Hemodynamic Monitoring in Patients with Hypotension after Myocardial Infarction*

The Role of the Medical Center in Relation to the Community Hospital

Blase Carabello, M.D.; Peter F. Cohn, M.D.; and Joseph S. Alpert, M.D.

Patients who develop hypotension after acute myocardial infarction are frequently transferred to medical centers for hemodynamic monitoring. To see if this practice is justified, we reviewed our experience with hemodynamic monitoring over a two-year period. Of 40 patients who underwent hemodynamic monitoring for hypotension, 28 were transferred from other institutions. Eleven (39 percent) of these 28 patients had a pulmonary capillary wedge pressure of 16 mm Hg or less. Ten (91 percent) of these 11 survived, compared with one survivor (8 percent) in the 13 transferred patients with a pulmonary capillary wedge pressure of 17 mm Hg or more (P < 0.001). The pulmonary capillary wedge pressure did not correlate well with the presence of a third heart sound on physical examination or with chest x-ray films. All hypotensive patients with a low pulmonary capillary wedge pressure received fluids to expand the blood volume as their major form of therapy. Thus, hemodynamic monitoring in patients with hypotension clarifies their status regarding blood volume and identifies those who will benefit from expansion of this volume. Transfer of hypotensive patients for hemodynamic monitoring seems justified, as their status regarding volume of blood is frequently difficult to ascertain by noninvasive means.

Although there has been improvement in the detection of and therapy for arrhythmias following acute myocardial infarction since the development of coronary care units in the 1960s, there has been little improvement in the rate of survival of patients who develop pump failure following acute myocardial infarction. For the approximately 15 percent who develop pump failure, the mortality remains extremely high.1-4 Although therapy in this group of patients has become increasingly aggressive, the outcome seems little changed. Patients who become hypotensive after an acute myocardial infarction, although their condition is often unstable, are frequently transferred from smaller hospitals to larger medical centers for aggressive management, including hemodynamic monitoring, counterpulsation with an intra-aortic balloon, and surgery. We reviewed our experience with hemodynamic monitoring in our coronary care unit to determine what effect such monitoring had on the management of patients and the outcome. We grouped our data from patients transferred from other hospitals in order to evaluate the role that hemodynamic monitoring played in their care and to determine if transfer for hemodynamic monitoring is justified.

**Materials and Methods**

From Jan 1, 1975 to Jan 1, 1977, a total of 74 patients underwent hemodynamic monitoring in the Levine Cardiac Unit of the Peter Bent Brigham Hospital, Boston. Charts from 67 of these patients were available for review. Forty had been transferred from other hospitals. Forty-four patients were men, and 23 were women. The average age was 59 years, and patients ranged in age from 30 to 89 years.

Forty-six patients underwent hemodynamic monitoring because of persistent hypotension, defined as a systolic blood pressure of less than 90 mm Hg despite therapy. Ten patients underwent hemodynamic monitoring for management of severe congestive heart failure without hypotension. Four hypotonic patients had hemodynamic monitoring to help determine if the cause of their hypoxia was pulmonary or cardiac. Three patients had hemodynamic monitoring for detection of acute ventricular septal defects, and one patient underwent hemodynamic monitoring to help manage therapy designed to reduce afterload in severe congestive heart failure. Three transferred patients with unstable angina underwent hemodynamic monitoring to determine the effect of angina on pulmonary capillary wedge pressure. Three additional transferred patients with high-grade ventricular ectopic activity underwent hemodynamic monitoring because they also were...
hypotensive. In these cases the hypotension was secondary to the ventricular ectopy and was not due to pump failure.

In the hypotensive group, 39 of 46 patients were diagnosed as having acute myocardial infarction by standard electrocardiographic and enzymatic criteria. Three additional hypotensive patients who had patterns of left bundle-branch block on their electrocardiograms were also judged to have had acute myocardial infarction by the clinical history and enzymatic patterns. The myocardial infarction was inferior in eight patients, anterior in 21 patients, anterior and inferior in seven patients, and subendocardial in three patients.

Pulmonary arterial pressure and pulmonary capillary wedge pressure were measured with Swan-Ganz catheters by methods previously described. The pulmonary capillary wedge pressure was verified by an appearance of a wave form typical of pulmonary capillary wedging which had a lower mean value than the mean pulmonary arterial pressure. In questionable cases, oximetric studies were also used to confirm the pulmonary capillary wedge pressure. Sixty-five patients had Swan-Ganz catheters inserted. Forty-one patients had both Swan-Ganz catheters and peripheral arterial catheters. Two patients had hemodynamic monitoring with peripheral arterial catheters alone.

Pertinent historical, physical, laboratory, electrocardiographic, radiologic, and hemodynamic data were culled from the charts. Univariate analysis was performed on 87 parameters, and statistical inference was made by the \( \chi^2 \) method.

**RESULTS**

During the two-year period of study, 1,030 patients were admitted to our coronary care unit, 945 (92 percent) of whom survived. Of the total group, 414 (40 percent) had acute myocardial infarctions. Of these 414 patients, 347 (84 percent) survived. Of the 1,030 admissions, 74 patients (7 percent) underwent hemodynamic monitoring. In the group of 67 patients with charts available who underwent hemodynamic monitoring, 31 (46 percent) survived. Forty-nine (73 percent) of these 67 patients had acute myocardial infarctions. Of the 67 patients in the group under study, 40 (60 percent) were referred from other institutions, while 27 patients (40 percent) were direct admissions. The rate of survival for the referred patients (45 percent; 22/49) was quite similar to the rate of survival in our direct admissions (48 percent; 13/27).

**Indications for Hemodynamic Monitoring**

The indications for hemodynamic monitoring in the whole group under study and statistics on survival according to those indications are listed in Table 1. The majority of patients underwent hemodynamic monitoring for persistent hypotension. The rate of survival in this group was 46 percent (21/46). The indications for transfer in the referred group are listed in Table 2. Persistent hypotension was the major reason for transfer to our institution. The rate of survival was 43 percent (12/28) in this group of patients.

### Table 1—Indications for Hemodynamic Monitoring in 67 Patients Admitted to the Coronary Care Unit

<table>
<thead>
<tr>
<th>Indication</th>
<th>No. of Patients</th>
<th>Percent of Group</th>
<th>No. of Survivors (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>46</td>
<td>69</td>
<td>21 (46)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>10</td>
<td>15</td>
<td>7 (70)</td>
</tr>
<tr>
<td>Cardiac vs pulmonary cause of hypoxia</td>
<td>4</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Possible tamponade</td>
<td>3</td>
<td>4</td>
<td>3 (100)</td>
</tr>
<tr>
<td>Possible ventricular septal defect</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Monitoring for afterload reduction</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>100</td>
<td>31 (46)</td>
</tr>
</tbody>
</table>

**Survival and Hemodynamic Monitoring**

Of the 46 patients who underwent hemodynamic monitoring because of hypotension, 18 (39 percent) had a value for pulmonary capillary wedge pressure that was equal to or less than 16 mm Hg, 24 patients had a value of 17 mm Hg or more, and four patients had no value recorded in their charts. The rate of survival of patients in the group with low pulmonary capillary wedge pressure was 83 percent (15/18), compared with 25 percent (6/24) in the group with high pulmonary capillary wedge pressure (P < 0.001). Twenty-eight of these 46 patients were referred because of hypotension; 11 patients (39 percent) had a value for pulmonary capillary wedge pressure of 16 mm Hg or less, and 13 patients (46 percent) had a value of 17 mm Hg or more, and four patients (14 percent) had no value recorded. Ten (91 percent) of the 11 hypotensive referred patients

### Table 2—Indications for Hemodynamic Monitoring in 40 Transferred Patients

<table>
<thead>
<tr>
<th>Indication</th>
<th>No. of Patients</th>
<th>Percent of Group</th>
<th>No. of Survivors (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>28</td>
<td>70</td>
<td>12 (43)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>3</td>
<td>7.5</td>
<td>0</td>
</tr>
<tr>
<td>Ventricular ectopic activity</td>
<td>3</td>
<td>7.5</td>
<td>2 (67)</td>
</tr>
<tr>
<td>Tamponade</td>
<td>2</td>
<td>5</td>
<td>2 (100)</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>3</td>
<td>7.5</td>
<td>2 (67)</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>1</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100</td>
<td>18 (45)</td>
</tr>
</tbody>
</table>
patients with a pulmonary capillary wedge pressure of 17 mm Hg or more received therapy with pressor agents, counterpulsation via an intra-aortic balloon, or surgery, singly or in combination. Of 18 patients who received counterpulsation via an intra-aortic balloon as part of their therapy, three (17 percent) survived.

Eight patients underwent surgery. Three patients underwent correction of a ventricular septal defect, but there were no survivors. Five patients underwent procedures for coronary revascularization combined with infarctectomy; one of these five survived.

**Factors Associated with Poor Prognosis**

Details of history, physical examination, ECG, chest x-ray film, and laboratory data were subjected to univariate analysis regarding their effects upon prognosis. A history of therapy with digitalis, tachycardia on admission, and an increase in the level of blood urea nitrogen (BUN) during the first five days of hospitalization were all associated with a poor prognosis. Nine (31 percent) of the 29 patients receiving therapy with digitalis survived, while 22 (58 percent) of the 38 patients who were not receiving digitalis survived ($P < 0.02$).

Sinus tachycardia, defined as sinus rhythm at a rate greater than 100 beats per minute on the admission ECG, was also associated with a poor prognosis. Eight (30 percent) of the 27 patients with sinus tachycardia survived, compared with 19 survivors (56 percent) out of 34 patients who were in normal sinus rhythm on admission ($P < 0.04$). Eighteen (86 percent) of the 21 patients whose BUN level was less than 25 mg/100 ml during the first five days survived, compared with only 12 survivors (28 percent) out of 43 patients who developed azotemia during the first five days ($P < 0.001$).

Twenty-one patients underwent hemodynamic monitoring for reasons other than hypotension. In each category, we believed that the numbers of patients were too small to reach meaningful conclusions.

**Complications**

One patient developed ventricular tachycardia during passage of the Swan-Ganz catheter into the right ventricle. His cardiac rhythm reverted to normal sinus rhythm with withdrawal of the catheter and administration of lidocaine. No further attempts were made to insert a catheter into this patient. He died two days later of pump failure. No other complications of hemodynamic monitoring were encountered.

**HEMODYNAMIC MONITORING OF HYPOTENSION AFTER MI**

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**Figure 1. Rate of survival of hypotensive transferred patients according to pulmonary capillary wedge pressure (PCWP).**

with low pulmonary capillary wedge pressure survived, whereas only one (8 percent) of 13 hypotensive referred patients with a pulmonary capillary wedge pressure of 17 mm Hg or more survived ($P < 0.001$) (Fig 1). Pump failure was the cause of death in all hypotensive patients who died.

Hemodynamic monitoring uncovered 18 patients in whom therapy to expand the blood volume might have improved their hemodynamic status. Six (33 percent) of these 18 patients had no third heart sound audible on physical examination, and 12 individuals (67 percent) had abnormal pulmonary findings on the chest x-ray film. Six of these latter 12 patients had chest x-ray films that showed pulmonary vascular redistribution, and six had frank pulmonary edema. Of 36 patients with a pulmonary capillary wedge pressure of 16 mm Hg or less, the chest x-ray film was interpreted as normal in four patients, as showing pulmonary vascular redistribution in 19 patients, and as showing pulmonary edema in 13 patients.

**Therapy**

Therapy was largely predicated upon the hemodynamic status. All hypotensive patients with a pulmonary capillary wedge pressure of 16 mm Hg or less, including 11 referred patients, received therapy to expand the blood volume. Such expansion of volume was accomplished with physiologic saline solution in 11 cases and with 0.5N saline solution in seven cases. The rate of survival was the highest in this group (83 percent; 15/18). No patients with low wedge pressure received therapy with counterpulsation via an intra-aortic balloon. Hypotensive
**DISCUSSION**

The Swan-Ganz catheter has been widely used in the monitoring of patients whose condition is hemodynamically unstable. The advantages of monitoring pulmonary capillary wedge pressure rather than central venous pressure have previously been shown. Frequently, ill patients are transferred from smaller hospitals to larger hospitals for hemodynamic monitoring and other aggressive diagnostic and therapeutic interventions. The ride in the ambulance itself may not be a benign procedure, since the condition of a small percentage of patients may become even more unstable en route. We therefore undertook this study to determine the effect that hemodynamic monitoring had on the course of illness in patients, particularly those transferred from other institutions.

The most common indication for hemodynamic monitoring and the most common cause for transfer was hypotension. Sixty-nine percent (46/67) of all patients undergoing hemodynamic monitoring had persistent hypotension, and of these, 91 percent (42/46) had had acute myocardial infarction. It is well known that the combination of hypotension and elevated left ventricular filling pressure is associated with a poor prognosis. In a recent study by Forrester et al, only 49 percent of such patients survived. These patients do poorly because hypotension in the face of elevated left ventricular filling pressure is usually due to severe pump failure. Once the optimal filling pressure is reached, further elevation does not produce further increase in cardiac output.

It was surprising to us that the pulmonary capillary wedge pressure was 16 mm Hg or less in 18 (43 percent) of 42 hypotensive patients in whom this pressure was measured. Eleven (61 percent) of these 18 were transferred from other institutions. A third heart sound was not heard in a third of these patients, and chest x-ray films in these individuals demonstrated pulmonary vascular redistribution in one-third and pulmonary edema in another third. Thus, on purely clinical grounds, it would have been difficult to know the status regarding the blood volume in many of these patients. This lack of correlation between pulmonary capillary wedge pressure and radiographic pulmonary edema is of greater magnitude than that found by McHugh et al, who noted severe mismatches between pulmonary capillary wedge pressure and chest roentgenographic findings in only 10 percent of patients. All six of our patients who had radiographic pulmonary edema and yet low pulmonary capillary wedge pressure had received therapy with diuretic drugs prior to the x-ray film. Posttherapeutic phase lag between the change in pulmonary capillary wedge pressure and the radiographic findings may explain this discrepancy.

All patients with hypotension and low pulmonary capillary wedge pressure received therapy to expand their blood volume. The rate of survival in this group was high (83 percent; 15/18), compared with 25 percent (6/24) in the group of hypotensive patients with high pulmonary capillary wedge pressure in whom therapy to expand the blood volume would not be expected to improve cardiac output.

The individuals with high pulmonary capillary wedge pressure and hypotension are patients with true cardiogenic shock secondary to severe pump failure, and the rate of survival in this group continues to be dismal. Our rate of survival of 25 percent (6/24) is similar to that noted in previous studies. Scheidt et al found a rate of survival of only 14 percent in a similar group of patients, while the rate of survival reported by Forrester et al in patients with cardiogenic shock was 49 percent. Our experience with therapy via counterpulsation with an intra-aortic balloon in patients with cardiogenic shock was also unfavorable. Only three patients (17 percent) survived out of 18 patients receiving therapy with counterpulsation via an intra-aortic balloon. This figure is in close agreement with previous studies.

It is obviously impossible to know what the outcome would have been in our patients had they not been transferred. The scanty data regarding the treatment of hypotensive cardiac patients in community hospitals shows a rate of survival in such patients of 10 to 46 percent, however, frequently in these studies, the definition of cardiogenic shock and the procedures used in caring for patients in shock are not given. Thus, it is difficult to compare our patients with the patients in these studies.

We found that previous therapy with digitalis, tachycardia, and azotemia were associated with a poor prognosis. All of these factors are indicators of severe left ventricular dysfunction and therefore tend to be coincidental with severe pump failure.

**CONCLUSIONS**

Hemodynamic monitoring is a useful tool in the management of patients who develop hypotension coincidental with myocardial infarction, because monitoring uncovers patients who have a relative depletion of the blood volume and who therefore benefit from expansion of that volume. Such depletion of the blood volume may be difficult to determine on clinical or noninvasive grounds. At the
present, while it is hoped that better noninvasive assessment of left ventricular function will be forthcoming, hemodynamic monitoring is still the safest and most effective way to assess left ventricular function in the coronary care unit. Thus, transfer of patients for hemodynamic monitoring seems justified.

REFERENCES

5 Marriott HJL: Practical Electrocardiography (5th ed.). Baltimore, Williams and Wilkins Co, 1972, pp 228-250