European Practice in Gynaecology and Obstetrics

Ultrasound in Obstetrics and Gynaecology

Edited by

Juriy W **Wladimiroff**

Sturla H **Eik-Nes**

Including CD

ELSEVIER

Ultrasound in Obstetrics and Gynaecology

Edited by

Juriy W Wladimiroff
Emeritus Professor of Obstetrics & Gynaecology
Department of Obstetrics & Gynaecology
Erasmus University Medical Centre
Dr Molewater plein 40
3015 GD Rotterdam
The Netherlands

and

Sturla H Eik-Nes
Professor of Obstetrics
Department of Obstretics and Gynaecology
National Center for Fetal Medicine
University Hospital of Trondheim
Trondheim
Norway

European Practice in Gynaecology and Obstetrics

ELSEVIER

Edinburgh London New York Oxford Philadelphia St Louis Sydney Toronto 2009

ELSEVIER

ISBN-13: 978-0-444-51829-3

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging in Publication Data
A catalog record for this book is available from the Library of Congress

Notice
Neither the Publisher nor the Editors assume any responsibility for any loss or injury and/or damage to persons or property arising out of or related to any use of the material contained in this book. It is the responsibility of the treating practitioner, relying on independent expertise and knowledge of the patient, to determine the best treatment and method of application for the patient.

The Publisher

Printed in China

European Board & College Obstetrics and Gynaecology

Ultrasound in Obstetrics and Gynaecology

European Practice in Gynaecology and Obstetrics

In the same series

Invasive Carcinoma of the Cervix (Volume 1)
Volume Editor: G. Body
ISBN: 2084299-306-3

Breech Delivery (Volume 2)
Volume Editor: W. Künzel
ISBN: 2-84299-314-4

Ovulation Induction (Volume 3)
Volume Editor: B. Tarlatzis
ISBN: 2-84299-316-0

Viral Infection in Pregnancy (Volume 4)
Volume Editor: G. Donders, B. Stray-Pedersen
ISBN: 2-84299-317-9

Endometrial Cancer (Volume 5)
Volume Editor: P. Bösze
ISBN: 0-444-51361-2

Paediatric and Adolescent Gynaecology (Volume 6)
Volume Editor: J.J. Amy
ISBN: 0-444-51360-4

Diabetes and Pregnancy (Volume 7)
Volume Editor: A. Van Assche
ISBN: 0-444-51513-5

Contraception and Family Planning (Volume 8)
Volume Editor: I. Milsom
ISBN: 0-444-51828-2

The Menopause (Volume 9)
Volume Editor: R. Erkkola
ISBN: 0-444-51830-4

www.elsevierhealth.com/series/ebcog/

Scientific Committee

Commissioning Editor: Pauline Graham
Development Editor: Lulu Stader, Greyling Peoples
Project Manager: Elouise Ball
Designer: Kirsteen Wright
Illustration Manager: Bruce Hogarth

Contributors

Domenico Arduini MD
Associate Professor
Cattedra Medicina dell'Eta Prenatale
Universita di Tor Vergata
Rome
Italy
Fetal biometry, estimation of gestational age, assessment of fetal growth

Bernard Benoit
Hôpital Princesse Grace
Monaco
Three-dimensional and four-dimensional ultrasound application in prenatal diagnosis

Harm-Gerd K.Blaas MD, PhD
National Centre for Fetal Medicine
St Olav's Hospital
University Hospital Trondheim
Trondheim
Norway
Investigation of early pregnancy

Bruno Cacciatore MD, PhD
Professor of Obstetrics and Gynaecology
Department of Obstetrics and Gynaecology
Helsinki University Hospital
Helsinki, Finland
Doppler ultrasonography in gynaecology

José M. Carrera PhD
Professor of Obstetrics and Gynaecology
Fetal Medicine Unit
Department of Obstetrics and Gynaecology
Institute University Dexeus
Barcelona
Spain
Investigation of early pregnancy

Rabih Chaoui
Centre for Prenatal Diagnosis and Human Genetics
Berlin
Germany
Three-dimensional and four-dimensional ultrasound application in prenatal diagnosis

Frank A. Chervenak MD
Given Foundation Professor and Chairman
Department of Obstetrics and Gynecology
Weill Medical College of Cornell University
New York
USA
Ethics and patient information

Werner Diehl
Department of Prenatal Diagnosis and Therapy
AK Barmbek
Hamburg
Germany
Multiple pregnancies

Francis A. Duck PhD, DSc
Medical Physicist
Department of Medical Physics and Bioengineering
Royal United Hospital
Bath
UK
Biological effects and safety aspects

Sturla H. Eik-Nes
Professor of Obstetrics and Gynaecology
Department of Obstetrics and Gynaecology
National Centre for Fetal Medicine
University Hospital of Trondheim
Trondheim
Norway
Physics and instrumentation
Amniotic fluid and placental localization
Examining the cervix by transvaginal ultrasound

Annegret Geipel MD
Priv. Doz. Dr. Med
Leitende Oberärztin Pränatalmedizin
Abteilung für Geburtshilfe und Pränatale Medizin
Universitätsklinikum Bonn
Sigmand-Freud-Str. 25
53105 Bonn
Germany
Evaluation of fetal and uteroplacental blood flow

Ulrich Gembruch
Professor of Obstetrics and Gynaecology
Abteilung fur Praenatale Medizin und Geburtshilfe
Zentrum fuer Geburtshilfe und Frauenheilkunde
Rheinische Friedrich-Wilhelms-Universitaet
Bonn, Germany
Evaluation of fetal and uteroplacental blood flow

Francesco Giacomello MD
Professor
Department of Surgery
University Tor Vergata
Rome
Italy
Fetal biometry, estimation of gestational age, assessment of fetal growth

Kurt Hecher
Professor of Obstetrics and Gynaecology
Department of Prenatal Diagnosis and Therapy
AK Barmbek
Hamburg, Germany
Multiple pregnancies

Eric Jauniaux MD, PhD, MRCOG
Professor in Obstetrics and Fetal Medicine
Academic Department of Obstetrics and Gynaecology
UCL
EGA Institute for Women's Health
Royal Free and University College London
London
UK
Assessment of the placenta and umbilical cord

Davor Jurkovic MD, PhD
Consultant
Early Pregnancy and Gynaecology Ultrasound Unit
Department of Obstetrics and Gynaecology
King's College Hospital
London
UK
Gynaecological pathology: the uterus

Laurence B. McCullough PhD
Dalton Tomlin Chair in Medical Ethics and Health Policy
Professor of Medicine and Medical Ethics
Associate Director for Education
Center for Medical Ethics and Health Policy
Baylor College of Medicine
Houston
Texas
USA
Ethics and patient information

Hylton B. Meire
Consultant Radiologist (Ultrasound)
Bromley
UK
Medico-legal implications of ultrasound imaging in obstetrics and gynaecology

Israel Meizner MD
Professor
Ultrasound Unit
Department of Obstetrics and Gynecology
Rabin Medical Center – Beilinson Campus
Petah-Tikun and Sackler Faculty of Medicine
Tel Aviv University
Tel Aviv, Israel
Prenatal diagnosis of fetal anomalies

Ana Monteagudo MD
Professor of Obstetrics and Gynecology
Department of Obstetrics and Gynecology
New York University School of Medicine
New York
USA
Scanning techniques in obstetrics and gynaecology

Eduard J.H. Mulder Msc, PhD
Professor
Department of Perinatology and Gynaecology
University Medical Center
Utrecht
The Netherlands
Fetal movement patterns and behavioural states

Kypros H. Nicolaides MD
Professor of Fetal Medicine
Department of Obstetrics & Gynaecology
Kings's College Hospital
London
UK
Prenatal diagnosis of fetal anomalies

David A. Nyberg MD
Seattle Ultrasound Associates
Seattle
USA
Normal fetal anatomy at 18–22 weeks

Rüdiger Osmers MD, PhD
Professor of Obstetrics and Gynaecology
Department of Obstetrics and Gynaecology
University Hospital Gottingen
Gottingen
Germany
Gynaecological pathology: tubes and ovaries
Doppler ultrasonography in gynaecology

Gianluigi Pilu MD
Associate Professor of Obstetrics and Gynaecology
Department of Obsetrics and Gynaecology
University of Bologna
Bologna
Italy
Prenatal diagnosis of fetal anomalies

Roberto Romero MD
Professor of Obstetrics and Gynecology
Wayne State University
and
Chief of the Perinatology Research Branch of the National Institute of Child Health and Human Development
National Institutes of Health
Bethsedu, MD
USA
Prenatal diagnosis of fetal anomalies

Rehan Salim MRCOG
Early Pregnancy and Gynaecology Ultrasound Unit
Department of Obstetrics and Gynaecology
King's College Hospital
London
UK
Gynaecological pathology: the uterus

Kjell Å. Salvesen Dr Med, PhD
National Centre for Fetal Medicine
St Olav's Hospital
University Hospital Trondheim
Trondheim
Norway
Examining the cervix by transvaginal ultrasound

Waldo Sepulveda
Professor of Obstetrics and Fetal Medicine
University of Santiago de Chile
San Jose Hospital
and
Director
Fetal Medicine Center
Clinica Las Cordes
Santiago, Chile
Prenatal diagnosis of fetal anomalies

Povilas Sladkevicius MD, PhD
Department of Obstetrics and Gynaecology
Malmö University Hospital
Lund University
Malmö
Sweden
Normal gynaecological anatomy (uterus, tubes, ovaries)

Vivienne L. Souter MD, MRCOG
Seattle Ultrasound Associates
Seattle
USA
Normal fetal anatomy at 18–22 weeks

Ilan E. Timor-Tritsch MD
Professor of Obstetrics and Gynecology
Department of Obstetrics and Gynecology
New York University School of Medicine
New York
USA
Scanning techniques in obstetrics and gynaecology

Lil Valentin MD, PhD
Professor in Obstetrics and Gynaecology
Department of Obstetrics and Gynaecology
Malmö University Hospital
Lund University
Malmö
Sweden
Normal gynaecological anatomy (uterus, tubes, ovaries)

Yves Ville MD
Professor of Obstetrics and Gynaecology
Service Gyneco/Obstetrique
Centre Hospitalier Inter Communal
Poissy
France
Invasive procedures in obstetrics

Gerard H.A. Visser MD, PhD
Professor of Obstetrics and Gynaecology
Department of Perinatology and Gynaecology
University Medical Center
Utrecht
The Netherlands
Fetal movement patterns and behavioural states

Kim Wherey MD
Seattle Ultrasound Associates
Seattle
USA
Normal fetal anatomy at 18–22 weeks

J. W. Wladimiroff
Emeritus Professor of Obstetrics & Gynaecology
Department of Obstetrics & Gynaecology
Erasmus University Medical Centre
Dr Molewater plein 40
3015 GD Rotterdam
The Netherlands
Amniotic fluid and placental localization

Preface

This textbook is the result of a joint venture between the International Society for Ultrasound in Obstetrics and Gynaecology (ISUOG) and the European Board and College of Obstetrics and Gynaecology (EBCOG). Both organizations play an important role in training.

The book aims to provide the reader with the information necessary for every-day ultrasonography in obstetrics and gynaecology, rather than a summary of the latest developments in the field.

The book follows the traditional pattern of starting with the physical and biological aspects of diagnostic ultrasound, followed by a wide range of clinical applications in obstetrics and gynaecology. Each chapter has been written by one or more experts actively involved in ultrasound teaching. Ultrasound images are presented either in the text or separately on a CD at the end of the book. Multiple choice questions are presented at the end to allow the reader to test his or her knowledge.

We hope that this textbook will serve all those who are active in day-to-day ultrasound scanning.

Juriy W. Wladimiroff, Sturla H. Eik-Nes

Contents

1

Physics and instrumentation

Sturla H Eik-Nes

ABSTRACT

This chapter provides an overview of the fundamental physical principles that make it possible to produce images of human tissue using sound. The physical laws are explained without the use of complicated formulas. Sound is a mechanical vibration in a medium such as air or human tissue. The upper frequency limit for sound to be heard by humans is 20 kHz. Frequencies above 20 kHz are called ultrasound. Medical images are made with a frequency above 3 MHz. The basic principle for making images of human tissue is to send a pulse into the tissue with a transducer and detect the echoes emerging from structures in the tissue. Imaging may be done in real time by electronic scanning. A variety of sizes and shapes of transducers have been produced for the various applications of ultrasound in medical diagnosis. A proper transducer must be used for a specific task. The ultrasound beam is the essential tool to make images. It must be focused by the user and the image must be properly adjusted with respect to the gain. Measurements can be made and a basic understanding of the resolution in the three planes is necessary for measurements and interpretation of the images. The main artifacts such as edge shadows, attenuation shadows, enhancements and reverberation must be understood. Basic principles of ultrasound scanning must be followed to extract the maximum information from the scan.

KEYWORDS

A-mode, artifacts, B-mode, focus, M-mode, real-time scanning, technical principles of ultrasound in obstetrics and gynaecology, time gain compensation.

INTRODUCTION

In the practice of clinical ultrasound in obstetrics and gynaecology, it is essential that the examiner has a basic understanding of the physics that makes it possible to produce images of human tissue using sound. In addition, the examiner must be able to handle artifacts properly, know about the basic performance of the instrument and be aware of artifacts, safety and risk factors.

This chapter provides an overview of the fundamental physical principles without the use of complicated formulas to explain the physical laws. The focus is to give the reader an overall understanding of how an ultrasound machine works and the skill to operate the machine and to manage the necessary adjustments in order to produce images of high quality for diagnostic use. For in-depth knowledge of the physics of ultrasound, the reader is referred to excellent textbooks. (See selected list at the end of this chapter.)

SOUND

Sound is mechanical vibrations travelling in a physical medium such as air, water, metal or even human tissue. Whether the airborne vibrations come directly from the source or are reflected, they produce impressions on the eardrums of our vestibular organs. We interpret these vibrations as sound.

Sound may be categorized according to various frequency levels:

- infrasound (0–20 Hz)
- audible sound (20–20 kHz)
- ultrasound (>20 kHz)
- diagnostic ultrasound (1–20 MHz).

Humans do not hear the infrasound but other species such as whales, dolphins, elephants, hippopotamuses and rhinoceros do; they use infrasound to communicate with other members of their species over long distances. The upper frequency limit for humans is 20 kHz. Frequencies above 20 kHz are called ultrasound. Some species may hear sound frequencies which for humans are categorized as ultrasound, for example mice (10–70 kHz), dogs (40–60 kHz) and bats (20–200 kHz). There is even some evidence that bats utilize the change in pitch of the echo to determine the relative movement of the object that reflects sound – the Doppler effect. Marine mammals may produce very complex signals ranging from low frequencies for long-range use to high frequencies for local chatting!

SHORT HISTORY OF THE DEVELOPMENT OF ULTRASOUND IN MEDICINE

In 1912, the passenger ship *Titanic* hit an iceberg on its maiden trip crossing the Atlantic from Southampton to New York. In the time that followed, physicists took an interest in using sound to detect large objects submerged in water. Initially their research for that purpose was unsuccessful. During World War I, the French physicist Paul Langevin was responsible for developing the hydrophones needed to detect submarines; this underwater sonar technology resulted in the first sinking of a German submarine in 1916. In 1917, Langevin invented the quartz sandwich transducer which served as the basis for the modern ultrasonic era. Between

World War I and World War II, the development of sonar (Sound Navigation and Ranging System) and radar (Radio Detection and Ranging) took place. The latter technique used electromagnetic waves rather than ultrasound.

The next important step was the use of ultrasound to detect flaws in metal using high-frequency ultrasound. The metal flaw detectors became increasingly important as World War II was approaching, but were reported after the war.[2,4] After World War II, Howry and Bliss, in Denver, started to experiment with sonar equipment and amplifiers from the navy.[7] They developed a pulse-echo technique in 1948–49, and later produced cross-sectional images of a human partly submerged in water. At the same time, Wild in Minneapolis developed a breast scanner and actually made a diagnosis of breast lesions with his device.[12] The Swedish physician Inge Edler and physicist Helmut Hertz, at the University of Lund, borrowed a metal flaw detector from Kockum's Shipyard in Malmö, Sweden. In 1953, they managed to trace the movements of the human cardiac valves by means of the sound waves emitted and received by their modified instrument.[5] This was the start of a new era in cardiology relying on sound technology.[6]

The next breakthrough was by the Scottish physician Ian Donald, in Glasgow, who conducted the basic research for the development of a machine for clinical use employing ultrasound to make two-dimensional images of human tissue. Donald had served in the Air Force during World War II and his past experience influenced his prototype machine, which consisted of two metal flaw detectors. His *Lancet* paper of 1958, 'Investigation of abdominal masses by pulsed ultrasound', is considered to be one of the most important for the development of clinical ultrasound.[3]

Since the late 1950s, the development of ultrasound in medicine in general and in the field of obstetrics and gynaecology in particular has continued in an exponential way. Breakthrough advances have been repeatedly made in spite of claims that the development of ultrasound in medicine has reached its physical limits.

SOUND, WAVES AND PROPAGATION

Sound is a mechanical vibration in a medium. The medium may be, for example, air, water or human soft tissue. The sound wave propagates through the medium as a longitudinal compression wave. When we think of waves we may picture a stone being thrown into a quiet lake and observe the concentric rings that propagate from the centre, or we may think of the waves in the ocean as seen from the shore or from a boat. These waves are *transversal* waves. Sound waves, however, are *longitudinal* waves and the medium that they travel through is subject to cyclic variations in pressure as the medium is being compressed or rarefied (Fig. 1.1).

Make a small experiment by putting your index finger on the top of your larynx, then make the sound of a z-z-z. With your finger you will feel the vibrations caused by your vocal cords that are your own sound system, that cause the z-z-z to be heard in the room. You have now produced longitudinal sound waves that travel

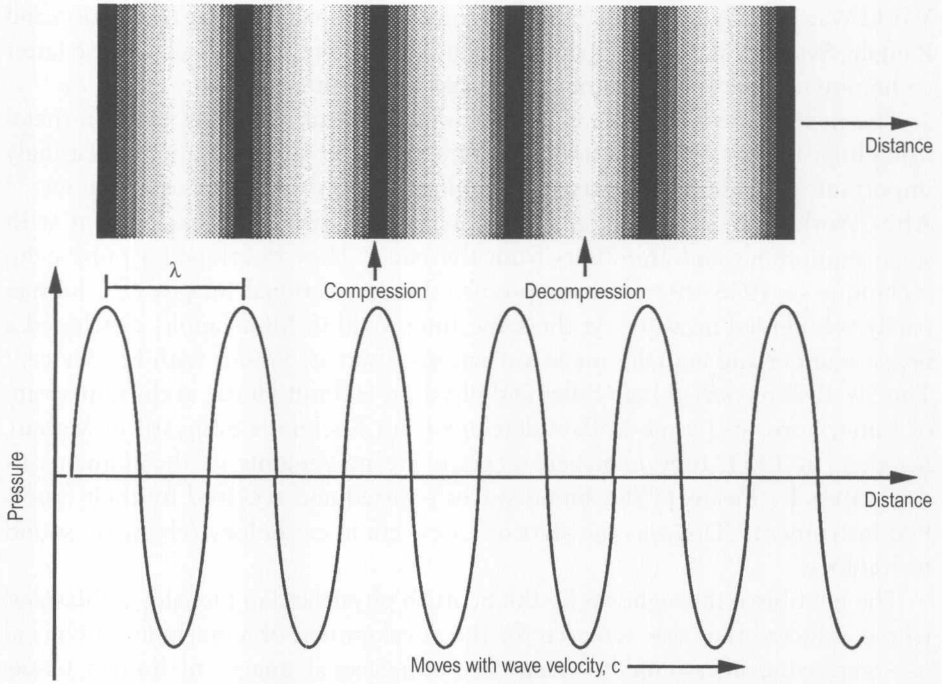

Fig. 1.1 (*Upper panel*) A schematic illustration of a sound wave as it travels in a medium causing periodic compressions and rarefaction of the medium. (*Lower panel*) The dislocation of the particles.

through the room and cause compression and rarefaction of the air in their path. When the sound waves hit the eardrums of someone in the room, the process is reversed and causes the eardrums to vibrate and the person will hear your z-z-z.

The sound wave is a longitudinal wave caused by compression and rarefaction of a physical medium in the direction of the movement of the wave.

This sound wave may further be described by *intensity* and *frequency*.

If you have a piano, you can carry out a small experiment in your living room by hitting A above middle C. You will hear a chamber tone with a frequency of 440 Hz. If you move up one octave on your piano and hit A, you will hear it at a frequency of 880 Hz. If you move up one more octave to the next A, you will hear an A note with the frequency of 1760 Hz.

The frequency tells us about the degree of highness or lowness of a tone. The frequency is the number of vibrations per second that produce the sound.

Hit the A on your piano very lightly and you will barely hear the chamber tone of 440 Hz; hit the key with force and you will hear the same chamber tone with the frequency of 440 Hz, but much louder. This tells us that the same tone may differ in *intensity* or *loudness*.

The intensity tells us something about the loudness or strength of the sound signal.

A sound wave travelling in a medium produces compression and rarefaction of the medium as shown in Figure 1.1. The velocity of propagation of the sound wave is dependent on the medium and is 330 m/s in air, 1480 m/s in water, 1589 m/s in