Association of Hypotensive State in Myocardial Infarction with Subsequent Metabolic Responses and Mortality in Elderly Subjects

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Ten elderly patients with typical findings of acute myocardial infarction were studied for two weeks on a metabolic ward. Blood pressures were determined hourly, and balances of nitrogen, water and electrolytes were computed daily. Surviving patients had higher blood pressures, lower heart rates, lost more weight, exhibited negative sodium balance and had earlier recovery from negative nitrogen and potassium balance. Early appearance of hypotension presaged clinical complications, unfavorable metabolic responses and a fatal outcome.

HYPOTENSION occurring in patients with myocardial infarction is associated with increased mortality when shock is present.

Many of these patients in shock succumb despite treatment with pressor amines. Such patients undergo severe stress and the high mortality raises the question of the adequacy of the metabolic responses.

Only a few studies describing the metabolic responses to myocardial infarction have come to our attention despite the plethora of communications dealing with the entity. Wilhelm reported in 1951 increased concentrations of serum potassium in all of 10 patients following myocardial infarction. Serum sodium concentrations were below 133 m Eq. per liter in seven patients. Donzelot and Kaufman noted eosinopenia and increased urinary excretion of 11-oxysteroids and 17-ketosteroids in four patients between the third and fifth days after infarction, and depressed excretion from the seventh to the fourteenth day. Such changes were interpreted as evidence of adrenal cortical reaction to injury.

The metabolic response to myocardial infarction would seem to be of particular import in the elderly subject because of the associated high mortality. A recent survey by Smart of 160 patients admitted to the King County Hospital (Seattle) with a diagnosis of myocardial infarction and covering a 30-month period indicated an overall mortality of 74 per cent, one-third dying within the first 24 hours. Besides advanced age (males averaged 67.4 years, females 70.4 years), most of these patients had clinical pathologic findings associated with a poor prognosis. The mortality was 96 per cent in 26 patients in shock, despite treatment with norepinephrine, while it was only 80 per cent in 36 untreated patients also in shock. Although the study conducted by Smart was not a controlled one, but a survey of the clinical records, it raises the question of the importance of hypotension after myocardial infarction in the elderly subject.

This report differentiates the hypotensive and metabolic responses in elderly patients who died from myocardial infarction from the changes occurring in those patients who survive. For the purposes of this study, hypotension was defined as systolic pressure below 90 mm. Hg.

Material and Procedure

Preliminary Observations

From August to December 1953, serum and urinary electrolytes were studied for seven-day periods in 15 consecutive patients with acute myocardial...
Changes in renal value

Since renal function was evaluated, it was suggested that these patients might be suffering from a metabolic derangement that could be accurately described. Thus, the serum sodium and potassium concentrations were measured at four-hour intervals during the first 24 hours of hospitalization, and the urinary sodium and potassium excretion were determined. The results of these determinations are presented in Table 1.

Table 1.—Preliminary Survey of Electrolyte Changes with Acute Myocardial Infarction (Mean Values in 15 Patients)

<table>
<thead>
<tr>
<th>Post-Infarction days</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Serum Concentration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K, mEq/L............</td>
<td>4.7</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.1</td>
<td>5.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Na, mEq/L...........</td>
<td>142</td>
<td>143</td>
<td>140</td>
<td>142</td>
<td>141</td>
<td>142</td>
<td>140</td>
</tr>
<tr>
<td><strong>Urinary Excretion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hr. volume, ml.</td>
<td>909</td>
<td>840</td>
<td>924</td>
<td>1233</td>
<td>1211</td>
<td>1104</td>
<td>1135</td>
</tr>
<tr>
<td>24 hr. Na, mEq.</td>
<td>67</td>
<td>40</td>
<td>40</td>
<td>47</td>
<td>32</td>
<td>31</td>
<td>25</td>
</tr>
</tbody>
</table>

Infarction (table 1). There was very slight elevation of serum potassium concentration from an initial value of 4.7 to 5.2 mEq per liter, and possibly slight renal conservation of sodium during this period. Since these patients were on the general wards of the hospital, it was not feasible to determine accurately the dietary intakes. These observations suggested that metabolic responses occurred after infarction, but the paucity of information precluded an adequate description.

Clinical Material

Seven men and three women, ranging in age from 52 to 82 with a mean of 72.2 years, were admitted to the Metabolic Ward with typical findings (table 2). Clinical shock was manifest on admission in one patient; four other patients exhibited hypotension. Based upon Schnur's Pathologic Index Ratings, after the first day, the predicted mortality ranged from 50 to 75 per cent.

Methods

Each patient was attended by a special nurse for 24 hours daily for two weeks. Blood pressures and heart rates were obtained hourly around the clock. Fluid intake and output were recorded, and daily body weights were obtained (Invalift). A trained dietitian estimated intake of calories, nitrogen, potassium, sodium and chloride daily. Sodium intake was limited to 400 mg. (17 mEq.), whereas calories were permitted ad libitum.

Vital capacity, venous pressure (with zero reference level 10 cm. above mattress with patient supine), arm-to-tongue circulation time (Decholin), erythrocyte sedimentation rate and hematocrit were done regularly two to three times weekly. Daily sodium and potassium concentrations in serum and urine were determined using a Baird flame photometer, with an internal lithium standard. Nitrogen was determined by a modified urease method. "Crude water balance" was calculated from the difference in measured intake and measured urine excretion, disregarding insensitive, sweat and fecal losses, but including any emesis. Marked diaphoresis was observed in only one subject, W. G., who had shock on admission and survived. None had any diarrhea. "Crude balances" for nitrogen, sodium and potassium were determined in a similar manner. The volume-distributions of Evans blue and sodium thiosulfate were determined during both the first and second weeks in six of the patients.

Three patients were treated with pressor amines for clinical shock (table 3). Once blood pressure appeared to be stable clinically, and patients were free of symptoms or signs of shock, pressor amines were

Table 2.—Clinical Findings on Admission in 10 Patients With Acute Myocardial Infarction

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, sex</th>
<th>History of:</th>
<th>BP, mm. Hg</th>
<th>Clinical shock</th>
<th>Congestive failure</th>
<th>ECG, diagnosis of infarction</th>
<th>PIR* (Schnur)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Living:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. D.</td>
<td>79M</td>
<td>6 years</td>
<td>+</td>
<td>+</td>
<td>98/65</td>
<td>Anterior</td>
<td>20</td>
</tr>
<tr>
<td>W. G.</td>
<td>52M</td>
<td>6 years</td>
<td>+</td>
<td>+</td>
<td>90/50</td>
<td>Anterior septal</td>
<td>125</td>
</tr>
<tr>
<td>M. B.</td>
<td>72F</td>
<td>7 years</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>LBBB</td>
<td>70</td>
</tr>
<tr>
<td>T. L.</td>
<td>71M</td>
<td>5 years</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Posterior</td>
<td>20</td>
</tr>
<tr>
<td><strong>Dying:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. McG.</td>
<td>77F</td>
<td>5 years</td>
<td>+</td>
<td>+</td>
<td>130/80</td>
<td>Anterior</td>
<td>60</td>
</tr>
<tr>
<td>C. K.</td>
<td>82F</td>
<td>5 mo.</td>
<td>-</td>
<td>-</td>
<td>70/50</td>
<td>Posterior</td>
<td>110</td>
</tr>
<tr>
<td>J. L.</td>
<td>71M</td>
<td>5 years</td>
<td>+</td>
<td>+</td>
<td>160/100</td>
<td>Anterior</td>
<td>65</td>
</tr>
<tr>
<td>D. v. T.</td>
<td>68M</td>
<td>7 years</td>
<td>+</td>
<td>+</td>
<td>98/72</td>
<td>Postero septal</td>
<td>70</td>
</tr>
<tr>
<td>A. B.</td>
<td>70M</td>
<td>7 years</td>
<td>+</td>
<td>+</td>
<td>106/68</td>
<td>Posterior</td>
<td>65</td>
</tr>
<tr>
<td>F. S.</td>
<td>80M</td>
<td>5 years</td>
<td>+</td>
<td>+</td>
<td>134/80</td>
<td>Posterior</td>
<td>65</td>
</tr>
<tr>
<td><strong>Mean:</strong></td>
<td>72.2</td>
<td>27 mo.</td>
<td></td>
<td></td>
<td>121/76</td>
<td></td>
<td>67</td>
</tr>
</tbody>
</table>

* Pathologic index rating.
discontinued despite the persistence of asymptomatic hypotension. All patients not already digitalized received digitoxin, because of appearance of congestive heart failure during their hospital course.

All observations were referred to the day of onset of myocardial infarction as determined from the clinical history. Following intensive study for two weeks, surviving patients were transferred to the general medical wards for further clinical observation. Death within four weeks after onset was attributed to myocardial infarction, even if other causes developed terminally. For study purposes, the data obtained on living patients has been grouped together for comparison with similar observations on patients who died within this four-week interval.

### Observations

The clinical course was typical of patients with acute myocardial infarction observed in this hospital (table 3). Except for slightly higher temperatures (1 F.) in dying patients on the first two days, there was no difference in mean febrile responses between these two groups. The mean white blood cell count fell from 12,010 to 9,900 in the surviving patients, and it increased from 10,700 to 12,400 in the dying patients. There were negligible changes in sedimentation rate between these two groups. Severe clinical shock was present on admission in W. G. who survived, whereas it developed after admission in three other patients who subsequently died. One of these resulted in sudden death on the sixth day. A cerebrovascular accident occurred in two patients, but only C. K. who also developed pneumonia and an urinary tract infection died. Two other patients had their postinfarction course complicated by multiple infections which caused death on the twenty-first and twenty-seventh days. Congestive heart failure was present during the hospital course in all patients but M. B. This hypertensive patient had a history of angina pectoris and congestive failure for a year before; she had more failure and left bundle branch block (which obscured electrocardiographic evidence of infarction) on admission. Her physical findings and course were typical of myocardial infarction, nevertheless.

Six of the 10 patients died within 4 to 28 days from the onset of infarction. The primary cause of death in these patients was considered to be myocardial infarction, even though various contributory causes were present.

### RESULTS

1. **Blood Pressure and Heart Rate**

Low blood pressure was a persistent feature in fatal cases (fig. 1). From the second to eighth days, the mean hourly systolic pressure
The mean systolic pressure of survivors gradually declined, until there was no significant difference in systolic pressure between surviving and dying patients after the first week. The hourly incidence of hypotension during the two weeks of observation was 24.9 ± 9.5 per cent for the dying patients versus 6.1 ± 6.4 per cent for the surviving patients ($p < .001$).

The hourly incidence of low diastolic pressures (under 60 mm. Hg) was 28.4 ± 5.1 per cent in surviving patients for the two-week period of study ($p < .001$). This difference was particularly marked during the second week.

The heart rate never exceeded 100 beats per minute for the first four days in the survivors (fig. 1), but it was frequently above 100 from the fifth to tenth days.

2. Serum Cations

The mean concentration of serum potassium ranged from 4.5 to 5.6 mEq per liter in surviving and dying patients (fig. 2). The mean concentration of serum sodium gradually fell in dying patients from an initial value of 143 to 134 mEq per liter in the second week (fig. 2).

3. Metabolic Balances

After the first five days, there was a slight, but significant difference ($p < .001$) in the daily sodium balance between surviving and dying patients (fig. 3). Due to the renal conservation of sodium in only the dying patients...
Sodium Balance (mEq./day)

Potassium Balance (mEq./day)

Nitrogen Balance (Gms./day)

Fig. 3. Mean daily balances show sodium loss, along with more rapid return to positive potassium, and nitrogen balance in patients who survived.

from the sixth to thirteenth days, there was a mean cumulative difference of \(-137\) mEq. sodium between these two groups.

Both nitrogen and potassium balances were negative initially in both groups of patients (fig. 3). The survivors recovered earlier, possibly due to greater caloric intake in these patients (fig. 4).

There was no significant difference in the crude water balances between these two groups (fig. 4). Despite this similarity and a greater caloric intake, but no significant differences in mean temperatures, the surviving patients still lost weight more rapidly (fig. 4). This latter difference suggested a better circulatory status and greater metabolic activity in surviving patients.

4. Volume Distribution of Sodium Thiosulfate

The changes in mean body weight and volume-distributions of sodium thiosulfate and Evans blue (T-1824) are shown in figure 5. There was a 4.5 per cent reduction in weight and 12 per cent decrease in volume-distribution of sodium thiosulfate from the first to second weeks in surviving patients. Dying patients, in contrast, showed less change in weight and 12 per cent increase in the thiosulfate space. In all instances the mean thiosulfate spaces ranged from 15 to 18 per cent of the body weight.
5. Derived Blood Volume

There was a negligible decrease in Evans blue space and derived red blood cell volumes (fig. 5), together with a slight rise in hematocrit from 38.3 to 40.3 per cent in surviving patients. The hematocrit fell in the dying patients from 41.8 to 36.3 per cent.

6. Venous Pressure and Circulation Time

The mean values for venous pressure and circulation time in the two groups of patients during the first and second week are shown in figure 6. Not only did the surviving patients have a larger volume distribution of sodium thiosulfate initially and greater fall by the second week, but they also exhibited higher venous pressures and circulation times initially than the dying patients.

DISCUSSION

The average age, relative severity of pathologic findings and mortality of the 10 elderly patients described in this report were roughly comparable with that of 160 patients with the same diagnosis who were observed in King County Hospital. Nevertheless, some selection was unavoidable, inasmuch as the patients had to survive the immediate vascular insult in order to be admitted to the Metabolic Ward for study. The 10 patients were representative of patients admitted to King County Hospital with myocardial infarction and surviving the first day. Due to the small number of patients studied, these observations only can be considered as preliminary.

Distinct differences were found in hypotensive, clinical and metabolic responses between patients who survived and those patients who died.

Although only two of the four surviving patients had congestive failure on admission in contrast to all six of the dying patients (table 2), venous pressure and circulation time were higher in the survivors initially. Thiosulfate space was also larger in these individuals.

Hourly observations of blood pressure continuously for two weeks revealed hypotension to be a conspicuous characteristic of patients who subsequently died. Not only was the
systolic pressure more frequently below 90 mm. Hg, but the diastolic pressure also was more commonly below 60 mm. Hg. There were phasic differences in incidence of heart rates over 100 per minute in addition.

Dying patients experienced more clinical complications than living patients (table 3). They ate less, lost weight more gradually, exhibited renal conservation of sodium, and more prolonged negative nitrogen and potassium balances. Thiosulfate space, venous pressure and circulation time were not as high initially, but thiosulfate space increased, rather than decreased, during the second week. Serum sodium concentration decreased slightly. These responses were compatible with adrenal cortical reaction to stress, but whether the magnitude of changes was proportional to myocardial and other insults remains unanswered. The fact that death occurred suggests the possibility of an inadequate adrenal cortical reaction, and raises the question of need for adrenal cortical supplementation. Lacking any data or quantitative differences in eosinopenia or urinary excretion of 11-oxy and 17-ketosteroids affords no opportunity for appraising this possibility. Furthermore, it is impossible to predict from these data whether hormonal therapy would be beneficial, as has been recommended by Breu.29

The fact that hypotension initially was one of the outstanding characteristics of dying patients indicates that observed clinical complications and quantitative differences in metabolic responses may well be associated with a hypodynamic circulation. Furthermore, the differences in venous pressure, circulation time and thiosulfate space suggest impaired mechanisms for venous return. An adequate evaluation of these possibilities awaits a study of serial hemodynamic observations in both living and dying patients.

Probably the major factor determining the prolonged circulation time was the central blood volume. Possibly surviving patients had more effective mechanisms for venous return of blood to the heart by virtue of the greater volume and pressure.

Finally, any inferences from this study to the overall problems of morbidity and mortality from myocardial infarction should be made with great caution due to the advanced age and small number of patients studied.

**Summary**

1. Ten patients with typical findings of acute myocardial infarction were studied for two weeks after admission to the Metabolic Ward of King County Hospital.
2. Six of these patients died of myocardial infarction and terminal complications within four weeks.
3. None of the survivors had hypotension or tachycardia, evaluated by hourly determinations, during first three days.
4. Systolic and pulse pressures diminished gradually in the survivors.
5. Surviving patients had higher mean venous pressures, circulation times and volume distribution of sodium thiosulfate initially, together with reductions in each of these factors during the second week. These changes were associated with greater loss of weight, negative sodium balance, and earlier recovery from negative potassium and nitrogen balances observed in these patients.
6. Dying patients exhibited a slight decrease in serum sodium concentration, renal conservation of sodium, expansion of volume distribution of sodium thiosulfate, as well as persistently lower blood pressures.
7. It is concluded that the early appearance of hypotension following acute myocardial infarction presaged clinical complications and unfavorable metabolic responses as well as a fatal outcome in these patients.

**SUMMARIO IN INTERLINGUA**

1. Esseva studiate 10 patientes con typic constatationes de acut infarimento myocardic. Le studios esseva executeate al Sala Metabolic del Hospital de King County a Seattle. Illos coperiva 2 septimanas post le admission del patientes.
2. Intra 4 septimanas, 6 del patientes moriva de infarimento myocardic con complicaciones terminal.
3. Nulle del superviventes habeva hypoten-
sion o tachycardia secundo le evaluatIon de determinaciones execute a intervalos de un hora durante le prime 3 dies.

4. Le superviventes mostrava un reduction gradual del pressures systolic e pulsar.

5. Le superviventes habeva inicialmente plus alte valores median del pression venose, del tempore circulatori, e del distribution voluminic de thiosulfato de natrium. Omne iste factores mostrava valores decrecente in le curso del secunde septimana. Iste cambios mentos esseva associate con un plus grande perdita de peso, un negative balancia de natrium, e un plus prompte rectification de negative balancias de kalium e nitrogeno.

6. Le patientes qui moriva exhibiva un leve reduction del concentration de natrium seral, retention renal de natrium, expansion del distribution voluminic de thiosulfato de natrium, e un persistent e plus marcate hypotension.

7. Nos conclude que le precoce apparition de hypotension post acute infarcimento myocardic esseva in iste patientes un presagio de complicationes clinic e de disfavorabile responses metabolic a termino mortal.

REFERENCES


Association of Hypotensive State in Myocardial Infarction with Subsequent Metabolic Responses and Mortality in Elderly Subjects
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