(Re)defining nurse and patient roles in routine postoperative neurosurgical care: empowering autonomy and strengthening collaborative roles

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Chapter 7
Patient participation in urine specific gravity screening for arginine vasopressin deficiency in an inpatient neurosurgical clinic

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Summary

Objective
Detecting hypotonic urine (specific gravity < 1005 g/l) is crucial for the early identification of arginine vasopressin deficiency (AVP-deficiency), a common complication after pituitary surgery. This study aimed to evaluate the agreement between urine specific gravity measurements taken by patients using urine test strips and those taken by nurses using a refractometer, to assess the reliability of patient-conducted measurements for diagnosing this condition.

Design
A prospective cohort study was conducted in a neurosurgical ward.

Patients
The study included 110 participants who collectively provided 609 specific gravity measurements.

Measurements
Specific gravity measurements were taken using Combur-10® urine test strips by patients and using an ATAGO MASTER-SUR/Nα refractometer by nurses. Agreement was analyzed using Weighted Kappa and Intraclass Correlation Coefficient (ICC).

Results
Moderate agreement was found between patient-conducted measurements and those from the refractometer (Kappa = 0.47, ICC = 0.69). Substantial to good agreement was observed between patient and nurse measurements using urine test strips (Kappa = 0.82, ICC = 0.89). A threshold of 1.015 g/l in test strip measurements ensured no cases of hypotonic urine were missed, reducing the need for nurse-led testing by 50%. Patient satisfaction was high (mean 7.8), while nurse satisfaction was lower (mean 6.4).

Conclusions
Although patients are less accurate than nurses in measuring specific gravity, they can reliably screen for hypotonic urine in AVP-deficiency diagnostics using urine test strips. A higher cut-off point improves diagnostic accuracy, enhances patient participation, and reduces the screening workload for nurses.

Introduction

Globally, the incidence of pituitary gland and (para)sellar tumours ranges from 1.29 to 3.49 per 100,000 people each year (1, 2). While endoscopic transsphenoidal surgery is the intervention of choice for most functioning pituitary adenomas and larger non-secreting tumors causing mass effect, smaller non-secreting microadenomas and prolactin-secreting adenomas are often managed with a watchful waiting approach or treated with medical therapy, such as dopamine-agonists (3). In the early postoperative phase, there is a high incidence of fluid balance disorders, characterized by polyuria in the first 24 hours postoperatively and later development of hyponatraemia due to transient altered regulation of arginine vasopressin (AVP) or other causes. (4, 5). The incidence of AVP deficiency (AVP-D) in the early postoperative phase varies widely, ranging from 2% to 54%, as also reported in a recent systematic review, which highlights the impact of differing diagnostic criteria and follow-up durations on reported rate (6, 7).

AVP-D manifests through symptoms including intense thirst (polydipsia), excessive urination (polyuria), and potential dehydration and electrolyte imbalances in case of impaired intake or thirst feeling (8, 9). Clinicians diagnose AVP-D using varying criteria, often based on polyuria thresholds (e.g., >300 mL/hr or >40-50 mL/kg/24 hr) and hypotonic urine with a specific gravity <1.005 g/L. Diagnostic approaches may also include sodium and osmolality measurements, though thresholds can differ between studies (5, 7, 10). In our hospital, we adhere to the criteria established by de Vries et al. (2021), which define hypotonic polyuria as diuresis >300 mL/h for three consecutive hours, urine specific gravity <1.005, and the presence of at least one of the following: serum sodium >145 mmol/L or serum osmolality >300 mOsm/kg (6).

Due to the abrupt nature of AVP-D, prompt detection is critical for mitigating the risks associated with potential electrolyte disturbances. Currently, nurses play a crucial role in managing postoperative fluid-related aspects in patients (11). Standard care involves monitoring patients' fluid intake, urinary output, and SG every 6 hours. The SG is measured until discharge from the hospital, while the fluid balance is monitored at home for 14 days after discharge (6). In this process, the ATAGO MASTER-SUR/Nα handheld refractometer is used to measure SG. Although refractometers are precise, their use can be complex and potentially challenging due to issues such as light interference affecting the readability of results (12). Studies have suggested that urine test strips could be an effective alternative for determining SG (13). Such easy to use urine test strips offer an additional promising opportunity for enhancing patient participation and alleviating the burden of tasks of nurses in the postoperative care process during hospital admission (14).

In the present-day healthcare landscape, patient participation has taken a prominent place. Active engagement of patients in their own care processes has been shown to improve the overall quality of care and enhance patients' understanding of their conditions (15). This approach has yielded positive outcomes in various medical fields, such as enhancing therapy adherence and improving health outcomes in cardiac patients (16, 17). For patients recovering from pituitary surgery, actively participating in monitoring their SG and thereby recognizing early signs of the potential onset of AVP-D may be beneficial. This involvement may enhance their understanding of the clinical relevance and, once diagnosed, management of AVP-D (18).

To date, no study has explored the feasibility and accuracy of patient participation using urine test strips for SG measurement post-pituitary gland tumour surgery in a hospital setting. We aimed to investigate the agreement between SG measurements taken by patients using urine test strips and those performed by nurses with a refractometer.

Materials and Methods

Design and setting

This study was conducted as a prospective cohort study on the neurosurgical ward of an academic hospital in the Netherlands. It aimed to evaluate the level of agreement between SG measurements obtained using urine test strips by patients and those obtained by nurses using the ATAGO MASTER-SUR/Nα refractometer. Additionally, we assessed both patient and nurse satisfaction. Data collection occurred between February 2022 to January 2024.

Participants
Participants were recruited by the primary researcher upon their admission to the neurosurgical ward, prior to undergoing pituitary gland tumour surgery. Eligibility criteria required individuals to be 18 years of age or older. Excluded were patients with insufficient proficiency in Dutch or English, cognitive impairments, postoperative neurological deficits, significant visual limitations (defined by an inability to read the numbers on the test strip), colour blindness, mobility limitations, dependence on chronic catheter use, or urostomy.

Intervention and procedures
Two tools for measuring urine SG were used: the Combur-10® urine test strips (Roche Diagnostics, Basel, Switzerland) and the ATAGO MASTER-SUR/Nα refractometer. The Combur-10 measures various urine components, including SG in intervals of five points, ranging from 1.000 to 1.030 g/l. Due to the fixed five-point intervals of the Combur-10 test strips, a reading within a range (e.g., 1011-1015 g/l) cannot determine an exact SG value. The refractometer measures SG in one-point intervals from 1.000 to 1.060 g/l. Each patient provided six urine samples between 08:00 and 20:00 starting the day after surgery. For each sample, SG measurements were taken by the patient using a test strip, a nurse using a test strip and the refractometer. Patients and nurses conducted their readings independently. Test strip results were read after one minute according to the manufacturer's instructions, while the refractometer was used according to hospital guidelines. The refractometer was calibrated at the start of the study. All ward nurses (n=60) received training in using both tools, with refresher sessions every six months. This training was managed by the study group, which included the primary researcher and five nurses who also selected participants and trained patients. An infographic was created to enhance patient understanding and compliance. Study progress was communicated through the department newsletter.

Data collection
Patients reported outcomes of the urine test strip on a designated form, while nurses entered results into the electronic patient file. Data collected included gender, age, education level, SG, urinary catheterization, bedrest periods, patient-reported thirst, serum osmolarity, sodium levels, fluid balance, and desmopressin administration.
The primary researcher and study group routinely cross-checked data, and a second researcher reviewed it independently twice. To understand how satisfied patients are with self-measuring SG a short questionnaire was developed. Patients rated three questions on a scale from 1 (completely disagree) to 10 (completely agree): their ability to measure SG using a urine test strip, how well they could read the SG value, and their overall opinion on self-measuring SG. Nurses rated their perspective on patients' ability to measure SG and their overall opinion on it.

Outcomes
The primary outcome was the agreement between SG measurements by patients using Combur-10® urine test strips and the ATAGO MASTER-SUR/Nα refractometer. Secondary outcomes included the agreement between SG measurements by patients and nurses using urine test strips, as well as between nurses' test strip measurements and the refractometer. Additionally, patient and nurse satisfaction was assessed.

Sample size
We aimed to include 100 patients, each providing six urine samples, for a total of 600

samples. This sample size was chosen to reflect typical clinical scale and ensure robust statistical power. Although no formal power calculation was done, the sample size is expected to provide sufficient power to detect substantial agreement with an Intra Correlation Coefficient (ICC) of 0.7, assuming a 95% confidence level and 80% power.

Statistics

Analyses were performed using SPSS version 29.0. Descriptive statistics for categorical variables are reported as raw numbers and percentages, while continuous variables are presented as means with standard deviations. Normality of continuous data was assessed using the Kolmogorov-Smirnov test due to the sample size (n=600). For categorical variables, no normality testing was performed, as they are presented using frequency distributions. The primary outcome was assessed using Kappa statistics and the ICC. Weighted Kappa accounts for the ordinal nature of the data by assigning varying weights to disagreements (19). To apply this method, continuous refractometer SG measurements were categorized to match the ordinal scale of the urine test strips. The following categorizations were performed in which the highest values were merged with lower values to create uniform scales: 1. patient strip vs. refractometer: converted the nine-category refractometer scale to six categories, 2. patient strip vs. nurse strip: reduced to a uniform six-category scale, and, 3. nurse strip vs. refractometer: aligned the nurse's seven-category scale to the refractometer's nine-category scale, standardizing it to seven points. The interpretation of Kappa values and ICC values is summarized in Table 1 for clarity and ease of comparison (20, 21). ICC analysis assumed continuous SG measurements, using a two-way mixed-effects model with patients' and nurses' measurements as random effects and measurement method as a fixed effect. This model was selected to account for inter-individual variability and measurement consistency across different instruments (22). Despite the non-normality of the SG measurement data, which persisted even after logarithmic and square root transformations, we proceeded with the ICC analysis given its robustness to deviations from normality (23). Sub-analyses were conducted based on gender, age, educational level (secondary education, vocational education, higher professional education, university), and individual measurements. Less than 5% of the data was missing, and cases with missing values were excluded, which had minimal impact on the overall analysis (24).

Table 1: Interpretation of Kappa and ICC Values

Statistic	Range	Interpretation
Kappa	0.00	Chance agreement
	0.10 – 0.20	Slight agreement
	0.21 – 0.40	Fair agreement
	0.41 – 0.60	Moderate agreement
	0.61 – 0.80	Substantial agreement
	0.81 – 0.99	Near-perfect agreement
	1.00	Perfect agreement
ICC	Below 0.50	Poor reliability
	0.50 – 0.75	Moderate reliability
	0.75 – 0.90	Good reliability
	Above 0.90	Excellent reliability

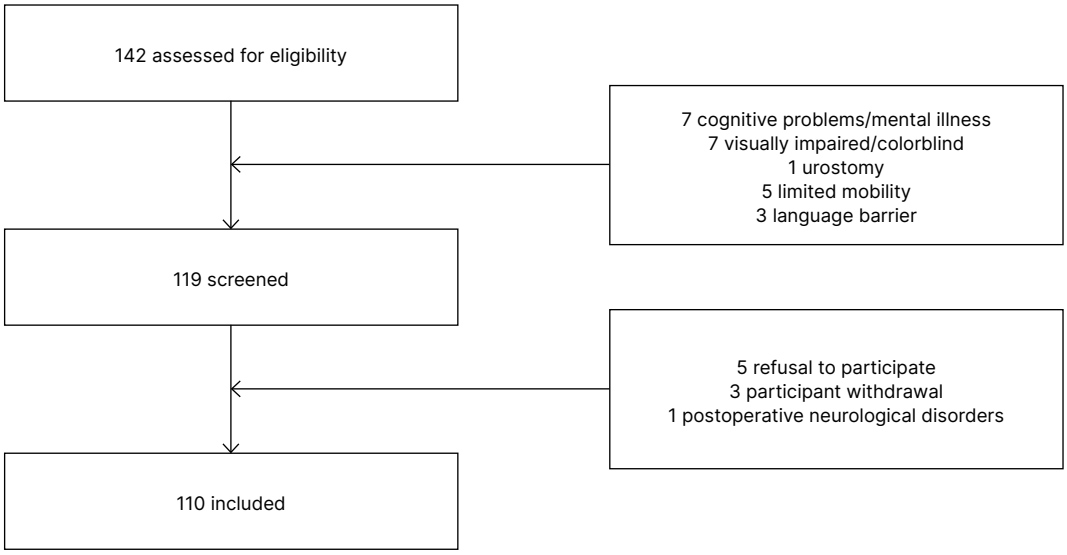
Ethics

Ethical approval for this study was evaluated by the Medical Ethics Committee of the Leiden University Medical Centre (METC LDD). The committee determined that the study (METC number N21.123), does not fall under the scope of the Medical Device Regulation or the Medical Research Involving Human Subjects Act (WMO) in the Netherlands. Specifically, the METC concluded that this study is not classified as a clinical trial, as it does not involve scientific research requiring participants to be subjected to invasive medical interventions, as defined by Article 1, paragraph 1, sub b of the WMO. As such, the study was exempt from full ethical review. Nevertheless, the study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (23). Informed consent was obtained from all participants prior to their inclusion in the study.

Results

A total of 142 individuals were assessed for eligibility and the final sample comprised 110 individuals (Figure 1).

Figure 1: Flowchart of patient selection



The characteristic of the study population are presented in table 2. Of the 110 patients, 71 (64.5%) had a macroadenoma and 39 (35.5%) had a microadenoma. The majority had hormone-secreting tumors (prolactinoma: 31, acromegaly: 25, Cushing's disease: 15, TSH-secreting adenoma: 1), while 25 had non-functioning adenomas, 12 had cystic lesions (Rathke's cleft cyst, epidermoid cyst, or other cysts), and 1 patient had a craniopharyngioma. All patients had an intact thirst sensation.

Table 2: Characteristics of study population

	N = 110
Sex, n (%)	
Female	74 (67.3)
Male	36 (32.7)
Age, years, mean (SD)	48.2 (16.3)
Length of hospital stay, days, mean (SD)	3.5 (1.2)
Indwelling urinary catheter, n (%)	14.0 (12.7)
Bedrest, n (%)	15.0 (13.6)
Hours bedrest, mean (SD)	24.0 (0)

The SG measurement counts varied depending on the method used. The total number of measurements for patient test strips (n= 617), for nurse test strips (n=609), and refractometer (n=611). In total, nurses missed recording 8 measurements test strip and the refractometer 6 measurements compared to patient records. The dataset includes 609 sets of measurements where all three methods were used. 11 out of 110 (10%) patients received desmopressin treatment based on clinical judgment for suspected AVP deficiency.

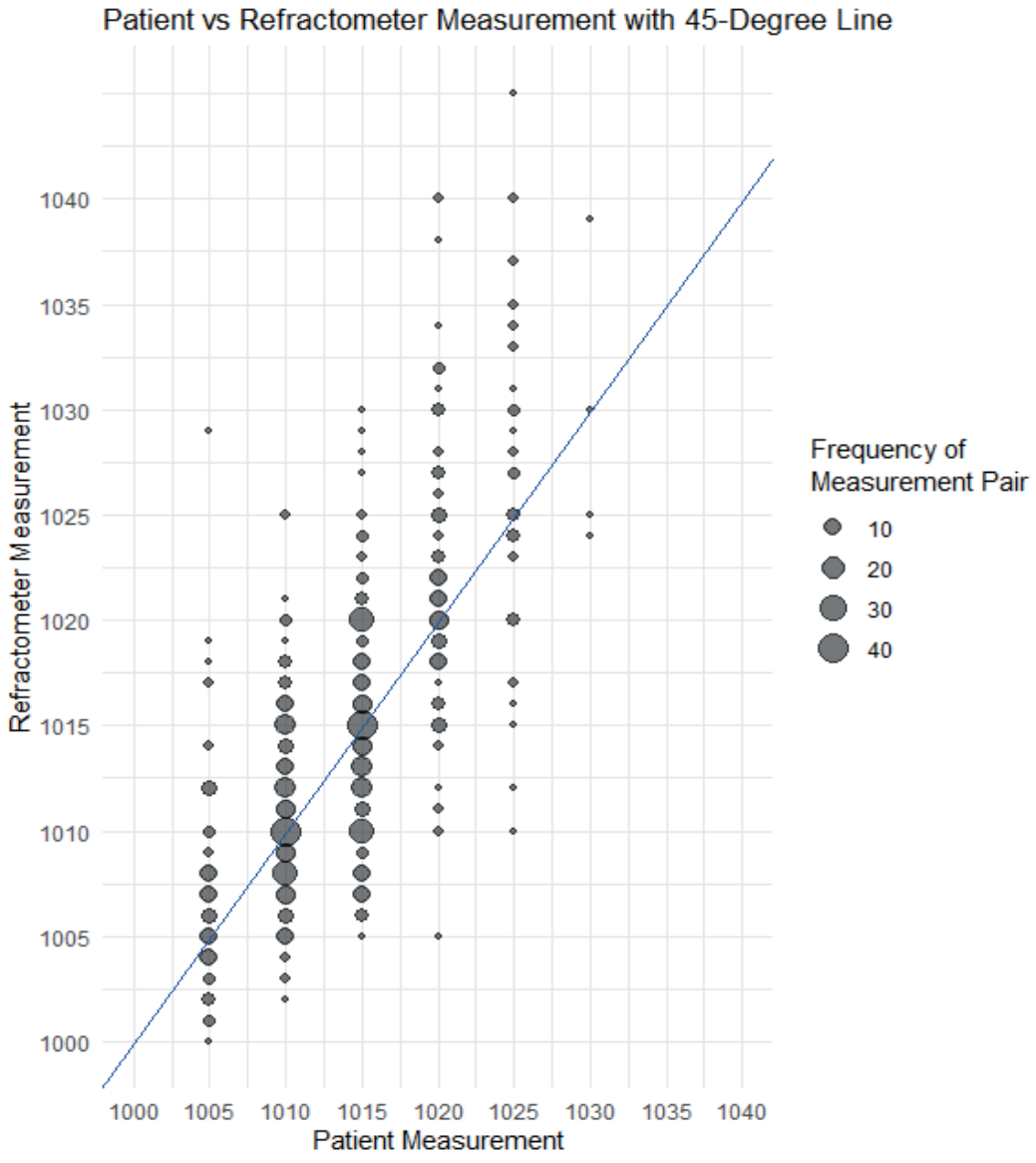
The scatter plot (Figure 2) and corresponding table (Table 3) compare SG measurements between patient test strip and the refractometer, revealing a concentration of measurements between SG values of 1.005 g/l and 1.020 g/l. SG measurements below 1.005 g/l were rare. Setting a threshold of 1.015 g/l for test strip measurements ensures that none of the corresponding refractometer or other test strip measurements fall below 1.005 g/l, thereby indicating that no cases of hypotonic urine (SG < 1.005 g/l) are missed. These measurements encompass 350/611 (57.5%) of the total.

Table 3: Crosstabulation of patient test strip measurement and refractometer SG measurements (g/l), categorized by the cut-off points from the urine test strip

Specific gravity patients ↓ /refractometer →	**1000 - 1005**	**1006 - 1010**	**1011 - 1015**	**1016 - 1020**	**1021 - 1025**	**1026 - 1030**	**1031 - 1035**	**Total**
1000 - 1005	30	30	9	4	0	1	0	74
1006 - 1010	13	91	59	21	3	0	0	187
1011 - 1015	0	47	88	53	14	4	0	206
1016 - 1020	0	3	12	33	29	12	8	97
1021 - 1025	0	1	2	8	11	9	12	43
1026 - 1030	0	0	0	0	2	1	1	4
Total	43	172	170	119	59	27	21	611

Legend: SG = specific gravity.

Figure 2: Scatterplot of patient test strip measurement vs refractometer SG measurements obtained by nurses with frequency of measurement pairs and line of agreement



The results of the Weighted Kappa and ICC analysis are presented in Table 4. Patient test strip vs. refractometry showed moderate agreement with a Kappa of 0.47 (95% CI: 0.42-0.51) and an ICC of 0.69 (95% CI: 0.64-0.73). Nurse test strip vs. patient test strip measurements showed substantial to good agreement with a Kappa of 0.82 (95% CI: 0.79-0.85) and an ICC of 0.89 (95% CI: 0.88-0.91). Nurse test strip vs. nurse refractometer measurements indicated moderate to good agreement with a Kappa of 0.55 (95% CI: 0.51-0.58) and an ICC of 0.77 (95% CI: 0.74-0.81). Sub-analyses by gender, age, educational level, and individual measurements revealed no significant differences. In addition, no significant differences were observed in the agreement between refractometer and urine test strip measurements of SG when comparing patients who received desmopressin with those who did not. As desmopressin administration was based on clinical judgment rather than confirmed AVP deficiency, and not all patients receiving desmopressin presented with low SG values (<1.005 g/L), this subgroup analysis was not presented in full detail. Clinically, when patients exhibited signs suggestive of post-operative AVP-D, such as low SG and high urine volume, this typically transient phase was pragmatically managed with a single dose of desmopressin rather than additional diagnostic analysis with plasma sodium and/or osmolality.

Table 4: Agreement Measures Between SG Measurement Methods

	Weighted Kappa	CI 95%	ICC	CI 95%
Patient strip vs. refractometry	0.466	0.424 - 0.509	0.688	0.641 - 0.729
Patient strip vs. Nurse strip	0.822	0.791 - 0.852	0.893	0.876 - 0.908
Nurse strip vs. refractometry	0.546	0.508 - 0.583	0.774	0.738 - 0.805

Legend
CI: Confidence Interval
ICC: Intraclass Correlation Coefficient

Patient and nurse satisfaction

The survey was completed by 93 out of 110 patients (84.5%). The mean score for measuring SG with a urine test strip was 7.9 (SD 1.6), the mean score for reading the SG value was 8.3 (SD 1.4), and the mean overall opinion on self-measuring was 7.8 (SD 1.4). Of the 60 nurses, 39 (65.0%) responded. They rated patients' ability to measure SG at 6.3 (SD 2.0) and their overall opinion on self-measuring at 6.4 (SD 1.8).

Discussion

Our study aimed to evaluate the agreement between SG measurements obtained by patients using Combur-10® urine test strips and those obtained by nurses using the ATAGO MASTER-SUR/Nα refractometer, as well as patient and nurse satisfaction with this approach. We found moderate agreement between patient test strip measurements and refractometry, suggesting some variability, but also supporting the potential for patient participation after pituitary gland tumour surgery. In contrast, the agreement between nurse test strip measurements and refractometer was higher. The strongest agreement was observed between patient test strip measurements and nurse strip measurements, confirming the reliability of patient measurements when compared to nurse measurements.

An SG value of less than 1.005 g/l is critical in the diagnostic process for AVP-D and

is measured in each urine sample postoperatively until discharge from the hospital (6). Our results showed that when patient test strip measurements were 1.015 g/l, the corresponding refractometer measurements were never below 1.005 g/l. Given this critical threshold for diagnosing AVP-D, this finding suggests that urine test strips can be safely used by patients for SG values of 1.015 g/l and higher. These measurements encompass 57.5% of the total, meaning that for over half of cases, re-measurement by a nurse is unnecessary. However, for the remaining 42.5% of measurements that fall below 1.015 g/l, we recommend verification by a nurse using a refractometer to ensure accuracy and correct diagnosis. This approach is supported by literature emphasizing the importance of collaborative efforts between patients and healthcare providers (25). Such teamwork can ensure accurate monitoring and timely intervention (26). In addition, utilizing this approach can significantly reduce the workload for nurses and minimize the need for additional materials (27).

During the study, 10% of patients (11 out of 110) received desmopressin treatment based on clinical judgment for suspected AVP-D. However, none of these patients met the full diagnostic criteria for AVP deficiency (AVP-D) as applied in our hospital, which are based on the criteria defined by de Vries et al (6). Our results showed no significant differences in the agreement between refractometer and urine test strip measurements of SG between patients who received desmopressin and those who did not. This suggests that desmopressin administration did not appear to influence the accuracy of SG measurements in this study. However, as desmopressin administration was based on clinical judgment rather than a confirmed diagnosis of AVP-D, this finding should be interpreted cautiously.

We observed a discrepancy between the test strip measurements and the refractometer readings, regardless of whether they were taken by patients or nurses. Several factors could have contributed. First, the interpretation of urine test strips can be challenging due to the colour differentiation required on a 5-point scale, which might be subtle and subject to variation in perception (28). Second, refractometers measure the refractive index of urine, which can be affected by the presence of substances such as proteins or glucose, leading to discrepancies compared to the urine test strips that use a colorimetric method (29). Third, patients may have less experience and practice with using urine test strips, potentially leading to less consistent results compared to nurses (30). However, we found no differences in the outcomes of earlier measurements compared to later measurements (e.g., measurement 1 vs. measurement 6), indicating that there was no learning effect, and patient performance remained consistent throughout the study.

The results demonstrated a good agreement between patient and nurse test strip measurements of SG, indicating that patients are capable to perform the test accurately. This aligns with previous literature demonstrating that patients can be effectively trained to use self-diagnostic tools in various settings (31, 32). This suggests that our patient cohort are similarly trainable, enhancing the generalizability of our findings to other patient groups.

Patient satisfaction scores indicated a generally positive reception towards self-measuring SG, with patients feeling confident in their ability to perform and interpret the measurements. Conversely, nurse satisfaction scores were somewhat lower. The difference in satisfaction scores is consistent with findings in the literature, where patients often report higher satisfaction with self-monitoring practices compared to healthcare providers, who may have concerns about accuracy and reliability (33). Ensuring proper training and continuous support to patients can help bridge this gap (34).

This study has several strengths. First, the study was conducted in a real-world clinical setting, enhancing the applicability of the findings. Second, the study design included independent SG measurements by patients as well as nurses, reducing the risk of measurement bias. Furthermore, the study achieved a high level of participation in the satisfaction survey. Limitations in our study included the fact that multiple measurements per patient were conducted, and the dependency between these measurements was not fully accounted for. This may have led to a slight underestimation of the variance. Similar to our study, Genders et al. discussed that in diagnostic accuracy studies, ignoring this correlation can be acceptable as it may not significantly impact the clinical decisions, although it may result in narrower confidence intervals (35). Furthermore, the study did not account for potential differences in SG measurements that could arise from variations in urine concentration at different times of the day or due to different dietary and hydration statuses of the patients. Additionally, the Combur-10 test strips used in this study measure specific gravity in fixed five-point increments (e.g., 1011-1015 g/l), which limits the precision of the reported values. To conclude, our inclusion criteria excluded patients with significant visual limitations, defined as the inability to read the numbers on the test strip, as well as patients with cognitive impairments or postoperative neurological deficits. Patients with pre-existing color blindness were also excluded; however, we did not reassess patients postoperatively who may have experienced improved color vision due to the resolution of chiasmal compression. While necessary to ensure the reliability of patient self-measurements, this may have led to an overestimation of the reduction in nursing workload observed in our study. Patients with visual or cognitive limitations may require additional nurse involvement in the screening process, which could affect the extent of workload reduction when applying this method to a broader patient population.

Currently, SG measurements are discontinued upon patient discharge from the hospital, while fluid balance monitoring continues at home. Extending the use of SG test strips to the home environment could be beneficial, as fluid balance disorders like chronic AVP-D often persist post-discharge. Potentially, SG test strips may also be used for early detection of postoperative SIADH (syndrome of inappropriate antidiuretic hormone secretion) while at home. Future research should therefore explore the integration of digital health technologies with home SG monitoring. Using smartphone applications or connected devices for real-time data to share with healthcare providers in real time could facilitate remote monitoring and timely medical advice, improving the management of postoperative AVP-D and other fluid balance disorders.

Conclusion

This study confirms that patients can effectively measure SG using urine test strips, with a moderate agreement to refractometer readings. The reliability of patient-conducted measurements is further supported by a strong agreement with nurse test strip measurements. Using a relatively high cut-off point of 1.015 g/l, no cases of hypotonic urine were missed, indicating that patient measurements are sufficient for SG values of 1.015 g/l and higher, without requiring re-measurement by nurses. For SG values below 1.015 g/l, verification by nurses using a refractometer is recommended to ensure diagnostic accuracy. High patient satisfaction with self-monitoring supports the potential for integrating patient-led SG measurements into postoperative care, thereby reducing the workload for nurses and enhancing patient participation and satisfaction.

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