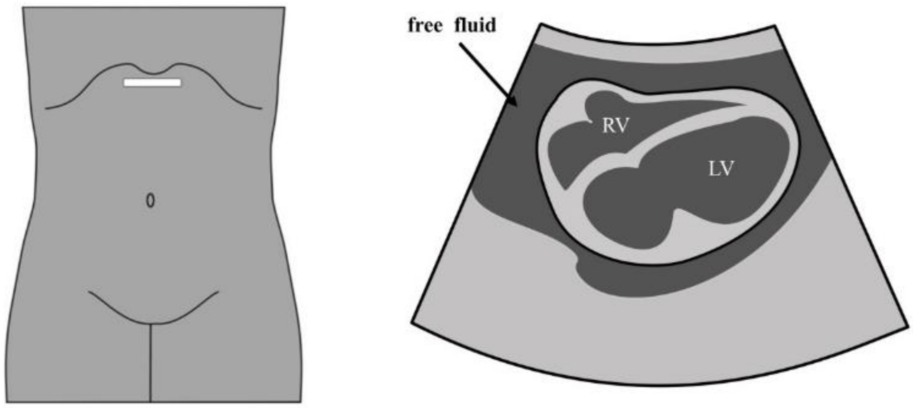

Fig. 21. Diagram of substernal projection. Fluid in pericardium (on right).

Comments:

- Asking the patient to breath in and increasing the depth parameter allow better visualization of the heart.
- Fluid collection in the pericardium appears as an anechoic area surrounding the heart muscle.

4.4. Suprapubic projection

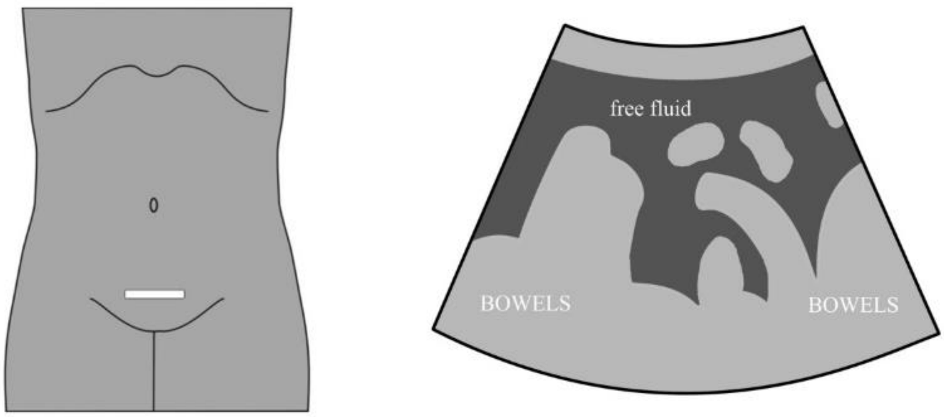

Fig. 22. Diagram of suprapubic projection.

Comments:

- Set the transducer both vertically and transversely.
- The examination should be performed prior to urinary bladder catheterization.
- There may be a small amount of fluid in the pouch of Douglas, depending on the phase of the patient's menstrual cycle.

5. Introduction to neck examination

The superficial location of the neck organs makes them easily accessible in ultrasound examinations. An ultrasound assessment of the neck covers the thyroid gland, parathyroid glands, salivary glands, lymph nodes, venous and arterial vessels, muscles and skin.

An ultrasound examination of the neck, as well as other anatomical regions, should be preceded by the patient's physical examination and analysis of the patient's medical history. A correlation of the ultrasound image with the reported symptoms, current blood test results, and previous results of imaging and histopathological examinations is important.

5.1. Transducer

An ultrasound examination of superficially located organs, including neck organs, is performed with linear probes with a frequency range of 5–12 MHz.

5.2. Preparation for the examination

No prior preparation is required.

Before the examination, the patient should uncover the neck and supraclavicular areas as well as remove jewelry (chains).

5.3. Examination technique

The examination is performed in the supine position on a flat surface.

It is acceptable to perform an ultrasound examination of the neck in a reclining or sitting position.

Complementary projections are made with the head tilted sideways.

6. Basic information on the examination of the neck organs

6.1. Thyroid

Before beginning the thyroid examination, it is necessary to become familiarized with the current results of TSH and free thyroid hormones (especially fT4), as well as the histopathological results from a fine needle biopsy (FNB) of the previously described changes.

The examination begins with assessment of the location and structure of the thyroid gland in the transverse projection. Then the size and homogeneity of the lobes and the isthmus in transverse and longitudinal projections are assessed.

During an ultrasound examination of the thyroid gland, the surrounding structures should always be assessed for pathology (parathyroid glands, lymph nodes, blood vessels).

Nomenclature:

Thyroid nodule – palpable lesion in the thyroid gland.

Focal lesion of the thyroid gland – a lesion visible on ultrasound examination, but not palpable.

Thyroid density (cohesiveness) – susceptibility to strain, assessed on the basis of the mutual ratio of the parenchyma of the thyroid lobes to the surrounding organs, primarily the carotid artery.

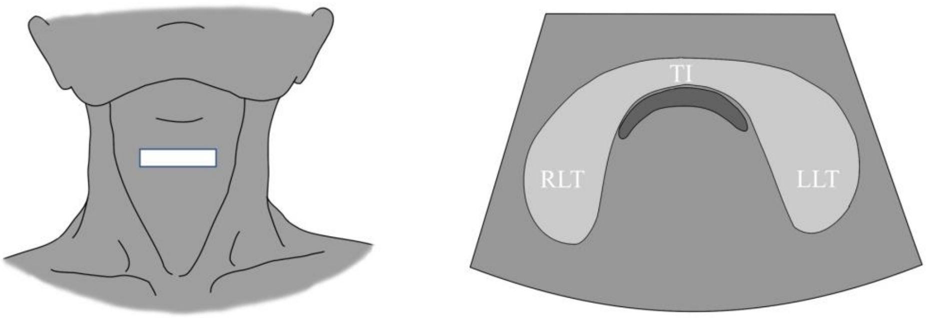

Fig. 23. Diagram of transverse section of thyroid gland from midline application.

Table IX. Characteristics of normal thyroid gland [10,15]

Location	symmetrical on thyroid cartilage
Structure	right and left lobes, isthmus, sometimes a pyramidal lobe is visible in midline
Echogenicity	hyperechoic in relation to muscles (decreased echogenicity → inflammation regardless of etiology)
Lobe dimensions	W (width) 20–25 mm, H (height) 15–20 mm, L (length) 50–60 mm
Isthmus thickness	5–10 mm
Volume (WxHxLx0.52)	< 20 ml in women, < 25 ml in men (increase in volume → goiter of thyroid gland)
Vascularization	regular distribution and course of vessels (increased vascularity in CD/PD examination → possible hyperthyroidism)
Density	intermediate (soft thyroid is modeled by carotid artery; stiff thyroid models course of carotid artery → possible fibrosis)

6.2. Parathyroid glands

Table X. Characteristics of normal parathyroid glands [3,15]

Number	from a few to a dozen
Location	at back wall of upper and lower poles of thyroid gland, can be also found inside (under capsule) of thyroid gland
Structure	homogeneously hypoechoic
Dimensions	circa 6 x 4 x 2 mm

Comments:

- The parathyroid glands are symmetrical endocrine organs that are not always visible on ultrasound.

6.3. Salivary glands

Table XI. Characteristics of normal salivary glands [11]

Number	three pairs of salivary glands: parotid, submandibular, sublingual
Structure	uniformly hyperechoic, irregularly shaped

Comments:

- Normal, non-enlarged lymph nodes may be present inside the salivary glands.

6.4. Lymph nodes

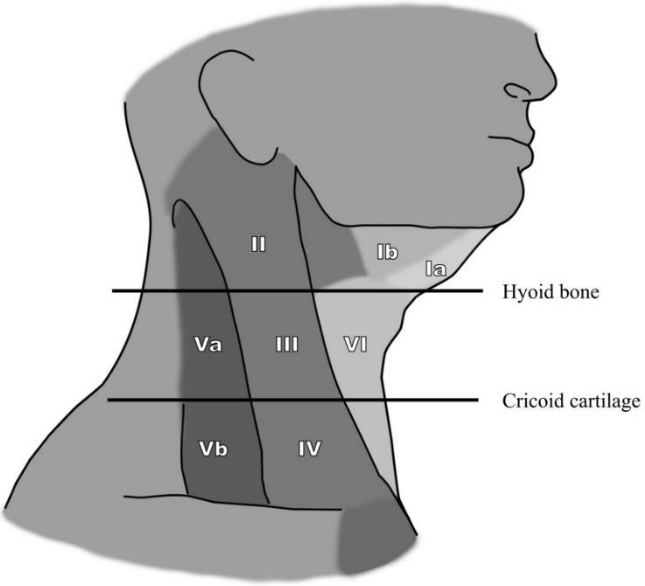

Fig. 24. Groups of lymph nodes in neck.

Table XII. Characteristics of normal lymph nodes [18]

Number	a few
Dimensions	up to 10 mm in short axis (Solbiati index – short axis/long axis < 0.5)
Shape	bean-shaped, oval
Structure	hypoechoic cortex up to 2.4 mm thick, hyperechoic core
Vascularization	blood vessels in hilum

Comments:

The lymphatic system in the neck is made up of a dense network of lymphatic vessels and lymph nodes, which are divided into six groups based on anatomical areas:

- Ia – submental, Ib – submandibular,
- II – upper internal jugular,
- III – middle internal jugular,
- IV – lower internal jugular,
- Va – superior posterior triangle, Vb – inferior posterior triangle,
- VI – central compartment

6.5. Veins of the neck

Examination of the vessels of the venous and arterial systems is performed in transverse and longitudinal sections.

Table XIII. Characteristics of normal jugular veins

Location	anterior and lateral to carotid arteries
Structure	thin-walled, with irregular transverse section shape caused by modelling of surrounding organs; veins are fully compressible when compressed with transducer
Blood flow	constant flow signal in CD/PD studies

Comments:

- Assessment of the venous system around the neck concerns mainly the jugular and subclavian veins for thrombosis. People with central venous lines and vascular ports are particularly vulnerable to thrombosis.

6.6. Arteries of the neck

The main arterial vessels in the neck area are the vertebral arteries (VA) and the common carotid arteries (CCA), which at the level of the CCA bulb at the mandibular angles are divided into internal (ICA) and external (ECA) carotid arteries.

Evaluation of the carotid arteries includes:

- measurement of the thickness of the intima-media complex in CCA,
- measurement of the systolic (PSV) and diastolic (EDV) flow velocities,
- assessment of the presence of atherosclerotic plaques (soft and calcified).

6.6.1. Morphological assessment of neck arteries

Normal arteries have a regular, round shape in the transverse section and they do not compress when pressed with the transducer. The morphological assessment includes measurement of the diameter of the artery, the thickness of the intima-media complex (IMT) and a survey for the presence of atherosclerotic plaques.

The sum of the diameters of the vertebral arteries (VA) is usually 6 mm. VA $<$ 2 mm indicates its hypoplasia.

The IMT in CCA should not exceed 0.6 mm in women and 0.7 mm in men.

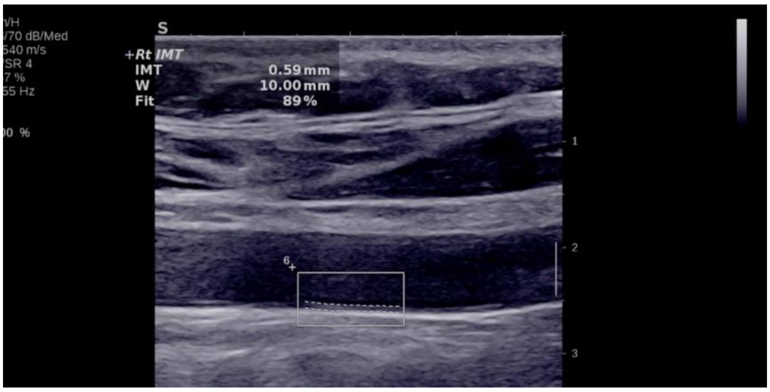

Fig. 25. Semi-automatic measurement of IMT of right CCA.

An atherosclerotic plaque is defined as IMT> 1.7 mm. There are two types of plaques, i.e. soft (hypoechoic) and calcified (hyperechoic). The measurement of atherosclerotic plaque thickness and length is obligatory.

The presence of atherosclerotic plaques is an indication for the measurement of artery stenosis at this level with application of the North American Symptomatic Carotid Endarterectomy Trial (NASCET) or European Carotid Surgery Trial (ECST) formula, and measurement of the blood flow velocity at the site of the stenosis and behind it.

Carotid stenosis measurement is mainly limited to the internal carotid artery because of its key role in supplying the brain with blood.

The morphological measurement consists in calculating the degree of stenosis by measuring the diameter of the artery behind the stenosis (A), the diameter of the artery at the center of the stenosis (B) and the estimate of the original width of the artery at the narrowest point (C) with the following formulas:

$$NASCET = (A-B)/A \times 100\% \ [11]$$

$$ECST = (C-B)/C \times 100\% \ [17]$$

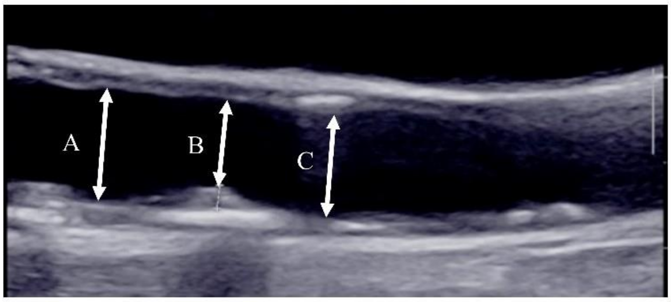

Fig. 26. ICA stenosis measurement, A – diameter of artery behind stenosis, B – diameter of artery at center of stenosis, C – estimate of original width of artery at stenosis.

The degree of arterial stenosis calculated according to the NASCET and ECST formulas is expressed as a percentage.

Since the two formulas use different measurements, the obtained results are different. Therefore, their equivalents have been identified to enable a comparative assessment [10].

Table XIV. Equivalent measurements according to NASCET and ECST formulas [16]

NASCET	ECST
30	65
40	70
50	75
60	80
70	85
80	91
90	97

6.6.2. Functional assessment of neck arteries

The carotid and vertebral arteries show constant cephalic flow, which determines the uninterrupted supply of blood to the brain, regardless of the phase of heart contraction – PSV (peak systolic velocity) and EDV (end diastolic velocity).

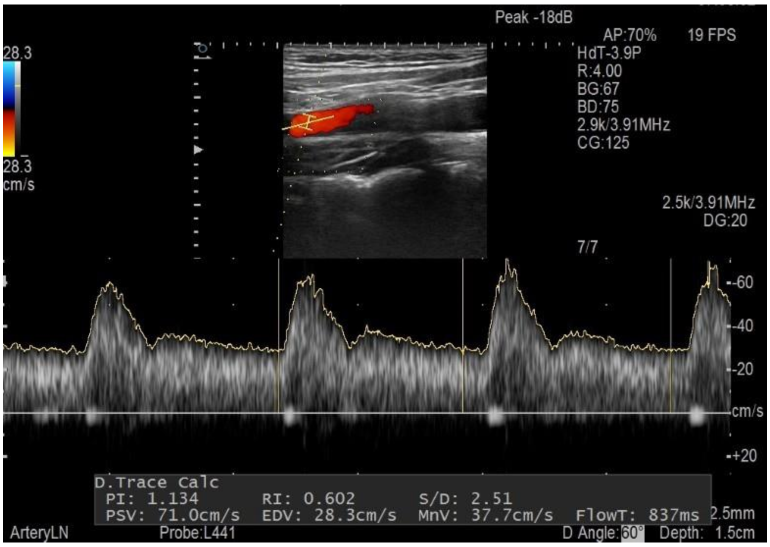

Fig. 27. Doppler measurement of ICA blood flow spectrum.

The measurement of the flow velocity is made by placing a gate in the lumen of the vessel with an angle of attack (the angle between the axis of the ultrasonic wave and the axis of blood flow in the vessel) equal to or less than 60 degrees.

Table XV. Normal flow values in arterial vessels of neck for peak systolic and end diastolic phases [10]

Artery	PSV (cm/s)	EDV (cm/s)
CCA	30–110	–
ICA	30–120	–
ECA	25–115	–
VA	< 60	> 10

The measurement of blood flow velocity in the carotid arteries, mainly ICA, allows one to assume the degree of their narrowing.

Table XVI. ICA stenosis grades based on PSV and EDV values using NASCET scale [1]

ICA stenosis based on NASCET	PSV (cm/s)	EDV (cm/s)
< 50%	< 125	–
50–70%	> 125	< 110
70–79%	> 270	> 110
80–99%	–	> 140
Total occlusion	no blood flow	no blood flow

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8. Ilustrations

9. Tables