BMJ Open Quality

Quality of fluid balance charting and interventions to improve it: a systematic review

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To cite: Leinum LR, Krogsgaard M, Tantholdt-Hansen S, *et al*. Quality of fluid balance charting and interventions to improve it: a systematic review. *BMJ Open Quality* 2023;**12**:e002260. doi:10.1136/bmjoq-2023-002260

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjoq-2023-002260).

Received 10 January 2023
Accepted 3 December 2023

Check for updates

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ABSTRACT

Introduction Fluid balance monitoring is pivotal to patients' health. Thus, fluid balance charting is an essential part of clinical nursing documentation. This systematic review aimed to investigate and describe the quality of fluid balance monitoring in medical, surgical and intensive care units, with an emphasis on the completeness of charting data, calculation errors and accuracy, and to evaluate methods used to improve fluid balance charting.

Materials and methods Quantitative studies involving adult patients and reporting data on fluid balance monitoring were included in the review. We searched MEDLINE, Embase, CINAHL and the Cochrane Library. The risk of bias in the included studies was assessed using tools developed by the Joanna Briggs Institute.

Results We included a total of 23 studies, which involved 6649 participants. The studies were quasi-experimental, cohort or prevalence studies, and every third study was of low quality. Definitions of 'completeness' varied, as well as patient categories and time of evaluation. Eighteen studies reported the prevalence of patients with complete fluid balance charts; of those, 10 reported that not more than 50% of fluid balance charts were complete. Studies addressing calculation errors found them in 25%–35% of charts, including omissions of, for example, intravenous medications. The reported interventions consisted of various components such as policies, education, equipment, visual aids, surveillance and dissemination of results. Among studies evaluating interventions, only 38% (5 of 13) achieved compliance with at least 75% of complete fluid balance charts. Due to the heterogeneity of the studies, a meta-analysis was not possible.

Conclusion The quality of fluid balance charting is inadequate in most studies, and calculation errors influence quality. Interventions included several components, and the impact on the completion of fluid balance charts varied.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Fluid balance charting is a widely used tool in clinical practice but is well known for being inadequate. The low quality of fluid balance charting, as well as the prevalence of calculation errors, has been reported in studies across the world. However, a review of quality and interventions to improve it is lacking.

WHAT THIS STUDY ADDS

⇒ This review provides an overview of the quality of fluid balance charting and identifies interventions intended to improve it. We found that the quality is inadequate in medical, surgical and intensive care settings due to missing documentation or calculation errors. In addition, interventions often have not achieved sufficient improvement, some hardly any.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study indicates a need for further exploration of barriers and facilitators in fluid balance monitoring to gain knowledge to develop robust and effective interventions.

INTRODUCTION

A healthy body is in a state of fluid balance, but hospitalised patients are at risk of fluid balance disorders. Thus, fluid balance monitoring has clinical relevance to treating the patient correctly and helps determine the appropriate prescribing of fluids and diuretics essential to achieve or maintain homeostasis and healing.[1] The standard fluid balance monitoring method is keeping a fluid balance chart to document the patient's fluid input and output. Fluid balance charting is considered a fundamental nursing task and has been an essential tool in hospital practice for over 50 years.[2]

Fluid balance is the difference between the amount of fluid taken into the body and the amount excreted or lost. The Australian Nurses Dictionary defines it as 'a state in which the volume of body water and its solutes (electrolytes and non-electrolytes) is within normal limits, and there is a normal distribution of fluids within the intracellular and extracellular compartments'.[3]

In hospitalised patients, fluid disorders are among the most common problems encountered in clinical practice[4] across medical and surgical wards, and fluid balance disorders such as overhydration and dehydration can seriously affect patients' health. Overhydration is associated with complications such as peripheral oedema and dyspnoea[5] and increased mortality in patients with sepsis, cerebral haemorrhage and heart disease.[6–8] Further, dehydration is associated with an increased risk of constipation, urinary tract infections and falls, prolonging hospitalisation and impairing the quality of life.[9–12] Postoperative fluid balance monitoring is pivotal[13] as both overhydration and dehydration can lead to complications and prolonged hospitalisation following an operation.[14–16]

Three main elements can assess fluid balance: clinical assessment, blood chemistry review and fluid balance charts. Clinical assessment includes vital signs, capillary refill time, tissue turgor, the amount and colour of the urine, feeling of thirst and daily weight.[17] However, some of these factors have not been proven to be significantly associated with fluid balance but are used in clinical practice. Blood chemistry review may comprise creatinine and urea as well as electrolytes such as sodium and potassium.[18]

A fluid balance chart is a non-invasive tool that aims to keep an accurate record of a patient's fluid status over 24 hours. The document should indicate if the patient is in fluid balance, deficit or overload.[1 2 18] The input consists of fluids ingested orally, parenteral nutrition and intravenous fluids including medications (eg, antibiotics). Whether blood products should be counted in the fluid balance calculation is debatable.[2] Any fluid given orally, through feeding tubes or intravenously is considered part of the fluid balance chart. The output includes all fluid losses that can be measured: urine, nasogastric drainage, vomit, liquid stool and output in drains and tubes. It differs if insensible losses from the lungs, skin and respiratory tract are included.[2 17]

Fluid balance charting seems relatively straightforward. Still, monitoring is often inadequate due to staff shortage and lack of time and training,[1 18–20] and the charts can be challenging to interpret and calculate.[21] Further, fluid volumes are estimated based on visual assessment. Studies have shown such estimations are unreliable[22 23] and affected by, for example, the colour of the fluids and the shape of the container used.[23 24] To clarify the scope and characteristics of the problem, a systematic overview of the literature can provide information on the quality of fluid balance in different wards and settings along with possible interventions to improve fluid balance charting.

This systematic review investigates and describes the quality of fluid balance monitoring with an emphasis on completeness, calculation errors and accuracy. The primary outcome of the review is to evaluate the completeness of fluid balance charts. Secondary outcomes include the frequency and size of calculation errors, the occurrence of missing calculations (totals) and fluid balance monitoring accuracy. Furthermore, it provides an overview of interventions used to improve fluid balance charting.

METHODS

This systematic review involves quantitative studies addressing the quality of fluid balance charting in medical and surgical wards and intensive care units (ICUs).

The review is registered in the PROSPERO database of systematic reviews (registration number: CRD42021249004). Throughout the review process and in reporting the results, we worked in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[25]

We did not involve patients or the public in this systematic review's design, conduct or reporting, as it referred to specific nursing care requiring professional knowledge and insight.

Search strategy and study selection

We developed the search strategy in cooperation with an information specialist and searched the following databases—CINAHL, Embase, MEDLINE and the Cochrane Library—in November 2020 and February 2021. We repeated the search in October 2022. Additionally, we searched PROSPERO for relevant ongoing or recently completed systematic reviews and ProQuest Dissertations and Theses Global for grey literature.

The nursing environment has changed enormously during the last decades with, for example, accelerated patient pathways, implementation of electronic patient records and increased workload due to staff shortage. Thus, we restricted the searches to the publication period of 2010–2021 to evaluate contemporary practice. It included a thesaurus (eg, MeSH Terms) and free-text search, which was structured according to the PI(CO) form.[26] The keywords used included "fluid balance" OR "urine output" AND "measure" OR "charting" AND "accuracy" OR "completeness" OR "quality" (search strategy as online supplemental material). Studies published in English, Danish, Norwegian and Swedish were considered for inclusion.

Two reviewers (LRL and ST-H) independently screened records using the software Covidence.org, which removed duplicates. First, we screened titles and abstracts based on the predetermined selection criteria and then assessed them for eligibility through full-text reading by four reviewers (LRL, MK, ST-H and NA). Reasons for the exclusion of full-text studies are provided in the PRISMA diagram. Any disagreements were resolved through discussion.

Eligibility criteria

We chose studies presenting quantitative data on fluid balance monitoring originating from fluid balance charts. Therefore, studies assessing fluid balance using invasive procedures requiring intubation or insertion of a catheter as required in measuring, for example, central venous pressure were not eligible. We excluded studies addressing fluid balance assessment only in the intraoperative phase. Only studies reporting data on total fluid balance based on input and output measurements were selected so that those exclusively reporting a single parameter (eg, urinary output) were excluded. We included studies regarding the fluid balance on a specific day as recorded in a fluid balance chart, and studies addressing the cumulative fluid balance based on fluid balance charts of several days during admission. Studies conveying fluid balance disturbances developed over time, for example, prior to admission, were only included if the study addressed fluid balance charting quality.

Research involving hospitalised patients 18 years or older and specifying the number of included patients was considered eligible. We included all study designs except case reports as long as the eligibility criteria were met. Conference abstracts were omitted.[27]

Quality appraisal method

Two reviewers (LRL and MK) assessed all included studies independently using quality appraisal tools developed by Joanna Briggs Institute (JBI, https://jbi.global/critical-appraisal-tools) for rigorous assessment of their methodological quality and to determine if they addressed possible bias in the design, conduct and analysis.[28]

Studies designed as preaudits/postaudits performed before and after an intervention targeted to improve the quality of fluid balance monitoring were defined as quasi-experimental. A prevalence study is a kind of cross-sectional study undertaken to determine the prevalence[26] of, for instance, completed fluid balance charts conducted as retrospective or prospective audits. Studies were classified according to the outcome of interest; thus, for example, cohort studies could be assessed as a prevalence study if the outcome of interest was reported as a prevalence.

We rated the quality of studies as low, moderate, or high depending on the number of positive answers in the JBI instrument. The quality was rated as low if fewer than 50%, moderate if between 51% and 80%, and high if more than 80% of questions received a positive answer.[29 30] We did not exclude any studies due to their low quality.

Data extraction and synthesis

Before data extraction, we developed a customised instrument inspired by a generic template in Covidence (https://www.covidence.org/) and adjusted it as necessary. Two reviewers (LRL and MK) independently extracted all data and resolved disagreements through discussion until a consensus was reached.

The data extraction included characteristics of studies (eg, first author, country, year of publication, setting, study design), participants (age, sex, reason for admission) and results on fluid balance monitoring. Completeness was defined as the proportion of complete fluid balance charts, and a complete fluid balance chart covers all intake and output and enables calculation of the 24-hour fluid balance. If applicable, we further extracted documentation of oral fluid intake, intravenous fluids, urine output, calculated totals and calculation errors. Calculation errors were defined as discrepancies between nurses' calculations and researchers' recalculations and comprised both erroneous mathematical calculations and incorrect calculations due to omissions of certain fluids. Furthermore, we collected data on interventions, determined as any activity or action taken with the aim of improving certain outcomes.[31] We extracted the number of repeated data collections if there were multiple preinterventional or postinterventional data collections and recorded all data.

RESULTS

Study selection

We identified 12 519 titles from screening the databases and removed 1971 duplicates. The remaining 10 548 studies were screened against the title and abstract. We included a total of 237 articles for full-text reading and assessed them for eligibility. We excluded 214 papers as they did not meet the inclusion criteria. The remaining 23 papers were included in this review. The selection process is presented in a PRISMA flow diagram[25] (figure 1).

Characteristics of included studies

We identified 23 eligible studies published between 2010 and 2021; 10 were published between 2010 and 2014[32–41] and 13 between 2015 and 2021.[42–54] The studies were conducted in 12 different countries on five continents; of those, 10 originated in the UK.[32 36 40–43 45 47 49 54] A total of 6649 patients participated in the research, varying from 24 patients to 2199 in each study. Most studies addressed fluid balance charting on a specific day; however, two studies reported cumulative fluid balance. General characteristics, aims and findings are presented in table 1.

Divergent definitions characterised studies; the words 'complete', 'adequate' and 'accurate' were often used interchangeably. Moreover, in the most studies, no definition was provided. Among those defining the term, there were inconsistencies in addition to disagreements on which elements were included in fluid balance calculations.[2 17] A prerequisite for performing a meta-analysis is including at least two comparable studies. Due to substantial heterogeneity among studies concerning the definition of outcomes, a meta-analysis was not possible. Therefore, we performed a narrative synthesis of the findings.

Quality appraisal

The studies comprised 12 studies categorised as quasi-experimental,[33 40–43 45–47 49–51 54] 3 cohort studies[32 37 44] and 8 prevalence studies (cross-sectional studies).[34–36 38 39 48 52 53] All were appraised using the JBI tools for assessing quasi-experimental and prevalence studies. Thus, the cohort studies were evaluated using the tool for prevalence studies as the outcome of interest was presented as a prevalence.[32 37 44]

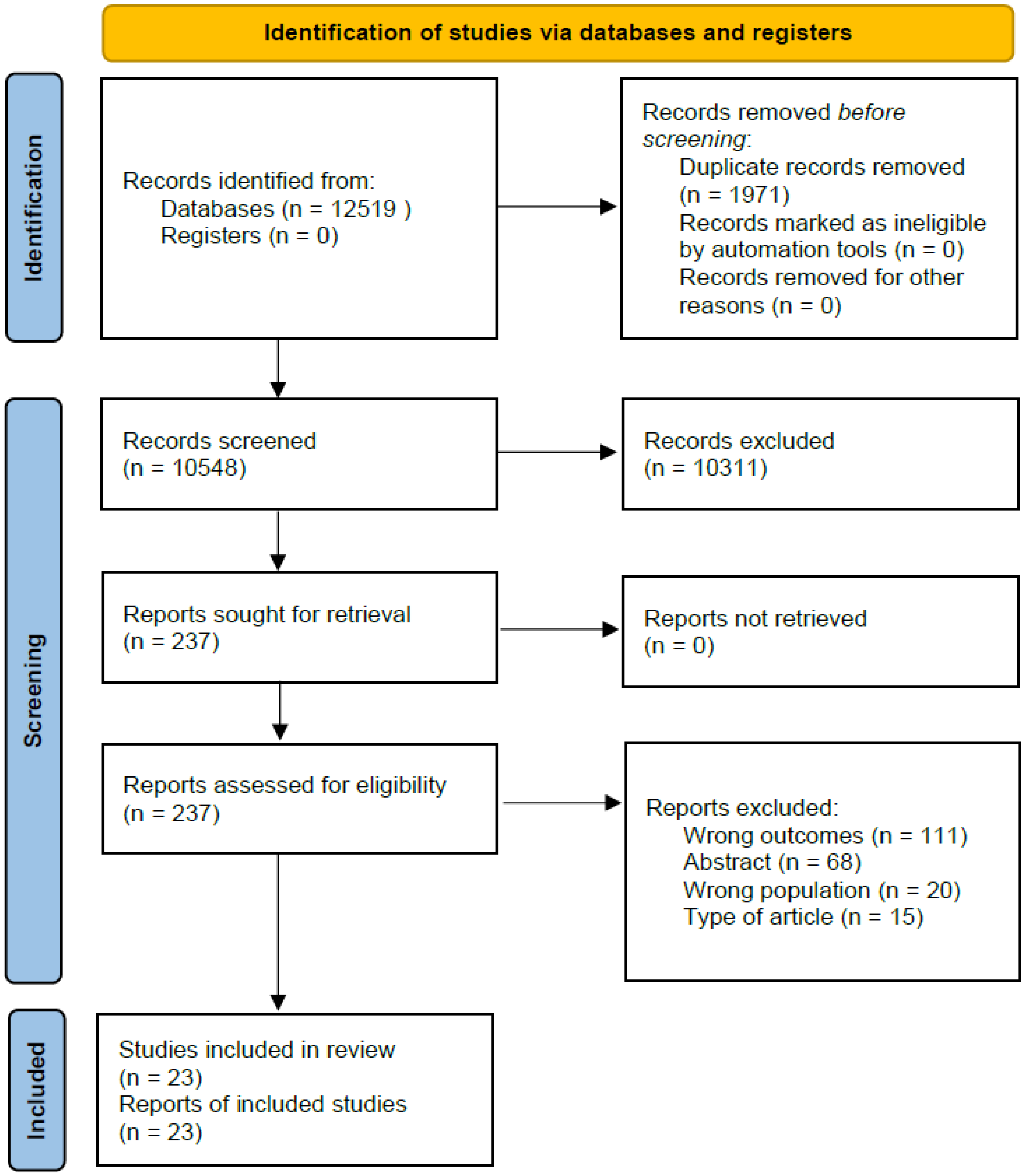

Figure 1 PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Only 3 studies were of high quality,[37 48 53] 12 of moderate quality[32 34–36 38 39 43–46 50 52] and 8 of low quality.[33 40–42 47 49 51 54] Details of the quality appraisal can be found in table 2. All studies assessed to be of low quality had a quasi-experimental design, explained by the higher risk of bias in quasi-experimental studies compared with prevalence studies. Reasons for a poor assessment could be missing characteristics of study participants, lack of a control group and only one pretest.

Prevalence of complete fluid balance charts

Of the included studies, 18 reported the prevalence of patients with fluid balance monitored using a fluid balance chart. Of those, seven found a proportion of complete fluid balance charts of no more than 25%,[33 43 45 46 48 50 54] three studies found a proportion between 26% and 50%,[36 40 47] and in five studies, the proportions were reported to be between 51% and 75%.[32 37 39 41 42] Only three studies reported that more than 75% of patients had a complete fluid balance chart[34 35 38] (figure 2).

Calculation errors and accuracy

Seven studies investigated the prevalence of calculation errors in fluid balance charts.[34 36 38 39 44 49 54] Four were performed in ICUs.[34 38 39 44] One study examining miscalculations in an ICU found a median calculation error in the daily fluid balance charts of 58 mL (range 1–1464 mL) and a cumulative median calculation error of 131 (range 1–2405 mL).[44] Another study found a calculation error of more than 500 mL in 26.1% of fluid balance charts; the calculation error was between 1000 and 2000 mL in 6.8%

Table 1 Characteristics of included studies

Author(s), year, country	Aim	Design	Setting and participants	Sample size	Outcomes regarding fluid balance monitoring	Key findings
Aitken *et al*, (2013); UK[32]	AKI Quality of care	Cohort study	Medical, surgical, AKI	243	Adequate FBD (%), inaccurate FB chart (%)	51.8% of patients with AKI had adequate FBD; 43.4% of the remainder had inaccurate FB charts in case notes.
Alexander and Allen (2011) USA[33]	Policy for FB monitoring	Quasi-experimental	Medical oncology units	427	Compliance with FBD	Before intervention, 12% of patients with indication of FB monitoring had FBD vs 84% after.
Asfour (2016); Egypt[52]	Accuracy of FB monitoring	Cross-sectional	ICU except dialysis	100	Accuracy of calculated FB compared with researcher's calculation	65% of FB charts were accurate and 35% were inaccurate.
Baird *et al*, (2019); UK[42]	AKI prediction score	Quasi-experimental	Orthopaedic surgery	78	FB monitoring (%)	Before intervention, 62% had adequate FB monitoring postoperatively vs 66% after.
Davies *et al*, (2017); UK[43]	Reduce AKI alerts	Quasi-experimental	Orthopaedic trauma	75	Running hourly input, 6 hourly input subtotal, 6 hourly output subtotal and 24-hour total FB	Before intervention, 80% had running 1 hour totals vs 96% after; 36% had 6 hour output vs 68% after. Before intervention, 12% had 24-hour totals vs 72% after and 32% after 6 months.
Davies *et al*, (2019); Australia*[44]	Relationship between calculated FB and BW	Prospective cohort study	ICU, requiring CRRT	61	FB charts with calculation errors (%), median deviation in millilitres	Calculation errors prevalent in 27% of charts. Median daily calculation error: 58 mL (range 1–1464 mL). Median cumulative calculation error: 131 mL (range 1–2405 mL).
Diacon and Bell (2014); South Africa[34]	FB monitoring and measurement accuracy	Cross-sectional	ICU	103	FBD (%), calculation errors (%), deviation in millilitres	95.1% had FBD. Calculation errors: 68.9% deviated 0–500 mL, 13.5% 500–1000 mL, 6.8% 1001–2000 mL, 5.8%>2000 mL
Eastwood *et al*, (2012); Australia[35]	Patients receiving IV fluids (%)	Cross-sectional	All inpatients except ICU, ED and PACU	326	Percentage with FB charts maintained (%)	94% of patients receiving intravenous fluids had FB charts vs 44% receiving no intravenous fluids.
Herrod *et al*, (2010); UK[36]	Prevalence of dysnatraemias and precipitating factors	Cross-sectional	Surgery Na<130 or >150 mmol/L	55	Complete FB charts (%) Charts with FB calculated (%), median inaccuracy in FB calculation	28% had complete FB charts before dysnatraemia vs 44% after; 37% of charts had no FB calculation. Median calculation error: 72 mL (IQR 9–313 mL) before dysnatraemia vs 130 mL (IQR 71–400 mL) after
Joslin *et al*, (2015); UK[45]	AKI recognition and management	Quasi-experimental	AKI	192	Complete FB chart on first day of AKI (%), days with complete FBD (%)	Before intervention, 25% had completed FB charts on first day of AKI vs 34% (p=0.23) after. Before intervention, FBD was completed in 32% of patient days vs 45% after (p=0.002).

Continued

Table 1 Continued

Author(s), year, country	Aim	Design	Setting and participants	Sample size	Outcomes regarding fluid balance monitoring	Key findings
Liaw and Goh (2018); Singapore[46]	Fluid intake charting	Quasi-experimental	Acute surgery	60	Deduction of input/output at midday and over 24 hours. Calculation of 24 hours FB. Involving patients in fluid intake documentation	Before intervention, 3.3% of the FB charts were complete (midday and 24 hours totalling) vs 100% 1 month and 6 months later. Before intervention, patients were involved in 10% of cases vs 87% 1 month later and 83% 6 months later.
Lim *et al*, (2021); Singapore[53]	Ordering and documenting fluid in- and output	Cross-sectional	Acute care hospital	2199	Accuracy of FBD defined by recording in millilitres	Overall accuracy 77%. Oral and intravenous fluids 100% accurate, output accurate in 21% of cases
Madu *et al,* (2021); UK[54]	Chart completeness and accuracy	Quasi-experimental	General medicine	82	Accurate measurements, calculation errors, complete documentation	Before intervention, 25% of measurements were accurate vs 39% after 1 month and 5% after 6 months, correct daily totals in 20% vs 40% after 1 month and 15% after 6 months, 14% of charts complete vs 31% after 1 month and 5% after 6 months
Møller *et al*. (2013); Denmark[37]	Quality improvement	Prospective cohort study	Acute surgery, PPU	1650	Quality-of-care indicator: daily FBD	Before intervention, 74% had FBD vs 79% after. RR 1.07 (95% CI 1.02 to 1.13; p=0.010)
Perren *et al*, (2011); Switzerland*[38]	Accuracy of FBD; agreement w BW	Cross-sectional	ICU	147	Complete FB charts, FB charts with calculation errors	12% were excluded due to an incomplete FB chart; 33% of nurse-registered cumulative FB was inaccurate, errors: −3606 mL to +2020 mL. Mean absolute error of 445±668 mL
Pinnington *et al*, (2016); UK[47]	Complete FBD	Quasi-experimental	Three wards	120	Complete FB charts	Before intervention, 32% of FB charts were completed correctly vs 92% after. In AKI patients, 20% had FBD before vs 91% after.
Szmuda *et al*, (2014); Poland[39]	Calculation errors; FBD and chart completeness	Cross-sectional	NICU and NHDU, SAH	41	Complete FB charts, FB miscalculations	63.4% of FB charts were complete, 80.2% in NICU and 58.7% in NHDU (p<0.01). Fluid intake miscalculations in 27.4% of charts. Most common errors: underestimating intake (80.6%), omitting drugs (66.9%)
Tura *et al*. (2020); Ethiopia[48]	Managing postpartum haemorrhage	Cross-sectional	Obstetric	45	Standard of care criteria: fluid intake/output chart is maintained	In 13.3%, a fluid intake/output chart was maintained.
Vincent and Mahendiran (2015); UK[49]	Quality of FB monitoring	Quasi-experimental	General medicine	147	FBD, indication of FBD. Chart completion: boxes filled of all total boxes. Accurate totals=<10% error	Before intervention, 67% were on FBD (indicated in 53%) vs 38% after (indicated in 93%). Average chart completion rate before intervention was 50% vs 70% after. Average chart accuracy was 41% before vs 61% after.

Continued

Table 1 Continued

Author(s), year, country	Aim	Design	Setting and participants	Sample size	Outcomes regarding fluid balance monitoring	Key findings
Wakeling (2011); UK[40]	FBD and FB complications; Hydrant drinking aid	Quasi-experimental	Orthopaedic, surgery, urology	313	Complete FB charts (%)	Before intervention, 19%–50% of FB charts were complete vs 29–62% after. Completeness improved (5–18 percentage points).
Walker *et al*. (2012); UK[41]	Improve guideline adherence	Quasi-experimental	Acute wards	101	Completion of FB charts	Before intervention, 62.3% had FBD vs 70.8% after (p=0.36).
Yang *et al*, (2019); Taiwan[51]	Compliance with FB monitoring	Quasi-experimental	Congestive heart failure	24	FB charts used with electrolytes and physical assessment. Patients involved in FBD	Before intervention, 58% had FB charts with physical assessment vs 100% after; 42% were involved in recording before intervention vs 75% immediately after.
Zhu *et al*, (2018); China[50]	Non-pharmacological fever management	Quasi-experimental	Infectious disease, HIV	60	Formal assessment of fluid in- and output volume documented	Before intervention, 0% had fluid input/output documented vs 73% 10 days after intervention.

*Studies addressing cumulative fluid balance.

AKI, acute kidney injury; BW, body weight; CRRT, continuous renal replacement therapy; ED, emergency department; FB, fluid balance; FBD, fluid balance documentation; ICU, intensive care unit; NHDU, neurosurgical high-dependency unit; NICU, neurosurgical ICU; PACU, postanaesthetic care unit; PPU, perforated peptic ulcer; SAH, subarachnoid haemorrhage.

and above 2001 mL in 5.8%.[34] A third study conducted in an ICU reported inaccuracies in 33% of fluid balance charts.[38] The size of the errors was between −3606 mL and +2020 mL, and the mean absolute calculation error was 445 mL±668 mL.[38]

A study in a neurosurgical ICU and a neurosurgical high-dependency unit reported calculation errors in 27.4% of fluid balance charts. It stated that the most frequent cause of calculation error was the underestimation of fluid intake (80.6%) primarily because of omissions of intravenous drug therapy (66.9%).[39]

Another study reported a median calculation error of 72 mL (IQR 9–313 mL) and 130 mL (IQR 71–400 mL) before and after the development of dysnatraemia among surgical patients; 37% did not perform a calculation of fluid balance.[36] In a general medical ward, daily totals and balances were correct in only 20% of fluid charts before quality improvement initiatives.[54]

Moreover, an investigation of the accuracy of fluid balance charts among general medical inpatients found that the mean accuracy was 41% (<10% error was considered accurate) before initiating interventions to improve quality.[49] One study defined accuracy as recorded fluid balance calculations matching the researcher's calculated fluid balance from observation and prescription.[52] Another study defined accuracy as documenting fluid in millilitres and calculated it as each recording in millilitres divided by all recordings, finding an overall accuracy of 77%. All oral and intravenous fluids were recorded correctly, but only 21% of output recordings were correct.[53]

Quality improvement interventions

Of the included studies, 13 describe the implementation of an intervention to improve the quality of fluid balance charts evaluated by comparing preinterventional and postinterventional audits.[33 37 40–43 45–47 49–51 54] The interventions included organisational changes and adoption of policies,[33 37 45] teaching and education (physical or e-learning),[33 40–43 45–47 49–51 54] dialogue,[41 43 46] visual aids such as posters[33 43 45 47 49 54] and messages on computer background wallpapers,[41 55] surveillance (eg, through monthly audits)[50 51] and disseminating the results.[37 41 46 51] Furthermore, several interventions incorporated some equipment such as scoring tools,[42] care bundles,[45] changed fluid balance charts,[43 47 49 51] calculators[49 54] and a drinking aid.[40] Characteristics of interventions are presented in table 3.

The effect of the implemented interventions varied, and so did the time from intervention to evaluation. In five studies, the researchers achieved an improvement, indicating that at least 75% of fluid balance charts were complete and correctly filled after the intervention.[33 37 46 47 51] In another five studies, the final result was within the interval of 50%–75%.[40–42 49 50] The quality improved by 4–20 percentage points in four of the latter, but a single study reported an improvement from 0% to 73%.[50] Three studies found that less than 50% of fluid

Table 2 Quality appraisal of included studies

JBI tool	Author(s), year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	%	Quality appraisal
Quasi-experimental studies	Alexander and Allen (2011)[33]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Baird *et al* (2019)[42]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Davies *et al* (2017)[43]	Y	N	N*	N	Y	Y	Y	N	N	56	Moderate
	Joslin *et al* (2015)[45]	Y	Y	N*	N	N	Y	Y	N	N	56	Moderate
	Liaw and Goh (2018)[46]	Y	N	N*	N	N	Y	Y	N	Y	56	Moderate
	Madu *et al* (2021)[54]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Pinnington *et al* (2016)[47]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Vincent and Mahendiran (2015)[49]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Wakeling (2011)[40]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Walker *et al* (2012)[41]	Y	N	N*	N	N	Y	Y	N	N	44	Low
	Zhu *et al* (2018)[50]	Y	N	N*	N	N	Y	Y	Y	N	56	Moderate
	Yang *et al* (2019)[51]	Y	N	N*	N	N	Y	Y	N	N	44	Low
Q1: Is it clear in the study what is the cause and what is the effect? Q2: Were the participants included in any comparisons similar? Q3: Were the participants included in any comparisons receiving similar treatment/care other than the exposure or intervention of interest? *Note: 'No' is considered good. Q4: Was there a control group? Q5: Were there multiple measurements of the outcome both before and after the intervention/exposure? Q6: Was follow-up complete, and if not, were differences between groups in terms of their follow-up adequately described and analysed? Q7: Were the outcomes of participants included in any comparisons measured in the same way? Q8: Were outcomes measured in a reliable way? Q9: Was appropriate statistical analysis used?												
Prevalence	Aitken *et al*[32]	Y	Y	N	Y	Y	Y	Y	N	Y	78	Moderate
	Asfour[52]	Y	Y	N	N	Y	Y	Y	N	Y	67	Moderate
	Davies *et al* (2019)[44]	Y	Y	N	Y	Y	Y	Y	N	Y	78	Moderate
	Diacon and Bell[34]	Y	Y	Y	N	Y	Y	Y	N	Y	78	Moderate
	Eastwood *et al*[35]	Y	Y	N	Y	Y	Y	Y	N	Y	78	Moderate
	Herrod *et al*[36]	Y	Y	N	Y	Y	Y	Y	N	Y	78	Moderate
	Lim *et al*[53]	Y	Y	Y	Y	Y	Y	Y	N	Y	89	High
	Møller *et al*[37]	Y	Y	Y	Y	Y	Y	Y	Y	Y	100	High
	Perren *et al*[38]	Y	Y	N	Y	N	Y	Y	N	N	56	Moderate
	Szmuda *et al*[39]	Y	Y	N	Y	Y	Y	Y	N	Y	78	Moderate
	Tura *et al*[48]	Y	Y	Y	Y	Y	Y	Y	N	Y	89	High
Q1: Was the sample frame appropriate to address the target population? Q2: Were study participants sampled in an appropriate way? Q3: Was the sample size adequate? Q4: Were the study subjects and the setting described in detail? Q5: Was the data analysis conducted with sufficient coverage of the identified sample? Q6: Were valid methods used for the identification of the condition? Q7: Was the condition measured in a standard, reliable way for all participants? Q8: Was there appropriate statistical analysis? Q9: Was the response rate adequate, and if not, was the low response rate managed appropriately?												

*'No' is considered good
JBI, Joanna Briggs Institute; N, no; Y, yes.

balance charts were completed and correct after an intervention.[43 45 54] A final study found an immediate quality improvement (72% complete fluid balance charts); however, after 6 months, the quality decreased to 32%.[43]

DISCUSSION

This systematic review had three major findings. First, we found that although fluid balance charting is common practice in medical, surgical and ICUs, the quality of fluid balance charting is inadequate. Second, calculation errors are also common. Third, all interventions included at least two components, but the time of evaluation and the impact on the completion of fluid balance charts varied.

Quality of fluid balance charting

Half of the included studies reported that less than 50% of the fluid balance charts were complete and correctly filled,[33 36 40 43 45–48 50 54] indicating that insufficient fluid balance documentation is a considerable challenge. Fluid balance charts guide clinical decisions, including prescription of intravenous fluid or medication and interventions to ensure appropriate care and reduce the risk of complications and fluid balance disorders. Thus, a thoroughly kept fluid balance chart contributes valuable data. On the contrary, it can be counterproductive if not adequately completed and put patient safety at risk by leading to erroneous conclusions.[19 20 56]

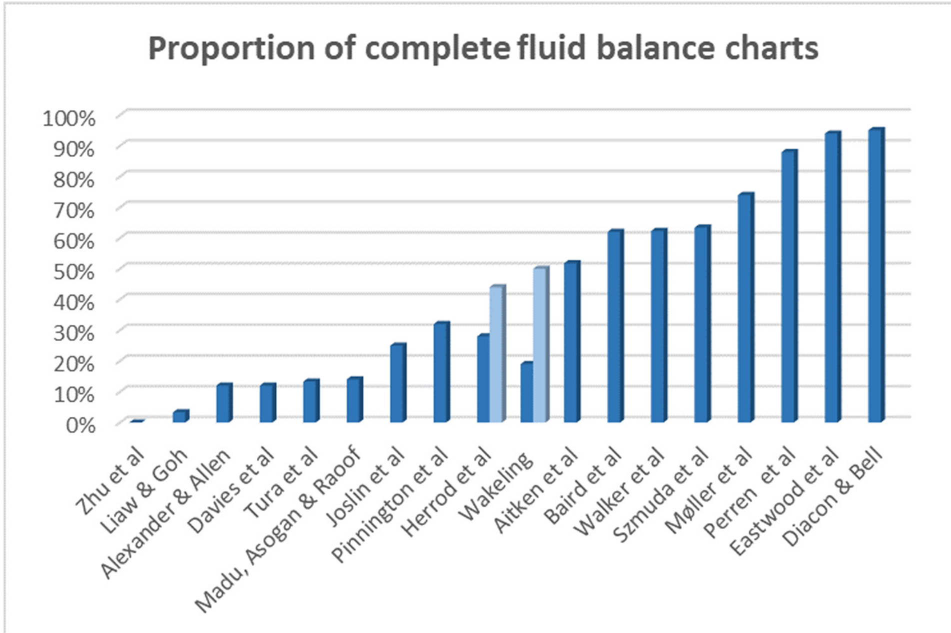

Figure 2 Overview of reported proportions of complete fluid balance charts preintervention. Two columns per study indicate that the study reported percentages from more than one ward.

A compelling question related to the quality of fluid balance monitoring is what is meant by 'complete' fluid balance charts. A fluid balance chart may seem complete even though some documentation is missing, indicating that certainty regarding the completeness of charts can only be determined through observations. Divergent definitions or no definition at all complicate the comparison of results. The variety of definitions may, thus, express a lack of shared understanding of fluid balance monitoring. Studies show that a standardised nursing language can improve communication among healthcare professionals, adherence to standards of care and quality of care.[57 58] Therefore, a shared definition of complete fluid balance monitoring may improve charting accuracy and would enable comparisons across settings.

Calculation errors

The second major finding was that erroneous calculation of fluid balance was a common and significant problem, with calculation errors in 25%–35% of the fluid balance charts.[34 38 39 44] Further, erroneous daily fluid balance chartings lead to increased cumulative errors[44] with a range of several litres.[38] Naturally, the size of calculation errors determines whether they are of clinical significance in a specific patient category. Thus, it may be of greater interest to determine how many had a calculation error deviating, for example, more than 500 mL as this may be clinically relevant. One study reports that 26.1% had a calculation error of more than 500 mL, and half of those exceeded 1000 mL.[34] However, establishing the clinically relevant accuracy threshold is difficult as it varies based on patient variables like diagnosis and age. Further, as the severity of the illness and comorbidities of patients rise, the vulnerability towards fluid balance disturbances increases, and the margin of error is reduced.[59] Anyhow, this review demonstrates the necessity of improving fluid balance charting accuracy to ensure the charts' credibility and utility.

According to several authors, the cause of errors was the manually calculated fluid balance.[34 39 44] However, calculation errors can be conceptual, arithmetical or computational[60] and may occur due to interruptions and time pressure.[61] Ensuring access to pocket calculators[44 49] or applying electronic patient records automatically calculating fluid balance based on documented information[39] may minimise computational errors. A study evaluated the effect of a clinical information system and found that it saved time, for instance, due to automatic fluid balance calculation. Furthermore, staff positively evaluated the electronic record as it improved charting quality.[62] Another study reported that most nurses (75%) believed electronic health records improved nursing documentation.[63]

Another cause of errors was a lack of documentation, such as omitting intravenous medication.[39] Omissions in nursing care are recognised as a comprehensive challenge related to the shortage of nurses and high patient-to-nurse ratios.[64] A qualitative study exploring regularly missed nursing care highlighted fluid balance monitoring as an essential theme.[55] Reasons for this lack may include staff shortage, inappropriate use of staff resources and ineffective delegation.[55]

Additional challenges are an inaccurate estimation of oral fluid volumes and potential typing errors if data are entered manually.[44] It is possible that a higher degree of automation can prevent these types of inaccuracies.

Table 3 Characteristics of interventions

Author(s), year	Type of intervention	Elements in intervention	Time from implementation to evaluation
Alexander and Allen (2011)[33]	Organisational/policy Education Visual aids	Development of fluid balance measurement policy, computerised physician order, education of nurses and medical staff, educational poster	2 months
Baird *et al* (2019)[42]	Equipment Education Disseminating results	Development of AKI prediction tool+intervention bundle including fluid balance monitoring, educating doctors to use the tool, presenting results at audit meetings	Immediately following each of four PDSA cycles
Davies *et al* (2017)[43]	Equipment Education/dialogue Visual aids	Redesign of fluid balance charts, posters, discussions at nursing handover, e-learning modules, informing junior doctors and encouraging close monitoring	1 month and 7 months
Joslin *et al* (2015)[45]	Organisational/policy Education Equipment Visual aids	Hospital-wide programme to improve AKI recognition and management, AKI care bundle, educating nurses and doctors, posters on all wards, announcements on hospital intranet and screensavers	2 years
Liaw and Goh (2018)[46]	Equipment Education/dialogue Disseminating results	Disseminating audit results to nurses, creating dialogue and developing strategies to overcome barriers, developing an intake chart for patients including pictorial guide, educating ward staff, providing a feedback box	2 months and 6 months
Madu *et al* (2021)[54]	Education Visual aids Equipment	Teaching sessions, picture messages/posters, doctors prescribing fluid balance charts, weighing scales and calculators, advising staff to engage patients in recording	4 weeks and 6 months
Møller *et al* (2013)[37]	Organisational/policy Disseminating results	Nationwide quality improvement through mandatory registration of quality-of-care indicators in the database, annual publication of results.	2 years
Pinnington *et al* (2016)[47]	Equipment Visual aids Patient education	Implementation of a hydration assessment tool, hydration chart, fluid balance chart, urine colour chart posters and a patient information leaflet	<6 months*
Vincent and Mahendiran (2015)[49]	Equipment Education Visual aids	New fluid balance chart, e-learning module for nurses and HCA, posters, attendance at nursing handover, change of chart changeover (noon–noon), calculators available	<3 months*
Wakeling (2011)[40]	Education Equipment	Teaching sessions on hydration and fluid balance charting, implementing the Hydrant drinking aid	<4 weeks
Walker *et al* (2012)[41]	Education/dialogue Visual aids Equipment Disseminating results	Audit findings presented at meetings, key messages on computer background wallpapers, prompt on general medicine admission proforma, training of medical staff, intravenous guideline, communicating the importance of FBC at nursing handovers	6 months
Yang *et al* (2019)[51]	Equipment Education Surveillance	Developing self-learning materials, modifying fluid balance charts, integrating into nursing information system, educating nurses and performing audits	Immediately after
Zhu *et al* (2018)[50]	Education Equipment Surveillance	Educating nurses and patients, patient leaflets, integrating into nursing information system, head nurse monitoring performance	Immediately after

*Estimated from information in the paper.
AKI, acute kidney injury; FBC, fluid balance chart; HCA, Healthcare assistant; PDSA, Plan-Do-Study-Act.

Interventions

The third major theme in this review was to evaluate interventions developed to improve the quality of fluid balance monitoring. Across studies, multiple components were identified as tools to improve fluid balance charting. All interventions involve several interacting components, and most target different groups or behaviours; hence, all analysed interventions can be characterised as complex. The advantage of an intervention containing several elements is that it may address various challenges simultaneously, thus increasing the probability of success.[65] On the other hand, interventions perceived as simple are more easily evaluated and implemented.[66] Therefore, an effective intervention should include all parameters in fluid balance charting as simply as possible.

All interventions except one involve education offered to doctors, nursing staff, or patients, but the impact varies. Possible reasons for this are the information's relevance, delivery and whether all stakeholders received this education. Interestingly, four of the five most effective interventions include some patient involvement either by involving patients in recording fluids[46 51] or informing patients through tailored education or leaflets.[47 50] This indicates that involving patients in their care during hospitalisation may be beneficial. Two systematic reviews found that involving patients with chronic diseases in self-monitoring motivates them to manage their condition[67] and improves outcomes such as readmission rates.[68]

In addition, the form of delivery may affect the results (eg, whether teaching was delivered to staff on all shifts, the duration of teaching). However, these details were only sporadically described. A review addressing electronic health record education found that training should be interactive and based on daily routines and nursing workflow.[69] This may also apply to fluid balance monitoring education, but studies are needed to identify effective learning strategies to enhance the quality.

Moreover, integrating equipment (eg, care bundles or visual aids such as posters) is widely used in both effective interventions and those with hardly any effect, making it difficult to determine whether these are useful solutions. A review examining barriers and facilitators in implementing care bundles found that the number and complexity of elements affected compliance. Fewer elements and low complexity were associated with increased compliance,[70] as were evaluative and iterative implementation strategies (eg, performing audits and developing stakeholder relationships). Furthermore, providing feedback was more effective than reminders such as posters and screen savers.[70]

Another tool is electronic patient records, which are integrated into nursing practice in many clinical settings. Taking advantage of the opportunities of electronic patient records, such as computerised physician orders,[33] electronic reminders, and integrating fluid balance documentation[50 51] and fluid balance calculation,[56] may improve fluid balance charting.

Hence, automating fluid balance charting by using electronic patient records combined with equipment developed to automatically measure fluid intake and output may enhance charting quality. However, understanding the barriers and enablers in fluid balance charting is necessary to create effective solutions.

Other factors may affect the effectiveness of an intervention (eg, the intervention's extensiveness, whether the components are well chosen and how they are interrelated). The implementation strategy itself is of utmost importance, addressing resistance towards the intervention and increasing acceptance.[71] However, most included studies describe these aspects superficially or not at all.

A final factor that may influence the observed effects of interventions is the time of evaluation, which varied among studies from immediately to 2 years after implementation. The timing of the evaluation can have a significant impact, as shown in one study that found an immediate improvement from 12% to 72%; however, compliance fell to 32% after 6 months,[43] indicating that a short-term improvement may not lead to long-term behaviour change. This phenomenon is described as a 'honeymoon period', and researchers should be cautious when interpreting effects less than 6 months from implementation.[72] Among the most effective interventions (≥75% completed fluid balance charts), two were evaluated 6 months or more after implementation,[37 46] whereas the three others were assessed after less than 2[33 51] and 6 months.[47]

Recommendations

Calculation errors pointed to in this review may be prevented by using electronic patient records, where fluid balance calculations are performed automatically and are no longer based on human calculation.[39 44 62] By exclusively using fluid containers with measuring lines or through automated measuring inaccuracies related to estimations can be avoided.[22 23] Additionally, interactive teaching based on daily practice for all stakeholders[54 69] and involving and motivating patients to self-monitor may enhance quality.[46 67] Care bundles should have few components, be straightforward, and of low complexity.[66 70] Continuous attention to fluid balance charting (eg, through disseminating audit results) is required to achieve and maintain improvement.[70]

Limitations

This systematic review had several limitations. To begin, we conducted a broad search for literature, including only published papers. Due to the widespread problem of fluid balance charting in clinical practice, we suspect much information is available only for internal use. Thus, this review represents the quality of fluid balance monitoring generated by a systematic method but not necessarily a complete overview. Furthermore, we limited our search to the time frame of 2010 to the present, thus excluding older literature. The rationale for this decision was that the main objective of the review was to evaluate recent quality, but by analysing previous studies, we may have obtained different knowledge.

Other limitations relate to the studies included, the quality of which varied. Every third study was of low quality; thus, the power of the conclusions drawn based on them is limited. Nevertheless, we did not exclude low-quality studies as we chose not to risk omitting research from daily practice. Second, the studies are characterised by significant heterogeneity in defining outcomes, and the patients included are not comparable. Finally, the timing of the evaluation of interventions differed, making comparisons across studies difficult.

Conclusion

In conclusion, the quality of fluid balance monitoring varies, but most studies report it as inadequate, influenced by calculation errors. Implemented interventions designed to improve the quality of fluid balance monitoring had varying impacts, and in most studies, the effect was unsubstantial. Furthermore, a short-term improvement may not lead to long-term behaviour change.

Therefore, there is a need for in-depth qualitative knowledge to understand nurses' attitudes towards and opinions of fluid balance monitoring and the perceived barriers. Further, increased knowledge of the patients' perspective may be beneficial. Based on this understanding, innovative and robust fluid balance monitoring methods must be developed.

Contributors LRL developing study design and search strategy, screening abstracts and titles, full text reading, data extraction, analysis, writing first draft of manuscript. MK full text reading, data extraction, analysis, revising manuscript. ST-H screening abstracts and titles, revising manuscript. IG developing study design, revising manuscript. AOB developing study design, revising manuscript. NA developing study design, full text reading, revising manuscript. NA is the guarantor of this study.

Funding Interreg Öresund-Kattegat-Skagerrak, grant number: NYPS 20341110.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

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