Atlas of Head and Neck Ultrasound

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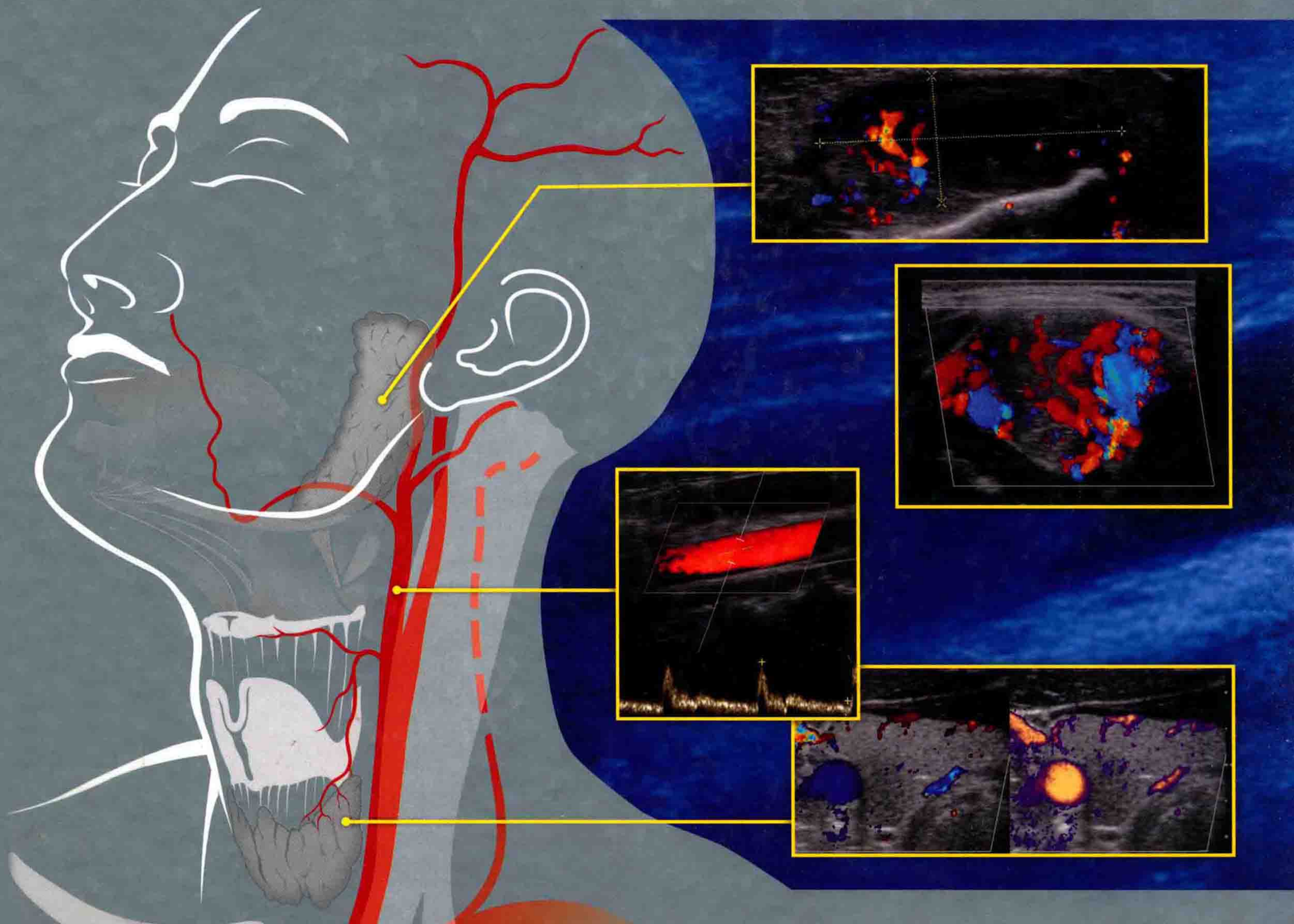

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For an overview of the available content, see the List of Videos on pages XII and XIII.

System requirements:

	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.

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Preface

Since the first application of ultrasound in the examination of the head and neck in the second half of the last century, technical advances in this dynamic imaging modality have led to a greater understanding of the anatomy and pathology in this area.

Digital imaging processing and state-of-the-art transducer technology now yield an image quality with submillimeter resolution, which enables even the smallest tissue changes to be seen and which, for certain indications, is superior to that of computed tomography (CT) and magnetic resonance imaging (MRI). New procedures, such as tissue harmonic imaging, compound imaging, elastography, panoramic views, and contrast-enhanced ultrasound, together with color Doppler scanning, combined in one system, provide information not only on the appearance of an organ but also on its function and activity.

CT and MRI are claimed to give a comprehensive picture of the head and neck. However, the disadvantages of these methods, in comparison with ultrasound, are obvious: an imaging technique that is not universally and immediately available causes delay in the diagnostic and therapeutic management. Furthermore, it is essential to have all the necessary information available in order to interpret the findings; that is to say, the clinical history, laboratory findings, clinical findings on examination, and the results of the endoscopy. It is principally the treating physicians who are in possession of all this information and who are also in a position to perform the ultrasound scans themselves, thus enabling them to assess the findings in the overall context.

The more extensive and complicated the technical possibilities, the more difficult it is to adjust system parameters and interpret the data obtained. A thorough grounding in the technical basics, anatomical landmarks, and typical constellations of the findings is indispensable.

For this reason, ultrasonography is a method that depends greatly on the examiner; one of our aims in producing the atlas is to counteract this frequently voiced criticism. The fact is, however, that ultrasound is no less, but equally no more dependent on the examiner than are CT and MRI. Experience comes only with practice. We have therefore tried to provide a practical manual that is as relevant as possible for routine application.

During their more than 20 years' experience, the authors have provided continuing professional education and ultrasound courses to try to overcome the problems and stumbling blocks that continue to beset the use of this fascinating method of examination.

This atlas is intended not only to give beginners a systematic introduction to the basics of head and neck ultrasonography but also to provide more experienced users with the opportunity of gaining further in-depth knowledge. We have chosen the layout especially to give rapid access to everyday problems. The comprehensive text in Section 1 on ultrasound basics should also provide a step-by-step introduction to the individual topics. To provide an overall picture of the ultrasound appearance of the head and neck, we have also included more complicated interdisciplinary topics, such as the thyroid gland and blood vessels. As far as possible, we have used images from the latest ultrasound systems, so that the findings demonstrated are of optimal quality. In addition to static images on the pages of the book, we can also present the material as video clips so that readers can check their understanding of the material. Thus the web-based part of the atlas offers the reader further access to typical findings. These video clips allow one to identify anatomy, allow pathology to be seen even more clearly, and illustrate the particular advantages of ultrasonography as a dynamic procedure.

Thanks to its noninvasive nature and high informational value, we consider ultrasound to be an indispensable component in the diagnosis and treatment of conditions of the head and neck. And this is confirmed by more than 3500 examinations performed every year in our department at our clinic.

Heinrich Iro
Alessandro Bozzato
Johannes Zenk
November 2012

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Abbreviations

AACE American Association of Clinical Endocrinologists
ARFI acoustic radiation force impulse
ATA American Thyroid Association
BCC basal cell carcinoma
bTSH basal TSH
CCA common carotid artery
CCDS color-coded duplex sonography
CEA carcinoembryonic antigen
CHD coronary heart disease
CI compounding imaging
CPS contrast pulse sequence
CRP C-reactive protein
CT computed tomography
CW continuous wave
DGC depth gain compensation
ECA external carotid artery
ECST European Carotid Surgery Trial
ENT ear, nose, and throat
ESR erythrocyte sedimentation rate
FFT fast Fourier transform
FNAB fine-needle aspiration biopsy
FNAC fine-needle aspiration cytology
GSM grayscale median
ICA internal carotid artery
IJV internal jugular vein
IMT intima–media thickness
MALT mucosa-associated lymphatic tissue
MEN2 multiple endocrine neoplasia
MI mechanical index
MIP maximum intensity projection
MRI magnetic resonance imaging
NASCET North American Symptomatic Carotid Endarterectomy Trial
NTM nontuberculous mycobacteria
PEIT percutaneous ethanol injection therapy
PET-CT positron emission tomography–computed tomography
PI phase inversion (in Chapter 14)
PI pulsatility index (in Chapter 2)
PRF pulse repetition frequency
PSV peak systolic velocity
PW pulsed wave
RI resistance index
TB tuberculosis
TGC time gain compensation
THI tissue harmonic imaging
TPO Ab antibodies to thyroid peroxidase
VA vertebral artery

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III Advanced Ultrasound Methods and Outlook

I General Considerations

1 Basic Principles of Ultrasound

Gert Hetzel

Knowledge of the physical and technological principles of ultrasound is the key to understanding sonographic images and findings and for evaluating the opportunities and limits of the method.

Physical Principles of B-mode Ultrasound Scanning

The sound wave is a purely mechanical wave. Reflections of transmitted ultrasound waves from features deep inside tissues are the basis of ultrasound diagnostics. These are processed into a sectional image corresponding to a section of the human body.

Influence of the Ultrasound Frequency

The definition of "ultrasound" is with reference to the human hearing range, which is 16 Hz to 20 kHz. Diagnostic ultrasound uses a frequency range between 2 MHz and 30 MHz (**Fig. 1.1**).

For most of today's applications in the field of ear, nose, and throat (ENT), center frequencies between 5 and 18 MHz are used, typically 7.5 MHz. This range offers the required penetration and high spatial resolution.

The propagation velocity of ultrasound waves depends on the material in which they propagate. A mean sound wave velocity of c = 1540 m/s (a value averaged from different soft tissues and standardized internationally; close to the sound wave velocity in water) is assumed for the different types of tissue in the human body. If the run time of a sound signal is measured, a reflection can be clearly allocated to the place of its origin with a given sound wave velocity.

Frequency (f) and velocity (c) determine the wavelength (λ) of the propagating sound wave:

$$\lambda = c/f$$

For example:

$$f = 7.5\,\text{MHz} \quad \text{implies} \quad \lambda = 0.2\,\text{mm}$$

The wavelength λ is the theoretical limit of resolution, which can never be fully reached. Since the wavelength is shorter for higher sound frequencies, the maximum reachable resolution will be higher with higher sound frequencies.

The frequency is an important factor influencing image quality.

Ultrasound is attenuated when passing through tissues, for example, by absorption. **Absorption** (attenuation) is the loss of sound energy—for example through its conversion into heat—and increases with increasing travel distance through the medium. Absorption depends on a tissue-specific absorption constant and the ultrasound frequency (**Fig. 1.2**).

Owing to this frequency-dependent attenuation of sound energy, the depth of penetration in a tissue depends not only on the tissue but importantly on the frequency.

Absorption losses can be compensated, within certain limits, by depth-dependent echo amplification control (**DGC**, depth gain compensation; or **TGC**, time gain compensation) within the ultrasound system.

The depth of **penetration** is the maximum distance between the ultrasound transducer and the deepest structures inside the tissue that can still be imaged without interference by noise. As noted, the frequency substantially influences the penetration: the depth of penetration is *inversely proportional* to the frequency. For this reason, certain working frequency ranges have proven advantageous, depending on the specific application. High frequencies are suitable for imaging near-surface structures, whereas lower frequencies are suitable for greater field depths.

Generation of Ultrasound

Piezoelectric Effect

When an electrical voltage is applied to a piezoelectric element, the element will mechanically deform. Conversely, an electrical voltage will be generated by the mechanical deformation of a piezoelectric element. Piezoelectric elements are used for ultrasound generation (**Fig. 1.3**). Alternating electrical pulses induce these elements to oscillate. The frequency of oscillation depends on the structure (e.g., thickness) and the technological features of the element. Conversely, when

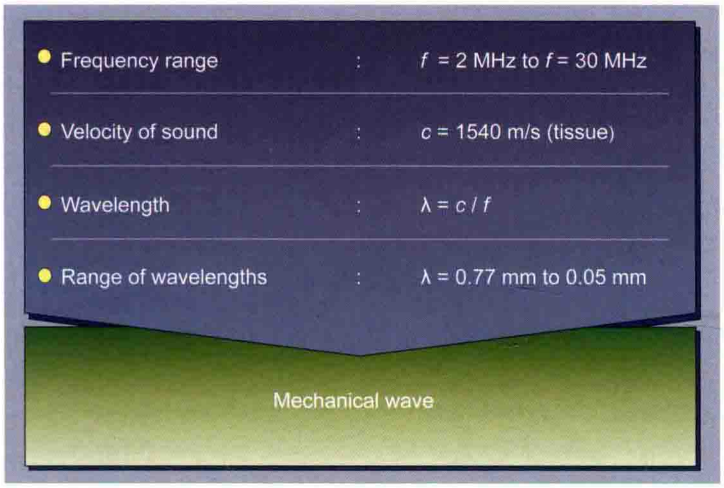

Fig. 1.1 Frequency and wavelength relationships. (Courtesy of Siemens AG.)

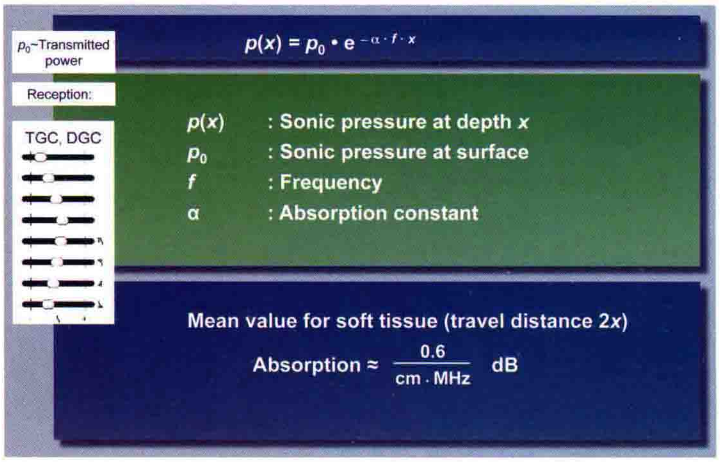

Fig. 1.2 Frequency-dependent attenuation of ultrasound according to the law of absorption. DGC, depth gain compensation; TGC, time gain compensation. (Courtesy of Siemens AG.)