Supplementary Figure 1

a1

Contents

a2

Welcome to the **Module Overview** page of SonoForKlinik e-learning. The icons will take you directly to the corresponding **learning units**!

- Ultrasound basics
- Vascular
- Spleen
- Pancreas
- Gallbladder
- Liver
- Kidney
- Bladder
- Prostate + Semenal vusli
- Uterus + Ovaries
- E-Fast
- Peripheral veins

b1

Modul 1: Retroperitoneum, sagittal plane

1.3 Ultrasound image formation, sagittal plane

The ultrasound image in the sagittal plane shows a section of the patient, which is created as follows: Imagine the patient "cut through" along the longitudinal axis of his / her body and then look from **the right side at the left half of the body** (Fig. 1.3.1). The ultrasound beam then provides a **coffee filter-shaped** section of this half of the body, depending on the position of the transducer. Where is **cranially, caudally, ventrally and dorsally** located on this ultrasound image (Fig. 1.3.2)?

The **cranial part** of the patient is found on the **left edge of the ultrasound image** and the caudal part on the **right edge** of the ultrasound image. The patient's **ventral side** is found at the **top of the frame** and the **dorsal side** at the **bottom** (why?). The ultrasound machine calculates the time differences of the reflected ultrasound waves: ventrally located structures appear at the top of the image, because the reflected waves need to travel a shorter distance in order to return to the ultrasound beam. The caudal structures are deeper. They appear at the bottom of the image, because the ultrasound waves travel a longer distance to reach them .

It is extremely important to understand this principle and the way the ultrasound images are created, so please read the paragraph again in peace.

Fig.1.3.1 Ultrasound image formation, sagittal plane

Fig.1.3.2 Ultrasound image, sagittal plane

b2

Reference plane: Sagittal plane

- ultrasound beam entering the patient's body through a longitudinal axis
- body structures are being visualized from the right direction of the patient
- Depending on the type of the transducer, the ultrasound machine provides a coffee-filter-shaped section of half of the patient's body.

Dissolve

Quiz
Where is cranially, caudally, ventrally and dorsally directed?

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c1

3.3.3 Gallbladder

The location of the gallbladder close to the transducer and the position of the liver, that serves as a sonographic acoustic window, enable optimal imaging of the gallbladder (linear transducers can also be used). It is important that the patient is fasting for the examination (pre-prandial examination).

Ultrasound assessment of the gallbladder is done in two planes. In order to demonstrate it in the sagittal plane, firstly you need to define the **right medioclavicular line (at the level of the mamilla)**. To do this, the transducer is placed on this imaginary line just below the ribs (**Fig.3.3.14**). In order to visualize the gallbladder in a longitudinal view, make fine readjustments by tilting and rotating the transducer. The same applies when looking for the liver hilus.

Fig.3.3.14 Medioclavicular line (MCL)
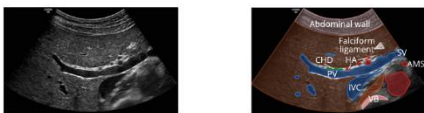Gallbladder: Positioning the transducer.
Blue line: MCL

c2

Ultrasound probe movements: gallbladder sagittal view

Test: Look at this videoclip and memorize the ultrasound probe movements in order to obtain a sagittal view of the gallbladder.
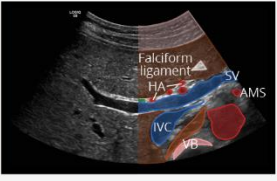
Tipp
- Place the transducer on the right midclavicular line (level of the mamilla) directly below the costal margin
- Give breathing commands and, if necessary, tilt the ultrasound probe cranially

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Fig.3.3.6 Ultrasound images of the liver hilus **Left** image: Legend see above. **Right:** Following

On this image you can see the **portal vein (8)** entering the **liver (1)**. The structures that pass through the hepatoduodenal ligament can be seen on the following order here: ventrally → dorsally: Common hepatic duct (CHD), hepatic artery, portal vein). The **CHD (11)** is located ventrally and can be recognized as a slightly hyperechoic structure with a small hypoechoic lumen. Two transverse sections of the **proper hepatic artery (10)** can usually be seen next to it (why?). Like many arteries in our body, the proper hepatic artery has a spiral course (which else? → Splenic artery). The anatomical structures can be recognized on the right edge of the image, similarly to the image where the left renal vein is seen crossing the aorta. A **vertebral body (yellow)** is seen dorsally, next to the **abdominal aorta (3)** and the **origins of the renal arteries (4,5)**, which however are quite difficult to recognize here.

Above the aorta, the **left renal vein (blue line)** is seen running into the **Vena cava (2)** "clamped" by the **SMA (7)**. Above it, a small section of the **pancreas** is visualized **(9)**.

Fig.3.3.8 Sagittal plane, Liver hilus Color mode Note the thin black structure: CHD (arrow)

d2

Reference plane: Liver hilus sagittal plane, ventral view

Look at the following ultrasound images and clips and try to recognize all the structures! Try to understand the structures in each scanning plane! The use of color Doppler helps to differentiate between blood vessels and bile ducts!

Color   Clip

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Supplementary Figure 2

a1

The **portal vein (6)** is seen ventrally to the inferior vena cava. The portal vein is entering the **liver (9)** through the so-called hepatoduodenal ligament or liver hilus (which structures are missing here?). As discussed before, the liver serves as an acoustic window. The use of the color mode can help to identify the origins of the celiac trunk **(Fig. 2.4.6.B)**.

On this plane we can follow the course of the portal vein until we identify the liver hilus, as described in module 3 (standard plane: liver hilus). Basic knowledge of the anatomy is quite important. It is, for example, difficult to describe all structures precisely on a still image; it is better to be able **to follow the structures** and then try to identify them correctly.

Fig.2.4.6.B Standard plane: Celiac trunk, Color mode

a2

Reference plane: transverse view of the celiac trunk

Review what you have learned so far and **identify the anatomical structures** in the clips. Pay attention to the great vessels (inferior Vena cava and abdominal Aorta) and branches of the celiac trunk.

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To assess the gallbladder in **transverse view**, the transducer is then rotated 90 degrees counterclockwise. Tilt the transducer in order to assess the whole organ and measure it.

Fig.3.3.17 A Positional variants left lateral position

Fig.3.3.17 Gallbladder, transverse view

In addition to the above mentioned scanning techniques, there is also the possibility to scan the gallbladder **through the intercostal space or in the left lateral position**. This is preferable in cases of poor visualization, caused by overlying bowel gas. The patient can also be scanned **on a standing position** (why?). Gallbladder stones located in the infundibulum will then move towards the fundus, where they can be better visualized.

b2

Clip: transverse view of the gallbladder

Test: On this videoclip you can see an ultrasound examination of the gallbladder in transverse plane. Note the ultrasound probe movements and memorize the examination procedure.

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c1

Q4: 1,47 cm

Liver — Kidney — Renal pelvis and caliceal dilatation — Psoas major muscle — Parenchyma

Liver — Kidney — Renal pelvis and caliceal dilatation — Psoas major muscle — Parenchyma
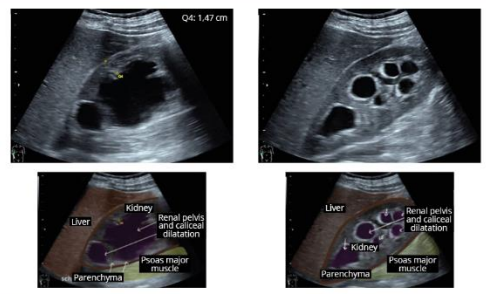
Image: Right kidney, sagittal view: Pay attention to the sonographic findings in the event of increasing urinary retention (caliceal dilatation, thinning of the cortex, reduced sinus reflex, obtuse fornix angle, flattened papillae) → Hydronephrosis Grade 3–4
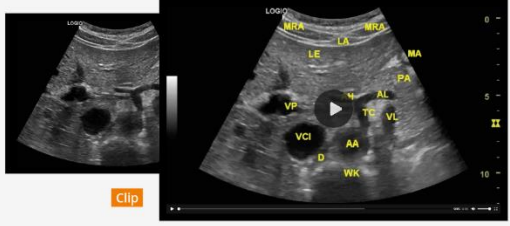
c2

Hydronephrosis

Describe the **findings** shown on the ultrasound images and clips and assess the **degree of hydronephrosis**. Identify the renal parenchyma and the renal pelvis!

Liver — Renal pelvis and caliceal dilatation — Kidney — Psoas major muscle — Parenchyma

Dissolve Clip   Hide Clip

Sagittal view of the right kidney: Beware of the ultrasound findings in the event of progressive hydronephrosis (caliceal dilation, thinning of the cortex, reduced sinus reflex, obtuse fornix angle, flattened Papillae) → Hydronephrosis grade 3–4.

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DD: kidney parapelvic cysts; ampullary renal pelvis?

Retroperitoneum: Bleeding? Aneurysma? Mass?

Pregnancy?

Catheter / Splint?

Prostatic hyperplasia?

Intraabdominal masses?

Urinary tract obstruction

Urinary bladder mass?

Ureteral jet bilaterality and symmetry?

Renal pelvis?

Tract stones? Concrements?

Female pelvis: ovarian mass / uterine mass?

Gastrointestinal disorders: Appendicitis? Diverticultitis?

d2

Urinary tract obstruction (hydronephrosis)

Think about the **causes and differential diagnoses** that come into question in the case of urinary tract obstruction.

Retroperitoneum: Bleeding? Aneurysma? Mass?

Catheter / Splint?

Urinary tract obstruction

Intraabdominal masses?

Ureteral jet bilaterality and symmetry?

Tract stones? Concrements?

Gastrointestinal disorders: Appendicitis? Diverticultitis?

Dissolve

Note: Should you recognize a urinary tract obstruction on ultrasound, try to identify the underlying cause!

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Supplementary Figure 3

Question example 1

Which **artifacts** are marked by the **arrows**?

1. Artefakt:
2. Artefakt:
3. Artefakt:
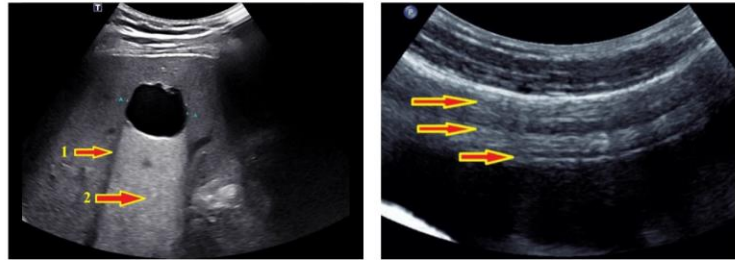
Question example 2

Which **ultrasound modes** can be found in the pictures?

1. Ultrasound mode:
2. Ultrasound mode:
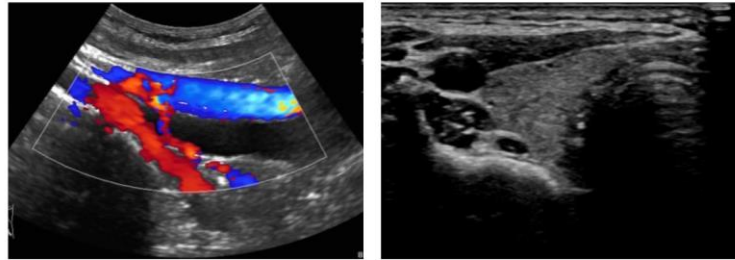
Question example 3

Label the image according to the correct **anatomical orientation**. Which **reference plane** is presented here? Take the attached ultrasound image into consideration.

Reference plane:
1:                    2:
3:                    4:
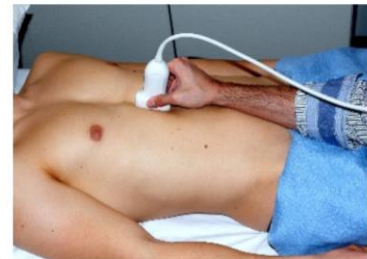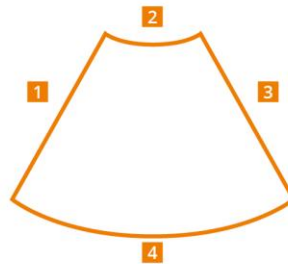
Question example 4

· Complete the following sentence: The higher the frequency, the _____ the depth of penetration.

· Complete the following sentence: The lower the frequency, the _____ the depth of penetration.

Question example 5

· Complete the following sentence: The correct terminology for "dark" areas in the ultrasound image is:

_____

· Complete the following sentence: The correct terminology for "bright" areas in the ultrasound image is:

_____

Question example 6

Which types of **ultrasound probes** are shown here?

1:
2:
3:

Supplementary Figure 4

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:

1:          2:   3:
4:          5:   6:
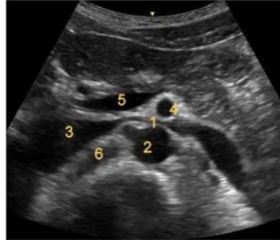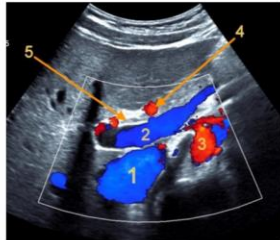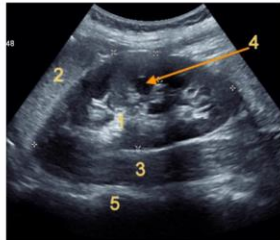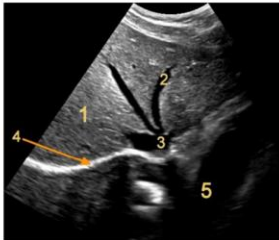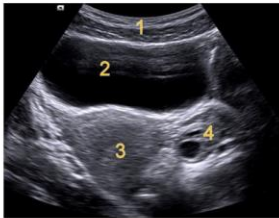
Supplementary Figure 5
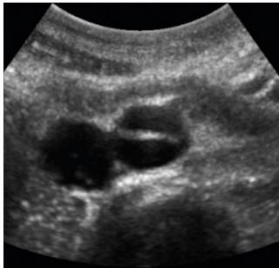
Pathological finding:

Pathological finding:
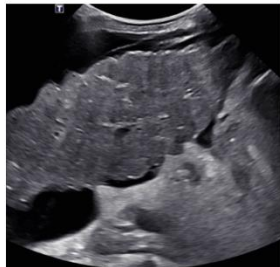
Pathological finding:

Pathological finding:

Pathological finding:

Pathological finding:
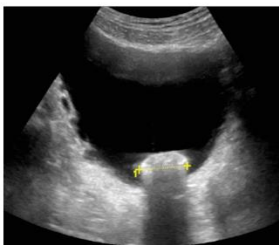
Pathological finding:

Pathological finding:

Supplementary Figure 6

EXAM TIME (P2)
Person 1: Topic 2, Topic 1, Topic 4
Person 2: Topic 7, Topic 3, Topic 6
Person 3: Topic 5, Topic 9, Topic 8

EXAM TIME (P3)
Person 1: Topic 2, Topic 4, Topic 8
Person 2: Topic 7, Topic 9, Topic 3
Person 3: Topic 5, Topic 1, Topic 6

Topic 1: Right kidney
Topic 2: Cava collapse test
Topic 3: Vena portae
Topic 4: Gallbladder

Topic 5: Liver examination left hepatic lobe
Topic 6: Spleen

Topic 7: Retroperitoneum with aorta
Topic 8: Right liver lobe
Topic 9: Left kidney

Supplementary Figure 7

Supplementary Figure 8
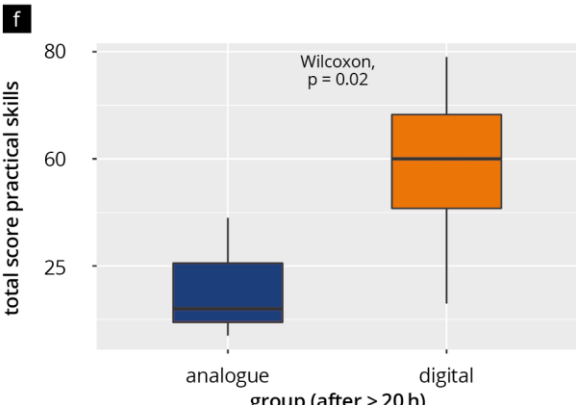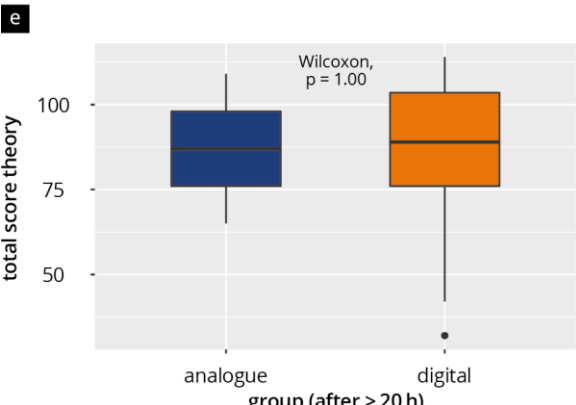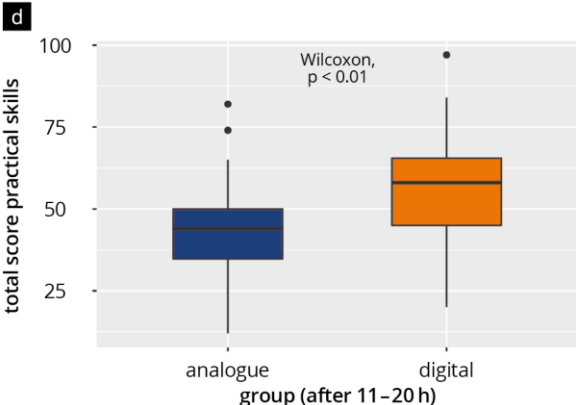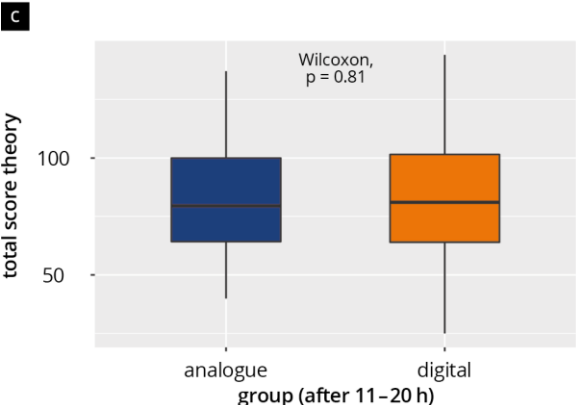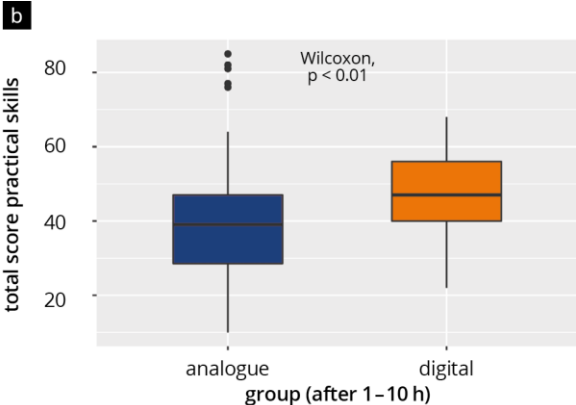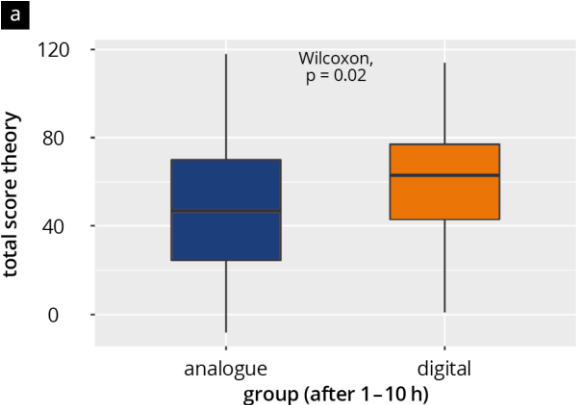
Supplementary Table 1: Learning objectives of abdominal sonography modules

Module	Learning objectives	
0 **Basics**	Device operation, transducer position, patient management/positioning, documentation on two planes, basic ultrasound physics, artifacts, screen orientation, transducer types, ultrasound terminology, essential keyboard functions, and ultrasound limitations	
	Normal findings (image acquisition and identification in the sagittal and transverse plane)	**Pathologies**
1 + 2a **Vessels**	Abdominal aorta, celiac trunk, superior mesenteric artery, renal arteries, left and right common iliac arteries, inferior vena cava, hepatic veins, splenic vein, portal vein, and renal veins	Aortic plaque, aortic aneurysm, aortic dissection, vena cava inferior congestion, benign and malignant lymph nodes
2b **Pancreas**	Pancreatic head and body, pancreatic duct, uncinate process, pancreatic tail	Acute and chronic pancreatitis, concretion in the pancreatic duct, pancreatic lipomatosis, pancreatic carcinoma, congested pancreatic duct
3 **Portal area of liver, biliary tract, gallbladder**	Hepatocholedochal duct, proper hepatic artery, portal vein, intrahepatic bile ducts, gallbladder pre- and postprandial	Portal vein dilatation, portal vein thrombosis, cholestasis, tumor in the biliary duct, biliary calculus, gallstone, cholecystitis, sludge and hydrops, cholesterol polyp
4 **Liver**	Hepatic vein star, portal vein plane, intrahepatic bile ducts, liver segments	Diffuse liver lesions (hepatic cirrhosis, hepatic steatosis), benign and malignant focal lesions, and intrahepatic cholestasis
5a **Kidneys**	Longitudinal and transverse organ axis, kidney width and length, pyelon/parenchyma ratio, psoas muscle as lead structure "glide sign", hepatorenal Morrison's pouch, splenorenal recess	Form variants, angiomyolipoma, chronic renal failure, renal carcinoma, nephrolithiasis, urinary stasis, pyelonephritis, and polycystic kidney
5b **Spleen**	Longitudinal and transverse organ axis with measurements, splenic vein, pancreatic tail, volume determination	Splenomegaly with collateral, accessory spleen, splenic infarction, splenic calcification, splenic cysts, splenic rupture, and malignant focal lesions
6 **Pelvic organs**	Urinary bladder including volume determination, urinary bladder jet with color Doppler, prostate including measurement, seminal vesicles, uterus including measurement, ovaries, rectum, rectovesical pouch, Douglas pouch, common iliac arteries and veins	Urinary bladder sludge and coagulum, urinary retention, residual urine, chronic cystitis, urinary bladder carcinoma, ascites/free fluid in Douglas pouch, prostate hyperplasia, ovarian cyst, uterine myoma, and intrauterine device

Supplementary Table 2: Comparison of various content, didactic, and design aspects of teaching media lecture notes versus the e-learning module

Lecture Notes	E-Learning
Volume	
320 pages	1084 slides
Text format	
Continuous text	Continuous text and bullet points
Availability and requirements	
Hardcopy	Internet connection
Layout and contents	
Preface	Welcoming page
Table of contents	Overview page
- Divided into modules	- Divided into tracts and systems
- Page numbering for subjects	- Navigational menu to subjects
Navigated by turning pages	Navigated by clicking through study cards or the navigational menu
Order of subjects	
1. **Basic knowledge and clinical relevance/questions**	1. Learning objectives
2. **Anatomical basics**	2. Anatomical basics
3. **Sonography instructions**	3. Workflow/questions
4. **Standard cross-sections and measurements**	4. Sonography instructions
5. **Checklist: Theory**	5. Standard cross-sections and measurements
6. **Pathologies (facts, sonomorphology)**	6. Checklist theory + practical tasks pathologies (facts, sonomorphology)
7. **Checklist: Practical tasks**	
Design	
Recurring categorized colors, e.g., summaries, checklists	
Colorful	Subtle coloring
The number, format, and size of figures/ images varies per page	Usually 2-4 figures, or images, or videos per study card
Images	
Varying formats	Resizing and zoom via click functions
Images are often labelled, and structures are highlighted	Images labelled and structures highlighted via the click function
Videos	
None	Examination procedures, normal findings, and pathologic findings

Supplementary Table 3: Results of Evaluation$_{pre}$ (T1) and Evaluation$_{inter}$ (T2) regarding the use of learning materials in general, satisfaction with digital teaching, and use of ultrasound learning media

Use of learning materials (T1)				
Item	**Control group**	**Study group**		**p-value**
	n	**n**	**%**	
Use of digital media for medical degree				0.51
No	0	2	1	
Yes	100	134	99	
Duration <10h/Week	18	25	18	
Duration =10-20h/Week	64	59	43	
Duration ≥ 20h/Week	18	52	38	
Use of digital media in private				0.14
No	0	4	3	
Yes	100	132	97	
Duration <10h/Week	19	26	19	
Duration 10-20h/Week	44	66	49	
Duration ≥20h/Week	37	40	29	
Use of digital media for sonography				0.08
No	98	126	93	
Yes	2	10	7	
Duration ≤10h	2	9	7	
Duration 10-20h	0	0	0	
Duration >20h	0	1	1	
Use of books for sonography				0.74
No	95	130	96	
Yes	5	6	4	
Duration <10h	4	6	4	
Duration 10-20h	1	0	0	
Duration >20h	0	0	0	
Use of sonography learning materials (T2)				
Use of learning media for preparation				**<0,01**
No	0	0	**0**	
Yes	100	136	**100**	
Duration <10h	63	57	**42**	
Duration 10-20h	34	59	**43**	
Duration >20h	3	20	**15**	
Use of module: Basic knowledge				**0.99**
No	100	131		
yes	0	5		
	Mean ±SD	**Mean ±SD**		
Use of chapter: Normal findings (max. 9)	9 ±0	8.79 ±1.37		0.31
Use of chapter: Pathologic findings (max. 9)	9 ±0	8.62 ±1.84		0.44
Satisfaction with digital courses (T2)				
Likert answering format. Range from 1= completely/very good to 7= not at all/very bad				
Before Covid-19 pandemic	4.86 ±1.67	4.51 ±1.85		0.15
During Covid-19 pandemic	3.54 ±1.31	2.89 ±1.10		**<0.01**
Desire for future expansion of courses	1.77 ±1.28	2.08 ±1.32		**0.02**

Supplementary Table 4: Evaluation results for motivation at different time points (T1-T3). Likert answering format with a range from 1= completely/very good to 7= not at all/very bad.

Item	Control group	Study group		p-value
Evaluation_{pre} (T1)				
	Mean ±SD	**Mean ±SD**		
Influence of the format, appearance, and design of a teaching medium on motivation for participation in a university course	1.98 ± 0.97	1.93 ± 1.04		0.53
Motivation for participation in sonography course before course	1.60 ± 0.68	1.55 ± 0.72		0.42
	n	**n**	**%**	
Motivation for attending a university course				0.43
Good book	7	8	6	
Good E-learning	13	19	14	
Both	80	105	77	
None	0	4	3	
Evaluation_{inter} (T2)				
	Mean ±SD	**Mean ±SD**		
Motivation for course participation due to learning medium	2.57 ± 1.32	2.68 ± 1.43		0.89
Higher motivation for course participation due to the use of a different learning medium	3.91 ± 2.37	5.07 ± 2.14		**<0.01**
Higher motivation to participate in the course due to a combination of several learning media	3.08 ± 2.11	4.07 ± 2.19		**<0.01**
Evaluation_{post} (T3)				
Motivation for further study of sonography after course participation	1.71 ±0.83	1.43 ± 0.79		**<0.01**
Use of learning medium for follow-up of the course	2.61 ±1.69	1.96 ± 1.25		**<0.01**
Higher motivation to follow up on the course due to the use of a different teaching medium	3.58 ±2.49	4.73 ± 2.38		**< 0.01**
Higher motivation for course follow-up in combination with other teaching media	3.01 ±2.19	3.53 ± 2.22		0.06

Supplementary Table 5: Evaluation results for training concept and course preparation at time point T3 (evaluation$_{post}$). Likert answering format with a range from 1= completely/very good to 7= not at all/very bad.

Evaluation$_{post}$				
Item	**Control group**	**Study group**		**p-value**
	Mean ±SD	**Mean ±SD**		
Course concept				
Expectations met by the course	2.53 ±1.19	1.89 ±0.77		**<0.01**
Clarity and structure of course concept	2.82 ±1.55	1.98 ±0.93		**<0.01**
Clarity/representation of learning objectives	2.17 ±1.19	1.73 ±0.82		**<0.01**
Achievement of learning objectives	2.56 ±1.23	2.06 ±0.97		**<0.01**
Illustration of learning content with examples	2.25 ±1.29	1.68 ±087		**<0.01**
Satisfaction with the teaching materials	2.66 ±1.41	2.03 ±1.01		**<0.01**
Satisfaction with course organization	3.28 ±1.67	2.15 ±1.20		**<0.01**
Satisfaction with the length of the course	3.95 ±1.89	3.16 ±1.50		**<0.01**
Tutors' technical skills	1.06 ±0.24	1.12 ±0.32		0.15
Tutors' teaching skills	1.17 ±0.46	1.12 ±0.33		0.68
Course preparation/theory lectures				
Appropriateness of the additional preparation time during the course	3.88 ±1.9	2.61 ±1.36		**<0.01**
Extensive use of preparation time	3.54 ±1.74	3.16 ±1.45		0.09
Optimal use of the practical phase due to the preparation phase	3.27 ±1.66	2.44 ±1.22		**<0.01**
Appropriateness of the content of the work assignments	2.91 ±1.59	2.40 ±1.20		**0.03**
Comprehensibility of work assignments	1.71 ±0.90	1.67 ±0.90		0.70
	n	**n**	**%**	
Desire for accompanying lectures on				
Sonography technique				**<0.01**
Yes	36	15	11	
No	64	121	89	
Execution of an ultrasound examination				**<0.01**
Yes	60	50	37	
No	40	86	63	
Normal findings				**<0.01**
Yes	60	39	29	
No	40	97	71	
Pathologies				**<0.01**
Yes	66	27	20	
No	34	109	80	

Supplementary Table 6: Comparison of the evaluations of the learning materials at times T2 (Evaluation$_{inter}$) and T3 (Evaluation$_{post}$). Likert answering format with a range from 1= completely/very good to 7= not at all/very bad.

Control group lecture notes			
	Evaluation^{inter}	**Evaluation^{post}**	
	Mean±SD	**Mean±SD**	**p-value**
Design and structure	2.34 ±1.19	2.13 ±1.21	0.066
Duration	2.13 ±1.22	2.11 ±1.25	0.269
Comprehensibility of content	2.23 ±1.17	1.83 ±0.85	**0.012**
Font size	1.54 ±0.93	1.53 ±0.96	0.714
Size of images	1.87 ±1.13	1.85 ±1.09	0.944
Number of images	1.93 ±1.21	1.94 ±1.28	0.784
Proportion of text to images	2.04 ±1.19	2.02 ±1.20	0.810
Design/coloring	1.98 ±1.26	1.87 ±1.36	0.170
Total score	2.00 ±0.79	1.91 ±0.91	0.099
Total mark	1.89 ±0.65	1.91 ±0.71	0.812
Study group E-learning			
Technology	1.54 ±0.69	1.45 ±0.56	0.298
Navigational menu	1.92 ±1.10	1.81 ±1.03	0.309
Learning videos	1.67 ±0.70	1.57 ±0.60	0.262
Study cards	1.80 ±0.75	1.62 ±0.61	**0.060**
Design	1.93 ±1.09	1.67 ±1.04	**0.016**
Cognitive ergonomics	1.67 ±0.93	1.55 ±0.92	0.134
Interactivity	2.04 ±1.21	1.85 ±1.04	0.236
Total score	1.80 ±0.67	1.65 ±0.58	0.**022**
Total mark	1.87 ±0.82	1.70 ±0.70	0.060

Supplementary Table 7: Subjective assessment of competencies by the participants at T1 (evaluation$_{pre}$), T2 (evaluation$_{inter}$), and T3 (evaluation$_{post}$). Likert answering format with a range from 1= completely/very good to 7= not at all/very bad.

Item	Evaluation^{pre}			Evaluation^{inter}			Evaluation^{post}		
	Control group	Study group	P-value	Control group	Study group	P-value	Control group	Study group	P-value
	Mean ±SD	Mean ±SD		Mean ±SD	Mean ±SD		Mean ±SD	Mean ±SD	
Total Score									
Subjective competency	5.44 ±0.98	5.51 ±1.15	0.37	4.49 ±1.2	4.39±1.33	0.77	2.37 ± 0.71	2.42± 0.78	0.60

Item	Initial value			Delta					
				Evaluation$_{pre}$ -> Evaluation$_{inter}$			Evaluation^{inter} -> Evaluation^{post}		
Total score	5.44 ±0.98	5.51 ±1.15	0.37	0.95 ±1.27	1.09 ± 1.46	0.41	2.12±1.27	1.97± 1.38	0.30
Theoretical knowledge	4.69 ±1.45	4.74 ±1.65	0.69	0.74 ±1.51	0.96 ±1.95	0.45	1.37 ±1.39	1.07 ±1.36	0.22
Equipment use	6.19 ±1.13	6.14 ±1.16	0.56	1.07 ±1.78	1.07 ±1.74	0.80	2.85 ±1.69	2.59 ±1.63	0.29
Transducer handling	5.67 ±1.48	5.93 ±1.43	0.10	1.10 ±1.97	1.11 ±1.96	0.77	2.51 ±1.83	2.61 ±1.66	0.57
Spatial orientation	4.65 ±1.35	4.86 ±1.52	0.20	0.72 ±1.42	0.84 ±1.73	0.49	1.46 ±1.53	1.54 ±1.67	0.73
Sonoanatomical assignment	5.31 ±1.23	5.35 ±1.37	0.63	0.95 ±1.57	1.28 ±1.87	0.09	1.95 ±1.57	1.65 ±1.77	0.13
Organ visualization	5.46 ±1.31	5.64 ±1.43	0.17	1.03 ±1.65	1.21 ±1.74	0.30	2.03 ±1.69	2.13 ±1.75	0.89
Organ assessment	5.98 ±1.19	5.93 ±1.43	0.89	1.08 ±1.64	1.22 ±1.72	0.38	2.26 ±1.61	2.21 ±1.77	0.82
Patient guidance	5.57 ±1.47	5.42 ±1.68	0,71	0.91 ±1.71	1.16 ±1.99	0.27	2.57 ±1.69	1.97 ±1.83	0.01

Supplementary Table 8: Results of the theoretical tests at time points T1-T3 in terms of the overall score and per specific competency (basic knowledge, standard cross-sections, orientation structures and pathologies) of the study group and control group.

Competency	Theory$_{pre}$			Theory$_{inter}$			Theory$_{post}$		
	Control group	Study group		Control group	Study group		Control group	Study group	
Score (max. points)	Mean ±SD	Mean ±SD	p-value	Mean ±SD	Mean ±SD	p-value	Mean ±SD	Mean ±SD	p-value
Total (199)	17.3 ±14.80	17.5 ±14.8	0.88	79.0 ±37.0	91.0 ±30.3	0.013	128.0 ±24.6	133.0 ±24.4	0.10
Basic knowledge (33)	7.0 ±5.23	6.1 ±4.6	0.2	19.2 ±5.83	20.9 ±5.11	0.08	24.5 ±4.29	27.4 ±3.77	<0.01
Standard cross-sections (151)	16.7 ±14.1	16.6 ±13.7	0.96	72.1 ±32.2	83.4 ±26.2	<0.01	111.0 ±17.2	115.0 ±18.9	0.02
Orientation structures (65)	6.18 ±7.36	7.73 ±6.86	0.13	30.6 ±15.6	36.3 ±12.3	<0.01	51.2 ±7.97	52.4 ±8.51	0.13
Pathology recognition (48)	0.56 ±1.11	0.90 ±1.84	0.37	6.89 ±6.37	7.65 ±6.24	0.24	17.4 ±9.07	17.9 ±7.58	0.85

Supplementary Table 9: Comparison of change in competencies between the theoretical tests at the time points T1, T2, and T3 in overall score and specific competencies (basic knowledge, standard cross-sections, orientation structures, and pathologies) of the study group and control group.

	Theory test					
Competency	**Delta T1-T2 control group**	**Delta T2-T2 study group**		**Delta T2-T3 control group**	**Delta T2-T3 study group**	
	Mean±SD	**Mean ±SD**	**p-value**	**Mean ±SD**	**Mean ±SD**	**p-value**
Total score	61.7 ±31.0	73.5 ±27.4	**0.005**	49.0 ±21.0	42.0 ±17.5	**0.019**
Basic knowledge	12. 2 ±5.8	14.8 ±6.0	**0.002**	5.3 ±5.3	6.5 ±4.0	**0.025**
Standard cross-sections	55.3 ± 26.8	66.8 ±24.4	**0.002**	38.6 ±21.0	31.8 ±6.2	**0.017**
Orientation structures	23.8± 13.2	28.6 ±11.7	**0.006**	20.5 ±11.2	16.1 ±8.7	**0.003**
Pathology recognition	6.3 ±6.1	6.8 ±5.8	0.365	10.5 ±5.9	10.2 ±5.3	0.518

Supplementary Table 10: Influence of preparation time on examination performance at time T2. *Significance calculations should be viewed with caution due to the small group size.

Preparation time	Control group	Study group	p-value
Duration 1h =<10h (n)	63	57	
Theory$_{inter}$ *Mean ±SD*	49.0 ±27.9	60.8 ±24.9	**0.02**
Practice$_{inter}$ *Mean±SD*	39.4 ±17.4	47.2 ±10.9	**<0.01**
Duration 10h - 20h (n)	34	59	
Theory$_{inter}$ *Mean ±SD*	82.9 ± 23.8	81.5 ±26.4	0.81
Practice$_{inter}$ *Mean ±SD*	43.6 ±15.3	55.8 ±14.7	**<0.01**
Duration > 20h (n)	8*	20*	
Theory$_{inter}$ *Mean ±SD*	87.0 ±22.0	86.0 ±23.1	1.0
Practice$_{inter}$ *Mean ±SD*	36.0 ±11.5	58.4 ±13.6	**0.02**