Abnormal erythrocyte Na$^+$ transport has been reported in patients with essential hypertension and some first-degree relatives. The two major techniques now employed for estimating Na$^+$ transport—Na$^+$/Li$^+$ countertransport and Na$^+$/K$^+$ cotransport—are rather intricate and time consuming. Furthermore, the precise nature of the transport processes being measured is not clear. We have developed a simpler, more direct technique based on measurement of $^{22}$Na$^+$ accumulation by erythrocytes. $^{22}$Na$^+$ uptake by red cells from patients with essential hypertension averages twice normal. Indeed, of 21 patients with essential hypertension, only 2 patients had values within the upper end of the normal range. In 12 patients with secondary hypertension and no family history of essential hypertension, erythrocyte $^{22}$Na$^+$ accumulation was within normal limits. Control experiments indicate that our technique for estimating red cell $^{22}$Na$^+$ uptake is highly reproducible and shows little day-to-day variation. This procedure for the assessment of erythrocyte Na$^+$ transport should be useful in differential diagnosis and the presymptomatic identification of individuals genetically prone to essential hypertension.

**MATERIALS AND METHODS**

**Patients**

In all patients studied, the diagnosis of essential hypertension was based on a supine diastolic pressure $>$95 mm Hg ($\times 2$) and a variety of exclusionary criteria including normal renal function and normal intravenous pyelogram. The 12 patients with secondary hypertension had non-neoplastic renal diseases. Controls were defined by normal blood pressure (supine diastolic pressure $>$85 mm Hg) and no family history of hypertension. All subjects were white, the majority being of northern European descent. In all cases, informed consent was obtained prior to venipuncture.

**Methods**

Venous blood (10 ml) was collected in heparinized vacutainers. The blood was washed 3 times in a buffer comprised of 145 mM KCl, 5 mM NaCl, 10 mM Tris(hydroxymethyl)aminomethane (Tris), 10 mM morpholinopropanesulfonic acid (MOPS), 10 mM D-glucose, and 0.1 mM ouabain, pH 7.40, at 37°C. The buffy coat was removed during the washing procedure. Of washed, packed erythrocytes of known hematocrit (-75 vol %), 0.5 ml was admixed with 0.5 ml of the same buffer containing 0.1 $\mu$Ci of $^{22}$Na$^+$ (New England Nuclear, Boston, Mass.) (final specific activity approxi-
mately 20 μCi/mmmole). Incubation of the cell suspension was carried out in a shaking water bath at 37°C for 30 min, at which time the cells were rapidly washed 3 times (total time ~9 min) in 5 volumes of ice-cold wash buffer containing 75 mM MgCl2, 85 mM sucrose, 10 mM D-glucose, 10 mM Tris, and 10 mM MOPS, pH 7.40, at 37°C. Of washed packed cells, 0.3 ml was combined with 0.6 ml of 10% trichloroacetic acid, vortexed vigorously, and centrifuged for 5 min at 1000 g. Of the clear supernatant, 0.3 ml was removed for liquid scintillation counting, and the hematocrit of the remaining packed cells was determined. From the known specific activity of 22Na+ in the 1-ml incubation volume, the unidirectional Na+ influx was calculated as follows:

1) \[ 1000 \mu l (total \text{ incubation} \text{ volume}) - \mu l \text{ RBC in incubation} = \text{extracellular volume} \text{ (usually 600-650 \mu l)} \]

2) \[ \text{extracellular volume} \times 0.005 \text{ (mmole Na+}/ml) - \text{extracellular Na+ (\mu mole)} \]

3) \[ \text{cpm} \text{ 22Na+ in incubation} - \text{extracellular Na+ (\mu mole)} = \text{cpm}/\mu \text{mole Na+} \]

4) \[ \frac{\text{cpm/300 \mu l TCA extract}}{\text{hematocrit of washed RBC/100}} \times 20 \text{ (volume and time)} = \text{cpm/ml RBC/hr} \]

5) \[ \frac{\text{cpm/ml RBC/hr}}{\text{mmole Na+}/liter RBC/hr (apparent Na+ influx)} \]

Na+/Li+ countertransport was determined as described by Canessa and coworkers.3

RESULTS

The accumulation of 22Na+ by red cells is linear over a period of at least 4 hr (Fig. 1). This linearity is consistent with the fact that the internal 22Na+ concentration is only 1%-3% of the external 22Na+ concentration after a 30-min period. Therefore, the flux of 22Na+ is largely unidirectional and unopposed by backflux of intracellular isotope.

The results of studies of patients with essential and secondary hypertension and normal controls are shown in Fig. 2. The average difference in the rate of 22Na+ influx between patients with essential hypertension and normal controls is approximately twofold (t = 8.87; p < 0.001). In fact, of the 21 patients with essential hypertension, only two have values that overlap the upper range for normal controls. In contrast, patients with secondary hypertension have normal values for 22Na+ influx. Sixteen of the patients with essential hypertension were receiving antihypertensive medications, and 5 were not. Comparison of the mean 22Na+ influx values for these two groups (0.537 versus 0.507 mmole Na+/liter RBC/hr; t = 0.402, p > 0.30) indicates that such therapy has no consistent effect on the 22Na+ permeability of washed erythrocytes.

The reproducibility of the 22Na+ influx technique was assessed through repeated determinations on labo-

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Fig. 1. Na+ flux in erythrocytes from a patient with essential hypertension (----) and a normotensive control (---) during 6-hr incubation. The measurement and calculation of Na+ accumulation were performed as described in Materials and Methods.

Fig. 2. Comparison of erythrocyte 22Na+ flux values for 21 patients with essential hypertension, 12 with secondary hypertension, and 21 normal controls. The average rate of red cell Na+ influx for patients with essential hypertension is twice that for normal controls (0.527 ± 0.128 versus 0.286 ± 0.044 mmole Na+/liter RBC/hr; t = 8.87; p < 0.001). The average value for patients with secondary hypertension (0.233 ± 0.060 mmole Na+/liter RBC/hr) is close to that for normal controls.
correlation between

These limited investigations suggest an excellent

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loading of erythrocytes approaches involve prolonged

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personnel over several months. As shown in

table, little temporal fluctuation occurs in either the

assay itself or the values obtained for each individual.

Finally, to determine whether interindividual differ-

ences in rates of 22Na+ influx might be related to

variations in Na+/Li+ countertransport,3 we carefully

measured these two parameters in a series of 5 normal

controls and 2 patients with essential hypertension.

These limited investigations suggest an excellent
correlation between the two procedures (Fig. 3).

DISCUSSION

The results indicate that measurement of 22Na+ influx is reproducible and readily identifies most patients with essential hypertension. In addition, it appears that our procedure may also detect individuals with a genetic predisposition to essential hypertension. Investigations of 34 members of three kindreds, each founded by a progenitor with essential hypertension, indicate that approximately 50% of the offspring (F1 and F2) have increased red cell Na+ permeability. Many of these latter are not yet hypertensive (results not shown).

Our procedure for determining red cell Na+ transport abnormalities that may be linked with essential hypertension compares favorably with the other published techniques.3,7 Furthermore, the alternative approaches involve prolonged loading of erythrocytes with Li+ or Na+ and, in the latter procedure, altering membrane permeability with an organic mercurial. In both cases, the red cells are incubated from 3 to 20 hr before any determinations of cation transport are made. Thus, neither of the previously published techniques is easily adapted to clinical use.

It should be pointed out that the accumulation of 22Na+ by red cells under our conditions may reflect a combination of several (ouabain-insensitive) transport processes. Nonetheless, when our procedure and that of Canessa et al.3 are applied to individual blood samples, the results correlate very well. It should be noted that we have employed a K+-rich buffer system in order to minimize competition between 22Na+ and Na+. This permits the use of smaller amounts of isotope, but does not alter the relative values obtained. Thus, the performance of this procedure in a Na+-rich buffer or plasma also yields a twofold difference in apparent Na+ influx between patients with essential hypertension and those with secondary hypertension or normotensive controls. Therefore, the differences that we report are not due to K+-induced changes in membrane Na+ permeability.

In sum, our assay for determining red cell Na+ influx is simple, reproducible, and rapid. It requires minimal expertise, can be adapted readily by clinical laboratories, and discriminates most patients with essential hypertension from those with secondary hypertension. This technique should be of utility in the diagnosis of essential hypertension and the identification of genetically predisposed individuals.

ACKNOWLEDGMENT

We thank Drs. Sylvia Azar and Philip Dunham for helpful discussions and Drs. Morris Davidman and Miguel Azar for providing patient material.

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Assessment of red cell sodium transport in essential hypertension

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