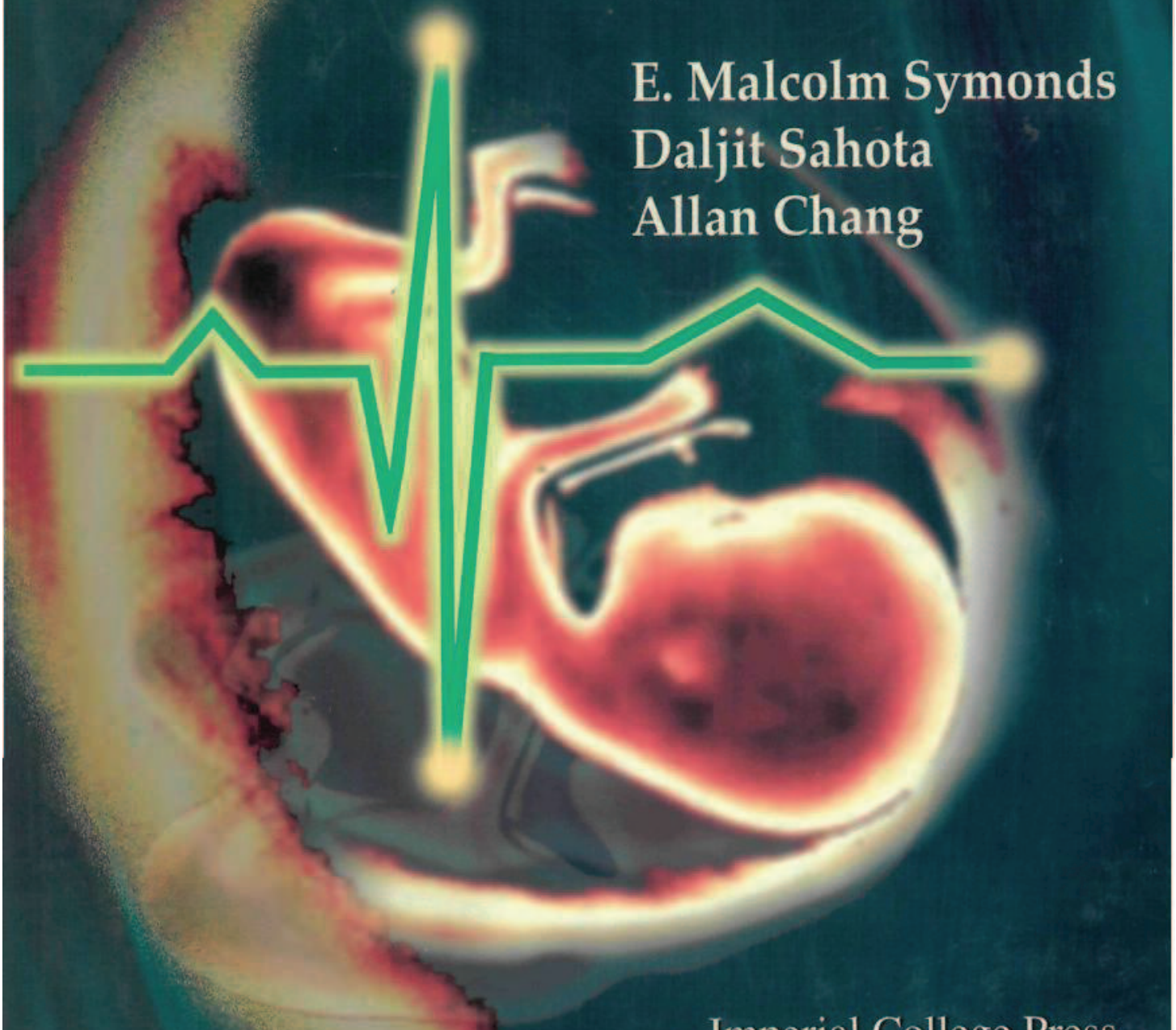
Cardiopulmonary Medicine from Imperial College Press

Fetal Electrocardiography

E. Malcolm Symonds
Daljit Sahota
Allan Chang



Imperial College Press

Fetal
Electrocardiography

CARDIOPULMONARY MEDICINE FROM IMPERIAL COLLEGE PRESS

Series Editor: Robert H. Anderson
National Heart & Lung Institute, London

Published:

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E. Malcolm Symonds
University of Nottingham

Daljit Sahota
Allan Chang
The Chinese University of Hong Kong

ICP
Imperial College Press

Published by

Imperial College Press
57 Shelton Street
Covent Garden
London WC2H 9HE

Distributed by

World Scientific Publishing Co. Pte. Ltd.

P O Box 128, Farrer Road, Singapore 912805

USA office: Suite 1B, 1060 Main Street, River Edge, NJ 07661

UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

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

FETAL ELECTROCARDIOGRAPHY

ISBN 1-86094-171-0

Printed in Singapore by Uto-Print

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Introduction

There has been a number of excellent books published in recent years on the subject of fetal monitoring. Their primary function has been to examine the nature of the fetal heart rate and the physiology and pathophysiology of the regulation of the fetal heart beat and how this can be applied to the detection of fetal asphyxia and the prediction of adverse outcome for the fetus, either in terms of fetal death or brain damage. Over the last decade, there has been much debate and re-evaluation of the effectiveness of counting the fetal heart rate in achieving these objectives, although it must be pointed out that techniques of electronic monitoring were never actually introduced to prevent fetal damage but were introduced to prevent intrapartum fetal death. The initial historical studies produced very promising results in reducing intrapartum death rates as measured against the incidence of antepartum stillbirths. The Dublin randomised study of fetal heart rate monitoring (MacDonald *et al.*, 1985) was conducted on a large number of normal subjects and failed to show any difference in perinatal mortality between those infants monitored electronically and those monitored by intermittent auscultation. As fetal death in such a group has a very low prevalence, the study was inadequate to actually prove that point even though the numbers involved in the study were, by conventional standards, large.

The more difficult issue relates to the prevalence of cerebral palsy and whether electronic monitoring has had any impact on this problem. The widely held view is that the prevalence of cerebral palsy has, if anything, increased, although recent analysis of Bristol data (Pharoah, 1996) shows that the prevalence of cerebral palsy has fallen in mature infants but has risen in low birth weight infants, suggesting that the increased survival of very low birth weight infants has carried its own price and that intensive intrapartum observation of the fetus may have achieved its objectives as far as the mature fetus is concerned.

The fetus, as with the adult of the species, survives in a buffered environment and, therefore, its biochemical response to hypoxia and asphyxia is linear only until the extreme limits of compensation are reached. This is

too late for intervention if the fetus is to be delivered in a healthy state. However, over-interpretation of abnormalities of the fetal heart rate has led to unnecessary intervention associated with high operative delivery rates.

Outcome measurements are further bedevilled by the knowledge that many infants who manifest cerebral palsy provide no evidence that the processes of parturition and fetal acidosis play any part in the pathology of the brain damage and where it must be concluded that either an episode of fetal asphyxia occurred before the onset of labour or that there was a genetic or infective problem that produced the abnormality.

This book is not about fetal monitoring although clearly it has implications for that subject. Over the past decade, the Departments of Obstetrics & Gynaecology at the University of Nottingham and the Chinese University of Hong Kong have collaborated on joint projects studying the nature of the fetal electrocardiogram waveform and intervals and its relationship to fetal health. The technical developments in Nottingham date back to the 1970s when the initial developments in signal acquisition and signal processing were produced in a collaboration between the Department of Obstetrics & Gynaecology and the Department of Electrical and Electronic Engineering.

The history of research on the fetal electrocardiogram dates back nearly a hundred years but progress has been intimately related to computer and chip technology. Unlike heart rate, the components of the ECG waveform are multiple and their interface is complex. The mass of information produced by detailed analysis of the ECG requires computer technology if the information is to be used in real time. Furthermore, the methods of analysis required to interpret the significance of the waveform pattern are numerous and complex. Understanding the fundamental physiology of electrical activity in the heart is a prerequisite for studying the subject of fetal electrocardiography. As we hope that this book will be a source of information and stimulation for both medical and engineering researchers in this field, we make no apologies for including basic descriptions of those subjects.

In assessing the relationship between the electrical activity in the fetal heart and in the conduction system, it is important to address the issues related to outcome and the biochemistry of fetal asphyxia. Increasingly, the

research community has become aware of the fact that the relationship between fetal acidosis and outcome is complex. It is clear that some infants will survive profound fetal acidosis without suffering damage to the brain stem or cortical damage or intraventricular haemorrhage. The specific effect of reduced cerebral blood flow and the damage inflicted by free-oxygen radicals may be as important as any absolute changes in pH. The ability of the fetal heart to survive biochemical insults is considerable and the changes in the heart may therefore be at some remove from damage suffered by the brain. In using parameters from the fetal ECG as a tool for assessment of the health of the fetus, we are adopting a relatively oblique but accessible pathway.

In the interpretation of the parameters of the FECG, it is important to remember that ischaemia in the fetal myocardium has an entirely different pathogenesis to the common forms of ischaemic heart disease in the adult. The lesions that produce ischaemic heart disease are generally focal and occur in an intact individual. The fetus usually has normal coronary vessels but lives in an environment where it is entirely dependent on the placenta. In effect, it is permanently attached to a large dialysis unit. This means that the biochemical changes that occur during chronic asphyxia are generally mediated by the placenta but its capacity for coping with the different features induced by chronic oxygen deprivation may not be consistent. For example, asphyxia in either the fetus or the adult will produce a shift of K^+ from the intracellular location into the extracellular and intravascular spaces. As the placenta faces into a maternal circulation where the acid–base and electrolyte environment may be normal, does the fetus lose potassium into the maternal circulation, and if so, does the fetus effectively manifest a hypokalaemic intracellular environment? Ischaemic changes in the fetal heart are diffuse and therefore the changes in the ECG differ in many aspects from those seen in the adult.

With some notable exception, most of the attempts to use the fetal ECG for recognition of biochemical changes have followed the same pathway as the interpretation of heart rate and the R–R interval but the ECG offers many different measurements and therefore does not offer the constraints imposed by using a single parameter. Yet, most of the work in this field —

certainly until the 1980s — has tended to simply take single parameters and attempt to reproduce the same profile of analysis that has been used for heart rate. It is clear that the changes in the ECG are often subtle and will only become gross in the agonal stages of fetal asphyxia and are therefore of no value in preventing fetal demise. Furthermore, it is apparent that in using a single lead system attached to the presenting part of the fetus, there are constraints in measuring change in the morphology of the ECG. These difficulties are further compounded by the fact that any change of the position of the electrode may change the shape of the waveform, particularly in relation to the ST segment and T-wave configuration.

However, considerable advances have been made in the computerisation of data and in the techniques for removing electrical noise and artefacts by the use of sliding averages. Digitised data can be used not only in the continuous measurement of individual parameters and time intervals but also in examining the interaction between variables to see if the sensitivity and accuracy of fetal monitoring can be enhanced. Are we approaching the analysis of this mass of information in the right way or are there better techniques that would allow "computer" recognition of abnormal states? The application of neural networks takes a step in this direction, but so far, it has not been found to enhance precision. The method also has the disadvantage of being impossible to trace how a particular decision is reached. Provided that the end result allowed more efficient interpretation of the ECG, the use of such a technique would be justifiable, but that has so far not proven to be the case.

Whilst the primary objectives of this book are to review the history and the current status of fetal electrocardiography, we would be remiss if we did not take the opportunity to speculate on possible future technical developments in this field, and also to consider further the question of suitable outcome measurements and analysis of the ECG in relation to those factors.