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An Evaluation of Test Sticks Used for the Measurement of the Specific Gravity of Urine from Patients with Stone Disease

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Summary. A test stick for the measurement of the SG of the urine of stoneformers was examined. In 230 spontaneously voided urines and 45 25 h-urines the SG was measured by the test stick and compared with urinometer measurements. The two methods showed a good correlation ($r = 0.86$). Due to the principle of reaction of the SG-teststick a direct relationship of the SG-values to the sodium concentration and to the ionic strength of urine was found. There is no correlation between the relative supersaturation of CaOx and the SG-determination (urinometer, test stick). The handling of the SG-test stick is simple and can be easily performed by the patient.

Key words: Urolithiasis, Urine dilution, Specific gravity, Test stick.

Introduction

Urinary dilution is helpful in the management of patients with recurrent urolithiasis. The degree of urinary dilution can be measured as a function of density known as specific gravity (SG). The most precise estimate of urinary concentration is the measurement of osmolality, which requires special laboratory equipment. Urinometers are easy to use and have been used for rapid estimation and for patient screening tests. Test sticks are routinely used for certain urine analytes, and we have explored their use for the determination of SG. The determination of SG by test stick was compared both with urinometer values of SG and with the results of quantitative analysis of urinary components.

Materials and Methods

The SG was determined in 230 spontaneously voided urine samples with the SG testpad of N-Labstix SG (Miles Laboratories, Elkhart, Indiana) and then with the urinometer (Zylometer, Wellcome).

The specific gravity of 45 24 h-urines was determined by both mentioned methods. In addition 12 other important parameters for urolithiasis were determined. The following methods were used:

sodium	flame photometer
potassium	flame photometer
calcium	atomic absorption
magnesium	atomic absorption
ammonium	sensitive electrode
anorganic phosphorus	phosphorus molybdate reaction
anorganic sulphate	nephelometry
chloride	coulemetry
urine acid	enzymatic
citric acid	enzymatic
oxalic acid	gas chromatography
pH-value	glas electrode

The relative supersaturation of calcium oxalate was calculated with the computer program (EQUIL) from the given parameters [5, 7]. Correlations were calculated for the comparative measurement of SG and for certain parameters in 24 h-urines.

Principle of the Specific Gravity (SG) Test Stick

The testpad contains a polyelectrolyte (poly/methyl vinyl ether/maleic anhydride) as well as the pH-indicator bromthymol blue. The deprotonization of acidic groups of this polyelectrolyte is promoted by electrolytes in the solution. The released protons react with the pH-indicator bromthymol blue. The resulting colour change is related to the ionic concentration or specific gravity of the urine sample.

The determination is performed as follows: The test stick is dipped into the urine, excess liquid must be wiped off and after 45–60 s the result can be obtained from the colour-scale. The difference between two colour blocks is 0.005 units (g/cm^3).

The colour reaction of the test zone depends on the pH-value and therefore the acidity of the urine samples influences the results. The manufacturer of the test stick recommends that the SG-value should be corrected by adding 0.005 when the pH-value is 6.5 and above.

When using the urinometer, the urine samples must be cooled to room temperature before measuring. Elevated temperatures require a correction. For a 3 degree increase of temperature above 20 °C an adjustment of + 0.001 has to be made.

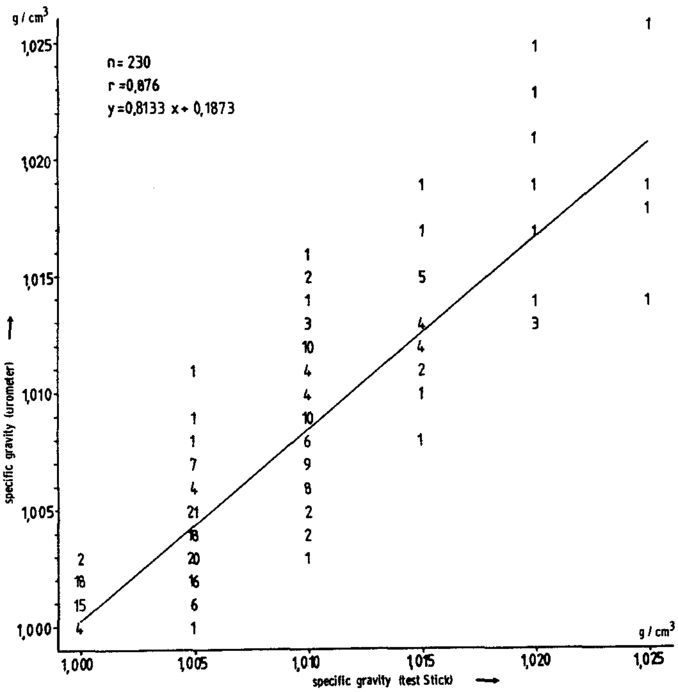

Fig. 1. Method comparison between SG test stick and urinometer

Results

1. Comparative Measurements SG-Test Stick/Urinometer

The results of measurements of SG with test stick and urinometer of 230 spontaneously voided urine samples showed a good correlation between both methods. The coefficient of correlation was $r = 0.8760$ (Fig. 1). Nearly identical results were obtained with the 45 24 h-urine samples ($r = 0.8739$).

The correlation analysis has a limited value, since there is a stepwise reading of the test stick results. There would have been better correlations for all calculations, if intermediate values could have been read. This effect is shown for the urinometer (Table 1).

To prevent recurrent stone formation it is necessary not to exceed a certain ionic concentration of urine. 1.015 g/cm^3 as an upper limit of density is generally proposed. Due to the coarse scale of the test stick we put this value to 1.010 g/cm^3 to ensure more reliability. The calculations of correlation with the limiting value of 1.010 g/cm^3 showed that there is a better correlation between test stick and urinometer results ($r = 0.78$) with values $\leqslant 1.010$ than with values > 1.010 ($r = 0.63$). This result can be explained by the more distinguished colour shades at lower SG-values.

2. Relationship Between Ionic Concentration and Specific Gravity

Lithogenous and inhibitory substances were quantitatively determined in 45 24 h-urines. Corresponding to the principle of the test stick a positive correlation between the urine SG and the sodium concentration was found (Fig. 2). For the divalent ions calcium and magnesium there is only little correlation to the test stick SG (Ca: $r = 0.064$; Mg: $r = 0.232$). Other substances participating in the formation of calculi show a weak correlation with the SG (anorganic phosphorus: $r = 0.363$; oxalic acid: $r = 0.184$).

Table 1. Correlation between SG and various ions

variable Y	X	number n	coefficient of correlation r
1. SG-urinometer	SG-stick	230	0.8760
SG-urinometer > 1.010	SG-stick	52	0.6341
SG-urinometer ⩽ 1.010	SG-stick	178	0.7802
2. SG-stick (laboratory)	SG-stick (patient)	87	0.9207
SG-urinometer (laboratory)	SG-urinometer (patient)	87	0.977
3. SG-urinometer	SG-stick	45	0.8739
4. sodium	SG-stick	45	0.5673
sodium	SG-urinometer	45	0.7174
5. calcium	SG-stick	45	0.0644
calcium	SG-urinometer	45	0.2836
6. magnesium	SG-stick	45	0.2324
magnesium	SG-urinometer	45	0.5533
7. inorganic phosphate	SG-stick	45	0.3634
inorganic phosphate	SG-urinometer	45	0.7267
8. oxalic acid	SG-stick	45	0.1836
oxalic acid	SG-urinometer	45	0.1767

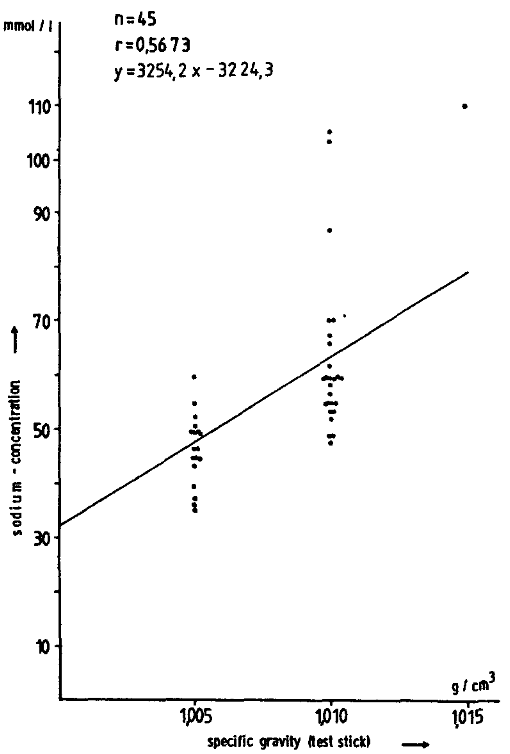

Fig. 2. Relationship between SG test stick value and sodium concentration

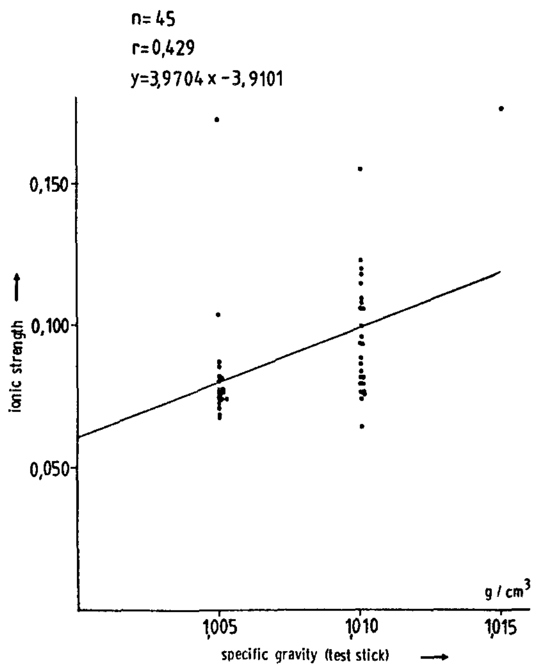

Fig. 3. Relationship between SG test stick value and ionic strength

Table 2. Concentration of lithogenic and inhibitory substances in 24 h-urine samples of patients with calcium oxalate calculi (n = 45, $\bar{x} \pm s$)

parameter	concentration (mmol/l)
volume (ml)	2,538 ± 467
pH	6.70 ± 0.43
Na	55.84 ± 15.46
K	16.64 ± 6.38
Ca	2.35 ± 1.16
Mg	1.84 ± 0.88
Cl	45.90 ± 9.24
PO4	11.18 ± 4.12
SO_4	7.68 ± 3.04
uric acid	1.19 ± 0.64
citric acid	1.42 ± 0.58
oxalic acid	0.186 ± 0.062

The results of the quantitative determination of lithogenic and inhibitory substances in 24 h-urines are summarized in Table 2. With the computer program "EQUIL" the relative supersaturation of calcium-oxalate and the ionic strength of the urine samples were calculated and related to the measured SG values. The result is that the SG of the test stick shows a good correlation to the ionic strenght of the urines (Fig. 3). However, there is no relation to the relative supersaturation of calcium oxalate. We found similar results for the urinometer (Table 3).

Discussion

The formation of urinary calculi only occurs when the solubility product of stone forming salts is exceeded. Therefore, attempts have to be made to encourage the patients

Table 3. Ionic strength and relative supersaturation of CaOx in 24 h-urine samples of patients with calcium oxalate calculi. Correlation to the SG (n = 45)

parameter	$\bar{x} \pm s$	coefficient of correlation	
		SG-stick	SG-urinometer
SG-stick	1.0080 ± 0.0027	–	–
SG-urinometer	1.0066 ± 1.0020	–	–
ionic strength	0.0920 ± 0.0250	0.4288	0.7412
relative supersaturation of CaOx	5.259 ± 2.826	0.0377	0.1231

to increase their fluid intake. This is especially important, since there are characteristic circadian rhythms for some of the stone forming substances and the urine volume [8, 13].

The emerging peaks of concentration have to be compensated. This can be done successfully by appropriate fluid intake i.e. special sorts of tea [1, 2, 9]. Depending on stone composition and the excretion of stone forming substances it is necessary to set up an appropriate daily program of fluid intake for each stone patient. Transpiration may reduce urinary volume in hot climates, even when fluid intake seems sufficient. The minimum volume of urine per day should be 2 l.

Patients can be motivated to adhere to a sufficient fluid intake by controlling their urine density. So far the urinometer was the method of choice, since all other methods were not suitable for direct use by the patient. However, even use of the urinometer requires certain technical ability.

Further it could be argued that the determination of urinary density was not performed continuously by the patients. Since test sticks are easier to handle and have been used for measuring the pH-value the use of test sticks to determine urinary density is advantageous.

The comparison between urinometer and the SG-test stick for 230 spontaneously voided urine samples showed only small differences in the mean values (Table 2). The coefficient of correlation was determined on 45 24 h-urine samples (Table 1).

In the literature similar relationships between SG-teststick results and osmolality [6, 12] and pyknometer [10] are described.

The test stick results $\leqslant 1.010$ correspond better to the urinometer values than that with $SG > 1.010$ (Table 1). Other investigations confirm this observation [3, 4].

The analysis of urine components showed, that sodium correlates significantly with SG, whereas Ca, Mg, PO_4 and oxalic acid show only poor positive relations (Table 1).

This is due to the principle of reaction of the SG-test stick. Therefore a good correlation is obtained between SG (test stick) and ionic strength, while the relative supersaturation of calcium oxalate shows no relationship to the SG (test stick and urinometer).

With regard to the semiquantitative, gradual scaling of the SG-teststick the authors want to point out that calculating the coefficient of correlation is not without problems. Thus the r-value gives general information about the relationship of two variables even in this case [4, 6, 10].

SG measurement by the test stick is independent of temperature, glucose, creatinine and urea.

The patient is able to learn the SG-measurement by the test stick easily. In 87 urine samples a good agreement between the results of SG-measurements (test stick) by the patients and by the laboratory assisten ($r = 0.9207$ was observed. However, for most of the patients it is not easy to correct the obtained SG-values if the pH-values are above 6.5.

From our investigation it follows that the pH-adjustment by the patient is not necessary for the control of sufficient urine dilution, if the reguired dilution is $\leqslant 1.010$. This problem has to be examined in further studies

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