MEDICAL PRACTICE

*Hospital Topics***Bedside haemodynamic monitoring: experience in a general hospital**

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Abstract

Bedside right heart haemodynamic monitoring was carried out on 55 occasions over 18 months in the cardiac care unit of a district general hospital. The technique was used to assist in the management of 27 patients with acute heart failure and 28 patients with resistant chronic heart failure by helping to select appropriate treatment. Although the catheters were flow guided, insertion and positioning were facilitated by fluoroscopy. The procedure was safe, with one complication arising; technical difficulties occurred in eight cases. Prediction of cardiac output and left ventricular filling pressure by clinical assessment proved to be accurate in only 55% of cases: in patients with acute heart failure there was a tendency to underestimate the cardiac output (25%) and overestimate the left ventricular filling pressure (37%), whereas in patients with chronic heart failure the filling pressure was more accurately estimated (71%). Haemodynamic measurement was often invaluable in selecting and adjusting treatment, particularly in critically ill patients.

Introduction

Since the introduction of right heart (Swan-Ganz) catheterisation¹ bedside haemodynamic monitoring has become established

in helping to manage critically ill patients. In Britain the procedure is mainly confined to specialist cardiac units—for example, after cardiac surgery or in the elective assessment of patients with chronic heart disease, particularly when vasodilator drugs are introduced.² There is, however, an equal need for haemodynamic monitoring in district general hospitals as part of the immediate management of emergency cases.

We reviewed the use of haemodynamic monitoring in a general hospital both in the emergency management of critically ill patients and in the elective investigation of patients with chronic heart failure.

Patients and methods**PATIENTS**

Fifty five patients underwent bedside haemodynamic monitoring in the cardiac care unit of this hospital during the 18 months from January 1981 to July 1982. There were 46 men and nine women (mean age 60 years, range 31-78 years). During this period 553 patients were admitted to the four-bedded unit, of whom 259 had acute transmural myocardial infarction, while most of the remainder had non-transmural myocardial infarction, unstable angina, or arrhythmias. The hospital is a 672 bedded general hospital serving a community of 200 000.

Table I gives the indications for bedside haemodynamic monitoring in the study patients. Cardiogenic shock was defined clinically as the syndrome of peripheral vasoconstriction, hypotension (systolic arterial pressure <80 mm Hg), and oliguria. Pulmonary oedema was defined radiologically on chest radiographs taken no more than two hours before haemodynamic monitoring began.

In the clinical and radiological assessment of the haemodynamic state the estimated cardiac output was defined as normal (3-10 l/min) or low (<3 l/min) and the estimated resting left ventricular filling pressure as high (>20 mm Hg), normal (5-20 mm Hg), or low (<5 mm Hg).

Patients with cardiogenic shock were expected to have low cardiac outputs and high left ventricular filling pressures; those with pulmonary oedema but without shock normal cardiac outputs but high

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TABLE I—Indications for bedside haemodynamic monitoring in 55 patients

	No of patients	Mean age (years)
<i>Emergency procedure</i>		
Acute cardiogenic shock*	9	61
Acute pulmonary oedema*	8	57
Chronic heart disease (acute deterioration)	10	50
Total	27	
<i>Elective procedure</i>		
Chronic heart failure:		
Breathlessness	25	61
Fatigue	3	70
Total	28	

*After acute transmural myocardial infarction.

filling pressures; those with chronic heart failure, whose main symptom was breathlessness, low cardiac outputs with high filling pressures; and those with fatigue as the predominant symptom low cardiac outputs and normal filling pressures.

EMERGENCY PROCEDURE

Seventeen patients underwent right heart catheterisation after presenting with acute transmural myocardial infarction. As there were 259 such patients, this represents an incidence of 7%. Nine of these patients had cardiogenic shock with pulmonary oedema and eight had pulmonary oedema without shock.

Ten patients, known to have chronic heart disease, presented with an unexpected acute deterioration unrelated to fresh myocardial infarction or arrhythmia. Haemodynamic measurements were made to determine the exact nature of their deterioration before starting appropriate treatment. Of these patients, five presented with radiological features suggesting pulmonary oedema and five with hypotension thought to be due to hypovolaemia in three cases but of uncertain cause in the other two.

ELECTIVE PROCEDURE

In 28 patients, who were in a stable state with chronic heart failure unresponsive to diuretics, haemodynamic monitoring was performed electively to assess cardiac output and left and right ventricular filling pressures so as to select the appropriate treatment.

HAEMODYNAMIC MONITORING TECHNIQUE

Triple lumen, balloon tipped, thermodilution catheters (Cardiovascular Instruments computer, model 600-017) were used routinely. Catheters were inserted under full sterile conditions by medical registrars with a senior nurse and cardiac technician assisting. The nature of the procedure and its indication were always explained to the patient, and often to the relatives also, and written consent obtained. All catheters were inserted percutaneously by the right infraclavicular approach into the subclavian vein under local anaesthesia and without premedication. If venepuncture at this site failed the left infraclavicular approach was used. The catheter was inserted either directly through a large bore introducer sheath (6F Intralet, Vygon) or by the Seldinger technique (Cordis catheter sheath system).³ Before insertion of the catheter the balloon was inflated and inspected for any defects. The catheter was advanced into the pulmonary artery with the balloon inflated. When positioned correctly in a pulmonary artery branch it would record a pulmonary artery wedge pressure during balloon inflation and a pulmonary artery pressure when deflated. Such a position was determined either by fluoroscopic screening or by continuous observation of pressure tracings during insertion.

After insertion of the catheter the skin entry site was cleaned with chlorhexidine and polymixin spray and covered with a sterile clear plastic film (OpSite, Smith & Nephew Ltd, Hull); the catheter was further secured with adhesive tape. The procedure usually took about 20 minutes and was not distressing to the patient.

Measurements of right atrial, pulmonary artery, and pulmonary artery wedge pressures were made using a Bell and Howell transducer.

Values were read both directly from a pressure monitor with digital readout and from the pressure wave forms recorded on a two channel paper recorder with a simultaneous electrocardiogram (Simonsen & Weel Ltd, Sidcup, Kent). The mid-chest was used as a zero reference point.

Cardiac output was measured by the thermodilution technique (Cardiovascular Instruments computer 600) using 10 ml boluses of 5% dextrose solution injected at room temperature. Multiple measurements were made to obtain a mean value from three readings with less than a 10% variation.

Between haemodynamic measurements 5% dextrose solution containing heparin 3000 U/l was infused slowly through the pulmonary artery channel to prevent blockage of the catheter. When necessary, intravenous drug infusions were given through the right atrial channel or side port extension of the introducer sheath. Catheters remained in situ for a mean of 36 hours (range one hour to four days). Catheters were not reused, whereas the transducer was sterilised with chlorhexidine in spirit before reuse.

STATISTICAL ANALYSIS

Statistical analysis was carried out using χ^2 tests.

Results

CLINICAL VALUE

Complete haemodynamic measurements were obtained in 51 of 55 procedures. Bedside haemodynamic monitoring showed that despite careful clinical and radiological assessment the overall haemodynamic state, as defined above, had been estimated correctly in only 28 (55%) cases; the cardiac output was estimated correctly in 36 (71%) and the left ventricular filling pressure in 32 (62%).

TABLE II—Accuracy of haemodynamic predictions in 55 patients

	No of patients			Values obtained*	
	Total	Adequate measurements obtained	Accurate haemodynamic prediction	Cardiac output (l/min)	PAWP (mmHg)
<i>Emergency procedure</i>					
Acute cardiogenic shock	9	6	3	2.8(0.3)	21(3)
Acute pulmonary oedema	8	8	6	3.7(0.2)	25(3)
Chronic heart disease (acute deterioration):					
Pulmonary oedema	5	5	1	6.7(1.2)	19(8)
Hypotension	5	5	3	2.4(0.3)	22(7)
Total	27	24	13		
<i>Elective procedure</i>					
Chronic heart failure:					
Breathlessness	25	24	14	3.4(0.2)	19(1)
Fatigue	3	3	1	2.6(0.4)	27(5)
Total	28	27	15		
Grand total ("")	55	51 (93)	28 (55)		

PAWP = pulmonary artery wedge pressure.

*Results expressed as means (standard error of mean).

When cardiogenic shock, hypotension, or fatigue suggested a low cardiac output in 17 cases measurements obtained in 14 showed that the cardiac output was low in 11 (79%) but normal in the remaining three despite the clinical presentation. Radiological pulmonary oedema suggested high left ventricular filling pressures in 38 cases. In 27 (71%) cases haemodynamic monitoring confirmed this, but in the remaining 11 (29%) the filling pressures were found to be normal or low.

Although clinical assessment was equally poor in both emergency patients and those studied electively, there were differences between these groups. In emergency cases there was a tendency to overestimate the left ventricular filling pressure (37%) and underestimate the cardiac output (25%). In patients studied electively the filling

pressure was more accurately estimated (71% correct), although the cardiac output was often lower than expected (30%).

By indicating inaccurate clinical assessment bedside haemodynamic monitoring ensured that therapeutic interventions were rational; continuous monitoring during treatment then allowed rapid and appropriate modifications to be made as necessary. For example, three patients admitted in cardiogenic shock after acute transmural myocardial infarction were found to have low filling pressures with low cardiac output.¹ They received plasma for volume expansion to increase filling pressures and cardiac output rather than vasodilators, which would have been deleterious. Two of these patients survived and the other died of shock. Two patients with acute pulmonary oedema, four other emergency cases, and six patients with chronic heart failure were found to have normal wedge pressures when clinically and radiologically it was thought that they would be high. In these 12 patients diuretics and nitrates were withdrawn or reduced accordingly.

Haemodynamic monitoring also allowed any adverse haemodynamic effect of treatment or other unexpected deterioration to be detected rapidly. In three patients receiving intravenous nitrates for severe pulmonary oedema wedge pressures fell rapidly to subnormal values, with reductions in cardiac output. Early recognition of this effect and careful volume expansion prevented any clinical deterioration.

Haemodynamic monitoring influenced correct diagnosis as well as management. One patient who had a myocardial infarction one year previously presented with severe breathlessness and hypoxia and was thought clinically and radiologically to have pulmonary oedema. Haemodynamic monitoring indicated normal values, excluding the diagnosis of heart failure. Subsequent investigations showed that lymphangitis carcinomatosa was the cause of the initial presentation.

COMPLICATIONS AND TECHNICAL DIFFICULTIES

The only clinical complication was inadvertent puncture of the subclavian artery in one case (table III). Technical difficulties included

TABLE III—Minor complications and technical difficulties in nine of 55 patients undergoing haemodynamic monitoring

	No of cases
Inability to enter right subclavian vein	1
Puncture of subclavian artery	1
Poor catheter positioning (inability to wedge)	3
Inability to measure cardiac output (catheter thermistor fault, 1; computer fault, 2)	3
Catheter blockage (loss of pressure monitoring)	1

inability to obtain initial filling pressures in three cases owing to poor catheter position. Instrument faults occurred on four occasions, preventing measurement of cardiac output on three occasions owing to thermistor or computer failure and causing loss of pulmonary artery pressure measurements because of catheter blockage on one occasion. The subclavian vein could not be entered in one other patient. No other complications, such as infection or thrombosis, occurred.

There was no difference in the incidence of technical difficulties in those patients studied as emergency or elective cases.

VALUE OF FLUOROSCOPY

Forty five patients (28 elective, 17 emergency) had catheters positioned with fluoroscopic guidance using a portable image intensifier at the bedside in the cardiac care unit or, before this was available, in the radiology department. Ten emergency cases admitted when bedside screening was not available had catheters positioned by direct observation of pressure tracings during insertion without fluoroscopic guidance, because the severity of their condition precluded transfer to the radiology department. When fluoroscopic guidance was used only 5% of procedures were complicated by poor catheter position leading to inability to record wedge pressures, whereas this occurred in 20% of insertions without fluoroscopic guidance. Although this difference was not statistically significant,

our clinical experience is that fluoroscopic screening, especially when performed at the bedside, permits a far simpler and more accurate catheter insertion.

CLINICAL OUTCOME

Of the 27 patients who were monitored after acute admission, 18 died in hospital. This high overall mortality reflects the poor prognosis of the severe conditions being managed but masks the importance of haemodynamic monitoring in the nine survivors; these included two of the patients who presented with cardiogenic shock, four of the eight patients with acute pulmonary oedema after acute myocardial infarction, and three other patients with chronic heart disease who had deteriorated acutely (with severe dehydration, pulmonary oedema, and severe pulmonary hypertension). In these acute cases (one third of the emergency cases) the haemodynamic information gained by bedside monitoring contributed greatly to rational treatment and the patients' survival.

Haemodynamic monitoring caused no complications during long term follow up (of six to 24 months) in these nine emergency cases and in the 28 elective cases.

Discussion

Our group of 55 patients, predominantly with severe heart failure, does not represent the complete range of clinical indications for haemodynamic monitoring, which includes severe trauma, postoperative collapse, septic shock, and "shock lung." Just as the clinical assessment of the haemodynamic state of our patients was often inaccurate, and consequently unreliable in determining appropriate management, similar clinical inaccuracy is as likely to occur in patients who are critically ill for other reasons.

Haemodynamic monitoring was found to be a safe and rapid method of obtaining a detailed objective assessment of cardiovascular function. Initial values provide diagnostic information and allowed specific treatment to be selected.^{5,6} Monitoring the trend of subsequent haemodynamic changes allows treatment to be adjusted appropriately. In critically ill cases, especially after myocardial infarction when the clinical condition is unstable and particularly difficult to assess, haemodynamic monitoring is essential if logical therapeutic interventions are to be made. The use of appropriate treatment in these cases, however, even with the additional haemodynamic information, may still be inadequate to alter the prognosis appreciably if the initial myocardial damage is severe.

When patients with chronic heart failure remain symptomatic despite conventional treatment elective haemodynamic studies provide an objective measurement of severity and enable a logical approach to treatment to be made. Unfortunately, acute responses to apparently appropriate therapeutic agents, even if beneficial, do not necessarily result in long term benefit.⁷

Although serious complications such as subclavian vein thrombosis and pulmonary valve damage may occur during right heart catheterisation, the incidence is generally low.^{8,9} In our experience only minor complications occurred rarely, both during elective and emergency procedures. Complications related to instrument faults also occur but seldom affect the patient. Catheter insertion by the right infraclavicular route was safe, well tolerated, and allowed comfortable fixation of the catheter to the upper chest wall. The initial insertion of an introducer sheath into the subclavian vein is useful as this allows the insertion of either a right heart catheter or a transvenous pacing wire at any time, and when the catheter or pacing wire is removed venous access is maintained. When fluoroscopic screening is used to determine the position of the catheter insertion is easier and tends to be more accurate, but this technique is not essential for safety.

Although these practical details are straightforward, haemodynamic monitoring should not be performed by inexperienced staff, as the correct use of the technique requires more skill

than simple central venous catheterisation.¹⁰ Careful interpretation of haemodynamic information is required as well as clinical experience in the management of severely ill patients.

The cost of bedside haemodynamic monitoring is relatively small considering the overall cost of modern intensive care. At current prices each procedure costs about £100 for disposable items. The initial outlay for a transducer, pressure monitor, and cardiac output computer is about £6000. Fluoroscopic screening is available in most radiology departments, but a portable bedside image intensifier in the cardiac care unit is an added advantage for right heart catheterisation as well as for emergency cardiac pacing.

An invasive and technologically specialised procedure requires careful application in a general hospital. It is becoming apparent that the district general hospital has an increasingly important role in the assessment of cardiological disease.¹¹ Bedside haemodynamic monitoring is now a well established technique which is often invaluable in the management of critically ill patients and can be performed safely and effectively in a general hospital.

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Contemporary Themes

Parental access and family facilities in children's wards in England

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The National Association for the Welfare of Children in Hospital works to improve the care of children in hospital. Twenty four years after the publication of the Platt report,¹ which recommended that parents should have unrestricted access to their children and that young children should be admitted with a parent, we still receive several telephone calls and letters each week from parents. Many require support for what they intuitively know is the right thing for them to do—to stay in hospital to help care for their child. A series of regional and national surveys² carried out by the association have shown a gradual relaxation of rules and a greater part being played by parents in the care of their sick children. Progress has been very slow, however; by 1975 only 19% of wards had introduced unrestricted access. In 1979 the Consumers' Association sample survey³ investigated the opinions of staff and parents and found a considerable gap between staff attitudes and parents' expectations. The Platt committee also stated: "We strongly recommend that children should not be nursed in adult wards."¹ The National Association for the Welfare of Children in Hospital celebrated its 21st anniversary in 1982, and this seemed an appropriate year to survey the situation, review the trends, evaluate the association's own work and update thoroughly the index of wards that is kept at its head office.

Methods

The survey covered all acute wards in England that nurse children up to the age of 16, excluding psychiatric units, day wards, and special care baby units. In practice, most children over the age of 12 were excluded as most are nursed in adult wards; such wards were included only if they nursed more than 50 young children a year. Experience has shown that practice on the ward does not always conform to hospital policy; as we were anxious to gather the same information that a parent would be given we approached ward sisters by telephone, and administered a questionnaire consisting largely of structured questions on access, overnight accommodation, and facilities for parents.

Results

A total of 1143 ward sisters were approached; 1063 (93%) questionnaires were completed, of which 887 were considered suitable for analysis. Table I shows the designation of these 887 wards. Despite the recommendation of the Platt report, a total of 250 of the 887 wards in which children were nursed (28%) were adult wards. This shows little improvement since 1978, when 31.7% of all children aged under 16 were still being nursed in adult wards or annexes.⁴

In 1971 the Department of Health issued advice to health authorities to gather children together into comprehensive units.⁵ The largest proportion of wards studied, representing paediatric general and mixed medical and surgical wards, certainly fall into this category, as do many of the children's surgical wards, though some are still located in separate hospitals, isolated from other children's services. Most burns and plastic surgery wards; orthopaedic wards; ophthalmic wards; isolation wards; and ear, nose, and throat wards are not in

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