Sodium transport in erythrocytes: differences between normal children and children with primary and secondary hypertension

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SUMMARY The following measurements were made in normal children, children with primary hypertension, and children with secondary hypertension: erythrocyte intracellular sodium concentration, total sodium efflux rate constant, and maximum binding of ouabain to erythrocytes reflecting the number of sodium/potassium adenosine triphosphatase pump sites. Children with primary hypertension had a significantly higher mean erythrocyte intracellular sodium concentration (8.2 compared with 6.6 and 6.7 mmol/l cells), and significantly lower total sodium efflux rate constant (0.5071 compared with 0.6983 and 0.6197) and maximum binding of ouabain to erythrocytes (9.1 compared with 11.7 and 11.0 nmol/l cells) than normal children and children with secondary hypertension, respectively.

Since the original report by Losse et al in 1960 that intracellular sodium was increased in the red blood cells of patients with essential hypertension, various abnormalities of ion transport have been reported in patients with primary hypertension, and it has been postulated that essential hypertension may be caused by disturbance of membrane electrolyte transport. Because it is difficult to study the cells in the walls of blood vessels where abnormalities may affect blood pressure, circulating blood cells—for example, leucocytes and erythrocytes—have been used to study the transport of electrolytes across membranes.

Few studies have been undertaken on transport of sodium across cell membranes in children with hypertension. We therefore undertook a study of erythrocyte sodium transport in children with primary hypertension and compared the findings with those in normal children and in patients with secondary hypertension.

Subjects and methods

We studied 15 normal children who acted as controls (range 5–15 years), 12 children with primary hypertension (age range 12–16 years), and 27 children with secondary hypertension (age range 5–15 years). The control children, whose blood was being taken for another reason during the course of investigations of minor illnesses, did not have any family history of hypertension. Children with primary hypertension showed significant increases in blood pressure (greater than the 95th centile for age) on repeated measurements and were not receiving antihypertensive treatment. No other causes for their hypertension were found on thorough examination. All patients with secondary hypertension had renal hypertension, and in most of these the blood pressure was renin dependent. All the children with primary hypertension had normal plasma renin activities for their ages (less than 899 ng angiotensin I/hour or 690 ng angiotensin I/hour. Eight of 27 children with secondary hypertension were receiving treatment; six were receiving propranolol and hydralazine, and two were receiving captopril. The study was approved by the ethical committee of the Hospital for Sick Children and the Institute of Child Health.

Samples of 5 ml of fresh heparinised blood were taken; 2 ml of each were used for measurement of the 22sodium efflux, and the remaining 3 ml were separated into plasma and erythrocytes at 3000 rpm. The erythrocyte intracellular sodium concentration was measured by flame photometry with IL 943 flame photometer (Instrumental Laboratory) after washing erythrocytes three times with 155 mmol/l of cold choline chloride (4°C). The 22sodium efflux rate constant was measured by a modification of the method used by Fitzgibbon et al; 4.0 µCi of 22sodium (22 µCi/ml, Amersham International) was
added to 2 ml of whole blood and incubated at 37°C for one hour. Labelled erythrocytes were obtained and washed four times with cold isotonic saline. A sample of 250 μl of packed erythrocytes was added to 500 μl of their own plasma, and reincubated at 37°C for one hour; 25 μl of a cell suspension were taken into counting tubes both before and after this incubation. Finally, 250 μl of incubated blood was centrifuged at 12000 rpm for three minutes (Eppendorf microcentrifuge) to obtain 125 μl of supernatant for counting.

In each tube 22sodium was counted with a LKB gamma counter (1282 Compgamma). The efflux rate constant (Ke) was determined by using the following equation: ln (natural log) \((1-N_t/N_0)\) = \(-\text{Ke} \times \text{time}\), where \(N_0\) = 22sodium present/unit volume of suspension of incubating cells (mean of the counts/unit volume of suspension taken at time 0 and 60 minutes), \(N_t\) = 22sodium present per unit volume of supernatant at time 60 minutes.

The binding of ouabain to erythrocytes was measured by a modification of the method used by Gardner and Conlon.8 Packed erythrocytes, which were washed three times with cold isotonic saline (4°C), were resuspended in trismetamol (TRIS) buffer (sodium chloride 130 mmol/l, sucrose 20 mmol/l, glucose 10 mmol/l, and TRIS 10 mmol/l, pH 7.4) to a packed cell volume of 0.15. A stock solution of ouabain (100 mmol/l in 10% ethanol) was prepared and kept at 4°C.

A sample of 100 μl of 3H ouabain (37 Ci/ml, Amersham International) was placed into a glass tube and evaporated under nitrogen. The residue was redissolved with 500 μl of isotonic saline, of which 100 μl was diluted in 2-6 ml of isotonic saline on assay. Two fold serial dilutions were then made four times. Of the erythrocyte suspension, 300 μl were incubated with 50 μl of the diluted radioactive ouabain at each dilution, and with 50 μl of isotonic saline or 1 mmol/l of cold non-radioactive ouabain at 37°C for two hours. Subsequently the unbound ouabain was removed by washing three times with isotonic saline, and the final pellet resuspended in 200 μl of 10% trichloroacetic acid. After centrifuging 100 μl of its supernatant was used for liquid scintillation counting (LKB; 1210 Ultron-beta) in 3 ml of Cocktail T (British Drug Houses).

Non-specific binding was estimated by replacing 50 μl of isotonic saline with 50 μl of 1 mmol/l of cold ouabain. The amount of ouabain specifically bound was calculated by subtracting the non-specific counts from the total counts. Maximum binding of ouabain to erythrocytes was calculated using a curve fitting computer programme. All determinations were calculated in duplicate.

Intra-assay coefficients of variation were 2.4%, 3.6%, and 6.2% for intracellular sodium concentration, total sodium efflux rate constant, and maximum binding of ouabain to erythrocytes, respectively. Results were expressed as mean (SEM) and analysed parametrically by the unpaired Student's \(t\) test.

**Results**

In the children with primary hypertension, mean erythrocyte intracellular sodium concentration was significantly higher (8.2 (0.63) mmol/l cells) than in

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Fig 1 *Intracellular sodium concentration in erythrocytes from normal children, children with primary hypertension, and children with secondary hypertension.*
sodium in erythrocytes. Firstly, there is sodium/lithium countertransport, which is equivalent to sodium/sodium countertransport. This channel is thought to exchange a single external sodium ion for a single internal one. This cannot affect the overall distribution of sodium across cell membranes and there is, therefore, some doubt about its physiological role. Canessa et al., however, reported that countertransport was increased in erythrocytes in patients with essential hypertension, suggesting that this system could be a marker for essential hypertension.

The second system that has been studied is frusemide sensitive sodium/potassium cotransport. This pathway lies dormant in the cell membrane unless intracellular sodium concentrations rise above a critical point, and acts as a supporting mechanism for sodium extrusion. Garay et al. reported that the activity of this system was decreased in erythrocytes of patients with essential hypertension.

Control children (6.6 (0.32) mmol/l cells), and in children with secondary hypertension (6.7 (0.26) mmol/l cells) (p<0.05) (fig 1). In children with primary hypertension, mean total sodium efflux rate constant was significantly lower (0.5071 (0.04)) than in control children (0.6983 (0.04)), and in children with secondary hypertension (0.6197 (0.03)) (p<0.001) (fig 2). The mean maximum binding of ouabain to erythrocytes that reflects the number of pump receptor sites was reduced in children with primary hypertension (9.1 (0.45) nmol/l cells) compared with controls (11.7 (0.73) nmol/l cells), and with those with secondary hypertension (11.0 (0.49) nmol/l cells) (p<0.005) (fig 3).

Discussion

There are several pathways for active transport of
tension, suggesting that this system could also be a marker for essential hypertension.11

A third system is the sodium pump, which is the best described and most widely studied pathway for cellular sodium homeostasis. The activity of the pump system is consistently low in white cells of adult patients with essential hypertension,12 13 but inconsistent results have been obtained by erythrocytes that are thought to be caused by the activity of the pump being much slower in erythrocytes than in white cells.9 It was impossible to study white cells in children, however, because more than 100 ml of blood would be required for each assay, so we chose to study erythrocytes by measuring erythrocyte intracellular sodium concentration, total sodium efflux rate constant, and maximum binding of ouabain to erythrocytes may have some diagnostic value in positively identifying children with primary as opposed to secondary hypertension, and may have a predictive value in identifying children who are at risk of developing essential hypertension in adult life. There is, however, substantial overlap among the groups of patients and further study is currently being undertaken to establish whether factors such as a family history of essential hypertension play a part in modifying transport of electrolytes across cell membranes. It is not yet known whether the erythrocyte sodium transport defect is caused by the hypertension, or is just a marker.9

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