Acute Hemodynamic Effects of Dopamine in Patients with Shock

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SUMMARY
The hemodynamic effects of dopamine were studied in 62 patients with clinical shock. In 36 patients with infection dopamine increased mean arterial pressure (MAP) 30%, and cardiac output (CO) 37%. Urine flow (UF) increased from 0.5 ml/min to 1.6 ml/min. Norepinephrine (NE) in 26 patients resulted in a higher MAP, lower CO, and similar UF. Isoproterenol (Isp) in 19 patients resulted in a lower MAP, higher CO, and a significantly lower UF. In 13 patients with cardiogenic shock dopamine increased MAP 6%, and CO 40%. UF increased from 0.6 ml/min to 1.1 ml/min. NE in eight patients resulted in a lower CO than during dopamine infusion, and Isp in five patients resulted in a higher CO. Dopamine improves MAP pressure, CO, and UF when shock is due to infection and is superior to Isp which does not increase perfusion pressure to adequate levels and does not improve UF. In patients with cardiogenic shock who have reduced CO and increased systemic vascular resistance, perfusion pressure tended to be adequate, and improved CO occurred with dopamine and Isp but not with NE. Although Isp increased CO more than dopamine, differences in regional perfusion are important in selection of the best inotropic agent and in most patients make dopamine the preferred agent.

Additional Indexing Words: Inotropic agent Cardiac output Left ventricular end-diastolic pressure Urine flow

Dopamine, a precursor of norepinephrine (NE), exerts positive inotropic and chronotropic effects, but differs from NE by causing nonadrenergic vasodilatation in mesenteric and renal vascular beds. Dopamine differs from isoproterenol (Isp) by causing vasoconstriction in certain other vascular beds through alpha-adrenergic receptor stimulation. Because of these hemodynamic effects, dopamine has been advocated for use in patients with shock not responding to volume expansion. This study was designed to evaluate the acute hemodynamic effects of dopamine in patients with various types of shock and to compare these with the effects of NE and Isp. In this manner we hoped to determine the conditions under which dopamine might be of most benefit.

Methods
Sixty-two patients were studied. Their ages averaged 56 years, with a range from 21 years to 78 years. There were 36 males and 26 females. Patients were selected for study because they fulfilled clinical criteria for shock, including diminished blood pressure, decreased pulse volume, obtundation, and oliguria. If a low central venous pressure suggested hypovolemia as the cause for shock, plasma volume expansion was undertaken prior to evaluation of vasoactive...
drugs. Ventilatory assistance, antibiotics, and other supportive measures were used as indicated. Efforts were made to maintain a constant underlying control state, thus permitting comparison of dopamine to NE and Isp without interposing additional variables unless required because of a change in the patient's condition. Because hemodynamic changes unrelated to therapy occur during shock, the study was designed to assess just the acute hemodynamic responses to each agent so that all three drugs could be evaluated within a 2- to 3-hr period. Each drug was infused at a constant rate for 30 min or until a new steady state was obtained. Hemodynamic measurements were made and the drug was discontinued. After a 30-min control period hemodynamic studies were repeated and the next drug infusion started. In a few patients it was not possible to achieve a steady state for the control period between drug infusions. The order in which the drugs were infused was randomized whenever possible. The infusion rates for each drug were adjusted to raise the mean arterial pressure (MAP) to between 70 and 90 mm Hg, or to increase MAP by 20 mm Hg in patients whose control pressures were not reduced. When a pressor response did not occur, the drugs were infused in amounts known from past experience to exert significant hemodynamic effects. Dopamine was infused in amounts of from 0.1 to 1.6 mg per min (average 0.75 mg per min).

Studies were performed in a specially equipped hemodynamic research unit adjacent to the Medical Coronary and Intensive Care Unit. Left ventricular pressures were obtained by passing a no. 7 or 8 F Lehman ventriculography catheter from a surgically exposed right brachial artery into the left ventricle under fluoroscopic control. The left ventricular end-diastolic pressure (LVEDP) was obtained by averaging several complexes through more than one respiratory cycle. When in doubt, the pressure at the peak of the R wave of the ECG was used as the LVEDP. Aortic root pressure and its electronically derived MAP were measured by slight withdrawal of the left ventricular catheter, which brought the catheter's side holes above the aortic valve but left the closed tip within the ventricle. While observing the pressure wave form on a display oscilloscope, the catheter could, at any time, be advanced until the side holes reentered the ventricle and the pressure contour changed from aortic to left ventricular. By this method both LVEDP and MAP could be repeatedly measured without the need for excessive catheter manipulation or fluoroscopy time. Central venous pressure (CVP) was measured from a catheter placed in the superior vena cava or right atrium. All pressures were measured using a Statham 23 Db transducer with the midchest position as the zero reference.

Cardiac output (CO) was calculated from an analysis of two or more indicator-dilution curves. Five mg of indocyanine green dye dissolved in 2 ml of diluant was injected into the central venous circulation, and arterial blood was sampled by constant withdrawal from the aortic root through a Gilford or Waters densitometer with a Harvard constant withdrawal pump. A Hewlett-Packard cardiac output computer model no. 130 was used for bedside assessment of CO and its changes. Heart rate (HR) was obtained from a continuously monitored ECG lead. Pressure pulses, indicator-dilution curves, and ECG were recorded on a Hewlett-Packard multichannel photographic recorder.

Stroke volume (SV), systemic vascular resistance (SVR), and left ventricular stroke work (LVSW) were calculated by the following formulae:

\[
SV \text{ (ml/beat)} = \frac{CO \text{ (liters/min)}}{HR \text{ (beats/min)}} \times 1000
\]

\[
SVR \text{ (mm Hg/ \text{liters/min})} = \frac{\text{MAP (mm Hg)} - \text{CVP (mm Hg)}}{\text{CO (liters/min)}}
\]

Urine flow (UF) was measured at frequent intervals from an indwelling catheter.

Statistical analysis was done by using the Student t-test for paired or unpaired observations. A P value above 0.05 was considered to denote that the difference between two mean values was not statistically significant (ns).

**Results**

**Clinical Characteristics**

Of the 62 patients studied, 37 patients did not respond to treatment and expired in shock, 15 patients improved and recovered from shock but expired later of their underlying illness, and 10 patients survived to leave the hospital.

We have separated these patients into three groups according to the probable cause of their shock syndrome (table 1). Thirty-six patients had shock associated with infection. Thirteen patients had cardiogenic shock due to...
DOPAMINE IN PATIENTS WITH SHOCK

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Table 1
Clinical Features and Outcome According to the Cause of Shock

<table>
<thead>
<tr>
<th>Cause of shock syndrome</th>
<th>No. of patients</th>
<th>Age (mean and range)</th>
<th>Sex</th>
<th>Outcome*</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Males</td>
</tr>
<tr>
<td>Infection</td>
<td>36</td>
<td>59 (33-78)</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Cardiogenic</td>
<td>13</td>
<td>59 (36-78)</td>
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<td>8</td>
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<tr>
<td>Miscellaneous</td>
<td>13</td>
<td>45 (21-62)</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

*Expired = patients failed to recover from shock; recovered = patients recovered from shock but expired at a later date from their underlying illness; survived = survived to be discharged from the hospital.

to acute myocardial infarction (five patients) or to cardiac failure complicated by proven or suspected pulmonary emboli (eight patients). In the remaining 13 patients shock was due to miscellaneous or multiple factors, including cerebral damage and pancreatitis, and/or followed cardiac arrest.

Hemodynamic Effects of Dopamine Compared to the Control State—62 Patients (Table 2)

Shock with Infection—36 Patients

In these patients dopamine infusion of 0.81 ± 0.06 mg/min (mean ± sem) resulted in significant increases in MAP (+30%), HR (+15%), CO (+37%), SV (+21%), LVEDP (+4.0 mm Hg), LVSW (+80%), and UF (+1.1 ml/min). CVP fell by 1.0 mm Hg (P < 0.05), and SVR was not significantly changed.

Cardiogenic Shock—13 Patients

During dopamine infusion of 0.59 ± 0.06 mg/min significant increases occurred in HR (+11%), CO (+40%), SV (+30%), and LVEDP (+2.4 mm Hg). SVR fell 20% (P < 0.01). Changes in MAP, CVP, LVSW, and UF were not statistically significant.

Shock of Miscellaneous Cause—13 Patients

In these patients infusion of dopamine at 0.77 ± 0.2 mg/min significantly increased MAP (+36%), HR (+12%), CO (+36%), SV (+21%), and LVSW (+96%). CVP, SVR, LVEDP, and UF were not significantly changed.

Hemodynamic Effects of Dopamine Compared to Norepinephrine and Isoproterenol

Shock Associated with Infection (Table 3)

The effects of dopamine and NE were compared in 26 patients with shock associated with infection. Dopamine was given first in 14 patients, and NE was the first drug given in 12 patients. Mean values for HR (114 vs. 105 beats/min) and CO (8.3 vs. 7.3 liters/min) were significantly higher during dopamine infusion. MAP (70 vs. 82 mm Hg), CVP (9.1 vs. 10.8 mm Hg), SVR (8.3 vs. 11.3 mm Hg/liter/min), and LVEDP (16.1 vs. 20.4 mm Hg) were higher during NE infusion. SV, LVSW, and UF were not significantly different during dopamine and NE infusions.

Nineteen patients with shock and infection received both dopamine and Isp. Ten patients received dopamine first and nine patients received Isp first. Significantly higher mean values for MAP (77 vs. 62 mm Hg), CVP (10.7 vs. 7.7 mm Hg), SVR (10.1 vs. 6.9 mm Hg/liter/min), LVEDP (19.4 vs. 11.6 mm Hg), and UF (1.2 vs. 0.4 ml/min) were present during infusion of dopamine. Values for CO (7.2 vs. 8.4 liters/min) and SV (65 vs. 72 ml/beat) were higher during NE infusion. Values for HR and LVSW did not differ significantly.

Cardiogenic Shock (Table 4)

Dopamine and NE were compared in eight patients with cardiogenic shock. Dopamine was the first agent evaluated in five patients and NE was evaluated first in three patients. Mean values for CO (4.2 vs. 3.0 liters/min) and SV (41 vs. 33 ml/beat) were significantly higher and SVR (18.1 vs. 31.2 mm Hg/liter/min) was significantly lower during dopamine infusion. MAP, CVP, HR, and UF were not significantly different. Values for LVEDP and LVSW (in two patients) were similar during infusion of both drugs.
### Table 2

**Hemodynamic Effects of Dopamine Infusion**

<table>
<thead>
<tr>
<th>Cause of shock</th>
<th>MAP (mm Hg)</th>
<th>CVP* (mm Hg)</th>
<th>HR (beats/min)</th>
<th>CO (liters/min)</th>
<th>SV (ml/beats)</th>
<th>SVR (mm Hg/liter/min)</th>
<th>LVEDP* (mm Hg)</th>
<th>LVSW (g-m)</th>
<th>UF* (ml/min)</th>
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<tr>
<td><strong>Infection:</strong></td>
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<td>23</td>
<td>23</td>
<td>36</td>
<td>36</td>
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<tr>
<td>Control</td>
<td>59 ± 2</td>
<td>10.5 ± 0.6</td>
<td>100 ± 4</td>
<td>6.1 ± 0.4</td>
<td>62 ± 4</td>
<td>9.1 ± 0.6</td>
<td>14.5 ± 1.2</td>
<td>39 ± 5</td>
<td>0.5 ± 0.2</td>
</tr>
<tr>
<td>Dopamine</td>
<td>75 ± 3</td>
<td>9.5 ± 0.8</td>
<td>114 ± 4</td>
<td>8.0 ± 0.6</td>
<td>72 ± 4</td>
<td>9.4 ± 0.7</td>
<td>18.5 ± 1.5</td>
<td>60 ± 5</td>
<td>1.6 ± 0.5</td>
</tr>
<tr>
<td>% change†</td>
<td>+30 ± 6</td>
<td>-1.0 ± 0.5</td>
<td>+15 ± 2</td>
<td>+37 ± 6</td>
<td>+21 ± 6</td>
<td>+6 ± 5</td>
<td>+4.0 ± 1.3</td>
<td>+80 ± 23</td>
<td>+1.1 ± 0.5</td>
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<td>&lt;0.01</td>
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<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.05</td>
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<td><strong>Cardiogenic:</strong></td>
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<td>5</td>
<td>5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>75 ± 5</td>
<td>13.6 ± 1.3</td>
<td>102 ± 5</td>
<td>2.8 ± 0.3</td>
<td>30 ± 4</td>
<td>23.0 ± 2.2</td>
<td>10.0 ± 2.5</td>
<td>29 ± 10</td>
<td>0.6 ± 0.3</td>
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<tr>
<td>Dopamine</td>
<td>78 ± 4</td>
<td>12.6 ± 1.3</td>
<td>112 ± 6</td>
<td>3.8 ± 0.4</td>
<td>36 ± 3</td>
<td>17.6 ± 1.3</td>
<td>12.4 ± 2.6</td>
<td>32 ± 8</td>
<td>1.1 ± 0.3</td>
</tr>
<tr>
<td>% change†</td>
<td>+6 ± 5</td>
<td>-0.9 ± 0.8</td>
<td>+11 ± 3</td>
<td>+40 ± 10</td>
<td>+30 ± 9</td>
<td>-20 ± 5</td>
<td>+2.4 ± 0.5</td>
<td>+39 ± 35</td>
<td>+0.4 ± 0.3</td>
</tr>
<tr>
<td>P value</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>NS</td>
<td>NS</td>
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<td><strong>Miscellaneous:</strong></td>
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<td>13</td>
<td>10</td>
<td>10</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>69 ± 9</td>
<td>8.1 ± 1.2</td>
<td>105 ± 5</td>
<td>7.0 ± 1.0</td>
<td>66 ± 9</td>
<td>9.8 ± 1.1</td>
<td>11.7 ± 1.6</td>
<td>65 ± 17</td>
<td>0.7 ± 0.2</td>
</tr>
<tr>
<td>Dopamine</td>
<td>85 ± 7</td>
<td>7.7 ± 1.2</td>
<td>116 ± 3</td>
<td>8.7 ± 0.9</td>
<td>75 ± 8</td>
<td>9.7 ± 1.2</td>
<td>13.6 ± 2.7</td>
<td>84 ± 14</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>% change†</td>
<td>+36 ± 13</td>
<td>-0.5 ± 0.6</td>
<td>+12 ± 2</td>
<td>+36 ± 10</td>
<td>+21 ± 7</td>
<td>+3 ± 6</td>
<td>+2.0 ± 1.7</td>
<td>+96 ± 34</td>
<td>-0.3 ± 0.2</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.05</td>
<td>NS</td>
<td>NS</td>
<td>0.02</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Changes for CVP and LVEDP are given in mm Hg. Changes for UF are given in ml/min. Values given are the means ± 1 standard error. P value was determined by Student t-test for paired observations.

†Percent change from control for each group was calculated by averaging the individual percent changes. Because of large individual variations, percent change calculated in this manner yields values different from what would be expected by comparing the means of the control and dopamine infusion values.

Abbreviations: MAP = mean arterial pressure; CVP = central venous pressure; HR = heart rate; CO = cardiac output; SV = stroke volume; SVR = systemic vascular resistance; LVEDP = left ventricular end-diastolic pressure; LVSW = left ventricular stroke work; UF = urine flow; No. = number of patients studied; NS = not significant (P value above 0.05).
### Table 3

Comparison of Dopamine to Norepinephrine and Isoproterenol in Patients with Shock Associated with Infection

<table>
<thead>
<tr>
<th>First drug used</th>
<th>MAP (mm Hg)</th>
<th>CVP (mm Hg)</th>
<th>HR (beats/min)</th>
<th>CO (liters/min)</th>
<th>SV (ml/beat)</th>
<th>SVR (mm Hg/liter/min)</th>
<th>LVEDP (mm Hg)</th>
<th>LVSW (g-m)</th>
<th>UF (ml/min)</th>
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<tr>
<td>No.</td>
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<td>26</td>
<td>15</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>Dopamine</td>
<td>14</td>
<td>70 ± 3</td>
<td>9.1 ± 0.8</td>
<td>114 ± 5</td>
<td>8.3 ± 0.6</td>
<td>73 ± 5</td>
<td>8.3 ± 0.6</td>
<td>16.1 ± 1.9</td>
<td>51 ± 6</td>
</tr>
<tr>
<td>NE</td>
<td>12</td>
<td>82 ± 2</td>
<td>9.8 ± 0.4</td>
<td>105 ± 5</td>
<td>7.3 ± 0.6</td>
<td>69 ± 5</td>
<td>11.3 ± 0.8</td>
<td>20.4 ± 1.7</td>
<td>56 ± 6</td>
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<tr>
<td>P value</td>
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<td>Dopamine</td>
<td>10</td>
<td>77 ± 5</td>
<td>10.7 ± 1.0</td>
<td>111 ± 5</td>
<td>7.2 ± 0.5</td>
<td>65 ± 5</td>
<td>10.1 ± 1.0</td>
<td>19.4 ± 1.9</td>
<td>55 ± 6</td>
</tr>
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<td>Isp</td>
<td>9</td>
<td>62 ± 3</td>
<td>7.7 ± 1.2</td>
<td>114 ± 5</td>
<td>8.4 ± 0.6</td>
<td>72 ± 4</td>
<td>6.9 ± 0.5</td>
<td>11.6 ± 2.0</td>
<td>51 ± 5</td>
</tr>
<tr>
<td>P value</td>
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<td>&lt;0.01</td>
<td>NS</td>
<td>&lt;0.01</td>
<td>0.05</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>NS</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Values given are the mean ± 1 standard error.
P value was determined by the Student t-test for paired observations.
Abbreviations: NE = norepinephrine; Isp = isoproterenol; others are the same as for table 2.

### Table 4

Comparison of Dopamine to Norepinephrine and Isoproterenol in Patients with Cardiogenic Shock

<table>
<thead>
<tr>
<th>First drug used (no. of patients)</th>
<th>MAP (mm Hg)</th>
<th>CVP (mm Hg)</th>
<th>HR (beats/min)</th>
<th>CO (liters/min)</th>
<th>SV (ml/beat)</th>
<th>SVR (mm Hg/liter/min)</th>
<th>LVEDP (mm Hg)</th>
<th>LVSW (g-m)</th>
<th>UF (ml/min)</th>
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<td>8</td>
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<tr>
<td>Dopamine</td>
<td>5</td>
<td>82 ± 4</td>
<td>12.6 ± 1.7</td>
<td>102 ± 9</td>
<td>4.2 ± 0.5</td>
<td>41 ± 4</td>
<td>18.1 ± 1.9</td>
<td>13.5; 10.0</td>
<td>59; 46</td>
</tr>
<tr>
<td>NE</td>
<td>3</td>
<td>92 ± 5</td>
<td>14.8 ± 1.9</td>
<td>94 ± 7</td>
<td>3.0 ± 0.4</td>
<td>33 ± 4</td>
<td>31.2 ± 6.0</td>
<td>14.0; 10.0</td>
<td>48; 50</td>
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<tr>
<td>P value</td>
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<td>87 ± 6</td>
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<td>33 ± 4</td>
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<tr>
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<td>12.0 ± 1.2</td>
<td>107 ± 7</td>
<td>4.3 ± 0.6</td>
<td>40 ± 5</td>
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Values given are the mean ± 1 standard error, except for values for one- or two-patient groups.
P value was determined by the Student t-test for paired observations.
Abbreviations: same as for tables 2 and 3.
Five patients with cardiogenic shock received dopamine and Isp. Two of these patients received dopamine first and three received Isp first. There were no significant differences in any measured variable; however CO (3.3 vs. 4.3 liters/min) and SV (33 vs. 40 ml/beat) tended to be higher, and SVR (23.0 vs. 19.5 mm Hg/liter/min) tended to be lower during infusion of Isp.

Adverse Effects

Few adverse effects were observed which would be directly related to dopamine, NE, or Isp. Ventricular tachycardia developed shortly after dopamine infusion was begun in one patient with shock due to acute myocardial infarction complicated by second degree atrioventricular block. The infusion was stopped and the tachycardia soon disappeared. Because this patient was in shock, Isp was then given while preparations for endocardial pacing were being made. Ventricular fibrillation occurred during Isp infusion and the patient was successfully defibrillated. Ventricular pacing was instituted and no further difficulties were encountered.

Another patient developed supraventricular tachycardia during infusion of dopamine. This arrhythmia disappeared shortly after the infusion was stopped. These two patients have not been included in the series because hemodynamic measurements could not be obtained during the brief time they received dopamine.

One patient developed ischemic necrosis of subcutaneous tissue secondary to unrecognized extravasation of an intravenous NE solution. Although this is a well-recognized complication of NE infusion it has not been reported following dopamine infusion.

Several very obtunded patients became slightly agitated while receiving dopamine. Whether this effect was secondary to improved cerebral blood flow or to direct stimulation of the central nervous system could not be determined. We have not, however, seen evidence of central nervous system stimulation in other patients during dopamine infusion.

One patient with infection showed an unexpected and unexplained hemodynamic response to dopamine (fig. 1). In this patient dopamine infusion (0.24 mg/min) resulted in a moderate fall in MAP, CVP, HR, and SVR, while CO fell slightly.

Although peripheral vasodilatation could partially explain this response, the fall in both HR and CO was unusual and suggested a negative chronotropic and inotropic effect. Return to control values occurred shortly after dopamine was stopped. This response was not due to failure of adrenergic receptors since there was a normal response during subsequent infusion of NE (0.0024 mg/min) and Isp.
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(0.0046 mg/min). Hemodynamic deterioration during dopamine infusion was observed in a few other patients, but was not reversed when dopamine was stopped and was considered to have been due to progression of the underlying illness.

Discussion
The cardiovascular actions of dopamine have been elucidated by both experimental and human studies. Dopamine is similar to both NE and Isp in exerting positive inotropic and chronotropic effects on the heart by stimulation of beta-adrenergic receptors. It causes vasoconstriction of capacitance and resistance vessels by stimulation of alpha-adrenergic receptors. Dopamine reduces coronary vascular resistance by increasing myocardial oxygen need rather than by a direct effect on the coronary vessels. At low concentrations dopamine causes vasodilatation in renal and mesenteric vascular beds. This action is not blocked by either alpha- or beta-adrenergic blocking agents but can be competitively blocked by haloperidol, suggesting the existence of dopamine-specific receptors.

Dopamine has been shown to be natriuretic when given to patients with congestive heart failure but not in patients with cirrhosis. Improved renal blood flow and/or alterations on intrarenal hemodynamics are postulated.

Dopamine has been used in the treatment of experimental endotoxic and hemorrhagic shock. Improved MAP, CO, renal blood flow, and decreased hepatic pooling have been found. Metabolic deterioration, however, may continue despite hemodynamic improvement.

Hemodynamic abnormalities following experimental myocardial infarction have also been improved during dopamine infusion, suggesting the ability of dopamine to reverse depressed myocardial function induced by coronary artery ligation.

MacCannel et al. found dopamine valuable in improving MAP, CO, and urine flow in several patients with shock, some of whom had had oliguria during prior treatment with NE or metaraminol. Recently Tally et al. reported their experience with dopamine in the treatment of 22 patients with various types of shock. Hemodynamic responses to dopamine and Isp were compared. Several types of responses were observed; however, they found seven patients who showed a better hemodynamic response to dopamine than to Isp, and concluded that in five of these seven, Isp was probably detrimental.

We have separated our patients according to the etiology of their shock syndrome. Such a separation may be somewhat artificial in elderly patients because those who develop shock associated with infection in addition frequently have impaired cardiac function. Our 36 patients with shock thought to be primarily due to infection had lower mean values for MAP and SVR, and higher values for CO than did our 13 patients with primary cardiogenic shock. As a group these 36 patients showed a good response to dopamine infusion. MAP rose from a mean for the group of 59 mm Hg to 75 mm Hg. Since SVR was not significantly changed the improvement in MAP appears to have been due to improvement in CO which increased from 6.1 liters/min to 8.0 liters/min.

Many of these patients had marked hypotension and SVR tended to be normal or reduced. The absence of an elevated SVR in the presence of shock also may occur following myocardial infarction, during bacteremia, or as a terminal event. In such patients, especially in the elderly, hypotension of itself may result in poor cardiac function since areas supplied by arteriosclerotic vessels may not be adequately perfused until arterial pressure is increased.

We compared dopamine and NE in 26 patients with shock due to infection. Although NE resulted in a significantly higher mean arterial pressure (MAP) than did dopamine, it was possible to maintain MAP at adequate levels with dopamine in all but a few patients. CO was significantly higher with dopamine than with NE and LVEDP was significantly lower. However, mean values for UF were
similar with both agents. Our data thus do
not clearly show superiority of either dopa-
mine or NE in these patients. Because dopa-
mine infusion results in higher CO and lower
LVEDP than does NE infusion, it might be
considered that dopamine is the more desir-
able of the two agents as long as perfusion
pressure is adequate.

Dopamine was compared to Isp in 19
patients with shock and infection. MAP
averaged 77 mm Hg during infusion of
dopamine and 62 mm Hg during Isp infusion.
Although CO was higher during infusion of
Isp, UF was significantly greater during
infusion of dopamine. From this data it
appears that dopamine is superior to Isp in the
treatment of most patients with shock due to
infection. Although CO may be markedly
increased during Isp infusion, vasodilatation
in skin and skeletal muscle\(^{26}\) may cause this
increased CO to be distributed to nonvital
areas while persistence of an inadequate
perfusion pressure prevents improved blood
flow in certain vital areas. Dopamine, which
also increases CO, does not cause widespread
vasodilatation and thus improves perfusion
pressure. In addition, dopamine may improve
blood flow to renal and splanchnic vascular
beds by selective vasodilatation in these
areas.

Our experience with dopamine in treating
patients with cardiogenic shock is somewhat
difficult to assess. Although each of the 13
patients of this category was in clinical shock
and had reduced or unobtainable blood
pressure by cuff, many were found on direct
pressure measurement to have an adequate
perfusion pressure. Patients with clinical shock
but without significant hypotension tend to
have a low CO and elevated SVR.\(^ {27}\) Treatment
of these patients should be directed
toward improving CO and flow distribution.
Elevation of perfusion pressure is necessary
only when significant hypotension is present.

In our patients with cardiogenic shock
dopamine infusion resulted in a mean increase
in CO of 40%, while MAP increased only 6%
and UF increased from 0.6 to 1.1 ml/min.
Unlike patients with shock due to infection,
dopamine infusion reduced SVR by 20%. This
fall in SVR may have been caused by a
reduction in compensatory vasoconstriction
secondary to improvement in hemodynamic
status.\(^ {28}\) It is also possible that in patients
who are already vasoconstricted secondary
to increased endogenous catecholamine activity,
the vasodilatory effects of dopamine predomi-
nate over the vasoconstrictive effects.

We compared dopamine to NE in eight
patients with cardiogenic shock. In these
patients dopamine seemed to be the better of
the two drugs and resulted in a higher CO and
lower SVR than NE. In only two of these
patients was control MAP under 70 mm Hg.
Thus it remains to be seen whether or not
dopamine will be superior to NE in patients
with cardiogenic shock who have significant
hypotension.

![Figure 2](image-url)

The mean value for left ventricular stroke work
(LVSW) is plotted against the mean value for left
ventricular end-diastolic pressure (LVEDP) in 23
patients who received dopamine and norepinephrine
(upper panel) and for 18 patients who received dopa-
mine and isoproterenol (lower panel).

*Circulation, Volume XLIV, August 1971*
Only five patients with cardiogenic shock received both dopamine and Isp, and none of these patients had severe hypotension prior to therapy. No statistically significant differences were observed, but CO tended to be higher during infusion of Isp. When hypotension is not an important factor we have found Isp to be a very effective agent for the treatment of patients with reduced CO and increased SVR. Increases in CO of 100% or more are not uncommon and indicate that Isp can be expected to increase CO more than dopamine in most patients with normotensive cardiogenic shock not due to acute myocardial infarction. Dopamine, because of its selective effects on peripheral vascular beds, might still offer advantages over Isp even at a lower CO. Further studies, especially those designed to measure changes in regional perfusion, will help answer this question.

Regardless of the cause of shock, infusion of dopamine caused an increase in LVSW. Since LVEDP was also increased during dopamine infusion, the changes in LVSW do not necessarily indicate improved ventricular function. When the relationships between LVSW and LVEDP during dopamine infusion are compared to the same relationships during NE and Isp infusions (fig. 2), dopamine occupies a position between the two other drugs. Dopamine, NE, and Isp each undoubtedly results in increased myocardial oxygen demand. Preliminary data suggest that, of these three drugs, only dopamine, when given to shock patients, results in a favorable change in transmyocardial lactate metabolism.

Interpretation of UF data was difficult because a few patients had very large increases in UF during dopamine infusion while most remained oliguric. Although the 36 patients with infection (table 2) showed a significant increase in UF—from 0.5 ml/min
to 1.6 ml/min—during dopamine infusion, in one of these patients UF increased by 15.3 ml/min.* In patients with cardiogenic shock and shock of miscellaneous cause, changes in UF during dopamine infusion were not statistically significant. In order to see if hemodynamic factors determined the UF response to dopamine infusion, 49 patients taken from all groups and having control UF values of less than 0.75 ml/min were separated on the basis of their UF response to dopamine infusion (fig. 3). Fourteen patients responded to dopamine by significant increases in UF (mean, +2.5 ml/min; range, +0.7 to 15.3 ml/min); in 35 patients UF did not improve with dopamine. No hemodynamic differences during either the control or dopamine infusion periods were found between these two groups. We thus assume that in our patients factors not identifiable by hemodynamic measurements influenced the effect of dopamine infusion on UF. Undoubtedly some of our patients had renal tubular damage secondary to antecedent hypotension and renal ischemia. Failure to increase UF during dopamine infusion should not be taken as absolute evidence for renal shutdown, however, since five patients with reduced UF persisting during infusion of dopamine had an adequate UF during infusion of NE.

In comparing UF during dopamine and NE infusion there was no significant difference in patients with either infection or cardiogenic shock. Although most patients who had an adequate UF during dopamine infusion also had an adequate UF during NE infusion, there were five patients, already mentioned, who did not respond to dopamine, but showed a significant improvement in UF during NE infusion.

Comparing dopamine to Isp, dopamine was the superior agent with regard to improving UF in the group of patients with shock due to infection. We believe this is due to the inability of Isp to either elevate MAP to levels commensurate with optimal renal perfusion or to increase renal blood flow by selectively reducing renal vascular resistance. 4 5 Dopamine and Isp were compared in only five patients with cardiogenic shock and, although no difference in UF was seen, more studies will be required to assess the relative value of these two agents on UF in this group of patients.

Acknowledgment

The dopamine used in this study was furnished through the courtesy of Amaran-Stone Laboratories, Inc. We wish to acknowledge the invaluable assistance of Mrs. Patricia Berg and Mrs. Patricia Normile in the preparation of this manuscript.

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*Circulation, Volume XLIV, August 1971

*This patient also had a large increase in UF during NE infusion, but, because he received low molecular weight dextran between infusion of dopamine and NE, he was excluded from the data tabulated in table 3.
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Circulation. 1971;44:163-173
doi: 10.1161/01.CIR.44.2.163
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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