Simple Portable Device for Sampling a Whole Day’s Urine and its Application to Hypertensive Outpatients

OSAMU TOCHIKUBO, M.D., SUSUMU UNEDA, M.D., AND YOSHIHIRO KANEKO, M.D.

SUMMARY To simplify 24-hour urine collection for epidemiological and clinical examinations, we devised a portable, semiautomatic urine sampling cup with divided partitions. The cup, 6.6 cm in diameter and 14 cm in height, is double-bottomed and has a pipe-shaped scale and a cock leading to the lower compartment. It is so devised that \( \frac{1}{m} \) of the urine volume excreted into the upper compartment each time remains in the pipe scale, and then comes down into the lower compartment by manipulating the cock. The urine in the lower compartment remains when the urine in the upper compartment is discarded. The cup is carried in a vinyl bag. By repeating this manipulation, \( \frac{1}{m} \) of the total urine excreted during 24 hours can be collected in the small cup (proportional sampling method). When the 24-hour urinary sodium excretion measured by the conventional method and that measured by this method were compared, the correlation coefficient \((r)\) was 0.98, and the average variation was 2.0 ± 10.8 (SD) mEq (n = 32). Use of this device for outpatients was convenient and enabled counseling on salt intake. (Hypertension 5: 270–274, 1983)

KEY WORDS • 24-hour urine collection • proportionally sampling method • sodium intake • hypertension

A S is known, restriction of salt intake is important in preventing and treating hypertension. The Japanese Ministry of Welfare and Health recommends an intake of less than 10 g of salt a day, while the United States authorities advise less than 5 g. However, the actual determination of daily salt intake in individuals and in epidemiological investigations is not easy. There are two ways to determine salt intake, namely, by recording the amount and quantity of each type of food eaten and calculating its salt content from tables or actual flame photometric analyses of food portions; and by determining the amount of sodium excreted in the urine. The former method is not quite accurate, the latter is onerous, necessitating the patient to carry about 1 to 2 liters of urine, which makes collecting a day’s urine cumbersome. We have developed a device to facilitate the collection of urine so that sodium, other electrolytes, creatinine, hormones, and various substances can be determined. We have ascertained the accuracy of this method and applied it to outpatients for measuring their salt intake.

Methods

Principal Concept and Explanation of the Urine Collection Device

It is onerous for a patient to collect urine amounting to 1 to 2 liters over a 24-hour period, necessitating the use of a voluminous container. Indeed, it is impractical for workers on the job. In our method the measurement is actually done with a small sample, and the concentration of a substance in the sample then is multiplied by the total volume of urine excreted in a day. When the volume voided each time is represented as \( L_i \), the collected portion is \( \frac{1}{m} \) (which is \( L_i \)), and the occurrence of voiding per day is \( N \). Then, the volume of urine (\( V \)) voided in a day is

\[
\sum_{i=1}^{N} L_i = \sum_{i=1}^{N} mL_i = m \sum_{i=1}^{N} L_i = m \Delta V
\]

provided that the value \( m \) is constant. For example, substance A is at a given content level, \( A_i \), in a voiding and \( A_i \) in its sample portion (\( a_i \)) is then \( A_i = m a_i \). The concentration of A substance in the entire day’s output of urine should be
24-HOUR URINE-SAMPLING DEVICE/Tochikubo et al.

\[
\text{Co} = \frac{\sum_{i=1}^{N} A_i}{\sum_{i=1}^{N} L_i},
\]

and this would be equal to the sum of \(N\) times \(1/m\) fraction,

\[
C_m = \frac{\sum_{i=1}^{N} a_i}{\sum_{i=1}^{N} l_i}.
\]

Hence, without storing a whole day's urine, the amount of a substance excreted daily in the urine can be calculated according to the formula

\[
\frac{\sum_{i=1}^{N} A_i}{\sum_{i=1}^{N} m_a} = m \frac{\sum_{i=1}^{N} l_i}{m_a} = m \Delta V C_m
\]

by sampling the \(1/m\) fraction in each voiding (proportionally sampling method).

Such sampling would enable a smaller urine sample to be taken and thus be more portable and practical. This method would be inexpensive and facilitate the collection of the \(1/m\) fraction of each urine voiding by a simple method. Taking these conditions into account, we devised the following sampling technique.

**Partition Cup**

The partition cup has three compartments (fig. 1): a main compartment, a pipe with cross-sectional areas of \(S_a\) and \(S_c\) respectively, and a subcompartment. The urine is voided into the main compartment. Between the compartments there is a three-way stopcock, which facilitates the transfer of the urine from the main compartment to the pipe and subsequently to the subcompartment through apertures A, B, and C, in a single operation. The aperture with stopcock D is used for removal of the urine sample from the subcompartment (fig. 1). The subject voids into the main compartment with stopcock A opened, and B and C closed. If \(h\) is the height of the level of urine, then the volume of the urine in the pipe is \(h s_c\); when A is closed and B and C are opened, the portion \(h s_c\) in the pipe is placed in the subcompartment. The opening of C permits escape of the displaced air to allow for the transfer of the portion \(h s_c\). If \(d\) is the sectional area of the wall thickness of the pipe, then \(h (S_c - d)/h s_c = (S_c - d)/S_c = m\). Hence, a constant fraction of each urine voiding, liter/m, can be collected in the subcompartment and tightly contained in it when stopcock A is opened, and B and C are closed. Then, the cup can be put in a vinyl bag to be carried about. By repeating this manipulation, liter/m of the total urine excreted during 24 hours can be collected.

**Examination of the Accuracy and Practicality of the Partition Cups**

We prepared 300 partition cups (cup caliber = 66 mm; pipe caliber = 6 mm; wall thickness = 1 mm).

**Figure 1.** Partition cup. The urine is voided into the main compartment, and a constant fraction, \(1/m\), can be semiautomatically sampled and stored in the subcompartment. In one operation, it is possible to close stopcock A, and open stopcock B and C. Stopcock D is for removal of the urine sample. Photograph (right) shows the partition cup (6.6 cm diameter \(\times\) 14 cm height).
The mean $V/\Delta V$, determined with them, was $119.0 \pm 1.5$ (SD).

Since the ratio ($m$) varied with individual cups, each cup had its own ratio recorded beforehand. The result of the determinations obtained by the use of the standard daily collection method of urine in a urine container ($V_o$) was compared to $\Delta V$ obtained by the use of a portion sampled with the partition cup from inpatients without disorders of the kidney and the urinary tract. The patients included 25 men and eight women, 31 to 60 years old (mean = 43.3 ± 9 years). On the day of measurement, the first voiding at 6:00 a.m. was discarded. Subsequent voidings were collected and sampled until 6:00 a.m. the next morning.

The estimated volume of the urine collected in a day is $\Delta V$ multiplied by $m$. As items of quantitative analysis in the urine, Na, K, Cl, and creatinine, were selected, their concentrations as well as the 24-hour excretion rates were determined in $V$ ($V = V_o + \Delta V$) and $\Delta V$, and compared. Na and K were analyzed by flame photometry, Cl by chloridometry, and creatinine by the Jaffe method.

To confirm the utility of the partition cups, 259 of them were used on outpatients. The subjects included 95 patients (64 men and 31 women) with untreated essential hypertension, 90 (60 men and 30 women) with treated essential hypertension, and 74 (42 men and 32 women) suspected of hypertension but who, after examination, were found to be normotensive. The age of all subjects was under 60 years.

The importance of a low salt diet and the way of handling the partition cup was explained to all patients. They were handed a partition cup, of which the ratio $m$ was predetermined, with a vinyl carrying bag and a note explaining the procedure for using the device. Items analyzed were Na, K, Cl, and creatinine in the urine.

### Results

#### Accuracy of Sampling with the Partition Cup Examined in Hospitalized Subjects

Accuracy of sampling with this device was examined clinically in 33 inpatients (fig. 2). Data obtained from one woman were inexact and discarded; it was later found that, in this particular case, the sample leaked out of the built-in pipe because it was inadequately cemented at the bottom. Of the 32 remaining cases, in one woman and one man (Cases 1 and 3 in fig. 2) the cup was washed with water after each use; in another woman (Case 2) the stopcock had been used improperly. Correlation between $V$ ($V = V_o + \Delta V$) and $m\Delta V$ was satisfactory ($r = 0.967, m\Delta V = 1.035V - 0.002$), the mean error $\varepsilon$ [the average of $(m\Delta V - V)/V \times 100$] being $0.052 \pm 0.150$ liters or $3.3 \pm 9.9$ (SD) % respectively (table 1).

As for quantitative results of daily sodium excretion, $\varepsilon$, the mean difference between the figure obtained from the total daily urine stored and that estimated from the collection of its fractions sampled with the partition cup was 2.0 mEq, and $\varepsilon$ its standard deviation, 10.8 mEq. The correlation between them was satisfactory (table 1, fig. 3). The quantitative results for NaCl, K, and creatinine are shown in table 1. Excretions of NaCl per day were about equal in 32 cases, being $129 \pm 59.3$ mEq and $122.2 \pm 59.1$ mEq respectively, and the correlation...
TABLE 1. Difference and Correlation Between Whole Voiding of Urine and Partition Cup Sampling for a Day in 32 Subjects (24 Men, 8 Women)

<table>
<thead>
<tr>
<th>Determination</th>
<th>Na (mEq)</th>
<th>Cl (mEq)</th>
<th>K (mEq)</th>
<th>Cr (g)</th>
<th>Volume (liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole urine output of a day</td>
<td>129.0 ± 59.3</td>
<td>122.2 ± 59.1</td>
<td>42.8 ± 11.8</td>
<td>1.31 ± 0.30</td>
<td>1.51 ± 0.55*</td>
</tr>
<tr>
<td>Estimate by partition cup</td>
<td>131.0 ± 57.0</td>
<td>124.3 ± 56.7</td>
<td>44.1 ± 11.1</td>
<td>1.34 ± 0.36</td>
<td>1.56 ± 0.59†</td>
</tr>
<tr>
<td>Differences of results between whole urine output test and partition-cup test‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>concentration</td>
<td>-0.40 ± 5.3</td>
<td>0.2 ± 7.1</td>
<td>0.1 ± 2.5</td>
<td>0.00 ± 0.08</td>
<td></td>
</tr>
<tr>
<td>total urine/day</td>
<td>2.0 ± 10.8</td>
<td>2.1 ± 12.3</td>
<td>1.3 ± 4.4</td>
<td>0.03 ± 0.24</td>
<td>0.05 ± 0.15</td>
</tr>
</tbody>
</table>

*Volume of whole urine output was calculated as \( V = V_o + \Delta V \) (where \( V_o \) is the volume of classical collection of urine in the urinal, \( \Delta V \) is the amount of the partition cup and amount of a substance expected as Co \( \times V \) (Co = concentration in \( V_o \)).

†Estimated volume \( m\Delta V \) (\( m \) = constant of the partition cup) and \( C_m \times m\Delta V \) (\( C_m \) = concentration in \( \Delta V \)) were calculated.

‡\( e = (C_m - C_o) \) or \( (C_m \times m\Delta V - C_0V) \) was calculated in each subject, and mean (\( \bar{e} \)) or standard deviation (\( \bar{s}e \)) of them were determined.

coefficient between them was high \((r = 0.976)\). Therefore, the salt excretion can be approximately estimated by quantitative data on sodium alone.

Application of the Partition Cup for Outpatient Use

Data from 15 patients (6%) were excluded, because of a possible mistake in sampling. Estimated creatinine excretions and 24-hour urine volume per day were over 3 or under 0.5 g, and over 4 or under 0.4 liters, respectively. Therefore, we decided to discard these results.

The mean 24-hour excretion rate of sodium was 209 ± 73 (sd) mEq in normotensive persons, 220 ± 67 mEq in untreated essential hypertensive patients and 170 ± 72 mEq in treated essential hypertensives. Fifty cases (55%) of the treated patients on dietary management excreted 171 mEq or more of sodium. Most of these patients were not able to realize how much salt they were actually taking per day, and they believed that they had reduced salt intake substantially.

In 25 hypertensive patients with elevated sodium levels, the results of their analysis were shown to them, and it was recommended that they reduce their salt intake. Afterward, sodium analyses were repeated, and it was found that the sodium excretion rate was lowered in all cases, as shown in figure 4 (10.8 g/day to 7.5 g/day). Hence, this device was useful in providing dietary guidance for patients.

Discussion

The daily intake of sodium is estimated by analysis of the content of salt in foods, or by determination of its excretion in the urine. Since the former tends to give greater error, the latter is preferable. Sodium is excreted not only in the urine but also in feces (10 to 25 mg/day) and perspiration (0.1 g/liter); however, urine excretion is more accurate in revealing an altered intake of sodium within 1 to 2 days.

As a simplified sampling method, use of nocturnal urine has been suggested. However, this excretion value fluctuates so that 24-hour urine sampling is preferable. For the best estimation, urine analyses should be repeated several times on separate days, since sodium intake varies from day to day, and its excretion is also affected by various factors. To meet this need, the partition cup is constructed so that it can be used for 3 days successively, and its subcompartment can hold 60 ml or more of the urine samples.

Perhaps the partition cup might be used clinically, provided that its manufacture is standardized so that the relative caliber ratio of the cup to the pipe is constant. Quantitative data on the contents of urine output, namely, sodium and other substances, are within permissible limits, but the trouble is that one must entrust this device to patients and permit them to use the device themselves. Some of them neglect collections or make mistakes in using the device. To check for such mishaps, the creatinine level should be measured. Depending upon age, sex, and body weight, daily creatinine excretion in the urine is practically constant.
26 mg/kg/day in Japanese men and 14–22 mg/kg/day in Japanese women. If a figure obtained deviates from the above values, a mishap may be suspected, and resampling of urine is recommended to avoid possible mistakes.

With this technique, daily urine excretion of glucose, protein, catecholamines, aldosterone, and other hormones may also be estimated. When combined with the measurement of serum creatinine, 24-hour creatinine clearance can be determined. Thus, a number of additional clinical applications for this device may be expected.

Acknowledgment

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References

To THE EDITOR:


The study reported was conducted utilizing blood collected from some of the obese patients on whom norepinephrine levels were reported in a previous article by Sowers et al, Role of the Sympathetic Nervous System in Blood Pressure Maintenance in Obesity, J Clin Endocrinol and Metab 51: 1181, 1982. Blood samples were reanalyzed for dopamine, epinephrine, norepinephrine, prolactin, PRA, and aldosterone. Thus, the data reported over a 12-week weight reduction period were derived from blood samples collected as a continuation of the previous study. The studies were conducted in the UCLA Risk Factor Obesity Control Program under the direction of Drs. Morton Maxwell and Leslie Dornfeld, who should have been included as coauthors of the paper in Hypertension 4(5): 686-691. Thus, I wish to submit these two facts as a correction.

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