

Dipstick measurements of urine specific gravity are unreliable

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Abstract

Aim—To evaluate the reliability of dipstick measurements of urine specific gravity (U-SG).

Methods—Fresh urine specimens were tested for urine pH and osmolality (U-pH, U-Osm) by a pH meter and an osmometer, and for U-SG by three different methods (refractometry, automatic readout of a dipstick (Clinitek-50), and (visual) change of colour of the dipstick).

Results—The correlations between the visual U-SG dipstick measurements and U-SG determined by a refractometer and the comparison of Clinitek®-50 dipstick U-SG measurements with U-Osm were less than optimal, showing very wide scatter of values. Only the U-SG refractometer values and U-Osm had a good linear correlation. The tested dipstick was unreliable for the bedside determination of U-SG, even after correction for U-pH, as recommended by the manufacturer.

Conclusions—Among the bedside determinations, only refractometry gives reliable U-SG results. Dipstick U-SG measurements should be abandoned.

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Evaluation of the urinary concentration is an easy and valuable way of determining the fluid and electrolyte status of a patient. This can help in the day to day care of the critically ill, such as postoperatively and in the intensive care unit, and may be helpful in an outpatient setting. The urinary concentration depends on the presence of small (electrolytes, phosphate, urea, uric acid) and larger particles (proteins, glucose, radiographic contrast media) per unit of urine volume. The latter is obviously related to the state of hydration of the individual and depends largely on the amount of fluid reabsorbed along the renal tubule.

The concentration of solutes in the urine can be assessed by measuring its specific gravity or its osmolality. Urine specific gravity (U-SG) represents the relative proportion of dissolved solid components to the unit volume of a specific urine specimen. It reflects the relative degree of concentration or dilution of the urine specimen. Minimal amounts of urine are needed for determination of U-SG, an easy, rapid, non-invasive, and inexpensive way to obtain bedside information on the state of hydration of a patient at any age. Measurement of urine osmolality by freezing point depression in the routine laboratory is not practical for the

acute management of fluid and electrolyte abnormalities, certainly not in the very young. It is also a relatively expensive procedure. For these reasons many physicians rely on “dipsticks” (reagent strips) and/or refractometer measurements of U-SG.

Published experience on the use of U-SG measurements with commercially available dipsticks is controversial.^{1–5} In the present, prospective study the results of specific dipstick U-SG measurements were compared to other U-SG determinations in the same urine samples.

Methods

Within a few working days, 135 fresh voided urine specimens were collected from children visiting the outpatient renal clinic for various reasons (enuresis, urinary tract infections, malformations of the urinary tract, arterial hypertension, chronic renal insufficiency).

No preservative was used in the collecting bottle, each untreated urine specimen being immediately tested in the laboratory of the paediatric renal unit for osmolality (U-Osm; micro-osmometer, Advanced Instruments, Needham Heights, Massachusetts) and urine pH (U-pH) with a pH meter (TTT-titrator, Radiometer, Copenhagen, Denmark). The U-pH was measured as U-SG determinations may need adjustments according to U-pH (see below). The U-SG was determined with three different methods: (1) temperature corrected refractometry (Reicher-Jung Refractometer, Cambridge Instruments Inc., Buffalo, New York); (2) an automatic readout (Clinitek-50) of a dipstick (Multiple Reagent Strips, Bayer-Schweiz AG, Zurich, Switzerland); and (3) triple, simultaneous visual readouts of the same dipstick on all 135 urine samples by three independent laboratory technicians who each compared the obtained colour change with a standard colour chart provided by the manufacturer. None of the visual readout examiners was aware of the results obtained by the other(s). The automatic readout with Clinitek-50 is calibrated to add a constant of 0.005 to the U-SG results of alkaline urines with a pH ≥ 6.5 . Accordingly 0.005 was also added to the visual readout measurements of samples with a U-pH ≥ 6.5 . The reliability of the results of the various measurements, including the “uncorrected” and “corrected” (for U-pH) visual readout results of the alkaline urines, were analysed by linear regression.

Results

All tested urine samples were negative for glucose, protein, and blood. Figures 1, 2, and 3

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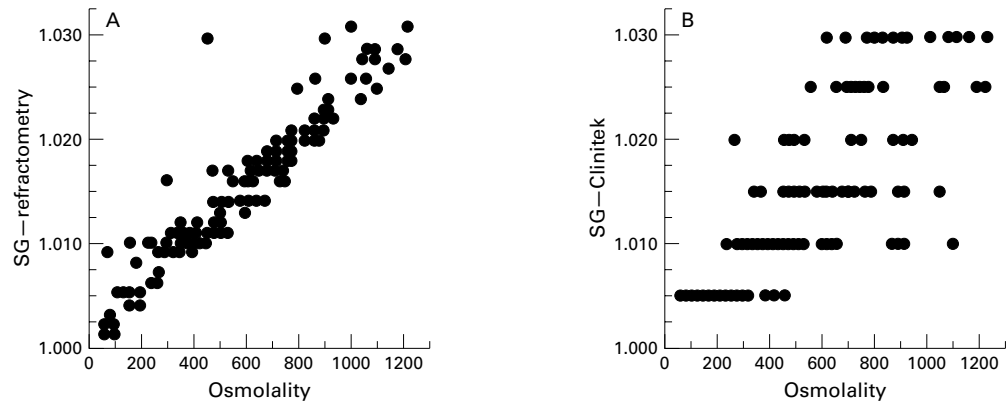


Figure 1 The relation between U-Osm and U-SG measured with a refractometer (A) as well as U-SG measured with a Clinitek-50 automatic readout of the Bayer dipstick (B).

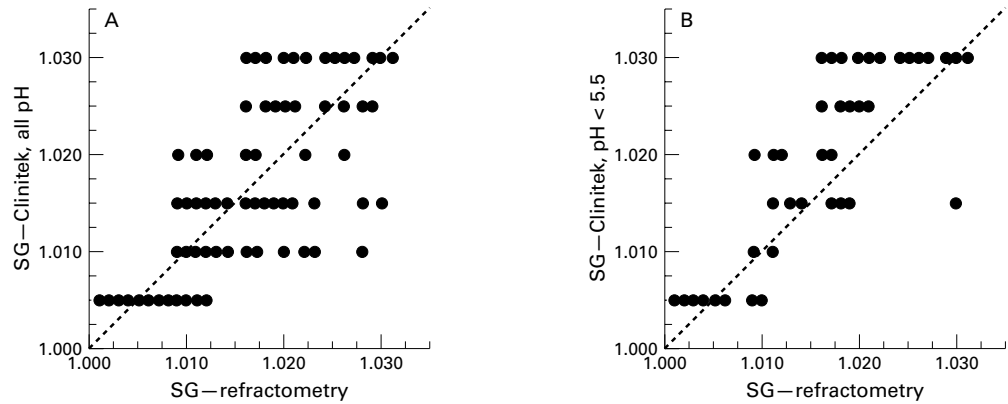


Figure 2 The relation between U-SG measured by a Clinitek-50 and U-SG refractometry, all pH (A) and the U-SG measured by a Clinitek-50 with pH < 5.5 (B).

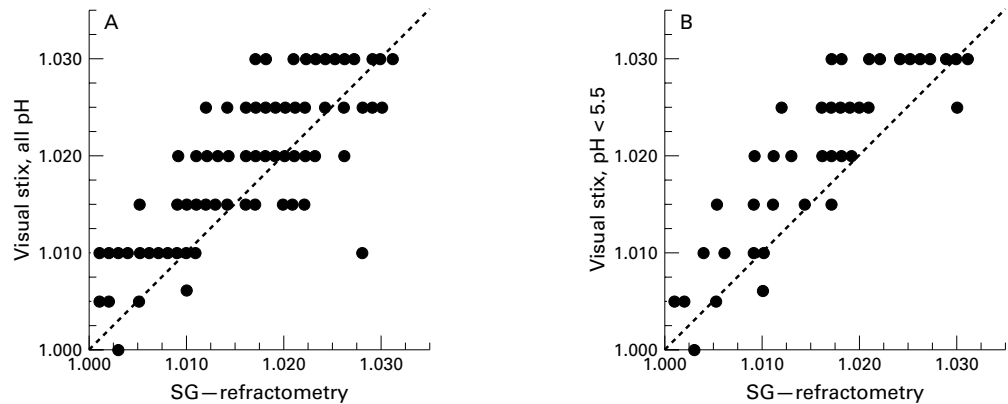


Figure 3 The relation between the visual U-SG measurements (all pH) of one laboratory technician (out of three) with U-SG refractometry (A) and the correlation of the same visual U-SG data, but with a pH < 5.5, with U-SG refractometry (B).

summarise the U-SG results. Figure 1A shows the very significant, linear, and positive correlation between U-SG measured by refractometry and U-Osm ($r^2 = 0.8930$; $y = 2.3786 \cdot 10^{-5}x + 1.016$). The relation between U-SG measured by Clinitek-50 and U-Osm was less satisfactory ($r^2 = 0.6103$, $y + 21780 \cdot 10^{-5}x + 1.003$; fig 1B) than that observed between U-SG refractometer and U-Osm. Far more important, however, is the wide dispersion of the data when comparing U-SG Clinitek-50 with U-Osm. At an U-SG-Clinitek-50 of 1.005, 1.010, and 1.020 the U-Osm varied from 45 to 481, 256 to 1085, and 244 to 918 mOsm/kg H₂O, respectively. The same pattern of variability was

observed when U-SG Clinitek-50 and U-SG obtained by visual observation were compared to the U-SG measured by refractometry (fig 2A,B). The three individually determined visual U-SGs all had low correlation constants versus U-Osm ($r^2 = 0.4676$, 0.5014, and 0.6475, respectively). They showed the same kind of wide scatter as found in fig 1B, for example. Elimination of alkaline urines did not significantly improve the variability of the data (fig 2B). When the visual readout dipstick data and U-SG Clinitek-50 values were correlated after division according to the U-pH (all pHs and pH < 5.5) the correlations did not improve and the large variability remained (fig 3A,B). A

comparison between the U-pH measured with the Bayer reagent strips and with a pH meter showed a good correlation ($r^2 = 0.9001$, $y = 0.88x + 0.8183$).

Discussion

The measurement of U-Osm by freezing point depression detects the total number of urine particles, independently of their size. Refractometry, a method based on the principle that a concentrated fluid breaks normal light differently from water, also detects all urine particles albeit according to the weight of the particles rather than to their number only. The size of large particles (proteins, sugars) may therefore interfere with accurate refractometry readings. The various available dipstick U-SG measurements evaluate U-SG by colorimetric methods. The specific SG reagent area of the dipstick has three major ingredients: a (cat)ion exchanger, bromthymol as colour indicator, and a variety of buffers. The urine concentration of H^+ and Na^+ ions increases after cationic exchange with the dipstick, inducing the bromthymol pH indicator to change from blue-green via green to yellow-green. These colour changes are empirically correlated to specific SG values. A strong alkaline or acid urine interferes with the accuracy of the measurement of U-SG by dipsticks. In contrast to refractometry, non-ionic urine constituents such as protein or blood are claimed not to influence the dipstick measurement of U-SG.

The present investigation shows that only the measurement of U-SG by temperature corrected refractometry is a valid alternative to U-Osm (fig 1A). The dipstick U-SG measurements were therefore related to the refractometry data, as all these methods can be used at the bedside. Both Clinitek-50 and the individual visual assessments of the colour change of the dipstick gave poor results when compared to U-SG refractometry (figs 1 and 3). The precision of the dipstick measurements did not improve with the correction by the constant 0.005 for U-pH > 6.5, as recommended by the dipstick manufacturer (fig 3).

Since 1983 numerous studies have addressed the reliability of the U-SG measurement with dipsticks in neonates, children, and adults. The reported experience, very often published from clinical (chemical) laboratories, is conflicting.¹⁻⁵ We will concentrate on the few U-SG data available in children. McCrossin and Roy measured U-SG in 130 urine specimens from a children's hospital in Australia.⁶ The Ames-N-multistix was unreliable and showed more or less the same variability as described in the present paper. The same dipstick was used to visually evaluate the U-SG in 98 urine specimens from 57 newborns by Gouyon and Houchan.⁷ Both papers did not recommend reagent strips for clinical use but suggested to use osmometry or refractometry. Assadi and Fornell⁸ also questioned the reliability of dipstick U-SG measurements in newborns. On the other hand, Leech and Penney⁹ found good correlations in neonates and adults in protein and glucose free urines. The regression equations, however, were different

for neonates and children less than 5 years of age compared to adults. More recently hospital based American nurses found good agreement between a reagent strip and refractometry on the same urine specimens of 1 day to 16 year old children.¹⁰

In our view the U-SG measurements with the Bayer Multiple Reagent Strips are not accurate, either by visual colorimetric testing or with the Clinitek-50 automatic readout. Consequently we suggest that the use of this specific test strip should be abandoned in clinical medicine for the measurement of U-SG, certainly when caring for newborn infants. Measurements of U-SG should be done exclusively with a temperature controlled refractometer, an easy and inexpensive bedside procedure with few "inbuilt" errors. It is a reliable alternative for the determination of U-Osm with a (micro)osmometer. The manufacturer of the tested dipstick apparently came to the same conclusion. Nowadays two additional Clinitek machines are available, the Clinitek-500 and the Clinitek-Atlas. The former measures U-SG with an improved colorimetric method, whereas the expensive (approx. SFr50 000 = US\$30 000) and bulky Clinitek-Atlas for use in large laboratories, measures U-SG from a dipstick by inbuilt refractometry. A plain refractometer (approx. SFr1000 = US\$600) seems a more practical and certainly more cost effective solution.

The inaccuracy of the dipstick measurements is apparently confined to U-SG. The pH measurement with the Bayer dipstick was reliable (data not given). Others have also found good results for dipstick measurements of protein, glucose, and other urine constituents, not tested by us. Therefore, only the use of a refractometer for U-SG, together with the visual or the Clinitek-50/500 readouts of the other urine parameters on a dipstick seems to give rapid, inexpensive, and reliable results.

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