THE MINUTE VOLUME OUTPUT AND THE WORK OF THE HEART IN HYPOTHYROIDISM

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Close association between aberrations in the function of the thyroid gland and disturbances in the physiology of the cardiovascular system has long been recognized. Because of the frequent occurrence of evidences of heart disease in patients with thyrotoxicosis many investigators have studied the cardiac minute volume output and other aspects of the circulation in this disease. In hypothyroidism, on the other hand, evidences of disturbed cardiovascular function are less prominent, and the cardiac output accordingly has been less thoroughly investigated.

In 1925, Means (1) reported marked diminution in the cardiac minute volume output in two cases of myxedema studied by Field and Bock. Two years later, Mobitz (2) observed a decrease in the cardiac output in one patient with myxedema, and Kinmonth (3) likewise observed a decrease in two additional cases. The results of the two latter observers are difficult to interpret, since the validity of the original ethyl iodide method (4) which they utilized has been questioned. Several years later, Bansi (5) (6) using the methods of Douglas and Haldane (7) and of Grollman (8), also found decreased cardiac output in three patients with myxedema.

The recent work of Blumgart and his associates (9) (10) (11) in establishing the value of total ablation of the normal thyroid gland in the treatment of chronic intractable heart disease made it advisable to study the cardiac output and related aspects of the circulation in hypothyroidism induced by this operation.

MATERIAL AND METHODS

Observations have been made on seven patients in whom hypothyroidism developed subsequent to total abla-

1 This paper is number XVII of the series entitled “Therapeutic Effect of Total Ablation of Normal Thyroid on Congestive Failure and Angina Pectoris.”

2 This investigation was aided by a grant from the William W. Wellington Memorial Research Fund of Harvard University.
The figures for the velocity of blood flow are the averages of two or more readings which did not differ from each other by more than two seconds. In three instances the velocity of blood flow was not measured on the same day as the cardiac output.

The cardiac minute volume output was calculated from the arteriovenous oxygen difference and the oxygen consumption, the latter being estimated from data obtained during the measurement of the basal metabolic rate. The work of the left ventricle was calculated using the formula of Evans and Matsuoka (15), \( W = QR + (wV^2/2g) \),\(^8\) disregarding the velocity component \( wV^2/2g \) since it represents only 1 to 3 per cent of the total work.

RESULTS

Cardiac output and work. The minute volume output of the heart was decreased in all 7 patients with hypothyroidism following total thyroideectomy (Table I, Figure 1). Measurements, made when the basal metabolic rates had decreased to between minus 25 and minus 37 per cent, re-

\(^8\) \( W = \text{work; } Q = \text{cardiac output per unit of time; } R = \text{arterial resistance (mean blood pressure } \times 13.6); V = \text{velocity of blood in aorta; } w = \text{weight of blood; } g = \text{acceleration due to gravity.}

![Figure 1. Relation between the basal metabolic rate and the cardiac index.](image)

The dots indicate measurements made on various patients at a single low level of metabolism. Measurements at various levels of metabolism in three patients are indicated by the circles, and open and closed triangles.

TABLE I
Cardiac output and related observations in hypothyroidism

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Height (inches)</th>
<th>Weight (pounds)</th>
<th>B. M. R. deviation from normal</th>
<th>Oxygen consumption</th>
<th>Anceous oxygen difference</th>
<th>Cardiac minute volume output</th>
<th>Cardiac index</th>
<th>Pulse rate (per minute)</th>
<th>Cardiac output (cc. per heart beat)</th>
<th>Blood pressure (mm. Hg)</th>
<th>Venous pressure (mm. Hg)</th>
<th>Arterial pressure (mm. Hg)</th>
<th>Arterial pressure (mm. Hg)</th>
<th>Vital capacity (cc.)</th>
<th>Work per minute</th>
<th>Work per beat</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. M. F.</td>
<td>53</td>
<td>62(\frac{1}{2})</td>
<td>137</td>
<td>-27</td>
<td>133</td>
<td>5.85</td>
<td>2.3</td>
<td>1.4</td>
<td>55</td>
<td>41</td>
<td>130</td>
<td>80</td>
<td>70</td>
<td>90</td>
<td>1200</td>
<td>2000</td>
<td>3.3</td>
<td>61</td>
</tr>
<tr>
<td>2. R. S.</td>
<td>58</td>
<td>60(\frac{1}{2})</td>
<td>139</td>
<td>-28</td>
<td>138</td>
<td>6.7</td>
<td>2.1</td>
<td>1.3</td>
<td>65</td>
<td>32</td>
<td>130</td>
<td>110</td>
<td>100</td>
<td>130</td>
<td>1200</td>
<td>2000</td>
<td>4.1</td>
<td>64</td>
</tr>
<tr>
<td>3. T. C.</td>
<td>55</td>
<td>70</td>
<td>178</td>
<td>-38</td>
<td>160</td>
<td>6.35</td>
<td>2.5</td>
<td>1.2</td>
<td>46</td>
<td>55</td>
<td>138</td>
<td>90</td>
<td>375</td>
<td>50</td>
<td>1200</td>
<td>2350</td>
<td>3.9</td>
<td>85</td>
</tr>
<tr>
<td>4. G. O.</td>
<td>55</td>
<td>69(\frac{1}{2})</td>
<td>194</td>
<td>-35</td>
<td>167</td>
<td>6.5</td>
<td>2.6</td>
<td>1.3</td>
<td>58</td>
<td>44</td>
<td>6.9</td>
<td>76</td>
<td>2350</td>
<td>40</td>
<td>1200</td>
<td>2350</td>
<td>3.4</td>
<td>59</td>
</tr>
</tbody>
</table>

Cases studied after total thyroideectomy

Cases studied before and after total thyroideectomy

Cases studied at various levels of basal metabolic rate after operation

\(7. S. F.\) | 53          | 64.5            | 154             | 5.95                         | 2.2                         | 1.2                      | 58                        | 40                       | 31                       | 110                     | 90                    | 2400                 | 4.5                | 54          | 58       |
| 153          | 154             | 5.85                         | 3.3                         | 1.9                      | 79                        | 42                       | 22                       | 116                     | 86                    | 2700                 | 4.5                | 54          | 58       |
| 163          | 155             | 6.35                         | 2.6                         | 1.4                      | 76                        | 34                       | 37                       | 104                     | 76                    | 2500                 | 3.2                | 42          | 42       |
2.2 ± 0.3 (16). The work of the left ventricle was correspondingly diminished.

The findings in Cases 5 and 6 studied both before and after operation, and in Case 7 studied at different levels of metabolism after operation indicate that as the basal metabolic rate falls, the minute volume output of the heart decreases progressively more rapidly than the oxygen consumption.

**Arteriovenous oxygen difference.** An increase of arteriovenous oxygen difference became evident at low levels of metabolism (Table I, Figure 2). The disproportionate decrease in the cardiac output noted above is associated with this progressive increase in arteriovenous oxygen difference (Cases 5, 6, and 7, Table I).  

**Velocity of blood flow.** The velocity of blood flow was usually decreased when hypothyroidism had developed (Table I). In Cases 3 and 4 the velocity of blood flow was not appreciably less than normal although the cardiac output was strikingly decreased. In some instances, therefore, the velocity of blood flow did not reflect accurately the work of the heart.

**Venous pressure, arterial pressure, and vital capacity.** The venous and arterial blood pressure

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4 Drs. T. R. Harrison and Harold J. Stewart have each studied one case after total thyroidectomy and have also observed this change in the arteriovenous oxygen difference. (Personal communications.)

**DISCUSSION**

Starr, Collins, and Wood in 1933 (17) demonstrated a high coefficient of correlation between the cardiac output and oxygen consumption in normal persons under basal conditions. The results of the present study in patients with hypothyroidism indicate, however, that as the basal metabolic rate falls, the minute volume output of the heart decreases progressively more rapidly than the oxygen consumption. This disproportionate decrease in cardiac output in hypothyroidism is accompanied by an increase in the arteriovenous oxygen difference and is in harmony with the observations of Field and Bock in two cases of spontaneous myxedema (1).

The increased arteriovenous oxygen difference found in hypothyroidism is not to be regarded as evidence of heart failure due to "myxedema heart." An increase has in fact been observed after total thyroidectomy in patients with congestive heart failure when the signs of cardiac decompensation were disappearing (unpublished data). The fact that the venous pressure was not increased in the above studied patients with marked hypothyroidism is additional evidence that the circulatory changes were not due to cardiac decompensation. Estimation of the size of the heart on x-ray examination before and after operation, furthermore, revealed enlargement after hypothyroidism had developed in only three of the seven patients of this series. The factor responsible for the increased arteriovenous difference has not been ascertained. Further work in this direction is now in progress.

Calculations from the data obtained in this study show that the work of the left ventricle is greatly diminished at low levels of metabolism following total thyroidectomy. This is in harmony with the concept advanced by Blumgart et al. (9, 10, 11) that the relief obtained in congestive failure and angina pectoris after thyroidectomy is due to lowered demands upon the heart in the hypothyroid state. It is significant that the patients studied experienced relief of their angina pectoris when the work of the heart decreased. Conversely, patients with spontaneous myxedema may
develop angina pectoris when treated with thyroid (18).

In hypothyroidism the marked decrease in cardiac output with its associated increase in arteriovenous oxygen difference results in a disproportionately greater decrease in left ventricular work than in basal metabolism. At very low levels of metabolism the rest afforded the heart becomes considerably greater than that which might be expected from the decrease in basal metabolic rate alone.

CONCLUSIONS

1. The minute volume output and the work of the heart are greatly diminished in hypothyroidism following total ablation of the normal thyroid gland.

2. The cardiac output decreases progressively more rapidly than the oxygen consumption as the basal metabolic rate falls in hypothyroidism. This disproportionate decrease in cardiac output is accompanied by a progressive increase in the arteriovenous difference.

3. In most instances the velocity of blood flow was decreased when the cardiac output was low. In some instances, however, the velocity of blood flow did not reflect accurately the work of the heart.

4. The venous pressure, arterial pressure, and vital capacity were not significantly altered after total thyroidectomy in the patients of this series.

BIBLIOGRAPHY


