Acute Effects of Low Doses of Alcohol on Left Ventricular Function by Echocardiography

By Cedar E. Delgado, M.D., Nicholas J. Fortuin, M.D., and Richard S. Ross, M.D.

SUMMARY
The ultrasound method for measuring the dimensions of the left ventricle was utilized to study the effect of oral doses of alcohol on left ventricular function in normal volunteers. Systolic time intervals were also measured. Seven subjects received 0.7 g/kg of ethanol (group I) and six subjects received 1.15 g/kg (group II). The peak blood alcohol levels in the two groups were 75 mg/100 ml and 138 mg/100 ml respectively.

There was a 6% decrease in the fractional change in the minor axis of the left ventricle in group I patients which resulted in a decrease in ejection fraction \(P < 0.05\). In group II patients, there was a 3% decrease in the fractional change in the minor axis of the left ventricle, but the change in ejection fraction was not significant. Since there was no significant difference between the physiological effects observed in groups I and II, the two groups were combined. In the combined group, at 30 minutes after the ingestion of alcohol, the heart rate was increased by 11%, the fractional change in the minor axis of the left ventricle decreased by 6%, the ejection fraction decreased by 4% \(P < 0.01\), and \(V_e\) decreased by 5%. These data suggest that in normal subjects myocardial contractility is depressed following the ingestion of alcohol.

Additional Indexing Words: 
Ethanol Ultrasound Systolic time intervals

PREVIOUS STUDIES in isolated heart muscle fibers suggest that acute exposure to alcohol is associated with a depression of myocardial contractility. In alcoholic subjects without evidence of cardiac disease Regan et al. reported that 12 oz of Scotch whiskey (162 ml ethanol) ingested in two hours produced transient depression of left ventricular function, evidenced by elevation of left ventricular end-diastolic pressure, and a simultaneous decrease in the stroke volume index. In normal volunteers the noninvasive systolic time intervals method has been used by Ahmed et al. in studies which showed that myocardial contractility was depressed by 6 oz of Scotch whiskey (81 ml ethanol) which produced blood levels from 75–110 mg/100 ml. The present study utilized echocardiography to record serial changes in ventricular function following acute alcohol ingestion in normal human volunteers. The echocardiographic measurements of ventricular dimensions were compared with systolic time intervals.

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Table 1

Systolic Time Intervals in Group I (0.7 g/kg)

| Blood alcohol ml/100 ml | Heart rate (beats/min) | BP systolic (mm Hg) | BP diastolic (mm Hg) | 8
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>59.7 ± 2.3</td>
<td>111.7 ± 4.5</td>
<td>68.6 ± 3.1</td>
<td>4.81 ± 0.16</td>
</tr>
<tr>
<td>30 min</td>
<td>74.48 ± 10.45</td>
<td>66.6 ± 3.3**</td>
<td>114.3 ± 4.3</td>
<td>71.1 ± 3.1</td>
</tr>
<tr>
<td>60 min</td>
<td>76.29 ± 06.21</td>
<td>66.9 ± 2.5*</td>
<td>109.0 ± 4.2</td>
<td>70.0 ± 2.7</td>
</tr>
<tr>
<td>90 min</td>
<td>68.07 ± 06.99</td>
<td>64.3 ± 2.7*</td>
<td>108.7 ± 4.5</td>
<td>69.7 ± 2.7</td>
</tr>
<tr>
<td>120 min</td>
<td>62.28 ± 10.20</td>
<td>65.7 ± 3.4*</td>
<td>107.6 ± 3.8*</td>
<td>66.9 ± 2.4</td>
</tr>
<tr>
<td>150 min</td>
<td>61.20 ± 08.29</td>
<td>64.0 ± 3.3</td>
<td>107.9 ± 4.8</td>
<td>69.7 ± 3.7</td>
</tr>
<tr>
<td>180 min</td>
<td>53.63 ± 07.17</td>
<td>67.3 ± 3.0**</td>
<td>109.7 ± 4.7*</td>
<td>68.8 ± 3.1</td>
</tr>
</tbody>
</table>

Mean values ± standard error are shown.
Statistical significance (paired t), *P < 0.05, **P < 0.01.
Abbreviations: Sd = end-diastolic diameter; Qs = electromechanical systole; Ss = end-systolic diameter; LVET = left ventricular ejection time; E.F. = ejection fraction; PEP = pre-ejection period; Vcf = Mean velocity of circumferential fiber shortening.

Results

The blood alcohol values are listed in tables 1 and 2 and are plotted in figure 1. Subjects in group I ingested 0.7 g of ethanol/kg in less than 30 minutes and

motion of the endocardial echo of the left ventricular posterior wall to the left side of the interventricular septal echo. An average of five beats was taken as the value for each dimension. At the completion of the study the records were coded. The minor axis dimension was measured independently by two observers without knowledge of the conditions at the time of study.

Derived Echocardiographic Volumes and Contractility Indices

Ventricular volumes at end diastole and end systole were calculated from $V = 1.047 S^\frac{3}{2}$. The stroke volume and ejection fraction were calculated from the end-diastolic and systolic volumes. $SV = EDV - ESV$, $EF = \frac{SV}{EDV}$. The fractional change of the left ventricular minor axis during systole ($\% \Delta S = S - S / S_0$). The mean velocity of circumferential fiber shortening ($V_{cf}$) was calculated from $V_{cf} = \frac{S_0 - S}{S_0 - S_0 \cdot dt}$. $dt$ was the left ventricular ejection time measured from the simultaneously recorded carotid pulse.

Systolic Time Intervals

Systolic time intervals were measured from simultaneous recordings of the carotid pulse, electrocardiogram, and phonocardiogram from the third left intercostal space. The Cambridge multichannel system was utilized for recording at a paper speed of 100 mm/sec. The following measurements were made: electromechanical systole (QSs) from the onset of the Q wave of the electrocardiogram to the first rapid deflection of the aortic component of the second heart sound; left ventricular ejection time (LVET) taken from the onset of the rapid upstroke of the carotid pulse to the incisura of the dicrotic notch; pre-ejection period (PEP) = QSs - LVET. A mean value of five beats was used as the value for each measurement. Blood pressure was obtained by sphygmomanometer and heart rate was measured directly from the electrocardiogram.

Blood Alcohol Determinations

Ethanol concentrations were determined in all serum samples by gas-liquid chromatography under the direction of Dr. Esteban Mezey at the Alcoholism Research Unit of the Baltimore City Hospitals.

Statistics

The results were analyzed by the Student’s paired t-test.
EFFECT OF ALCOHOL ON LV FUNCTION

following this a mean peak blood alcohol level of 75 mg/100 ml was attained at between 30–60 minutes. The blood alcohol concentration fell slowly and 70% of the peak concentration was still present at the end of three hours. Subjects in group II received the larger dose (1.15 g/kg) over a longer period (60 min) and in this group the mean peak blood alcohol value of 138 mg/100 ml was reached at 60 minutes. At 30 minutes the mean value was 86 mg/100 ml. At the end of three hours the blood level was 80% of the peak value.

The physiological observations are presented in tables 1, 2, and 3 for the low dose group, the high dose group, and total group, respectively. In group I, the low dose group (table 1), the heart rate increased from 60 beats/min to a value of 67 beats/min at 30 and 60 minutes. This 12% change was significant (P < 0.01) and persisted throughout the period of observation. There was a 6% decrease in the fractional change of the left ventricular minor axis %ΔS, as measured by the echocardiographic method (P < 0.01), and this resulted in a 4% decline in ejection fraction. Both measurements had returned to control values by 90 minutes. The changes in QS, LVET, and PEP were small and of borderline significance (P < 0.05) throughout the period of observation despite the 12% increase in heart rate.

In group II, the high dose group (table 2), the heart rate increased by 8% at 30 minutes, but the change did not achieve statistical significance. The fractional change in the minor axis %ΔS decreased by 3% at 60 minutes (P < 0.05). The associated decrease in ejection fraction did not achieve significance. The mean velocity of circumferential fiber shortening decreased from 1.22 ± 0.06 to 1.19 ± 0.06 circumferences/sec at 60 minutes (P < 0.001). There were no significant changes in the systolic time intervals. Thus, although the group II subjects ingested a larger quantity of alcohol over a longer time and had higher blood levels, the changes in heart rate and contractility were similar in direction, but smaller than in the group I subjects.

Because of this lack of significant difference between the physiological effects observed in the two groups, the two groups I and II were combined and the results of this combined group are presented in table 3 and plotted in figure 2. Heart rate increased by 11% from 62 to 68 beats/min at 30 minutes (P < 0.001) and remained significantly elevated

![Figure 2](http://circ.ahajournals.org/) Effects of Alcohol on Indices of Cardiac Function, total group. Time in minutes is shown on the abcissa. C = control values. Ejection fraction = ratio of stroke volume to end-diastolic volume. V, = velocity of circumferential fiber shortening. PEP = pre-ejection period.
The change in echocardiographic parameters during alcohol ingestion was significant by 4% at 30, 60, and 90 minutes. This resulted in a 4% decrease in ejection fraction which was significant at 30, 60, and 90 minutes. The mean velocity of circumferential fiber shortening (Vcf) decreased by 5% during the same 30–90 minute period (P < 0.01). All echocardiographic indices of contractility returned to baseline by 120 minutes. There were no significant changes in systolic time intervals QS, and LVET when groups I and II were analyzed together, as in table III. The PEP was increased at 180 minutes, but this change was of only borderline significance (P < 0.05).

**Discussion**

The direct measurement of the dimensions of the left ventricle by ultrasound has provided evidence of depression of myocardial contractility in normal volunteers following the ingestion of alcohol. The fractional change in the minor axis of the left ventricle in systole was decreased significantly at 30 and 60 minutes following the ingestion of alcohol. The indices of myocardial contractility derived from the measurement of the minor axis also showed depression. The changes were small (5–12%) in these healthy, young subjects but assume more significance when it is recognized that they occurred at a time when the heart rate was increased. An increase rather than a decrease in contractility would have been expected in healthy young subjects and, therefore, these small changes assume more significance if the association with increased heart rate is considered.

The effect of increased heart rate must also be considered in interpretation of the systolic time intervals. In this study there was no large change in these indices, but the improvement which would have been expected with tachycardia failed to occur. Ahmed et al., in a similar study, demonstrated decreased contractility as evidenced by increases in PEP and PEP/LVET in a group of normal volunteers.

Previous studies had reported an increase in heart rate and cardiac output and no impairment of the response to exercise following alcohol ingestion. These studies had been interpreted as indicating that alcohol had no significant effects on the normal heart.

### Table 2

**Systolic Time Intervals in Group II (1.15 g/kg)**

<table>
<thead>
<tr>
<th>Blood alcohol ml/100 ml</th>
<th>Heart rate (beats/min)</th>
<th>BP syst (mm Hg)</th>
<th>BP diast (mm Hg)</th>
<th>S_D cm</th>
<th>S_S cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>63.0 ± 3.0</td>
<td>118.8 ± 6.1</td>
<td>75.3 ± 3.5</td>
<td>4.99 ± 0.13</td>
<td>3.10 ± 0.15</td>
</tr>
<tr>
<td>30 min</td>
<td>86.50 ± 21.08</td>
<td>70.7 ± 3.9</td>
<td>120.0 ± 6.5</td>
<td>75.8 ± 4.0</td>
<td>4.99 ± 0.12</td>
</tr>
<tr>
<td>60 min</td>
<td>137.55 ± 07.72</td>
<td>67.7 ± 4.2</td>
<td>115.7 ± 7.9</td>
<td>74.0 ± 4.3</td>
<td>5.00 ± 0.11</td>
</tr>
<tr>
<td>90 min</td>
<td>126.32 ± 13.31</td>
<td>68.3 ± 4.9</td>
<td>114.3 ± 6.4</td>
<td>73.2 ± 3.9</td>
<td>4.91 ± 0.13*</td>
</tr>
<tr>
<td>120 min</td>
<td>130.06 ± 16.78</td>
<td>67.7 ± 5.6</td>
<td>115.2 ± 7.3</td>
<td>72.0 ± 3.9</td>
<td>4.97 ± 0.13</td>
</tr>
<tr>
<td>150 min</td>
<td>117.52 ± 12.25</td>
<td>64.8 ± 5.6</td>
<td>114.5 ± 7.3*</td>
<td>72.0 ± 4.0</td>
<td>4.97 ± 0.13</td>
</tr>
<tr>
<td>180 min</td>
<td>110.42 ± 12.03</td>
<td>66.3 ± 4.7</td>
<td>112.8 ± 5.2*</td>
<td>71.5 ± 3.1</td>
<td>4.89 ± 0.11*</td>
</tr>
</tbody>
</table>

Mean values ± standard error are presented. Statistical significance (paired t), *P < 0.05, **P < 0.01, ***P < 0.001. For abbreviations see table 1.

### Table 3

**Combined Group (13 Subjects)**

<table>
<thead>
<tr>
<th>Heart rate (beats/min)</th>
<th>BP syst (mm Hg)</th>
<th>BP diast (mm Hg)</th>
<th>S_D cm</th>
<th>S_S cm</th>
<th>S_D–S_S cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>61.8 ± 2.0</td>
<td>115.4 ± 3.8</td>
<td>71.8 ± 2.6</td>
<td>4.91 ± 0.11</td>
<td>3.14 ± 0.10</td>
</tr>
<tr>
<td>30 min</td>
<td>65.5 ± 2.5***</td>
<td>116.9 ± 3.7</td>
<td>73.3 ± 2.0</td>
<td>4.89 ± 0.10</td>
<td>3.23 ± 0.10*</td>
</tr>
<tr>
<td>60 min</td>
<td>67.2 ± 2.2**</td>
<td>112.8 ± 4.2</td>
<td>71.8 ± 2.4</td>
<td>4.89 ± 0.11</td>
<td>3.21 ± 0.09</td>
</tr>
<tr>
<td>90 min</td>
<td>66.2 ± 2.6*</td>
<td>111.3 ± 3.7</td>
<td>71.3 ± 2.3</td>
<td>4.86 ± 0.10</td>
<td>3.21 ± 0.10</td>
</tr>
<tr>
<td>120 min</td>
<td>66.6 ± 3.0*</td>
<td>111.1 ± 3.9</td>
<td>69.2 ± 2.2</td>
<td>4.87 ± 0.11</td>
<td>3.13 ± 0.10</td>
</tr>
<tr>
<td>150 min</td>
<td>64.4 ± 3.0</td>
<td>112.0 ± 4.1</td>
<td>70.7 ± 2.6</td>
<td>4.84 ± 0.11</td>
<td>3.11 ± 0.09</td>
</tr>
<tr>
<td>180 min</td>
<td>66.8 ± 2.7*</td>
<td>111.2 ± 3.4</td>
<td>70.1 ± 2.1</td>
<td>4.83 ± 0.10</td>
<td>3.13 ± 0.09</td>
</tr>
</tbody>
</table>

Mean values ± standard errors are shown. Statistical analysis (paired t), *P < 0.05, **P < 0.01, ***P < 0.001.
The current studies lead to another conclusion in that they confirm in man the effects of alcohol on contractility which have been observed in isolated heart muscle fibers and in both anesthetized and conscious intact animals. In these animal and in vitro studies concentrations of alcohol similar to those found in the blood of the subjects in the current study produced a reduction in contractility. The current study and that of Ahmed et al. demonstrate the direct effect of alcohol on the contractility of the normal human myocardium. These minor changes in contractility do not, however, impair the function of the heart as a pump. Presumably, compensatory mechanisms are responsible for the preservation of overall circulatory function in the presence of decreased contractility.

All evidence suggests that alcohol acts as a direct depressant of myocardial cell function. An alternative explanation, proposed by Regan, was that the effect was related to the change in plasma osmolarity and plasma volume.2 Ahmed gave normal volunteers alcohol and an isosmotic, isocaloric, isovolumic sucrose solution orally and measured systolic time intervals.8 Alcohol depressed and the sucrose increased contractility, and therefore increased osmolarity cannot be the explanation for the contractility changes seen after oral alcohol administration.

The lack of correlation between the blood alcohol concentration and the cardiac effects presents a problem in interpretation. In the first place, there was no significant difference between the hemodynamic effects of the two dose levels. Furthermore, the hemodynamic changes persisted for only 30 to 60 minutes, yet the blood alcohol remained elevated throughout the entire three hours of the experiment. In the low dose group, changes in ventricular function are seen at 30 and 60 minutes when the mean blood alcohol levels were between 70 and 80 mg/100 ml. Much higher blood levels between 110 and 120 mg/100 ml were present at 120, 150 and 180 minutes in the high dose group (II) and no alteration in cardiac function was apparent at that time. These observations could be explained by postulating that the time and concentration characteristics of the build up of blood alcohol in the blood during the first 30 to 60

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minutes determine the degree of myocardial depression and that the blood levels at later points in time are unimportant. It also appears that within those dosage ranges, the higher dose is not associated with a larger effect. This suggests that a threshold level is reached which produces depression of function, and this in turn initiates a compensatory reaction which restores the homeostasis.

A similar lack of correlation of blood level and effect was observed by Juchems who found that normal volunteers ingesting 0.9 to 1.9 ml/kg of ethanol evidenced a 13% increase in heart rate at blood levels of 85 mg/100 ml. No further increase in heart rate was observed with blood alcohol levels above 100 mg/100 ml. A similar effect was observed by Conway who found no correlation between blood alcohol levels and hemodynamic changes in eight patients with coronary artery disease. Both differing absorption and the compensatory responses of the autonomic nervous system have been suggested as responsible for this lack of relationship between dose and effect. Lack of absorption cannot be a factor in the current study and in others in which direct measurements of blood alcohol have been made. The compensatory response of the autonomic nervous system probably provides a better explanation. The role of the autonomic nervous system has been investigated by Wong who studied the effect of alcohol with and without beta blockade in anesthetized dogs. Her results show that the depressant effects of ethanol are greater in animals with autonomic blockade by atropine and propranolol. Horwitz and associates were not able to demonstrate an effect of autonomic blockade in modifying the response to ethanol in conscious dogs, but they used a smaller dose of propranolol than in Dr. Wong's study.

Acknowledgment

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