Cardiac Dilatation Without Hypertrophy from Reduced Ambient Pressure in Rats

By J. Clifford Stickney, Ph.D., David W. Northrup, Ph.D. and Edward J. Van Liere, Ph.D., M.D.

Short exposures of rats to greatly reduced ambient pressure after explosive decompression was found to result in cardiac dilatation. The dilatation, determined roentgenographically, was seen to persist for two or three days. Some rats were submitted to one long exposure, while others were repeatedly subjected to short exposures. Sacrifice of the rats sufficiently long after exposure to permit cardiac hypertrophy to develop revealed no evidence of it as determined from heart weight-body weight ratios.

Though based on a limited amount of published evidence, the injury hypertrophy theory of Eyster to account for increased myocardial mass after assumed damaging dilatation of the heart has had a good following. A transient dilatation of no more than 13.5 per cent increased frontal area as judged radiographically as a result of massive transfusions in dogs was stated to lead to a permanent hypertrophy in a matter of months. The theory has not gone unchallenged. Herrmann and Decherd tried huge and injurious transfusions of acacia solution in rabbits and rats without producing any significant cardiac hypertrophy. Holman has pointed out that experimentally, i.e., after arteriovenous fistulae in dogs, excessive dilatation may be present in the absence of increased myocardial mass. Similar findings have been noted clinically. Furthermore, a regression of hypertrophy has been observed in animals after removal of the presumed obvious cause: increased cardiac work due to aortic constriction or to an experimentally induced hypertension. Matas and Heninger have reported regression in a human case.

The tremendous cardiac dilatation, demonstrated in dogs explosively decompressed to 30 mm. Hg, suggested to us a means of testing the injury hypertrophy theory. This paper will present evidence that the rat heart dilates like that of the dog at low ambient pressures, but that the dilatation fails to induce any demonstrable cardiac hypertrophy.

Methods

The area of the x-ray heart shadow (36 inch target-film distance) of 11 male Wistar albino rats averaging 396 gm in weight was determined before and after exposure to reduced atmospheric pressures. Nembutal was used to immobilize the rats for x-raying, and, in all but 4 cases, for decompressing as well. The rats were exposed, after decompression within 0.4 sec, for 10 sec to an ambient pressure of 30 to 32.5 mm. Hg (72,400 to 70,700 feet). Roentgenograms were taken as soon as practicable after the exposure, and in most cases, again on the second and on the third days. Cardiac areas were measured with a planimeter used directly on high contrast positive prints of the original negatives.

For studying the effect of cardiac dilatation upon the development of cardiac hypertrophy three separate groups of albino rats of the Wistar strain were obtained. Each of these groups was subdivided into experimental and control groups and maintained identically, except for the decompressions. No anesthetic agent was used with these groups.

Group I decompressed rats consisted originally of 22 females which were subjected to one decompression as above, but duration of exposure was 20 sec. Ten of these rats died, most of them immediately, as a result of the exposure. The remainder were kept for six weeks to allow time for full development of hypertrophy. At this time both the decompressed rats and their controls were fasted 24 hours, weighed, decapitated and bled. The organs were weighed on a balance after washing free of blood, trimming and blotting.

The rats of groups II and III were males. The members of the experimental groups were subjected to a decompression in which the duration of the exposure was limited to 10 sec. Furthermore, exposure to the reduced ambient pressure was repeated...
at intervals of 4 or 5 days until each rat had had 8 exposures over about 5 weeks. The rats were then held for three more weeks and sacrificed for the determination of cardiac hypertrophy.

RESULTS

Shortly after a 10 seconds exposure to 30-32.5 mm. Hg there was cardiac dilatation present in 10 of 11 rats (table 1). The initial increase in the area of the heart shadow amounted to 18 per cent on the average, and was statistically significant at the 1 per cent level. Dilatation was still present on the second day in 4 of 9 rats observed, while the group as a whole still had an appreciable enlargement. By the third day but one heart was still enlarged, and the group average had essentially returned to control dimensions.

The results concerning heart weight-body weight ratios appear in table 2. Since body weights of decompressed and control rats were practically alike, there is no question as to the validity of the ratios. In no case were the differences between control and decompressed groups statistically significant; the value of p was greater than 0.20. A ratio of 4.09 in one decompressed rat of group I accounted for most of the difference in the averages there.

Incidentally, adrenal weight-body weight ratios (not in the tables) also revealed no statistically significant differences.

DISCUSSION

Although the rate of decompression used here was within the explosive range (below 1 second) the results of this, as well as of a previous study, do not suggest the presence of any great stress due to rate per se. The rat seems to be much less tolerant to exposure to reduced ambient pressures than the dog. The latter tolerated exposures to 30 mm. Hg for as long as 120 seconds (although mortality rate was not given), and cardiac dilatation persisting after recompression was that associated with a 12.5 per cent increase in transverse diameter of the heart. In the rat we found a 45 per cent mortality when duration of exposure was only 20 seconds. The residual cardiac dilatation after recompression from a 10 seconds exposure was that associated with 18 per cent increase in frontal area of the heart. In the dog it was concluded that myocardial damage was associated with the excessive dilatation due to expansion of gases as well as with the fulminating anoxia. It is problematic what stresses were acting in the rat, but one must conclude that they were formidable.

If a transient injurious cardiac dilatation is capable of setting in motion processes culminating in increased cardiac mass, it would seem that it should have been evident in any of our three groups of decompressed rats. In one group the insult was grave enough to cause death to a large proportion of the series. In the other two

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**Table 1.** Frontal Areas (Uncorrected) of X-ray Heart Shadows in Rats before and after 10 Seconds Exposure to 50 to 55 mm. Hg.

<table>
<thead>
<tr>
<th>Rat No.</th>
<th>Before</th>
<th>After 3-29 min.</th>
<th>After 17-23 hr.</th>
<th>After 40-48 hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm.(^2)</td>
<td>cm.(^2)</td>
<td>cm.(^2)</td>
<td>cm.(^2)</td>
</tr>
<tr>
<td>1</td>
<td>2.13</td>
<td>2.77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>2.06</td>
<td>2.58</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>2.32</td>
<td>2.77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>2.39</td>
<td>2.48</td>
<td>2.32</td>
<td>2.52</td>
</tr>
<tr>
<td>5</td>
<td>2.71</td>
<td>3.61</td>
<td>2.84</td>
<td>2.26</td>
</tr>
<tr>
<td>6</td>
<td>2.45</td>
<td>2.71</td>
<td>2.39</td>
<td>2.45</td>
</tr>
<tr>
<td>7</td>
<td>2.30</td>
<td>2.54</td>
<td>3.20</td>
<td>2.45</td>
</tr>
<tr>
<td>8</td>
<td>2.77</td>
<td>3.03</td>
<td>3.10</td>
<td>2.65</td>
</tr>
<tr>
<td>9</td>
<td>2.45</td>
<td>2.58</td>
<td>2.58</td>
<td>2.65</td>
</tr>
<tr>
<td>10</td>
<td>2.52</td>
<td>2.77</td>
<td>2.65</td>
<td>2.32</td>
</tr>
<tr>
<td>11</td>
<td>2.45</td>
<td>2.32</td>
<td>2.52</td>
<td>1.94</td>
</tr>
</tbody>
</table>

Average: 2.42 \(\text{cm.\(^2\)}\) 2.85* 2.75† 2.49

* Significant increase; p: <0.01.
† Borderline increase; p: 0.05.

**Table 2.** Heart Weight-Body Weight Ratios in Rats Exposed to 50 to 55 mm. Hg Ambient Pressure.

<table>
<thead>
<tr>
<th>Group No.</th>
<th>No. of Rats</th>
<th>Heart Wt. (Gm.)</th>
<th>Body Wt. (Kg.)</th>
<th>Heart Wt./Body Wt. (Gm./Kg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>12</td>
<td>228</td>
<td>3.14</td>
<td>2.29</td>
</tr>
<tr>
<td>I</td>
<td>12</td>
<td>224</td>
<td>2.84</td>
<td>2.84</td>
</tr>
<tr>
<td>II</td>
<td>10</td>
<td>345</td>
<td>2.85</td>
<td>2.85</td>
</tr>
<tr>
<td>II</td>
<td>15</td>
<td>332</td>
<td>3.04</td>
<td>3.04</td>
</tr>
<tr>
<td>III</td>
<td>18</td>
<td>312</td>
<td>2.65</td>
<td>2.65</td>
</tr>
<tr>
<td>III</td>
<td>17</td>
<td>310</td>
<td>2.32</td>
<td>2.32</td>
</tr>
</tbody>
</table>
groups the insult, though less severe, was repeated eight times. The cardiac dilatation involved was of the same order of magnitude as in the original study supporting the injury hypertrophy theory.1

The objection might be made that failure to reveal hypertrophy was the result of choosing improper times for the sacrifice of the experimental animals. In this regard Rather4 found increases in heart weight beginning as early as 2 days and becoming maximal after 40 in rats with experimentally induced renal hypertension. Since all our rats were killed within this time interval, the above objection does not hold provided that an injury hypertrophy develops at the same rate as a work hypertrophy.

It is entirely possible, though hardly likely, that the dog is peculiarly susceptible to hypertrophy following cardiac injury. Perhaps injury as an isolated stimulus is inadequate, and requires the presence of other factors to manifest its hypertrophy potential. Among such factors might be the nutritional state of the heart itself, or even that of the organism as a whole. Heart size, though influenced by growth hormone within certain limits, appears to be regulated by other mechanisms, not yet clearly defined.5 Injury might play a part here, though present evidence does not suggest that this is a common occurrence.

**SUMMARY**

It has been found that immediately following a 10 seconds exposure to 30 to 32.5 mm Hg ambient pressure, there is an 18 per cent increase in frontal x-ray heart area in 11 adult albino rats. In some rats, the dilatation has been found to persist into the third day.

Forty-four rats have been subjected either once to a 20 seconds exposure or eight times to a 10 seconds exposure to such reduced ambient pressures. No evidence has been found that the consequent cardiac dilatation gives rise to cardiac hypertrophy.

**SUMMARIO IN INTERLINGUA**

In experimentos con adulte rattos albin, il esseva constatate que un exposition de 10 secundas a un pression ambiente de 30 a 32,5 mm Hg esseva sequite immediatemente per un augmento, amontante a 18 pro cento, in le roentgenologic area frontal del corde. In certe casos le dilatation persisteva usque al tertiie die.

Quaranta-quattro rattos esseva subjicite a tal reducece pressiones ambiente (1) un vice durante 20 secundas o (2) octo vices durante periodos de 10 secundas. Esseva trovate nulle indication que le resultante dilatation cardiac produce hypertrophia cardiac.

**REFERENCES**

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