



Birgit Arabin

# Doppler Blood Flow Measurement in Uteroplacental and Fetal Vessels

Pathophysiological and Clinical Significance

Forewords by S. Campbell  
and E. Saling

With 79 Figures and 35 Tables

Springer-Verlag Berlin Heidelberg New York  
London Paris Tokyo Hong Kong Barcelona

PD Dr. med. BIRGIT ARABIN  
Universitätsklinikum Steglitz  
Frauenklinik  
Hindenburgdamm 30  
D-1000 Berlin 45

ISBN-13:978-3-540-51531-9      e-ISBN-13:978-3-642-74991-9  
DOI: 10.1007/978-3-642-74991-9

Library of Congress Cataloging-in-Publication Data. Arabin, Birgit, 1952– Doppler blood flow measurement in uteroplacental and fetal vessels: pathophysiological and clinical significance/Birgit Arabin. p. cm. Includes bibliographical references. ISBN-13:978-3-540-51531-9 (U.S.:alk.paper)1.Fetal blood. 2. Placenta – Blood-vessels – Ultrasonic imaging. 3. Uterus, Pregnant – Blood-vessels – Ultrasonic imaging. 4. Blood flow – Measurement. 5. Doppler ultrasonography. I. Title. [DNLM: 1. Blood Flow Velocity. 2. Fetal Blood. 3. Placenta-blood supply. 4. Ultrasonics. WQ 212 A658d] RG618.A73 1990 618.3'261–dc20 89-26303

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in other ways, and storage in data banks. Duplication of this publication or parts thereof is only permitted under the provisions of the German Copyright Law of September 9, 1965, in its current version, and a copyright fee must always be paid. Violations fall under the prosecution act of the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1990

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product liability: The publisher can give no guarantee for information about drug dosage and application thereof contained in this book. In every individual case the respective user must check its accuracy by consulting other pharmaceutical literature.

Typesetting: Brühlsche Universitätsdruckerei, Giessen  
2121/3130-543210 – Printed on acid-free paper

To my parents and my teacher,  
the late Professor Fred Kubli,  
whose own activities provided  
constant encouragement.

## **Foreword**

Doppler ultrasound is a hot topic at the present time. This is because studies of the uteroplacental and fetal circulation give fundamental information as to the physiology or pathology of placental function and the response of the fetal circulation to hypoxaemia. Dr. Arabin's clinical studies which are described in this book are an important contribution to knowledge in this field and will be of enormous interest not only to researchers but also to clinicians interested in learning how this latest technology can be integrated into their clinical practice.

London

STUART CAMPBELL

## Foreword

Although only three decades old, the field of perinatal medicine is marked by continuous new advances. Ultrasound diagnostic techniques comprise an important element of this new field. Dr. Arabin has taken the initiative to investigate the functional-diagnostic aspects of ultrasound. Among other things, she has further developed and refined the concept of “oxygen-conserving adaptation of fetal circulation” which originated in the Department of Obstetrics and Gynecology at the Neukölln Hospital Center in 1966. She thus has been able to show that the most reliable Doppler blood flow measurement predictors of a high risk to the fetus are (1) a decrease in the flow volume of the descending thoracic aorta and the umbilical artery and (2) an increase in the flow volume of the common carotid arteries. In this manner, namely by reducing the circulation of the trunk and limbs and increasing the cerebral circulation, the fetus attempts to protect the brain from severe hypoxic damage.

Besides these important observations, this monograph also contains numerous other data of great value to clinicians; for example, normal ranges with regard to quantitative and qualitative blood flow and comparisons of Doppler measurements with other methods for the detection of fetal risk.

A wide variety of clinicians and scientists will be able to use this book as a basis for their further studies.

Berlin

ERICH SALING

# Preface

The original plan for this book dates from 1985 and was the result of the clinical need to relate uteroplacental and fetal Doppler measurements to systematic normal values, to choose the most reliable parameters for the detection of fetal risk, and to determine their diagnostic value for obstetrical management decisions, in comparison to other methods of fetal monitoring.

The memory and the clinical approaches of my teachers, Professor Erich Saling and Professor Fred Kubli, have provided me guidance and inspiration. The manner in which this book was developed was influenced by the support and knowledge provided by Professor Stuart Campbell, Professor Juriy W. Wladimiroff, Professor Sturla Eik-Nes and Professor Joachim W. Dudenhausen. The help of Professor Martin Vogel and Dr. Ezra Jimenez, who analyzed the morphological placental findings, is gratefully acknowledged. Joachim Pachaly (physicist), Axel Mohnhaupt (engineer) and my research students Petra Bergmann and Martin Siebert have assisted me in preparing and analyzing the data. I am especially grateful to Dr. Ute Heilmann for her continuous editorial and personal assistance during the process of publishing.

Since completing the manuscript, more advanced Doppler techniques, mainly color Doppler, have become available, and there has been a substantial growth in our clinical experience, summarized in an ever increasing number of publications. The quality of imaging and research are thus always being improved. I am and shall be grateful for any constructive criticism, shared discoveries, or other contributions to my knowledge in this field.

BIRGIT ARABIN

# Contents

- 1 Introduction . . . . . 1**
- 1.1 Anatomical and Pathophysiological Principles . . . . . 2
- 1.1.1 Uteroplacental Hemodynamics . . . . . 2
- 1.1.2 Fetoplacental Hemodynamics . . . . . 3
- 1.2 Experimental Blood Flow Measurement in Animal and Clinical Studies . . . . . 4
- 1.2.1 Uteroplacental Hemodynamics . . . . . 4
- 1.2.2 Fetoplacental and Fetal Hemodynamics . . . . . 4
- 1.3 Development of Doppler Blood Flow Measurements . . . . . 4
  
- 2 Methodology . . . . . 7**
- 2.1 History of the Doppler Principle . . . . . 7
- 2.2 Fundamental Physical Principles . . . . . 8
- 2.3 The Doppler Technique in Medical Diagnosis . . . . . 9
- 2.3.1 The Doppler Spectrum . . . . . 9
- 2.3.2 Continuous-Wave Doppler Method . . . . . 10
- 2.3.3 Pulsed Doppler Method . . . . . 10
- 2.3.4 Processing of the Doppler Signal . . . . . 10
- 2.3.5 Safety of Doppler Ultrasound . . . . . 12
- 2.4 Description of Our Instrument (Duplex System) . . . . . 13
- 2.5 Practical Procedure . . . . . 15
- 2.5.1 Uteroplacental Vessels . . . . . 15
- 2.5.2 Umbilical Artery . . . . . 16
- 2.5.3 Fetal Descending Thoracic Aorta . . . . . 17
- 2.5.4 Fetal Common Carotid Artery . . . . . 21
- 2.6 Evaluation of Doppler Frequency Spectra . . . . . 21
- 2.6.1 Quantitative Evaluation:  
Blood Flow Velocity/Blood Flow Volume . . . . . 21
- 2.6.2 Qualitative Evaluation: S/D Ratio, Resistance Index,  
Pulsatility Index . . . . . 22
- 2.7 Patient Material and Measurements . . . . . 23
- 2.7.1 Normal Group . . . . . 23
- 2.7.2 Group with Follow-Up Studies of the Placenta . . . . . 24
- 2.7.3 Risk Group . . . . . 24



XIV Contents

2.8	Data Collection . . . . .	25
2.9	Statistical Analysis . . . . .	26
2.9.1	Major Influencing Factors . . . . .	26
2.9.2	Reproducibility . . . . .	27
2.9.3	Calculation of Standard Curves . . . . .	28
2.9.4	Possible Pathophysiological Interrelationships: Correlations Between Blood Flow Parameters and Placental Morphology . . . . .	28
2.9.5	Assessments of Clinical Significance . . . . .	29
2.10	Criticism of Method . . . . .	31
2.10.1	Physiological Variations . . . . .	31
2.10.2	Display of Doppler Spectrum . . . . .	31
2.10.3	Vascular Wall Filter . . . . .	32
2.10.4	Determination of Angle . . . . .	32
2.10.5	Vessel Diameter . . . . .	33
2.10.6	Instrument Used in Our Studies (8130 Duplex) . . . . .	34
<b>3</b>	<b>Results . . . . .</b>	<b>37</b>
3.1	Doppler Blood Flow Measurements in Normal Pregnancy . . . . .	37
3.1.1	Major Factors Affecting Fetal and Uteroplacental Blood Flow Parameters . . . . .	37
3.1.2	Reproducibility . . . . .	43
3.1.3	Normal Values of Uteroplacental and Fetal Blood Flow Parameters . . . . .	44
3.2	Pathophysiological Significance of Doppler Blood Flow Measurements . . . . .	61
3.2.1	Correlation Between Blood Flow Parameters and Pathomorphological Findings in the Placenta . . . . .	61
3.2.2	Blood Flow Parameters in Risk Pregnancies . . . . .	64
3.3	Clinical Significance of Doppler Blood Flow Measurements . . . . .	76
3.3.1	Comparison of Diagnostic Values of Blood Flow Parameters . . . . .	79
3.3.2	Comparison with Other Monitoring Parameters . . . . .	84
3.3.3	Studies in a Group with Loss of Recordable End-Diastolic Velocity in the Umbilical Artery and/or Fetal Aorta . . . . .	86
<b>4</b>	<b>Discussion . . . . .</b>	<b>97</b>
4.1	Physiological Aspects . . . . .	97
4.1.1	Dependence of Fetal Blood Flow Parameters on Heart Rate and Movement Status . . . . .	97
4.1.2	Dependence of Uteroplacental Blood Flow Parameters on the Location of the Vessel Relative to the Placenta . . . . .	99
4.1.3	Reproducibility . . . . .	99
4.1.4	Normal Values . . . . .	101

4.2	Pathophysiological Aspects . . . . .	104
4.2.1	Correlation Between Blood Flow Parameters and Pathomorphological Placental Findings . . . . .	104
4.2.2	Blood Flow Parameters in Risk Pregnancies . . . . .	107
4.3	Clinical Aspects . . . . .	111
4.3.1	Comparison of Blood Flow Parameters . . . . .	111
4.3.2	Comparison of Different Monitoring Parameters . . . . .	113
4.3.3	Studies in the Group with Loss of Recordable End-Diastolic Velocity . . . . .	114
4.3.4	Outlook for Other Obstetrical Uses of Doppler Ultrasound . . . . .	116
<b>5</b>	<b>Summary . . . . .</b>	<b>117</b>
<b>6</b>	<b>Conclusions . . . . .</b>	<b>121</b>
	<b>Appendix . . . . .</b>	<b>127</b>
	<b>References . . . . .</b>	<b>139</b>