

A Practice of
CARDIAC CATHETERISATION

DAVID MENDEL

A Practice of Cardiac Catheterisation

DAVID MENDEL

M.B.(Lond.) M.R.C.P.(Lond.)

*Consultant Physician to the Cardiothoracic Unit,
St Thomas' Hospital, London SE1*



BLACKWELL SCIENTIFIC PUBLICATIONS
OXFORD AND EDINBURGH

© BLACKWELL SCIENTIFIC PUBLICATIONS 1968

*This book is copyright. It may not
be reproduced in whole or in part without
permission. Application with regard to
copyright should be addressed to the publisher*

SBN: 632 04680 5

FIRST PUBLISHED 1968

DAVID MENDEL

M.B.(Lond.) M.R.C.P.(Lond.)

Consultant Physician to the Cardiovascular Unit,
St Thomas' Hospital, London SE1

Printed and bound in Great Britain by

WILLIAM CLOWES AND SONS LTD, LONDON AND BECCLES

Preface

In its early days, the extent of cardiac catheterisation was limited to the passage of a catheter through the chambers of the right side of the heart and into the pulmonary artery wedge position. Mean pressures were measured with saline or mercury manometers and the samples which were removed were usually analysed in the pathology laboratory by trained personnel. Having watched the procedure on one or two occasions, or better still having performed it once or twice with expert assistance, the beginner with no special scientific or experimental background was more or less fully equipped to perform catheterisations on his own. The apparatus was simple to understand and to use, and the procedure was usually performed by junior staff who would catheterise twenty or thirty patients whilst they held an appointment in a Cardiac Department and would not use the technique again after leaving the department.

These inexperienced operators would frequently obtain erroneous information or no information at all, but as the scope of the investigations was limited, the decision to offer surgical treatment was based largely on clinical findings and lack of catheterisation data did not materially affect the management of the patient.

Methods of investigation and surgical techniques advanced together and in the next phase of development more complex investigations were performed—and the data was ignored if it conflicted with the clinical findings. Curiously, this failure of the catheter findings to fit the clinical facts was attributed to some failure of clinical science rather than to weakness in the methodology.

This approach to cardiac catheterisation has persisted in spite of the fact that the procedures have been extended in scope and

sophistication and demand a good deal of manual dexterity. Complicated apparatus is used and the investigations are potentially very much more dangerous.

In the last few years, techniques have advanced so much that it is almost always possible to arrive at a diagnosis which is correct down to the smallest detail.

The skills of a good investigator are now in many ways similar to those of an airline pilot. Neither is qualified at his first solo. After gaining a licence to fly himself, the pilot has to advance a long way before he is qualified to carry passengers. Even then, a period as a co-pilot is demanded. Both jobs require a combination of manual and intellectual dexterity and once qualified the mistakes which are made are occasionally manual but more usually intellectual. Doctors are usually unwilling to consider anything as boring as a check list but the regular success of the investigations depends on a rigorous and persistent attention to detail. When this is maintained, the procedures appear to be very simple and straightforward. When it is not, things sometimes go well and sometimes disaster occurs. As in the case of the pilot of an airliner, disasters due to 'acts of God' have to be accepted, but those due to lack of attention to detail are really failures to exercise proper professional care.

The earlier position is now completely reversed and the quality of the data obtained depends largely on the skill and knowledge of cardiology of the investigator. If he is a poor craftsman or does not understand the techniques, the results may be meaningless and the patient may be subjected to an unnecessary thoracotomy. Because of this, it is my opinion that catheterisation should only be carried out by cardiologists or, under their guidance, by cardiologists in training.

This book is aimed at registrars who are starting their training as cardiologists, and is to a great extent the result of teaching assistants. It represents one man's practice, except in the chapters written by or in conjunction with others, where I felt that a technique was an essential part of the investigator's armamentarium, but my own experience of it was inadequate.

The book is meant to be a guide to the craft of catheterisation.

Some of the advice is so elementary that it may seem an impertinence to offer it to men at this level in their training. However, bitter experience has taught me that in a substantial proportion of cases, this level of advice is necessary.

Many techniques have been omitted, simply because the information can be got by other methods which I consider to be more satisfactory. Some are omitted because they are not used sufficiently widely, and others because the book is a primer.

Most of the techniques have parts in common and in order to avoid repetition, they are not restated in each chapter unless their description takes only a line or two. When they occupy a paragraph or more, the reader is referred to the appropriate chapter.

The catheter findings in various diseases are not discussed except in so far as they affect techniques. Any modern textbook of cardiology contains the findings. The aim of this book is to put the beginner in a position where he is able to obtain reliable data for himself.

The book contains very few references. It seemed better to devote the space to technical points. These technical minutiae have been picked up from innumerable sources or from experience, and in a work of this nature, there seems little point in attempting to attribute them to anyone in particular, especially as it is often difficult to remember who taught which point, or who originated it.

A list of useful further reading is given at the end of the book.

Contributors

Ronald D. Bradley, M.B. B.Sc. (LOND.), Clinical Physiologist, St. Thomas' Hospital, London.

D. Hywel Davies, M.D.(OXON) M.R.C.P.(LOND.), Senior Registrar, Cardiac Department, Guy's Hospital, London.

Ivor T. Gabe, M.D.(LOND.) M.R.C.P.(LOND.), M.R.C. Staff, Hammersmith Hospital, London.

Norman Pattinson, B.A. M.B. B.CHIR.(CANTAB) M.R.C.P.(LOND.) F.F.R. D.M.R.D., Director of the Departments of Radiology at the Middlesex Hospital, London, and at the London Chest Hospital.

Acknowledgements

I would like to thank all my teachers and colleagues, particularly Doctors Ivor Gabe and Hywel Davies who gave a great deal of advice in addition to the chapters which they wrote. Also, Dr Leslie Davies who read the manuscript and made many useful suggestions and Dr Dennis Deuchar who supplied a large number of invaluable hints. My thanks are due to John Norman, Chief Technician at the Institute of Cardiology, London, who criticised and contributed to the chapter on Electrical Safety, Dr Peter Nixon who did the same for the chapter on Atrial Septal Puncture, and Dr Anthony Clement who made a large contribution to the chapter on Anaesthesia. I am greatly indebted to Mr Colin Judge of Blackwell's Art Department who drew most of the figures from rough sketches.

Doctors Gerald Graham, Olive Scott, Leon Resnekov, Aubrey Leatham and Vivian Peckar all contributed.

My thanks are due to Dr Tom Foley who read the manuscript with his habitual thoroughness, and to my wife, who not only put up with the long drawn out process of the writing, but who also typed and retyped the whole of the manuscript.

Contents

Preface	ix
Contributors	xii
Acknowledgements	xiii
I Indications for cardiac catheterisation.	I
<i>Contra-indications. Getting the patient fit and ready for catheterisation. Preparation of the patient, pre-catheter examination and premedication. Choice of a suitable procedure</i>	
2 General anaesthesia for cardiac catheterisation and angio-cardiography	21
3 Electrical safety during cardiac catheterisation	29
4 Common factors in all types of catheterisation	36
5 Right heart catheterisation	64
6 Arterial puncture	99
<i>Arteriotomy and retrograde left heart catheterisation</i>	
7 Atrial septal puncture	134
8 Left ventricular puncture	155
9 Coronary arteriography	163
10 Catheterisation of infants	174
11 Miniature catheter techniques	185
12 Complications and resuscitation	192
13 Measurement of pressure	206
<i>Theory, damping, zero level, pressure tracings, pressure gradients, intracardiac manometers</i>	

14	Indicator dilution curves	248
15	Blood sampling and its uses	267
	<i>The Fick technique for measurement of the cardiac output.</i>	
	<i>Shunts. Pulmonary vascular resistance.</i>	
16	Angiocardiography	300
	Recommended Further Reading	335
	Index	339

BROAD INDICATIONS FOR INVESTIGATION

CHAPTER ONE

*The Indications for
Cardiac Catheterisation*

If it could be done without risk or discomfort and if there were enough investigators, all patients with heart disease would have the anatomy and function of all four chambers of the heart, the great vessels and the pulmonary, systemic and coronary circulations studied to the fullest possible extent. This would certainly apply to any patient who was a candidate for cardiac surgery.

This ideal state does not yet exist however, and usually the investigation is planned so that when the results of the clinical examination, electrocardiogram, chest X-rays, phonocardiogram, exercise test and the investigation are collected together, all information which is relevant to the future treatment of the patient is available.

Physicians vary in the extent to which they trust their clinical judgement and surgeons vary in the amount of information which they require before and during the operation. If the investigations are badly performed, the information obtained may be useless or even misleading and in these circumstances both physician and surgeon may decide that the patient loses nothing if the investigations are not done.

The amount of investigation to which patients with the same disease are subjected at various centres differs considerably, and it is impossible to lay down rigid rules in a situation where there is not only little agreement between experts, but where what is done is determined so much by personal experience, clinical judgement, manual skills and the availability of apparatus and staff.

BROAD INDICATIONS FOR INVESTIGATION

Exact figures for the mortality of cardiac catheterisation are not available, but it is probable that the figures are of the order of one per thousand during right heart investigations, and one in two or three hundred in left heart investigations. There is also a substantial morbidity. These are average figures and in some hands the mortalities are very much smaller than those quoted. In some hands they are much greater. Mortality varies to a large extent, but not entirely, with experience. Investigation is more dangerous in severely diseased patients but the benefit they will derive from successful surgical treatment justifies the additional risk.

Right heart catheterisation can therefore be carried out whenever it will yield information that will be useful in the management of a patient with heart disease. An example of this would be the investigation of an innocent murmur arising in the pulmonary artery which is preventing the patient from taking up a particular career, from entering a pension scheme or from taking up life assurance.

Left heart catheterisations and angiocardiograms, with their more substantial risk, should, in the author's opinion, be limited to patients who are being assessed for surgery or who are being assessed to rule out the possibility of surgery. Their use is also justified for the assessment of the effects of therapy, and although this usually means surgical therapy, it is sometimes necessary to assess the effects of drugs, electrical rhythm conversion or pace-making.

RESEARCH

Another factor which determines the type and extent of the investigations performed both in patients who may undergo surgery and those who certainly will not, is the extent to which the individual investigator is interested in research. Those who are interested use the opportunity afforded by routine investigation not only to

establish the diagnosis but also to study the heart and circulation, and this is not only ethically justified, it is essential. The routine procedures of today are largely the research projects of yesterday and research carried out during investigations in the past is mainly responsible for the increase in the understanding of heart disease which has permitted the advances in treatment to be made.

It is very much better to give drugs to patients who are being catheterised and measure the effects, than it is to give the drugs to patients without understanding their pharmacological effects. The effects and side effects of many of the drugs used in the treatment of heart disease are still not understood. The actions of a drug as venerable as morphine are still being determined by measurements made in intensive care units on seriously ill patients with myocardial infarctions, in whom the measurements made play no part in the treatment of the individual patient. The findings have modified our use of the drug.

In the author's laboratory, an attempt is made at each investigation to obtain some additional information, except when the patient is severely ill and an extension of the length of the procedure is not justified.

Experimental work should be done only if the patient is not exposed to any additional risk. A lengthening of the procedure or a small added discomfort is the most that a patient should be subjected to, and this only if the experiment is being performed by someone who has been properly trained in experimental method.

DISEASES IN WHICH NO CATHETERISATION IS NECESSARY

The amount of investigation which should be performed in patients with ischaemic and hypertensive heart disease is not yet determined. The vast majority do not have any form of investigation at the moment, but the availability now of an excellent and safe technique for the study of the coronary circulation (see Chapter 9) combined with the advent of new operations for the relief of angina may alter this situation.

In congenital heart disease in adults, one condition in which the physical examination and chest X-ray provides all the necessary information for diagnosis is coarctation of the aorta. In adults, now that plastic materials are available to join the two ends after the coarcted area has been resected, it is not necessary to establish the length of the coarcted segment. In infants, where multiple lesions so frequently coexist, investigation of this condition is essential.

In older children and adults patent ductus arteriosus is frequently diagnosed and operated on without prior investigation, but this practice does lead to occasional unnecessary thoracotomy in patients who have one of the other causes of a continuous murmur.

The author investigates the following groups of patients:

- 1 Any patient who is to undergo cardiac surgery except adults with coarctation of the aorta or calcified constrictive pericarditis.
- 2 Any patient who is in need of surgical aid but in whom there appears to be some cardiac contraindication to surgery. This impediment is usually a clinical diagnosis of too much pulmonary hypertension. The level of the pulmonary vascular resistance is measured.
- 3 Any patient whose heart disease is causing symptoms, but in whom there is some doubt about the exact diagnosis, or whose symptoms appear to be disproportionately severe.
- 4 Any symptomless patient with a lesion in which doubt about the diagnosis is affecting the patient's way of life or the advice to be given him. The extent of the investigation varies but in this category it is usually limited to the right side of the heart.
- 5 Any child with aortic stenosis in whom there is any evidence that the disease is more than trivial.

In our laboratory we do not investigate:

- 1 Patients in whom the diagnosis is obvious but in whom the risk of surgical treatment is greater than the risk of not operating.
- 2 Patients who are too old for the surgery of their particular condition.

CONTRAINDICATIONS TO CARDIAC CATHETERISATION

Modern methods of resuscitation have made possible the catheterisation of patients with a number of diseases which were once listed as being unsuitable. There are now no diseases which prevent the patient being catheterised if there is a possibility that he has a treatable condition.

If left bundle branch block is present, then right heart catheterisation may provoke right bundle branch block as well and then the patient will have complete heart block. Even this situation can now be controlled with modern resuscitation, and if the patient needs investigation before operative treatment, left bundle branch block is no longer a contraindication.

The present day contraindications to catheterisation are of two sorts and the *first* is the presence, or even the suggestion of intercurrent disease. If a patient is below his normal level of fitness at the time of catheterisation, the procedure should be postponed as it is elective, and there is rarely any urgency. There is always a remote chance that a patient may die during catheterisation and if this should occur in a patient who was not fit at the time of the procedure, the investigator will have placed himself in a difficult moral or even legal position. Our patients are examined clinically and the temperature, haemoglobin, erythrocyte sedimentation rate and white cell counts are checked the day before the procedure.

The *second* contraindication is if the patient is less fit than medical treatment can make him. There is argument among investigators about the extent to which medical treatment should be given before investigation is performed. In the author's department, patients are treated intensively if they are in heart failure until they have reached their peak of condition as evidenced by properly controlled heart rates and minimum weight. If too much digitalis is given, the patient is not catheterised until the evidence of the excess has gone. This procedure seems safer on first principles and it also usually ensures that 'functional' valve incompetence will have diminished or disappeared, and the residuum is more

likely to represent the best state of that heart without surgical interference. The opponents of this system say that patients should be catheterised as they are in real life outside the hospital, because they cannot maintain themselves in the unrealistically healthy condition that has been achieved with intensive medical care. Whilst it is true that the condition cannot usually be maintained outside hospital, the *symptoms* which the fully treated patient experienced *before* entering hospital are what guides the physician in recommending surgical treatment. The surgery will be done after intensive treatment, and it is the state of the heart then that the surgeon will wish to know. The better it is, the more likely is the patient to survive surgery, and prolonged bed rest may be necessary to get the patient fit enough for catheterisation and surgery.

A patient who has a raised blood urea, which has not had an opportunity to fall with bed rest, is not catheterised in our laboratory until it has fallen as low as medical treatment will take it. If it does not return to near normal limits, catheterisation may be performed but it is inadvisable to perform an angiogram as the poor renal function may impair the excretion of the contrast medium.

EXAMINATION OF THE PATIENT BEFORE CARDIAC CATHETERISATION

Once it has been decided to proceed with the investigation, attention is directed towards allaying the patient's fears (this is dealt with later in this chapter) and towards the most thorough clinical assessment of the patient's condition which is possible. This falls into two parts; the history and the exercise tests which allow an estimate of the patient's disability; and the examination, phonocardiogram, chest X-ray and electrocardiogram which usually allow an anatomical diagnosis to be made, common associations to be listed and a differential diagnosis where there is doubt.

The techniques of clinical examination need not be considered

here, but the method of testing the patient's exercise tolerance before the investigation will be described.

THE PHYSICAL WORKING CAPACITY

Maximum cardiac output in both normal and abnormal subjects is achieved when the heart rate is around 170 beats per minute. The relationship between output and heart rate is approximately linear, and so is the relationship between output and oxygen uptake and between output and ventilation. The linearity of these relationships which has been established by the careful studies performed by Swedish workers is the basis for the physical working capacity test which they have devised.

The patient is exercised for five minutes at increasing levels of exercise until his pulse rate reaches approximately 170 beats per minute or he is prevented from going on by any symptom of heart or lung disease. From the patient's performance at the various levels a straight line relationship can be established between work level and pulse rate. If the patient is unable to exercise until his pulse rate reaches 170, the line for pulse rate at the levels he has managed is extrapolated and the exercise level which he would have reached if his pulse rate had risen to 170 is his physical working capacity.

A number of different results is possible in the test:

- 1 The patient may have a normal physical working capacity (920 kilopond metres per minute in men, 580 K.P.M. in women, both $\pm 20\%$).
- 2 He may complain of symptoms which prevent him from reaching normal levels of exercise when his pulse rate has not yet reached 170. In this case the extrapolated pulse rate may reveal that his capacity is normal or that it is below normal.
- 3 He may reach a pulse rate of 170 at lower levels of exercise than normal and the level reached reveals the degree of incapacity.

The first two categories are straightforward. The third contains many different types of patient, including those who are badly out of training, those with lung disease and those with obesity. There are patients with mitral stenosis in whom the left ventricle is not