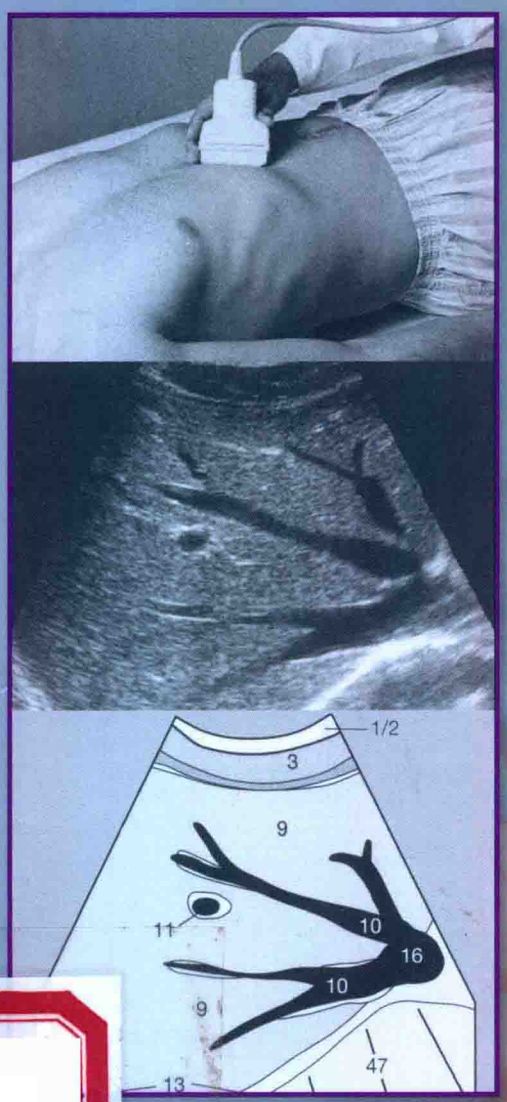
Ultrasound Teaching Manual

The Basics of Performing and Interpreting Ultrasound Scans

Matthias Hofer

3rd edition



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Ultrasound Teaching Manual

An Introductory Workbook

Third expanded and revised English edition

Matthias Hofer

782 figures and 43 tables

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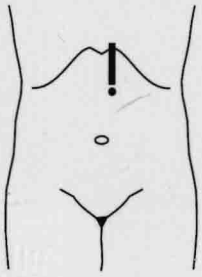
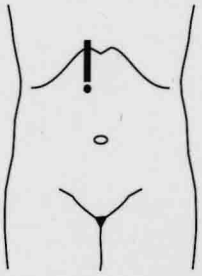
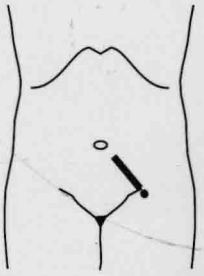
The Most Important Imaging Planes in Abdominal Ultrasound



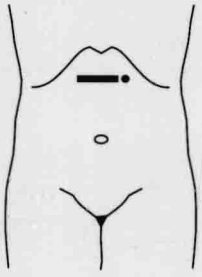
Sagittal upper abdomen,
left paramedian plane



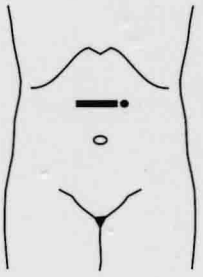
Sagittal upper abdomen,
right paramedian plane



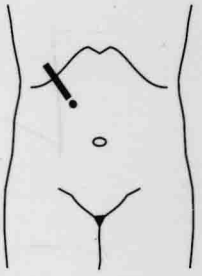
Oblique lower abdomen,
para-iliac plane



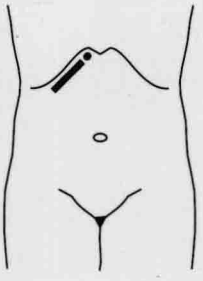
Transverse epigastric
upper abdomen



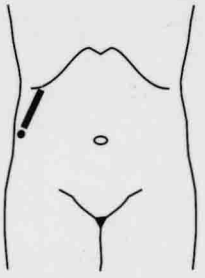
Transverse upper abdomen



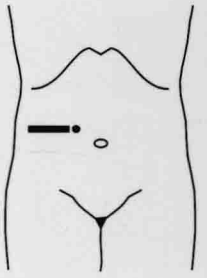
Oblique right upper abdomen
(portal vein)



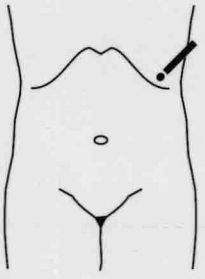
Right oblique subcostal plane
(hepatic venous star)



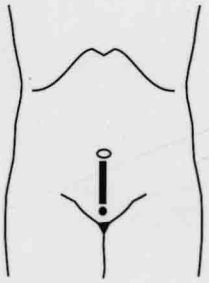
Longitudinal transhepatic plane
(right kidney)



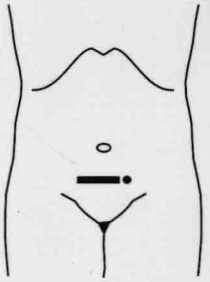
Transverse right mid-abdomen



High plane of the left flank



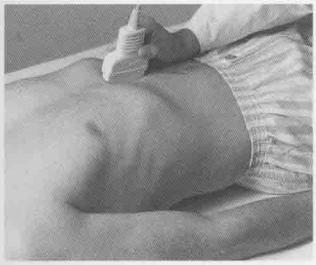
Median sagittal suprapubic plane

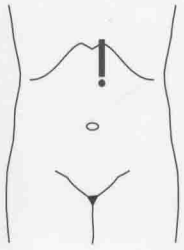


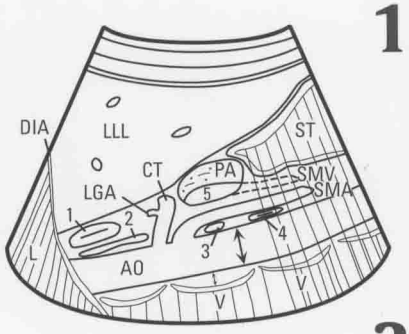
Transverse suprapubic plane

Please try to figure out which organ will be visualized in which image plane.
You will find the solution on the reverse side after flipping this page out.

Standard Planes with Corresponding Position of the Transducer and Diagrams

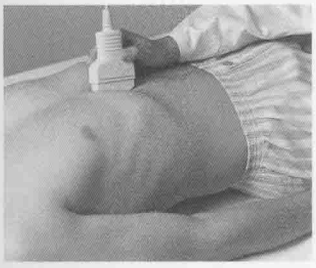


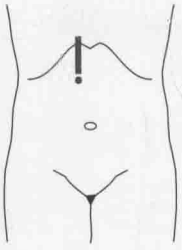


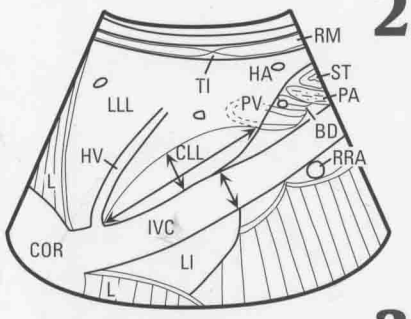


1. Sagittal upper abdomen, left paramedian plane (AO)

Visualized organs and vessels:
Lung (L), left lobe of liver (LLL), stomach (ST), pancreas (PA), aorta (AO), celiac trunk (CT), left gastric artery (LGA), superior mesenteric artery and vein (SMA, SMV), vertebra (V), diaphragm (DIA), five hypoechoic "eggs": esophagus (1), crus of diaphragm (2), left renal vein (3), duodenum (4), confluence of the portal vein (5)

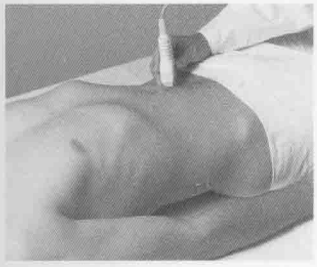


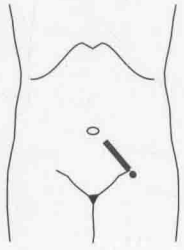


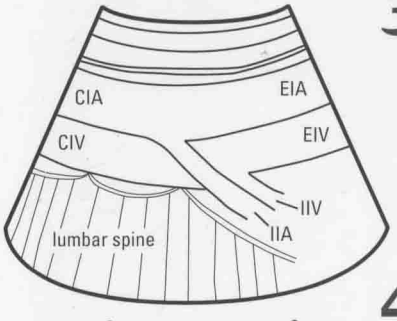


2. Sagittal upper abdomen, right paramedian plane (IVC)

Visualized organs and vessels:
Rectus abdominis muscle (RM), Left lobe of liver (LLL), tendinous intersection (TI), caudate lobe (CLL), stomach (ST), pancreas (PA), diaphragm, vertebra, right renal artery (RRA), inferior vena cava (IVC), hepatic vein (HV), bifurcation of portal vein (PV), hepatic artery (HA), bile duct (BD), heart (COR)

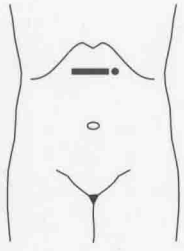


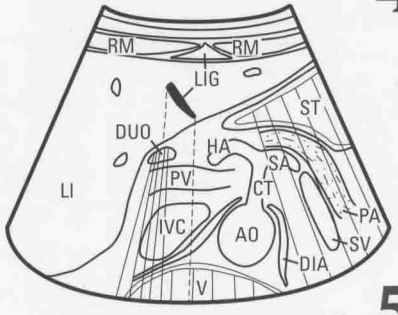




3. Oblique lower abdomen, para-iliac plane

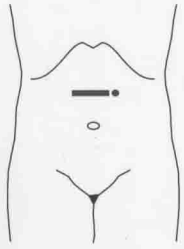
Visualized organs and vessels:
Small bowel, colon, psoas major muscle, bladder, lumbar spine, promontory. Iliac vessels: common iliac artery (CIA), external iliac artery (EIA), internal iliac artery (IIA), common iliac vein (CIV), external iliac vein (EIV), internal iliac vein (IIV)

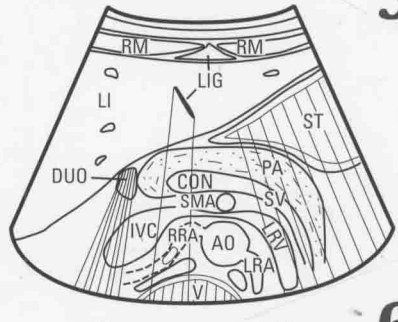




4. Transverse epigastric upper abdomen (celiac trunk)

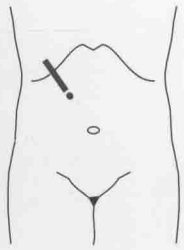
Visualized organs and vessels:
Rectus abdominis muscle (RM), teres and falciform ligament (LIG), liver (LI), stomach (ST), duodenum (DUO), pancreas (PA), celiac trunk (CT), hepatic artery (HA), splenic artery (SA), splenic vein (SV), portal vein (PV), inferior vena cava (IVC), aorta (AO), diaphragm (DIA), vertebra (V)

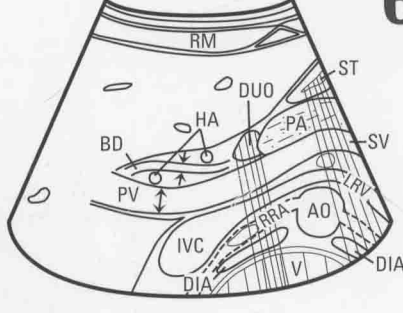




5. Transverse upper abdomen (left renal vein crossing)

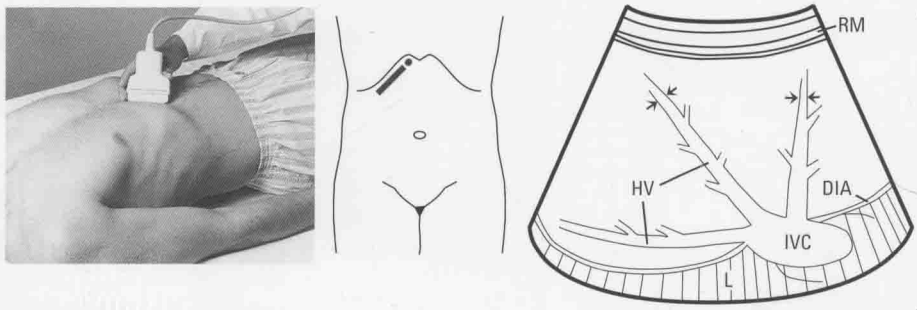
Visualized organs and vessels:
Rectus abdominis muscle (RM), teres and falciform ligament (LIG), liver (LI), stomach (ST), duodenum (DUO), pancreas (PA), splenic vein (SV), confluence of the portal vein (CON), superior mesenteric artery (SMA), left renal vein (LRV), inferior vena cava (IVC), aorta (AO), diaphragm (DIA), vertebra (V), left renal artery (LRA)





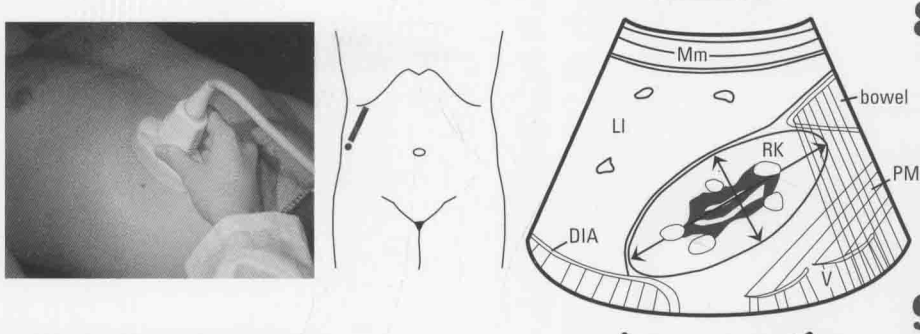
6. Oblique right upper abdomen (porta hepatis)

Visualized organs and vessels:
Rectus abdominis muscle (RM), teres and falciform ligament (LIG), liver (LI), stomach (ST), duodenum (DUO), pancreas (PA), hepatic artery (HA), bile duct (BD), portal vein (PV), splenic vein (SV), inferior vena cava (IVC), right renal artery (RRA), aorta (AO), diaphragm (DIA), vertebra (V), left renal vein (LRV)



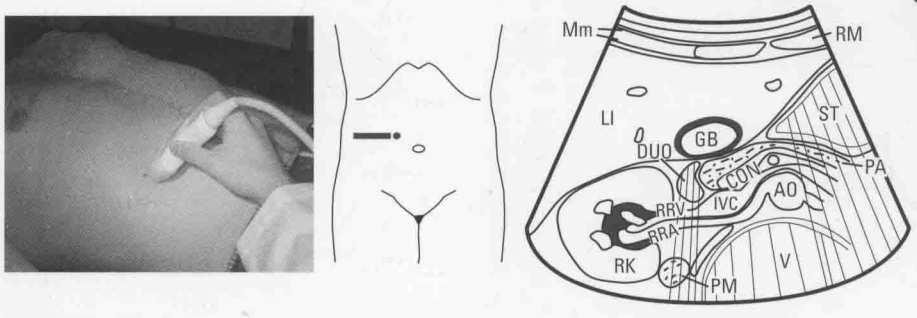
7. Right oblique subcostal plane (hepatic veins)

Visualized organs and vessels:
Rectus abdominis muscle (RM) and oblique muscles, liver, diaphragm (DIA), lung (L), hepatic veins (HV), inferior vena cava (IVC), heart



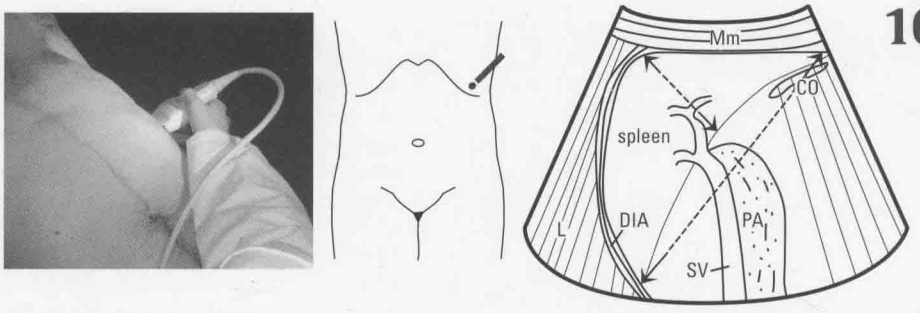
8. Longitudinal transhepatic plane showing right kidney

Visualized organs and vessels:
Oblique/rectus muscles (Mm), liver (LI), diaphragm (DIA), right kidney (RK) and adrenal gland, psoas major muscle (PM), colon, small bowel, lumbar spine (V)



9. Transverse plane showing right kidney and IVC

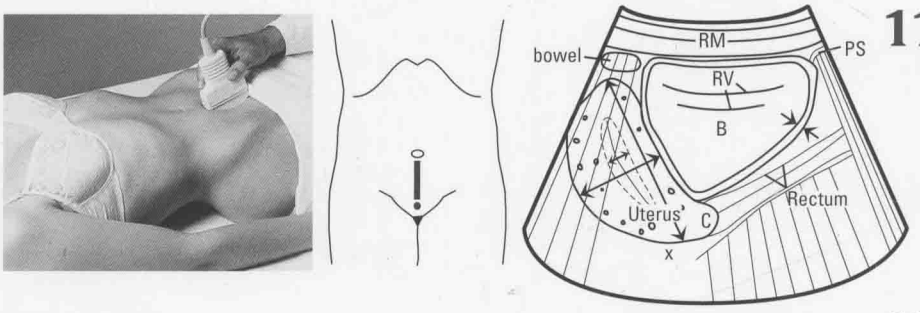
Visualized organs and vessels:
Oblique muscles (Mm), rectus muscle (RM), liver (LI), diaphragm, right kidney (RK), psoas major muscle (PM), duodenum (DUO), lumbar spine (V), pancreas (PA), stomach (ST), gallbladder (GB), right renal artery (RRA), right renal vein (RRV), rectus abdominis muscle (RM), aorta (AO), inferior vena cava (IVC), confluence of the portal vein (CON)



10. High plane of the left flank (spleen)

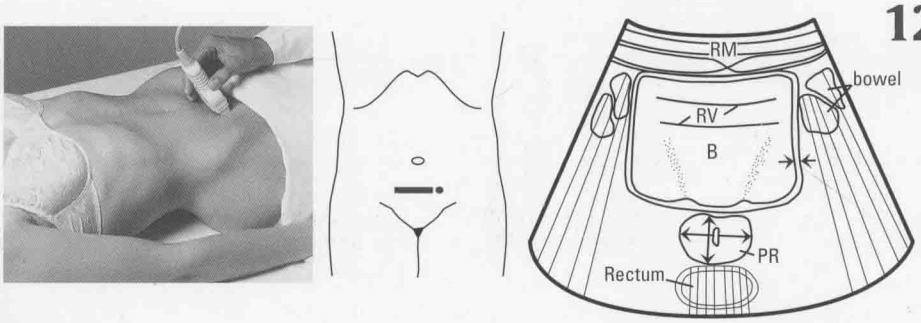
Visualized organs and vessels:
Intercostal muscles (Mm), lung (L), diaphragm (DIA), spleen, tail of pancreas (PA), colon (CO), small bowel, splenic vein (SV)

Caution:
Top edge of image = lateral
Bottom edge of image = medial



11. Median sagittal suprapubic plane (bladder and uterus)

Visualized organs and vessels:
Rectus abdominis muscle (RM), linea alba, small bowel, bladder (B), rectum, uterus or prostate, seminal vesicles, pubic symphysis (PS), pouch of Douglas (x), vagina (V), cervix (C), reverberation artifacts (RV)



12. Transverse suprapubic plane (bladder and prostate gland)

Visualized organs and vessels:
Rectus abdominis muscle (RM), linea alba, small bowel, bladder (B), rectum, uterus, ovaries or prostate (PR), seminal vesicles, reverberation artifacts (RV)

Ultrasound technique videos – the perfect supplement!

Dynamic video sequences, in which doctors perform ultrasound scans of abdominal organs and vessels, on MediaCenter.thieme.com supplement the *Ultrasound Teaching Manual*, giving you the opportunity to view the examination techniques in detail. The sequences are short (each about 2–5 minutes) to maximize their impact and make it easier to retain the material. The videos are divided into the following sections:

I. **Introduction for beginners.**
A brief demonstration of the systematic approach and examination sequence on an anatomic poster, covering:
- Retroperitoneum
- Porta hepatis
- Liver
- Gallbladder
- Kidneys
- Spleen
- Bladder
- Orientation in the female pelvis
- FAST
- Thyroid gland

II. **Handling the transducer.**
Precise examination sequences and tips for transducer positioning, covering:
- General introduction to transducer positioning
- Retroperitoneum
- Porta hepatis
- Liver
- Gallbladder
- Right kidney
- Left kidney
- Spleen
- Bladder
- FAST
- Thyroid gland

III. **Transducer positioning and resulting ultrasound images.**
Synchronized detailed explanations of scanning procedures of:
- Retroperitoneum
- Porta hepatis
- Liver
- Gallbladder
- Right kidney
- Left kidney
- Spleen
- Bladder
- Orientation in the female pelvis
- FAST
- Thyroid gland

System requirements on next page.

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This book cannot be returned once this panel has been scratched off.

	WINDOWS	MAC	TABLET
Recommended Browser(s)**	Microsoft Internet Explorer 8.0 or later, Firefox 3.x	Firefox 3.x, Safari 4.x	HTML5 mobile browser. iPad — Safari. Opera Mobile — Tablet PCs preferred.
	*** all browsers should have JavaScript enabled*		
Flash Player Plug-in	Flash Player 9 or Higher* ** Mac users: ATI Rage 128 GPU does not support full-screen mode with hardware scaling*		Tablet PCs with Android OS support Flash 10.1
Minimum Hardware Configurations	Intel® Pentium® II 450 MHz, AMD Athlon™ 600 MHz or faster processor (or equivalent) 512 MB of RAM	PowerPC® G3 500 MHz or faster processor Intel Core™ Duo 1.33 GHz or faster processor 512MB of RAM	Minimum CPU powered at 800MHz 256MB DDR2 of RAM
Recommended for optimal usage experience	Monitor resolutions: • Normal (4:3) 1024×768 or Higher • Widescreen (16:9) 1280×720 or Higher • Widescreen (16:10) 1440×900 or Higher DSL/Cable internet connection at a minimum speed of 384.0 Kbps or faster WiFi 802.11 b/g preferred.		7-inch and 10-inch tablets on maximum resolution. WiFi connection is required.

Tips for the Reader

How can you use this workbook optimally?
As you work through the individual chapters, you can benefit from several methodical and didactic features:

Find it quickly ...

- Find a chapter: you will find the respective tab for each chapter on page 5.
- Find tough quiz questions for in-depth study, also explained on page 5.
- Find cross-referenced figures: the figures are numbered according to the page on which they appear. For example, **Fig. 36.2** is on page 36.
- Find an explanatory figure or diagram supplementing the text. They are highlighted in light blue in the accompanying text and are almost always on the same page, eliminating the need to page through the book looking for them.
- Find numbered structures. Their reference numbers appear in bold in the accompanying text or on the back cover flap (the same number is used throughout the entire book).
- Find keywords on page 121 (or on pages 4 and 5).
- Find normal values and checklists. These are also provided on laminated, water-resistant, pocket-sized cards.

Why is this book called a "workbook"?
A unique feature of this book is that you can use every page as a quiz to test your knowledge. The diagrams contain reference numbers instead of labels. This means you can go through the material a second time and use any figure to test which structures you know and which you still have to learn. The quiz questions and drawing exercises have a similar purpose.

In this way, you can become familiar with several efficient study methods that allow you to integrate new material into your long-term memory faster – even though this requires you to take a more active approach to learning. Not only do I wish you good luck with this course, I also hope you have fun doing it!

Matthias Hofer, MD, MME, October 2012

List of Abbreviations

A.	Artery
Aa.	Arteries
AC	Abdominal circumference (fetus)
AG	Adrenal gland
AIUM	American Institute of Ultrasound in Medicine
AO	Aorta
ASD	Atrial septal defect
BPD	Biparietal diameter (fetus)
b/w	Black-white (B-mode) ultrasound
CCD	Chorionic cavity diameter
CCE	Cholecystectomy
CCW	Craniocerebral width of the external subarachnoid space
CHI	Contrast harmonic imaging
CRL	Crown–rump length (fetus)
CSF	Cerebrospinal fluid
CT	Computed tomography
CW	Continuous wave (Doppler)
d_{Ao}	Diameter of the aorta
DGC	Depth gain compensation
d_{VC}	Diameter of the vena cava
ERCP	Endoscopic retrograde cholangiopancreatography
ESWL	Extracorporeal shock wave lithotripsy
FL	Femur length (fetus)
FNH	Focal nodular hyperplasia
FOD	Fronto-occipital diameter (fetus)
GI	Gastrointestinal
HC	Head circumference
HCG	Human chorionic gonadotropin
IHW	Width of the SAS in the interhemispheric fissure
IUD	Intrauterine device
IVC	Inferior vena cava
IVF	In vitro fertilization
IVP	Intravenous pyelogram
LA	Lower abdomen
Lig.	Ligament
LN	Lymph node
M.	Muscle
MA	Mid-abdomen
MCL	Midclavicular line
MCU	Micturating cystourethrogram = voiding cystourethrogram
MHz	Megahertz (unit of frequency)
Mm.	Muscles
MRI	Magnetic resonance imaging
mW	Milliwatt
NHL	Non-Hodgkin lymphoma
NT	Nuchal translucency (fetus)
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Ultrasound Teaching Manual

An Introductory Workbook

Third expanded and revised English edition

Matthias Hofer

782 figures and 43 tables

Thieme

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Tips for the Reader

How can you use this workbook optimally?
As you work through the individual chapters, you can benefit from several methodical and didactic features:

Find it quickly ...

- Find a chapter: you will find the respective tab for each chapter on page 5.
- Find tough quiz questions for in-depth study, also explained on page 5.
- Find cross-referenced figures: the figures are numbered according to the page on which they appear. For example, **Fig. 36.2** is on page 36.
- Find an explanatory figure or diagram supplementing the text. They are highlighted in light blue in the accompanying text and are almost always on the same page, eliminating the need to page through the book looking for them.
- Find numbered structures. Their reference numbers appear in bold in the accompanying text or on the back cover flap (the same number is used throughout the entire book).
- Find keywords on page 121 (or on pages 4 and 5).
- Find normal values and checklists. These are also provided on laminated, water-resistant, pocket-sized cards.

Why is this book called a "workbook"?
A unique feature of this book is that you can use every page as a quiz to test your knowledge. The diagrams contain reference numbers instead of labels. This means you can go through the material a second time and use any figure to test which structures you know and which you still have to learn. The quiz questions and drawing exercises have a similar purpose.

In this way, you can become familiar with several efficient study methods that allow you to integrate new material into your long-term memory faster – even though this requires you to take a more active approach to learning. Not only do I wish you good luck with this course, I also hope you have fun doing it!

Matthias Hofer, MD, MME, October 2012

List of Abbreviations

A.	Artery
Aa.	Arteries
AC	Abdominal circumference (fetus)
AG	Adrenal gland
AIUM	American Institute of Ultrasound in Medicine
AO	Aorta
ASD	Atrial septal defect
BPD	Biparietal diameter (fetus)
b/w	Black-white (B-mode) ultrasound
CCD	Chorionic cavity diameter
CCE	Cholecystectomy
CCW	Craniocerebral width of the external subarachnoid space
CHI	Contrast harmonic imaging
CRL	Crown–rump length (fetus)
CSF	Cerebrospinal fluid
CT	Computed tomography
CW	Continuous wave (Doppler)
d_{Ao}	Diameter of the aorta
DGC	Depth gain compensation
d_{VC}	Diameter of the vena cava
ERCP	Endoscopic retrograde cholangiopancreatography
ESWL	Extracorporeal shock wave lithotripsy
FL	Femur length (fetus)
FNH	Focal nodular hyperplasia
FOD	Fronto-occipital diameter (fetus)
GI	Gastrointestinal
HC	Head circumference
HCG	Human chorionic gonadotropin
IHW	Width of the SAS in the interhemispheric fissure
IUD	Intrauterine device
IVC	Inferior vena cava
IVF	In vitro fertilization
IVP	Intravenous pyelogram
LA	Lower abdomen
Lig.	Ligament
LN	Lymph node
M.	Muscle
MA	Mid-abdomen
MCL	Midclavicular line
MCU	Micturating cystourethrogram = voiding cystourethrogram
MHz	Megahertz (unit of frequency)
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P

Image Formation

Ultrasound images are generated not by X-rays but by sound waves that are sent by a transducer into the human body and reflected there. In abdominal ultrasound, the frequencies used generally are between 2.5 and 5.0 megahertz (MHz; see p. 9).

The primary condition required for sound wave reflections is the presence of so-called "impedance mismatches." These occur at the interface between two tissue layers with different sound transmission properties (interfaces in **Fig. 6.2**). It is interesting to note that different soft tissues show only minor differences in the transmission of sound **(Table 6.1)**. Only air and bone are marked by massively different sound transmission in comparison with other human tissue.

For this reason ultrasound units can be operated at a preselected medium frequency of approximately 1540 m/s without producing any major inaccuracies in the calculated origin ("depth") of the echo. The processor computes the depth of origin of the echo from the time difference detected between emission of the sound impulse and return of the echo. Echoes from tissue close to the transducer **(A)** arrive earlier **(t_A)** than echoes from deeper tissues (t_B, t_C in **Fig. 6.2a**). The mean frequency is strictly theoretical since the processor cannot know which type of tissue was traversed.

Sound Transmission in Human Tissue

Air	331 m/s	
Liver	1549 m/s	
Spleen	1566 m/s	mean = 1540 m/s
Muscle	1568 m/s	
Bone	3360 m/s	

Table 6.1

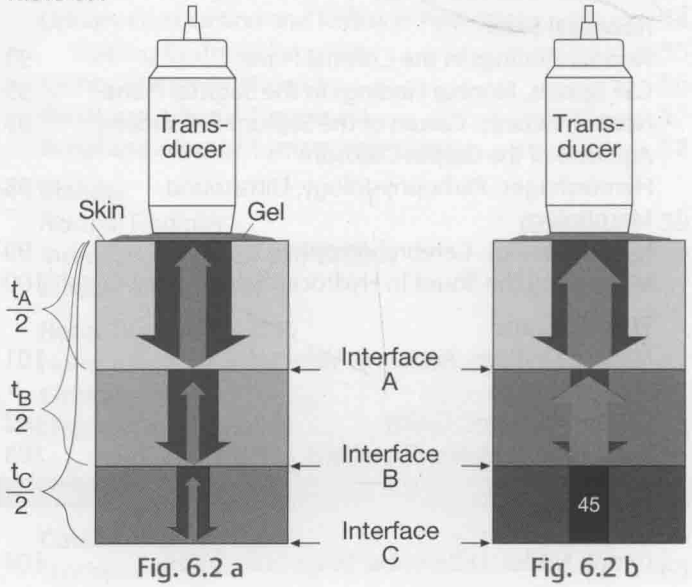

Fig. 6.2 a Fig. 6.2 b

Which Component of the Sound Wave is Reflected?

Fig. 6.2a shows three tissue blocks traversed by sound waves that differ only minimally in their transmission velocity (indicated by similar gray values). Each interface only reflects a small portion of the original sound waves (⬇) as echo (⬆). The right–hand diagram shows a larger impedance mismatch at the interface A between the different tissues **(Fig. 6.2b)**. This increases the proportion of reflected sound waves (⬆) in comparison to the tissues shown on the left. However, what happens if the sound waves hit air in the stomach or a rib? This causes a so-called "total reflection," as illustrated at interface B **(Fig. 6.2b)**. The transducer does not detect any residual sound waves deep to this structure from which it can generate an image. Instead, the total reflection creates an acoustic shadow **(45)**.

Conclusion: Intestinal or pulmonary air and bone are impenetrable by sound waves, precluding any imaging deep to these structures. The goal will later be to work around intestinal air or ribs by maneuvering the transducer. The pressure applied to the transducer against the abdominal wall (see p. 19) and the acoustic gel that displaces air between the surface of the transducer and the patient's skin (see p. 20) play a significant role.

From a "Snowstorm" to an Image ...

Do not get discouraged if at first you can only make a blinding "snowstorm" on ultrasound images. You will be surprised how soon you will recognize the ultrasound morphology of individual organs and vessels. **Fig. 6.3** shows two round polyps **(65)** in the gallbladder **(14)**, visualized as a black structure. The surrounding gray "snowstorm" corresponds to the hepatic parenchyma **(9)**, which is traversed by hepatic vessels **(10, 11)**. How can you quickly work out which structures in the image appear bright and which are dark? The key lies in the concept of echogenicity (see p. 7).

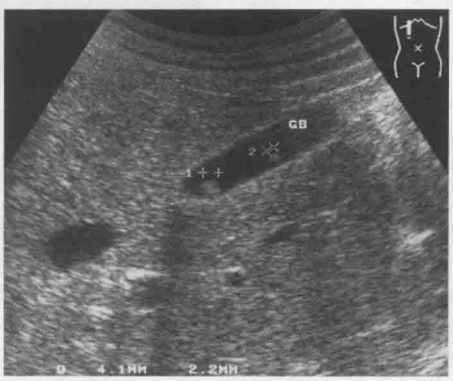

Fig. 6.3 a

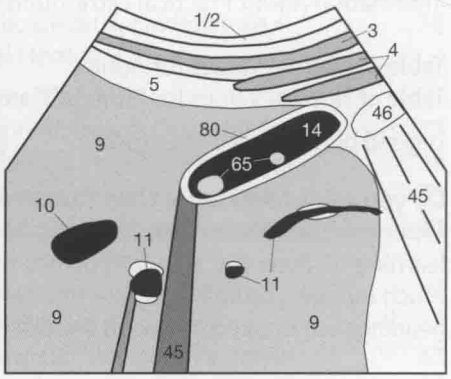

Fig. 6.3 b