HEMODYNAMIC ASSESSMENT OF ESSENTIAL HYPERTENSION
BY RADIOCARDIOGRAPHY AND
ANALOG COMPUTER SIMULATION

SHUNJI MOTOUMURA, MASAHICO KINOSHITA, AND KUNIHISA NAKAO

In order to understand the pathophysiology of essential hypertension, it is mandatory to know the dynamics of maximum and minimum blood pressure. The difficulty in knowing the hemodynamic patterns in essential hypertension is certainly attributable to our lack of knowledge of the influential factors in the natural history and pathogenesis of the disease.1,2

In this paper we emphasize the hemodynamic pattern of essential hypertension, and the influence of age on cardiac output and renal blood flow, considering the increase in peripheral resistance which is responsible for the high blood pressure.

MATERIALS AND METHODS
The subjects of this study were 65 hypertensive patients between the ages of 19 and 71 (average 50.4 years) with the clinical diagnosis of essential hypertension with cardio-renal compensation. They were divided into an untreated group of 46 cases and a treated group of 19 cases. From ocular fundus findings, the untreated group was further subdivided into a H0,1 group (32 cases of early hypertension) and a H2,3 group (14 cases of stable hypertension) according to Sheie's classification.

A radioisotope cardiogram (RCG) and a radioisotope renogram (RRG) were done in each case to obtain blood volume (BV), cardiac output (CO), cardiac index (CI) and renal blood flow (RBF). RCG analog simulation was applied to calculate the left and right ventricular volumes (VL, VR) and the heart volume (HV). Kinoshita's method* was employed for RCG and RRG was simulated by Hirakawa, et al.2 to compute RPF and RBF.

RESULTS
Untreated group: H0,1 group . . . . A group
H2,3 group . . . . B group
Treated group: . . . . . . . . . . . C group

1) All 3 groups showed normal blood volumes as shown in Table I. The mean values and standard deviations were: A group, 72.7 ± 10.8 ml/kg, B group, 75.1 ± 14.3 ml/kg, and C group, 75.1 ± 11.9 ml/kg. However, these did not indicate the age range within each group (Fig. 1, 2, 3).

2) A group had a higher mean value for CI (4.19 ± 0.891/min/M²) than B group (3.62 ± 0.76 l/min/M²). (see Table I). The highest values for CI were observed in the younger members of A

Key Words:
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Hemodynamics
Radioangiogram (RCG)
Radiorenogram (RRG)
Blood volume and cardiac output
Renal blood flow and cardiac output
Aging

* A scintillation counter 5cm in diameter with 3 x 2 inch NaI crystal was set by hand on the left sternal margin at the level of the fourth rib. Ten to twenty microcuries of 131I-RISA was injected into a cubital vein and the syringe immediately flushed with 10ml of normal saline. Seven minutes after injection, a blood sample was drawn to calibrate the extravascular volume. CO was derived from Veall and Huff's formula: CO = E/A x BV where E stands for the value obtained extracorporeally after 7 minutes and A for the area under the curve during the first circulation (CO/BV = E/A).

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group; with age the CI tended to decrease (Fig. 4). However, in B group, this correlation was not present (Fig. 5). C group showed a tendency to correlation similar to that of A group (Fig. 6).

3) For the ratio of BV/CO A group had a mean value of 0.64 ± 0.14 (range from 0.374 to 0.873), B group 0.75 ± 0.13 (range from 0.549 to 0.932) and C group 0.80 ± 0.19 (range from 0.153 to 1.224). There were no significant differences among the three groups. In A group BV/CO significantly increased with age (r: 0.71,
p < 0.01) (Fig. 7); however, in B and C groups this relationship did not hold (Fig. 8, 9).

4) CO/HV for A group, 15.7, was significantly greater than that for B group, 10.8 (p < 0.01) (Fig.10).

5) For A group the average V_L/V_R was 0.97, whereas that for B group was significantly higher 1.32 (Fig.10).

6) The average RPF was 532 ± 51 ml/min in A group with a range from 380 ml/min to 820 ml/min. B group had a mean value of 415 ± 93 ml/min, which was obviously lower than that for A group (Table 1).

7) In neither the A nor the B group was RBF/CO related to age. All three groups showed the same mean value, 0.13 (Table 1).
Relation between the Ratio of Blood Volume to
Cardiac Output and Age in Essential Hypertension

![Graph]

Fig.9.

Heart Volume and Cardiac Output
in Essential Hypertension

![Graph]

Fig.10.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>MEAN VALUES ± S.D. OF BLOOD VOLUME, CARDIAC INDEX, RENAL PLASMA FLOW, BV/CO AND RBF/CO ON HYPERTENSIVE PATIENTS GROUPED ACCORDING TO OCULAR FUNDUS FINDINGS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>No.</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>Untreated</td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>32</td>
</tr>
<tr>
<td>(H₀₁)</td>
<td></td>
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<tr>
<td>Group B</td>
<td>14</td>
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<tr>
<td>(H₂, 3)</td>
<td></td>
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<tr>
<td>Treated</td>
<td></td>
</tr>
<tr>
<td>Group C</td>
<td>19</td>
</tr>
<tr>
<td>(H₀₁, 2, 3)</td>
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</tbody>
</table>

**DISCUSSION**

It is generally said that the cardiac output increases during the labile stage of hypertension. It is also said that peripheral vascular resistance during this period is normal, but *Julius, et al.* stated that in the early stages of hypertension, peripheral vascular resistance was high relative to the cardiac output when compared with that of a normal group. This finding was primarily related to sympathetic factors. The aging factor has been little considered in the discussion of cardiac output; however, the finding by Brandfondrenner, Landdoune and Shock that the value for CI in twenty-year-olds is 3.72 ± 0.26 l/min/M² and in sixty-year-olds is 2.58 ± 0.51 l/min/M² suggests that aging is a factor of prime importance. In this study, there was a
significant correlation between BV/CO and aging in the early stages of hypertension, but this was not true in the group at the fixed stage of hypertension. This finding suggests that CO is more affected by a age than by hypertension, and further that BV/CO or blood circulation time is prolonged with age. The degree of correlation should be compared with that of a control group. However, these of correlation should be compared with that of a control group. However, these blood volumes and cardiac outputs were within the normal range. A more detailed investigation is necessary.

The heart volume was calculated by analog computer from RCG: \( V_H \) is the mean total volume of left heart (ventricle and auricle) in systole and diastole, likewise \( V_F \) is the volume of the right heart. In the A group there was no difference between the volumes of the right and left hearts. Yet the existence of hypertrophy of the left heart muscle, that is, concentric hypertrophy, cannot be denied. In the B group, the volume of the left heart was greater than that of the right heart and the existence of left ventricular hypertension can be assumed. As stated above, there is no significant difference in CI and BV/CO between the A and B groups, but CO/HV, which is considered to be the efficiency rate of heart muscle, is significantly higher in group A than group B. Severe cases of hypertension showed a decreased value indicating decreased efficiency of the heart muscles.

RBF was more reduced in group B than group A. It is a known fact that renal function, especially RBF, is reduced progressively with the degree of severity. The mean values for RBF/CO were the same value of 0.13 in all three groups. It is said that RBF/CO is normally 0.18 ± 0.025, that is renal blood flow is 18 ± 2.5 per cent of cardiac output. It seems that in hypertension the decrease in RBF is more marked than that in CO and that the change in RBF is primary in the hemodynamics of hypertension. The fact that the ratio of RBF to CO have same value in A, B, and C groups suggests that the effect on renal hemodynamics in hypertensive patients is not dependent on symptomatic severity nor on drugs but is an essential factor in the etiology of hypertension.

**SUMMARY**

In 65 patients with essential hypertension, divided into groups by ocular fundus changes and treatment, cardiac and renal functions were studied by RCG and RRG.

1. No difference in BV was detectable among the groups.
2. The CI was higher in young patients and lower with age.
3. The ratio of BV to CO apparently increased with age in the mild cases, but in the severe cases, it was independent of age.
4. In severe cases, the volume of the left heart increased and the efficiency rate decreased with increasing severity.
5. The ratio of RBF to CO was 13%, a value independent of the severity or treatment. The change in hemodynamics of hypertension is considered to be primarily a result of the decrease in RBF relative to the cardiac output.

**REFERENCES**


