Relation of arterial pressure with exchangeable and total body sodium and with plasma exchangeable and total body potassium in essential hypertension

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Summary
1. Arterial pressure, plasma electrolytes and exchangeable sodium were measured in 91 patients with essential hypertension and in 121 normal control subjects. Total body sodium, exchangeable potassium and total body potassium were also measured in some of the hypertensive patients.
2. Mean plasma sodium concentration was slightly but significantly lower in the hypertensive patients as a group, but mean values for other electrolyte measurements were close to normal or predicted normal.
3. Exchangeable sodium was not related to arterial pressure in normal subjects but in hypertensive patients exchangeable sodium correlated significantly with systolic and diastolic pressures. These correlations were significant with two methods of expressing exchangeable sodium, in the whole group of patients, in men and in older patients. Exchangeable sodium was not significantly related to arterial pressure in young patients.
4. Total body sodium also correlated significantly with systolic and diastolic pressures in hypertensive patients.
5. Exchangeable sodium was significantly related to age in hypertensive patients but not in normal subjects. Mean exchangeable sodium was significantly lower than normal in young patients.
6. Plasma potassium concentration was not related to arterial pressure in normal subjects but in essential hypertensive patients plasma potassium concentration, exchangeable potassium and total body potassium correlated negatively with systolic and diastolic pressures. These correlations were also significant in young, but not in old patients.

Key words: exchangeable potassium, exchangeable sodium, potassium, sodium.

Introduction
There are several ways in which sodium and potassium could be involved in the pathogenesis of essential hypertension [1–5], but mean values for exchangeable sodium (Na_e) are usually normal in patients with the disease [6]. One study [6] reports a significant correlation of arterial pressure and Na_e.

We report here a further analysis of the problem. Exchangeable and total body sodium, and exchangeable and total body potassium have been measured in patients with essential hypertension and the correlation of body electrolytes and arterial pressure tested. Comparison has been made with measurements of exchangeable sodium in normal subjects.

Methods

Ninety-one patients with essential hypertension and 121 normal subjects were studied. Essential hypertension was defined as previously [6] and details of the patients are to be given in a fuller report [7]. No patient had malignant-phase hypertension or was receiving treatment at the
time of study. Normal subjects were healthy volunteers with a blood pressure consistently below 140/90 mmHg. All patients and 22 normal subjects were studied in the wards of the Blood Pressure Unit while consuming a diet with a fixed sodium and potassium content. Mean urinary sodium and potassium content. Mean urinary sodium was slightly but significantly lower in the hypertensive patients (Table 1). However, the hypertensive patients were heavier than the normal subjects (75.9 and 66.9 kg respectively, matched for leanness index with 38 normal men and total body potassium in the hypertensive patients were also close to predicted normal values (99, 104 and 100% respectively). Naₚ was not different (100% in both groups for Naₚ related to leanness index). Naₚ was measured in all patients and normal subjects by isotope dilution [9] and was expressed as the ratio measured/expected for a normal individual of the same sex and body surface area or the same sex and leanness index [10]. Regression lines for the relation of Naₚ with body surface area, and of Naₚ with leanness index in normal female or male subjects, were used to derive these expected values. Exchangeable potassium (Kₑ) was measured by isotope dilution [9] in 60 hypertensive patients, total body sodium by activation analysis [11] in 38 patients and total body potassium by external counting of ⁴₀K [12] in 61 patients. These measurements were also expressed by the ratio measured/expected for a normal individual of the same sex, body weight and height; expected values were calculated from published data in normal subjects [13–15]. Blood pressure was measured in the recumbent position with a conventional sphygmanometer taking phase V as diastolic pressure; each pressure was the mean of at least six measurements obtained during a 36 h period before and during estimation of Naₑ.

**Results**

Normal subjects and patients with essential hypertension had similar mean ages (39 and 42 years respectively, \( P > 0.05 \)) and plasma potassium concentrations (4.1 mmol/l in both groups). Mean plasma sodium concentration and mean Naₑ were slightly but significantly lower in the hypertensive patients (Table 1). However, the hypertensive patients were heavier than the normal subjects (75.9 and 66.9 kg respectively, \( P < 0.01 \)) and when 38 hypertensive males were matched for leanness index with 38 normal men \( \text{Na}_ₑ \) was not different (100% in both groups for \( \text{Na}_ₑ \) related to body surface area and 99% in both groups for \( \text{Na}_ₑ \) related to leanness index). Mean values of total body sodium, \( Kₑ \) and total body potassium in the hypertensive patients were also close to predicted normal values (99, 104 and 100% respectively). \( \text{Na}_ₑ \) correlated closely with total body sodium in those patients in whom the latter was measured (\( r = 0.91, P < 0.001 \)), as did \( Kₑ \) with total body potassium (\( r = 0.96, P < 0.001 \)).

Arterial pressure and \( \text{Na}_ₑ \) were not significantly related in normal subjects (Table 1), but in the hypertensive group systolic and diastolic pressures were related to \( \text{Na}_ₑ \) and the relation was significant for both methods of expressing \( \text{Na}_ₑ \), for the whole group of patients and for older patients (Table 1). It was also significant for men (\( P < 0.01 \)) and for the subgroup matched for leanness index (\( P < 0.01 \)). Total body sodium also correlated significantly with systolic and diastolic pressures in the hypertensive group (\( r = 0.44 \) and 0.55 respectively, \( P < 0.01 \)).

Plasma potassium was not related significantly to arterial pressure in normal subjects, but in
hypertensive patients it correlated inversely and significantly with systolic and diastolic blood pressures (Table 1). These correlations were significant in the whole group and in young patients, but not in older patients. Exchangeable potassium and total body potassium were also related inversely to blood pressure in the hypertensive patients and again the correlations were significant in the whole group and in young patients (Table 1).

In normal subjects Na\textsubscript{E} was unrelated to age but in the hypertensive group it was significantly and positively related \((P < 0.001)\), rising from significant subnormality in young patients to slightly but insignificantly higher than normal values in older patients. Significant subnormality of Na\textsubscript{E} in young patients was seen with both methods of expression (Table 1), when the comparison was restricted to Glasgow hypertensive patients and Glasgow control subjects and when young hypertensive patients were matched for leanness index with normal subjects [7].

**Discussion**

The main findings of our study are the positive correlation of body sodium and the inverse correlation of plasma and body potassium with arterial pressure in hypertensive patients. Where measurements were made none of these correlations was found in normal subjects. If hypertensive patients are fatter than normal (as they were in this and other studies), Na\textsubscript{E} related to body weight would underestimate body sodium as adipose tissue has a lower electrolyte content than other tissues. Possible solutions are to relate Na\textsubscript{E} to calibrations for leanness index and body surface area and to match normal and hypertensive groups for leanness index. These methods were used here and are to be described in a fuller report [7]: the subnormality of Na\textsubscript{E} in young hypertensive patients and the correlation of Na\textsubscript{E} and arterial pressure in the hypertensive group were not explained by a difference of leanness index.

Our findings are relevant to several ideas on the pathogenesis of essential hypertension. One holds that excess dietary sodium is wholly or partly responsible for the disease [see 1, 2]; if increasing dietary sodium raises body sodium [16] and if increasing body sodium produces a greater increase of arterial pressure in hypertensive patients than in normal subjects, our data are compatible with the hypothesis, but only as a mechanism in older patients. Subnormal Na\textsubscript{E} and the absence of a relation of Na\textsubscript{E} and arterial pressure in younger patients suggests that some other mechanism is more important in the early stages.

Another view is that essential hypertension results from increased sodium content of vascular smooth muscle [4, 5]. The relation of our findings to this mechanism is not certain as only a fraction of total body sodium is within the cell and we have not determined the proportion in and outside the cell. The correlation of plasma potassium and arterial pressure (Table 1) is compatible with the hypothesis since decreased extracellular potassium has a vasoconstrictor effect, which may be mediated by the same cell-sodium mechanism [17]. However, the finding of a subnormal Na\textsubscript{E} in young patients does not agree with that version of the hypothesis which holds that expansion of the extracellular space in essential hypertension is the ultimate reason for the high intracellular sodium [4].

A third theory holds that the ability of the kidney to excrete sodium with rising arterial pressure (pressure natriuresis) is primarily impaired in essential hypertension [4, 18, 19] and that blood pressure rises to the point where sodium balance can be maintained, possibly with normal total body sodium. Again our data are only compatible with this as an important mechanism in older patients. The inverse correlation of arterial pressure with plasma potassium and body potassium raises the possibility than an abnormality of potassium is important in the early stages of the disorder. Dietary studies also point in this way [20, 21].

**References**


