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ORIGINAL RESEARCH

A pilot study to assess if urine specific gravity and urine colour charts are useful indicators of dehydration in acute stroke patients

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Abstract

Aim. The purpose of this pilot study was to examine whether urine specific gravity and urine colour could provide an early warning of dehydration in stroke patients compared with standard blood indicators of hydration status.

Background. Dehydration after stroke has been associated with increased blood viscosity, venous thrombo-embolism and stroke mortality at 3-months. Earlier identification of dehydration might allow us to intervene to prevent significant dehydration developing or reduce its duration to improve patient outcomes.

Methods. We recruited 20 stroke patients in 2007 and measured their urine specific gravity with urine test strips, a refractometer, and urine colour of specimens taken daily on 10 consecutive days and compared with the routine blood urea:creatinine ratios over the same period to look for trends and relationships over time. The agreement between the refractometer, test strips and urine colour were expressed as a percentage with 95% confidence intervals.

Results. Nine (45%) of the 20 stroke patients had clinical signs of dehydration and had a significantly higher admission median urea:creatinine ratio ($P = 0{\cdot}02$, Mann–Whitney *U*-test). There were no obvious relationships between urine specific gravity and urine colour with the urea:creatinine ratio. Of the 174 urine samples collected, the refractometer agreed with 70/174 (40%) urine test strip urine specific gravity and 117/174 (67%) urine colour measurements.

Conclusions. Our results do not support the use of the urine test strip urine specific gravity as an early indicator of dehydration. Further research is required to develop a practical tool for the early detection of dehydration in stroke patients.

Keywords: acute stroke, complications, dehydration, hydration, urine specific gravity

Introduction

Stroke patients may show signs of dehydration on admission, or develop signs during their hospital admission (Kelly *et al.* 2004). Stroke patients who are unconscious, have swallowing problems, are physically dependent, unable to communicate or confused are at increased risk of becoming dehydrated (Whelan 2001). Two thirds of all strokes occur in those aged over 65 who are more prone to water imbalance (Kedlaya & Brandstater 2002). Dehydration after stroke has been associated with increased blood viscosity, decreased blood pressure, venous thrombo-embolism, stroke mortality at 3 months and is associated with stroke recurrence (Bhalla *et al.* 2000, Kelly *et al.* 2004). Therefore, early identification of dehydration is important as it might allow us to intervene to prevent significant dehydration developing or reduce its duration and thus possibly improve patient outcomes. In this study, we hypothesized that clinically important dehydration would be associated with, and possibly preceded by increased urinary specific gravity (USG) or a change in urine colour (Ucol). Both of these tests are non-invasive and could be used by nurses at the bedside.

Background

Currently, no absolute definition of dehydration exists (Kavouras 2002). Dehydration can be described as a decrease in total body water (Lavizzo-Mourey 1987). Dehydration can also be categorized according to fluid compartment affected (intra or extracellar dehydration), sodium concentration (hypernatraemic dehydration) or tonicity of the fluid (hyper/hypo/iso tonic dehydration) (Vivanti *et al.* 2010). Initial dehydration after stroke is commonly hypotonic, and involves an excess loss of water compared with sodium and is associated with high sodium and plasma osmolality (Sheehy *et al.* 1999). It is caused by a lack of fluid intake due to drowsiness or dysphagia, fever due to the presence of infection, physical inactivity, episodes of vomiting and diarrhoea or a reduction in thirst (Kedlaya & Brandstater 2002).

The emergency mechanism to maintain water balance is via thirst, which is affected by an increase in plasma osmolality and a decrease in plasma volume. A higher plasma osmolality (> 296 mOsm/kg) in acute stroke patients has been associated with dehydration and a worse outcome 3 months after stroke (Bhalla *et al.* 2000). However, plasma osmolality is not routinely measured in stroke patients. More often, clinicians will base hydration status on routine blood indices such as raised or rising concentration of sodium, urea, haematocrit and the urea:creatinine (U:C) ratio (Kavouras 2002). Dehydration often develops during prolonged hospital stays so daily blood testing would be uncomfortable for patients, expensive and results are not immediately available at the bedside (Mentes *et al.* 2006). For these reasons blood testing is usually performed on hospital admission and quite frequently for the first few days in at risk patients but infrequently thereafter. Blood indicators of hydration status also do not alert staff early enough to intervene to prevent dehydration (Vivanti *et al.* 2008).

The primary control of water balance is via the kidneys under the control of arginine vasopressin (AVP) antidiuretic hormone. AVP levels will increase with a rise in plasma osmolality which can prevent water losses by decreasing urine output thereby increasing water reabsorption making urine concentrated and a darker yellowish colour (Kavouras 2002). In fact, evaluation of urinary concentration is considered an easy and inexpensive way to determine the hydration status of individuals (Mentes *et al.* 2006). Darker urine colour using a 8-point colour scale has been shown to reflect dehydration in healthy individuals and elderly nursing home residents (Armstrong *et al.* 1998, Mentes *et al.* 2006). However, it may not identify severe dehydration accurately in critically ill patients (Fletcher *et al.* 1999). The concentration of solutes in urine can also be assessed by measuring USG using a test strip or a bedside refractometry device (Simerville *et al.* 2005). USG can range from 1·003 to 1·030 Specific Gravity (SG) units, with a value greater than 1·020 SG units indicating relative dehydration (Simerville *et al.* 2005). Minimal amounts of urine are needed to determine USG and Ucol and they may be more useful markers of hydration than standard blood indices, because they are simple, non-invasive, rapid and inexpensive (de Buys Roessingh *et al.* 2001). However, stroke patients are often incontinent and may have co-morbidities (glycosuria and proteinuria are known to increase USG) or take medications that could affect the accuracy of the urine tests (Kavouras 2002). Therefore, it is not known if USG/Ucol are practical and/or reliable for assessing hydration status in acute stroke patients.

Methods

Aim

The aim of this small pilot study was to determine if measuring USG and Ucol was feasible in acute stroke patients and to examine their associations with changes in blood indices. We hypothesized that clinically important dehydration would be associated with, and possibly preceded by increased USG or a change in Ucol which could be used by nurses at the bedside. Earlier recognition might allow serious dehydration to be avoided or its duration shortened.

Design

An observational pilot study including a cohort of acute stroke patients admitted to an acute stroke unit in a large teaching hospital.

Participants

During the study period (1 April 2007 to 30 April 2008), we screened all patients admitted to our stroke unit with a suspected first or recurrent ischaemic or haemorrhagic stroke who were considered to be at risk of dehydration (i.e. severe stroke; dysphagia, immobile, reduced conscious level). We excluded patients at low risk of dehydration (i.e. mild strokes; mobile; eating and drinking normal diet on admission) or had a transient ischaemic attack, or did not consent.

Data collection

Senior stroke nurses identified patients on admission to hospital and recorded baseline details, including: demographic data; risk factors; prestroke medication; and prior history (i.e. renal impairment). Once the patient had consented to the study, ward nurses took a daily morning urine sample at first voiding or from a catheter for 10 days (or until death/discharge if sooner). If patients were incontinent of urine and not catheterized nurses squeezed a sample of urine from the pad or bedding if possible. We collected an early morning urine sample to prevent confounding by normal diurnal variation in urine as urinary concentration rises during the night and is usually at its highest between 4 AM and 8 AM in normal subjects (Buchsbaum & Harris 1971). This occurs because of reduced fluid intake at night; a nocturnal dip in blood pressure; increase in Antidiuretic Hormone (ADH) and recumbency. We also aimed to avoid any confounding due to morning medications, such as diuretics, which might cause patients to pass dilute urine while becoming dehydrated.

The ward nurses kept a record of the patient's clinical status daily for 10 days (or until death/discharge if sooner). They recorded: the date of dysphagia screening; methods of hydration (oral, feeding tube, intravenous/subcutaneous fluids, modified diets); daily fluid input and output; medications that might influence USG/blood measurements (e.g. diuretics); the patient's clinical hydration status; and routine blood results. They also recorded whether they deemed the patient to be dehydrated. Each patient had plasma urea-creatinine ratio and electrolytes taken routinely as part of their daily care. The local ethics committee did not approve blood tests beyond those performed routinely. Therefore, it was not possible to undertake a systematic study of blood tests taken at the same time to the USG readings. If the U:C ratio (mmol:mmol) was > 60, we judged the patient to be dehydrated (Kelly *et al.* 2004).

Research nurses not involved in the daily care of the patients collected and tested the daily urine specimens. They stored urine specimens in a fridge if there was any delay in testing the sample (Collins *et al.* 1993). They measured Ucol with an eight-point chart ranging from pale straw (score = 1) to greenish brown (score = 8) in the same room under the same lighting conditions and if Ucol fell between two colours the highest colour was recorded. A score > 4 is considered in the 'at risk' range of dehydration in people over 65 years (Mentes *et al.* 2006). They measured Ucol before USG to reduce any bias that could occur if USG was known. They measured USG first with urine test strips (Multistix SG reagent strips for urinalysis, Bayer Diagnostics MfG., Ltd., Bridegend, UK) and second with a digital hand-held refractometer device (model: DR-303; Index instruments Ltd., Ramsey, UK). The USG test strips scale ranges from 1·000 to 1·030 SG units with colour blocks in intervals of 0·005 SG units. The reagent strips were placed in the urine and the USG reading taken 60 seconds after removal. The refractometer was a temperature compensating device and readings were taken in intervals of 0·0001 SG units with a scale ranging from 1·000 to 1·050 SG units. Distilled water provided the calibration standard for the refractometer.

Ethical considerations

The study was approved by the Multi-Centre Research Committee in February 2007. Patients were identified by a nurse not involved in measuring the urine samples who obtained written, or witnessed verbal, consent from all patients, or if they lacked mental capacity, from an appropriate proxy.

Data analysis

We plotted the daily USG and blood U:C ratio measurements taken routinely to look for the temporal relationship between these parameters. The aim of plotting these data for each patient was to establish if an informative increase in USG occurs during the intervals between routine measurement of blood U:C ratio measurements and if a rise in USG precedes any observed rise in the U:C ratio, i.e. – does *USG provide an early warning of dehydration compared with the U:C ratio?*

We compared the USG measurements (both urine test strips and refractometer) and colour chart measurements. The agreement between the refractometer USG measurements was categorized to give results in the same format as urine test strip USG measurements, i.e. for the urine test strip value of 1·005 SG units, refractometer USG values of 1·0025 to 1·0074 SG units were taken. Each person contributed multiple urine samples and we measured USG with the refractometer and test strips in all samples. However, as these samples were repeated measures we cannot treat them as independent in terms of agreement between test methods. Therefore, we also measured agreement between methods for the first urine specimen collected after admission in each patient. We considered the USG measurements abnormal if greater than 1·020 SG units (Simerville *et al.* 2005) and Ucol abnormal if greater than 4 (Mentes *et al.* 2006). We calculated baseline plasma osmolality using the equation 2× (sodium + potassium) + glucose + urea (Bhalla *et al.* 2000). We tested data that were not normally distributed, such as age, blood indices, USG and Ucol, with the non-parametric Mann–Whitney *U*-test. We compared dichotomized variables with Fisher's Exact test. We performed all data analyses with SPSS for windows (version 14.0.2; SPSS Inc, Chicago, IL, USA. 2006) and Minitab (version 15.0.0; Minitab Inc, State College, PA, USA. 2007).

Results

We enrolled 20 stroke patients [median age 79 years, interquartile range (IQR) 73–86 years; 9 men] between 1 April 2007 and 30 April 2008. We collected 174 urine samples (median per patient = 10) and 85 blood tests (median per patient = 4) (Table 1).

Feasibility of measuring USG and Ucol

Of the 20 patients, two (one male and one female) had an indwelling urinary catheters and two male patients wore uro-sheaths. We found that we could not measure USG or Ucol on samples of urine squeezed from incontinence pads or bed linen. We found that fluid balance charts were incomplete in all patients. We did not obtain satisfactory measurements on 46 urine specimens taken from 12/20 (60%) patients because of: faecal contamination in two; urinary retention in one; discharge from hospital or died prior to end of study period in 36; and weekend samples were not collected and stored in fridge in seven.

Clinical signs of dehydration

Stroke nurses judged 9/20 (45%) patients to have clinical signs of dehydration on admission, including: poor skin turgor (n = 5); dry mouth (P = 9); and blue lips (P = 1). The number

Table 1 Comparisons in admission clinical features, blood tests and test strip USG between the nine stroke patients (45%) considered dehydrated and 11 (55%) considered hydrated by nurses on admission to hospital

Characteristic	Dehydrated (n = 9)	Hydrated (n = 11)	P value*
Median age (IQR)	76 (68, 82)	81 (78, 86)	0·23
Male gender, n (%)	4 (44)	5 (45)	1·00
Hypertension, n (%)	7 (78)	10 (91)	0·57
Diabetes Mellitus, n (%)	2 (22)	0	0·19
Previous stroke, n (%)	2 (22)	0	0·19
Previous TIA, n (%)	2 (22)	2 (18)	1·00
Known renal disease, n (%)	1 (11)	1 (9)	1·00
Dysphagia, n (%)	5 (55)	6 (55)	0·41
>4 medications, n (%)	3 (33)	7 (64)	0·37
Laxatives, n (%)	0	1 (9)	1·00
Steroids, n (%)	2 (22)	0	0·18
Ace-inhibitors, n (%)	2 (22)	4 (36)	1·00
Diuretics, n (%)	3 (33)	5 (45)	0·67
Diabetic medication, n (%)	1 (11)	0	0·45
Anti-depressants, n (%)	0	1 (9)	1·00
Median Blood Urea, mmol/L (IQR)	7·8 (5·6, 10·8)	5·0 (5·0, 6·7)	0·18
Median Blood Creatinine, μmol/L (IQR)	78 (56, 146)	95 (60, 116)	1·00
Median Blood U:C ratio, mmol:mmol (IQR)	105 (72, 122)	62 (51, 94)	**0·02**
Median Blood Sodium, mmol/L (IQR)	142 (139, 144)	138 (135, 140)	**0·01**
Median Blood Potassium, mmol/L (IQR)	4·2 (3·9, 4·5)	4·3 (4·0, 4·7)	0·41
Median Blood Glucose, mmol/L (IQR)	6·5 (5·6, 7·7)	5·8 (5·6, 6·3)	0·21
Median Haemtocrit DF (IQR)	0·42 (0·35, 0·44)	39 (0·37, 0·42)	0·60
Median Platelets 10^9/L (IQR)	297 (233, 379)	257 (188, 281)	0·09
Median Plasma Osmolality, mOsm/kg (IQR)	308 (298, 312)	298 (290, 303)	**0·04**
Median Test strip USG (IQR)	1·020 (1, 1·025)	1·010 (1·005, 1·015)	0·30
Median Refractometer USG (IQR)	1·022 (1·020, 1·032)	1·014 (1·011, 1·019)	0·09
Median Ucol (IQR)	6 (5, 7)	5 (3, 6)	0·24

Statistical tests: *Fisher's Exact test for nominal data and Mann–Whitney *U* for continuous data.
IQR, interquartile range; TIA, transient ischaemic attack; U:C ratio, urea:creatinine ratio; DF, decimal fraction; USG, urine specific gravity; Ucol, urine colour chart.

of prescribed medication, diuretic use or antidepressant medication was similar in those considered by nurses to be dehydrated or hydrated. Patients who were dehydrated had a significantly higher admission median blood sodium (142 vs. 138 mmol/L), U:C ratio (105 vs. 62 mmol:mmol), and median plasma osmolality (308 vs. 298 mOsm/kg) than those who were not dehydrated (all $P < 0{\cdot}05$, Mann–Whitney U-tests) (Table 1). Dehydrated patients also had a higher median test strip USG (1·020 vs. 1·010 SG units) and refractometer USG (1·022 vs. 1·014 SG units) and Ucol (6 vs. 5) than those hydrated, but these differences were not statistically significant (all $P > 0{\cdot}05$, Mann–Whitney U-test) (Table 1). Overall the within-subject agreement between the refractometer USG being > 1·020 SG units (indicator of dehydration) and nurses opinion that patients were dehydrated on admission was 84% (95% confidence intervals, CI, 60%, 97%).

Agreement between the refractometer and test strip USG measurements

Table 2 shows that of the 174 urine measurements, 70 (40%) refractometer and urine test strip measurements were in agreement (highlighted in bold) and when there was disagreement, the refractometer gave a higher score than the urine test strips in 79/174 (45%) samples. This pattern was similar for the first USG readings after admission for each patient. Of the 20 admission USG readings, eight (40%) were in agreement and where there was disagreement, the refractometer gave a higher score than the dipstick in 10/20 (50%) samples.

Agreement between the refractometer USG and Ucol measurements

To test the agreement between refractometer USG and Ucol, we dichotomized the variables into normal and abnormal values. Table 3 shows that of the 174 urine measurements, 117 (67%) refractometer USG and Ucol measurements were in agreement and 57 (33%) were in disagreement. In 47/57 (82%) samples in disagreement, the refractometer USG gave readings less than or equal to 1·020 SG units (suggesting hydration), while the Ucol gave values more than 4 (suggesting dehydration). This pattern was also observed in the first 20 USG readings taken after admission for each patient (Table 3). Where there was disagreement between USG refractometer and Ucol measurements (5/20, 25%), the refractometer gave a normal reading while Ucol was abnormal.

Trends in USG compared with the blood U:C ratio measurements over time

There was considerable variability over time in the USG regardless of the method of measurement and there were too few U:C ratio measurements (median = 4) per patient to reliably determine the temporal relationship between tests. Figure 1 is a representative plot from one patient who had seven blood U:C ratio measurements taken that were over 100 mmols:mmols (severe dehydration). This patient's daily urine test strip USG was often lower than the refractometer USG, but regardless of the method, the USG fluctuated between 1·008 and 1·023 SG units, i.e. does not suggest severe dehydration. In none of the 20 patients did we observe any absolute value of USG (e.g. > 1·020 SG units) or trend that reliably occurred before the routine U:C ratio measurements indicated that the patient was dehydrated (i.e. > 60 mmol:mmol).

Discussion

The results of this study highlighted that it is often not possible to collect daily urine samples from stroke patients because in trying to avoid catheterization there are practical

Table 2 The extent of agreement between urine specific gravity (USG) refractometer and urine test strip measurements for 174 USG measurement for each person combined (n = 20)

		USG test strip							
		1·000	1·005	1·010	1·015	1·020	1·025	1·030	All
USG refractometer	< 1·0024	**0**	0	1	1	0	0	0	2
	1·0025–1·0074	0	**2**	1	0	0	0	0	3
	1·0075–1·0124	1	8	**26**	3	0	0	0	38
	1·0125–1·0174	1	5	21	**10**	5	0	0	42
	1·0175–1·0224	2	2	6	8	**14**	9	1	42
	1·0225–1·0274	2	0	1	2	5	**10**	4	24
	≥1·0275	1	3	2	1	5	3	**8**	23
	All	7	20	58	25	29	22	13	174

The diagonal (highlighted in bold) represents the same USG measurement from both the refractometer and test strips.

Table 3 Agreement and disagreement (see in bold) between urine specific gravity (USG) refractometer and urine colour chart (Ucol) measurements for all urine measurements (n = 174) and the first urine measurements taken after admission (n = 20)

		USG refractometer					
		Normal ≤ 1·020		Abnormal > 1·020		All	
		n = 174	n = 20	n = 174	n = 20	n = 174	n = 20
Ucol	Normal range (1–4)	62 (36%)	6 (30%)	**10 (6%)**	**0**	72 (41%)	6 (30%)
	Abnormal range (5–8)	**47 (27%)**	**5 (25%)**	55 (32%)	9 (45%)	102 (59%)	14 (70%)
	All	109 (62%)	11 (55%)	65 (37%)	9 (45%)	174	20

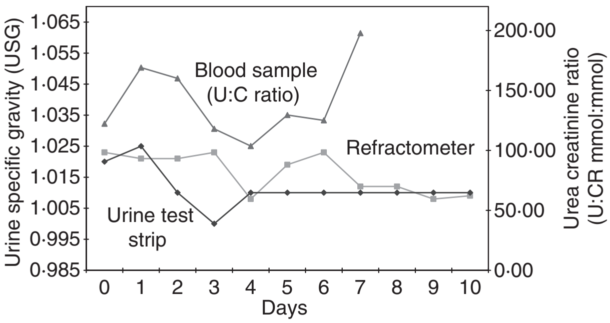

Figure 1 Tracing of daily (0–10 days) refractometer (middle line) and urine test strip USG measurements (bottom line – see the left y axis) in a patient who had blood urea:creatinine ratio > 80 mmols:mmols (top line – see the right y axis) during the study period.

difficulties in collecting specimens which are suitable for analysis from incontinent patients. The prevalence of incontinence in the acute phase of stroke is high and the use of incontinence pads as a first line intervention for incontinence limits the use of the refractometer USG and Ucol measurements (Mentes *et al.* 2006). Furthermore, the use of absorbent gelling materials in disposable pads can influence the optical/chemical properties of the urine and thus the accuracy of the USG measurements (Kirkpatrick *et al.* 1997).

We found that there was also no clear increase in USG, regardless of measurement method used, which preceded any increase in U:C ratio as the best indicator of dehydration routinely available. There was also poor agreement between different measures of USG and Ucol. The test strips consistently under estimated USG and the colour chart over estimated dehydration compared with the refractometer. Therefore, our study findings do not support the accuracy of the urine test strip USG and Ucol measurements as useful markers of hydration status in acute stroke patients.

Previous study findings have found inter-rater reliability of USG urine test strips and Ucol range from poor to average and the urine test strips have been found not to be reliable when compared with refractometry (Winkens *et al.* 1992, de Buys Roessingh *et al.* 2001, Stuempfle & Drury 2003). Our study findings also support those of Fletcher *et al.* (1999) who suggested that when high levels of dehydration are indicated by blood indices this may not be reflected in USG and Ucol as accurately as during mild dehydration. We also found that measurements of fluid intake and output were incomplete probably because, they are time consuming for nursing staff to complete (Watkins *et al.* 1997).

An interesting finding was that there was good agreement between nurses' opinion of the patient's hydration status (with all dehydrated patients having a dry mouth) and the refractometer USG readings and blood indicators of hydration status. A recent study by Vivanti *et al.* (2010) found that oral symptoms such as tongue furrows and dry mucous membranes were most indicative of dehydration in older adults. However, other clinical features of dehydration such as poor skin turgor and low venous pressure are considered unreliable and insensitive to mild to moderate dehydration and are often difficult to elicit in elderly patients (Vivanti *et al.* 2008). Acute changes in body weight after imposing fluid restrictions or exercise has also been described as a good indicator of hydration status, but may be affected by bowel movements as well as food and fluid and would be difficult and unethical to measure in sick immobile stroke patients (Vivanti *et al.* 2010). Other methods to determine hydration status including skin-fold thickness, axillary sweating and orthostatic tolerance tests all pose problems for immobile patients and have poor inter- and intra-reliability (Vivanti *et al.* 2008). Therefore, we suggest that further studies should aim to determine whether combining a practical subjective assessment such as the nurses' opinion with an objective measure such as the refractometer device provide a reliable measure of hydration status.

Limitations of this study include: the small numbers of patients in relation to urine samples so we are unable to assume that the readings taken from the same person on different days can be treated as independent in terms of agreement between test methods. However, repeat analyses of the first 20 urine tests on admission suggest similar patterns of agreement between the refractometer, test strips and urine colour chart. Moreover, the lack of daily measurements of U:C ratio or osmolality taken at a similar time to the USG readings and insufficient numbers of patients made it

What is already known about this topic

- Currently, dehydration in older people is under-recognized and has been associated with poorer outcomes after stroke.
- Study findings suggest that urine specific gravity and/or urine colour may be a reliable measure of hydration when compared with blood measurements and fluid balance input and output in young healthy athletes or children.
- It is not known if urine specific gravity and/or urine colour would be practical and reliable for assessing hydration status in acute stroke patients.

What this paper adds

- There was good agreement between nurses' opinion of the patient's hydration status and the refractometer urine specific gravity readings.
- There was poor agreement between urine colour chart measurements, refractometer and urine test strip measures of urine specific gravity.
- Urine specific gravity and urine colour did not provide an early warning of dehydration when based on routine urea:creatinine ratio measurements.

Implications for practice and/or policy

- Urine specific gravity test strip is not an accurate measure of USG.
- The aim of future studies should be to combine nurses' opinion of clinical features with refractometer urine specific gravity measurements which might contribute to the development of a practical tool which can be used by nurses at the bedside for the earlier detection of dehydration in acute stroke patients.

difficult to examine the possible reasons for the lack of observed relationship between urinary USG and blood tests. Indeed, the pattern of routine blood testing for stroke patients requires further investigation – for instance, if fewer blood tests are being taken in some patients, are we missing episodes of dehydration. We also aimed to reduce confounding of normal diurnal variation and medications in urine by using the first early morning urine specimen. However, normal physiological responses may well be disrupted to a greater or lesser extent in stroke patients who may be chronically recumbent, receiving enteral tube feeding or parenteral fluids and may have less of a nocturnal dipping in blood pressure and altered ADH secretions.

Any research into this area is hindered by a lack of easily measured and widely accepted 'gold standard' assessment of dehydration (Kavouras 2002). At present, blood tests such as plasma osmolality and the urea:creatinine ratio are regarded by physicians as the benchmark but are not sensitive indicators of less severe dehydration (Vivanti *et al.* 2010). It would have been interesting to determine the relationship of the USG measurements with blood indices such as plasma osmolality and fluid-regulating hormones such as arginine vasopressin (AVP), which is reported to increase linearly with urine USG, but neither are routinely measured and both require sophisticated and expensive laboratory techniques to determine results (O'Neil *et al.* 1992).

Conclusions

Given its frequency and potential for increasing risks of complications dehydration after stroke remains an important target for improvements in early detection, prevention and treatment. Further research is needed to develop a practical tool, perhaps by combining the refractometer USG measurements, urine colour chart results and nurses' opinion, which may provide earlier detection of dehydration when compared with the standard blood indicators of hydration status.

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Conflict of interest:

No conflict of interest has been declared by the authors.

Author contributions

AR, LS, DL, DH & MD were responsible for the study conception and design. LS, DL & DH performed the data collection. AR & CG performed the data analysis. AR was responsible for the drafting of the manuscript. AR, LS, CG, DL, DH & MD made critical revisions to the paper for important intellectual content. CG & MD provided statistical expertise. AR, LS & DH obtained funding. AR & DL provided administrative, technical or material support. AR supervised the study.

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