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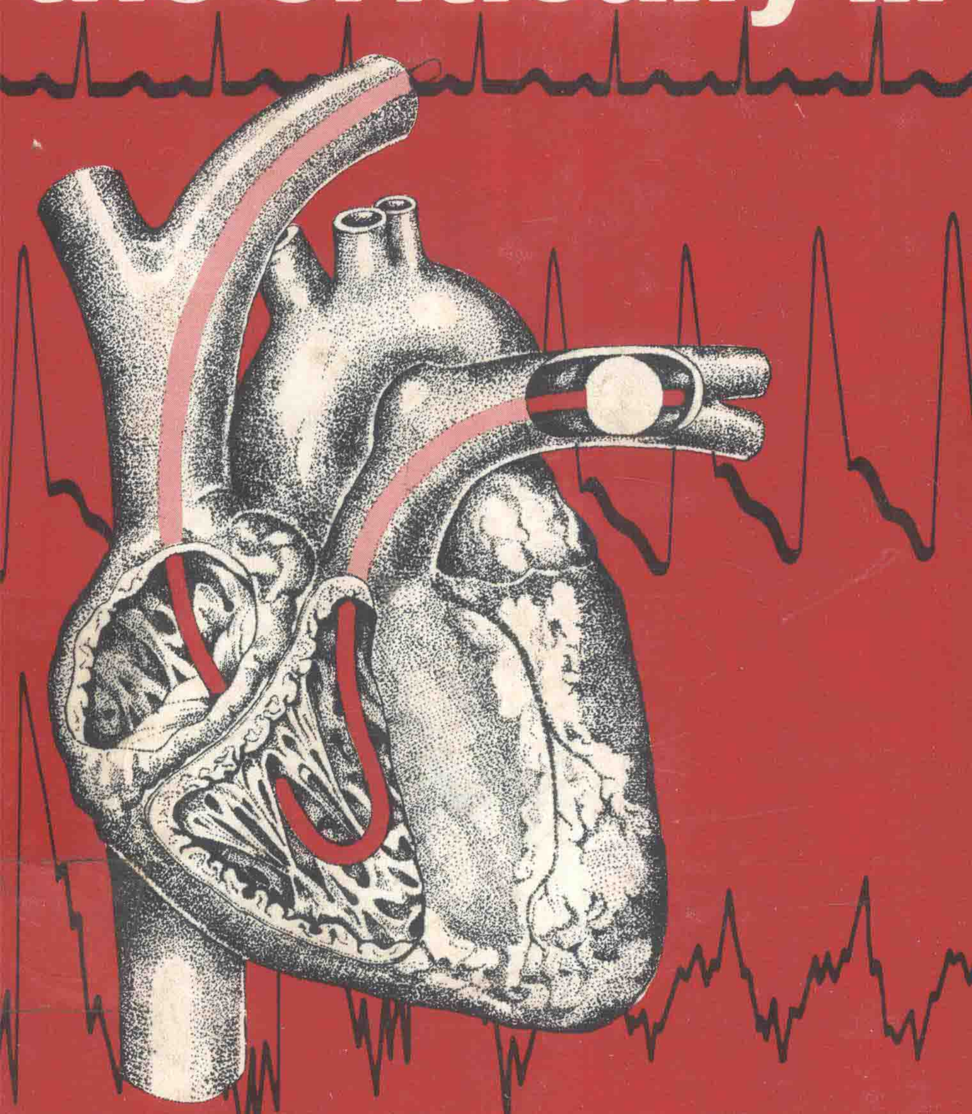
hemodynamic monitoring in the critically ill



HEMODYNAMIC MONITORING IN THE CRITICALLY ILL

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HARPER & ROW, PUBLISHERS

HAGERSTOWN

Cambridge
New York
Philadelphia
San Francisco

London
Mexico City
São Paulo
Sydney

1817

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 Printed in the United States of America. For information address Medical Department, Harper & Row Publishers, Inc., 2350 Virginia Avenue, Hagerstown, Maryland 21740.

(These papers were published originally in the Scientific Section of the September 8th, 1979, issue of the Canadian Medical Association Journal under the heading "Symposium on Hemodynamic Monitoring.")

6 5 4 3 2 1

Library of Congress Cataloging in Publication Data

Symposium on Hemodynamic Monitoring, Toronto, Ont., 1978.
Hemodynamic monitoring in the critically ill.

Updated papers originally presented at the symposium held in Toronto, May 1978, sponsored by the Ontario Heart Foundation.
Originally published in the Sept. 8, 1979, issue of the Canadian Medical Association journal.
Bibliography:
Includes index.
1. Cardiovascular system—Diseases—Diagnosis—Congresses. 2. Patient monitoring—Congresses. 3. Hemodynamics—Congresses. 4. Critical care medicine—Congresses.
I. Armstrong, Paul W. II. Baigrie, Ronald S. III. Title.
RC669.S89 1980 616'.028 80-17290
ISBN 0-06-140268-0

Hemodynamic Monitoring in the Critically Ill

To Beverley, Lisa and Kevin, and
to Mary,
for their love, patience and understanding,
which permits us to do what we do,
and helps to make it all worthwhile.

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Foreword

A decade has passed since hemodynamic monitoring was introduced as a convenient and practicable bedside technique for use in the critically ill. It therefore seems appropriate to take stock of this landmark development, to assess the benefits and the problems associated with its use, its place in contemporary medicine, and its potential future role.

What are the benefits?

It provides new diagnostic insights into confusing and difficult clinical problems. The clinician involved in managing a patient who is hemodynamically monitored has a unique opportunity to sharpen clinical skills by comparing them with physiologic data that is simultaneously recorded. Availability of such information brings the pathophysiology of disease alive at the bedside and has proven to be an important adjunct to traditional clinical evaluation. The limitation of conventional physical signs (such as estimation of the jugular venous pressure as an indicator of left ventricular failure) is now understood. Discordance between the findings of pulmonary rales and radiographic pulmonary congestion on the one hand and a normal pulmonary capillary wedge pressure on the other, in a vigorously diuresed patient with pulmonary edema, highlights an example of "phase lag phenomena." This is a compelling reminder that the rate of change of physiologic events may outpace more traditional means of assessment.

We believe that the opportunities this technique provides for learning and teaching, to all manner of medical professional personnel, are enormous and generally unsung. Identification of subtle alterations in the trend of physiologic measurements leads to anticipation of unfavourable developments. This permits a preventive approach rather than simply a reactive one. Exposure to hemodynamic monitoring provides not only a reminder of the limitation of clinical skills, but a stimulus to enhance them by incorporating the new learning it offers.

These lessons permit a wiser choice of therapy as well as the capacity to monitor the results of that therapy, adjusting it on a moment-to-moment basis. It is worth emphasizing that hemodynamic monitoring generates a continuous flow of information which demands rapid and frequent therapeutic decisions. These decisions involve the administration of potent agents such as vasodilators and catecholamines; a thorough knowledge of their pharmacology is a mandatory prerequisite to their use, since expertise in the techniques of monitoring alone is no guarantee against therapeutic misadventure. Moreover, monitoring is no substitute for common sense and careful clinical reasoning; even with the additional information it provides, the wisest and most difficult therapeutic decision may be only to observe.

Hemodynamic monitoring has served as a "gold standard" for a number of noninvasive assessment methods which range from traditional physical examination to interpretation of the electrocardiogram and chest x-ray. The validation of newer noninvasive techniques (such as M mode and two dimensional echocardiography and radionuclear imaging) has been considerably aided by the provision of a physiologic correlate. These noninvasive techniques may ultimately serve our patients better because of their wider availability, lower risk, and capacity to be repeated in both acute and convalescent phases of illness. Other areas of clinical research that have been facilitated by hemodynamic monitoring include the assessment of new pharmacologic agents, mechanical assist devices, and innovative cardiac and other surgical procedures.

What are the concerns regarding hemodynamic monitoring?

The relative ease of inserting a flow-directed catheter into the pulmonary artery has encouraged many who are inexperienced to perform this procedure. Appropriate interpretation of the data derived from this technique is less easy. An understanding of cardiovascular physiology is required. As in other new and specialized techniques, the development of a certain expertise must be followed by frequency of use adequate to ensure maintenance of initially developed skills. We estimate that a unit should not undertake this technique unless it is to be employed at least once per week. We must stress that, unlike many procedures which provide diagnostic insights, hemodynamic monitoring samples data continuously over time and therefore implies a commitment and availability of specially trained physicians and nurses.

Hemodynamic monitoring involves patient discomfort and risk, and the risks by no means conclude after catheter insertion. These factors, coupled with the effort and expense involved in both initiating and maintaining monitoring, dictate that indications for its use be carefully examined prior to its undertaking. In addition, discontinuation of monitoring requires careful planning and should be timed appropriately. The caring for monitored patients requires a special degree of finesse to ensure that the technologic interface between the patient and those caring for him does not obscure its fundamental purpose, *i.e.*, better care of the critically ill. Preoccupation with newly available physiologic data must not overshadow the nuts and bolts of good clinical medicine and total patient management.

While the cost of outfitting a hemodynamic monitoring operation is not prohibitive, it is expensive; the considerations of durability, portability, and available servicing are important ones. The exponential growth in the number of manufacturers of electronic equipment makes the choice of appropriate devices confusing for the novice. It is good to spend time in a unit, observing experienced personnel familiar with techniques and equipment. Technical support and a biomedical engineer(s) are a vital part of hemodynamic monitoring. They can provide advice regarding the purchase of equipment and its maintenance so as to minimize equipment failure. In the larger institution they serve as liaison between units to ensure compatibility of electronic devices in various locations. Their availability aids in ensuring that the physiologic information being gathered is both accurate and reproducible. They also aid in teaching physicians and nurses the basic technical skills necessary to operate independently and to troubleshoot hemodynamic monitoring equipment.

What does the future hold?

Looking ahead to the next decade, it seems probable that there will be continued refinement in the indications for hemodynamic instrumentation. This will lead to a decline in the number of procedures performed for diagnostic reasons as the newer noninvasive techniques emerge. Hemodynamic monitoring seems assured of a place in the short-term management of the critically ill patient where outcome can be materially affected by infusion of potent pharmacologic agents and insertion of mechanical assist devices. Whether such efforts will be rewarded with an improvement in the long-term prognosis is unclear. They certainly "buy the physician time," providing an opportunity to produce clinical stability, establish a definitive diagnosis, and where appropriate, proceed to acute or subacute surgical correction. Even if long-term prognosis is unaffected in critically ill patients, however, hemodynamic monitoring has proven itself a landmark development in the care of the critically ill.

Preface

In May of 1978 a symposium concerned with hemodynamic monitoring was held in Toronto, the first time such a meeting had taken place in Canada. It was sponsored by the Ontario Heart Foundation and co-sponsored by the University of Toronto Departments of Anaesthesia and Medicine and by the Royal College of Physicians and Surgeons of Canada.

The meeting was oversubscribed and enthusiastically attended by a cross-section of physicians, nurses and technicians from all parts of the country. This interest and enthusiasm appeared to be generated by acceptance of the technique's usefulness, a desire to expand its availability beyond the tertiary care centre, and the lack of current resource material dealing adequately with the subject. Accordingly we felt it would be valuable to collate, in an updated and comprehensive way, much of the material presented at that symposium; we believe that the material contained in this book may prove useful to others interested and involved in the care of the critically ill.

The book is divided into two parts: the first provides an historical and physiologic background of hemodynamic monitoring, followed by discussion of the equipment and techniques available. It concludes with a discussion of how this approach complements conventional clinical methods. Part II describes how this technique applies to specific categories of critically ill patients.

Appropriately, Drs. Swan and Ganz begin Part I by tracing historical development and providing their own perspective. Their innovation, *i.e.*, the balloon flotation catheter was a milestone: it permitted them to evaluate patients with acute myocardial infarction by acquiring sophisticated hemodynamic measurements. The tripen lumen, thermister tipped, Swan-Ganz catheter is simple and safe to insert and provides measurements of both right and left ventricular filling pressure as well as cardiac output. Armed with this tool, physicians have rapidly gained diagnostic, therapeutic, and prognostic insights which were hitherto unavailable.

In the second chapter, Drs. Gilbert and Hew discuss normal cardiovascular physiology and how it may become disordered in the critically ill. They define the determinants of cardiac output, coronary blood flow, and myocardial oxygen consumption, and indicate how these are measured. They point out how integration of the data emerging from hemodynamic measurements permits appropriate therapeutic decision-making.

In chapter three, Dr. Morton outlines the basic equipment requirements for hemodynamic monitoring. A working knowledge and familiarity with the component parts is necessary for those who propose to become involved. Since hemodynamic monitoring is a continuous process in the critically ill, technical malfunctions are apt to occur outside "normal working hours." The opportunities for collecting incorrect or frankly misleading data are many: the casual and uncritical user is especially susceptible to these.

In chapter four, Drs. Baigrie and Morgan discuss the technical considerations involved in catheter insertion. They outline the potential problems associated with invasive monitoring and divide them into two general categories, those related to technical pitfalls, and those secondary to patient complications. They present a trouble-shooting strategy to avoid these problems and to ensure that hemodynamic monitoring remains a safe, useful procedure.

Dr. Holder concludes the first part of the book by critically reviewing the clinical and ancillary noninvasive methods for evaluating the critically ill, with particular emphasis on those patients with acute myocardial infarction. He highlights specific instances in which clinically acquired data can be particularly misleading. He then discusses the improved assessment provided by hemodynamic monitoring.

Dr. King begins Part II of the text by stressing the importance of understanding the circulatory changes associated with normal breathing, mechanical ventilation, and respiratory disease as a prerequisite for the proper interpretation of hemodynamic measurements. He emphasizes that an awareness of potential pitfalls in patients with obstructive lung disease and those receiving mechanical ventilation is necessary for efficient use of the hemodynamic data obtained in these circumstances.

In chapter seven, Dr. Cairns discusses the hemodynamic classification of patients with acute myocardial infarction, and indicates how it guides therapy and helps to establish prognosis. Several clinical situations where monitoring may be helpful include: confusing or complicated presentations where diagnostic problems exist, complicating mechanical derangements, severe congestive cardiac failure, cardiogenic shock, and clinical research studies in acute myocardial infarction.

In chapter eight, Dr. Armstrong outlines the contributions that hemodynamic monitoring makes to the treatment of congestive heart failure. In particular, monitoring permits both an estimation of systemic vascular resistance and an understanding as to how it relates to left ventricular filling pressure, mean arterial pressure, and cardiac output in individual patients. Using this data, the hemodynamic profile formulated may influence the choice of therapy. Monitoring permits a wiser selection of inotropic and vasodilator agents as well as precise manipulation of blood volume. The response of short-acting agents can be efficiently determined, and this information then incorporated into long-range treatment.

In the final chapter, Drs. Pietak and Teasdale discuss anesthesia for the high risk patient, and indicate those likely to gain benefit from hemodynamic monitoring. They approach the problem systematically with a discussion of preoperative evaluation; they then move to an analysis of the induction, conduct, and emergence from anaesthesia, extending it through to the postoperative phase. They conclude by outlining the factors important to a successful outcome.

In chapter nine, Drs. Holiday and Doris discuss the special problems of the critically ill surgical patient. They indicate how invasive hemodynamic monitoring aids in the management of such patients and place it in the framwork of the complex multisystem monitoring which is often required.

Fundamental to the understanding of hemodynamic monitoring is an appreciation of certain physiologic concepts and measurements. To aid in this appreciation we have prepared a glossary of terms and abbreviations that are used throughout the symposium. For clarity and consistency we have indicated the synonyms that exist for certain terms, and have then selected one of these for subsequent use. The first time an abbreviation is used in each of the chapters it is again defined. Accompanying the glossary is a definition of derived hemodynamic indices with their appropriate units.

Acknowledgments

The editors wish to acknowledge the assistance of the Ontario Heart Foundation, the cover illustration provided by Mr. Stan Morton, the editorial assistance and cooperation of Dr. N.J.B. Wiggin, Scientific Editor of the Canadian Medical Association Journal, and the staff of Harper and Row, Publishers.

We are grateful for the dedicated and painstaking secretarial assistance of Anne Baron, Christine Ryder, and Lucy Rapp.

As the contents of this book demonstrate, hemodynamic monitoring requires a team approach. It is a pleasure to acknowledge the participation of a number of residents in training in both our institutions and the expert assistance of our technical support staff. Finally, we owe a special debt to our nurses whose dedication and caring is the cornerstone of management of the critically ill.

Paul W. Armstrong, M.D.
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Glossary

PRELOAD: end-diastolic fibre length; approximated in humans by end-diastolic volume or pressure.

AFTERLOAD: reflects left ventricular wall tension during systole; approximated by the product of left ventricular systolic pressure and radius.

CONTRACTILITY: force with which left ventricular ejection occurs independent of the effects of preload and afterload.

VENTRICULAR COMPLIANCE: distensibility of stiffness of relaxed ventricle: reciprocal of instantaneous slope of diastolic pressure-volume curve.

IMPEDANCE: relationship between instantaneous pressure and flow.

CO: cardiac output; the amount of blood pumped by the heart per unit of time.

CI*: cardiac index; expression of cardiac output adjusted for body surface area.

SV*: stroke volume; amount of blood pumped per heart beat.

EF*: the ejection fraction; percentage of emptying in a ventricular chamber.

SBP: systolic blood pressure.

MAP: mean arterial pressure.

ART_d: arterial diastolic pressure.

DBP: diastolic blood pressure.

RVEDP: right ventricular end diastolic pressure.

RAP: mean right atrial pressure.

CVP: central venous pressure.

RVFP: right ventricular filling pressure; determined from RVEDP, RAP, and CVP.

LVEDP: left ventricular end-diastolic pressure.

LAP: mean left atrial pressure.