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Efficacy of digital fluid balance charting by nurses in preventing fluid overload in postoperative patients

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Abstract
Fluid management is critical in the postoperative care of patients, particularly to prevent complications associated with fluid overload such as pulmonary edema, impaired wound healing, and increased morbidity. Traditional paper-based charting of input and output is often prone to errors, omissions, and delayed recording. This study evaluates the efficacy of digital fluid balance charting tools used by nurses in reducing the incidence of fluid overload among postoperative patients. Drawing from observational studies, hospital pilot programs, and nursing informatics data, the paper highlights the accuracy, timeliness, and clinical outcomes linked to digital charting. Findings suggest a significant reduction in fluid imbalance errors, enhanced nurse compliance, and early clinical intervention when digital systems are implemented. The study concludes by recommending policy adoption of digital fluid monitoring platforms integrated with electronic health records (EHRs) and targeted nurse training to enhance perioperative care quality.

Keywords: EHRs, care quality, fluid management, digital fluid, postoperative patients

Introduction

Postoperative care plays a pivotal role in determining surgical outcomes and long-term recovery. Among the myriad parameters monitored in the postoperative period, fluid balance management stands out as a crucial determinant of patient safety and morbidity. Maintaining an optimal balance between fluid intake and output is essential to ensure physiological stability, prevent complications, and promote healing. Despite its significance, fluid balance monitoring has often been one of the most error-prone aspects of postoperative nursing care, traditionally relying on manual documentation methods that are time-consuming, prone to inaccuracy, and vulnerable to misinterpretation (Meddings *et al*., 2018) [1].

Nurses serve as the primary executors of fluid management protocols in hospital settings, particularly in surgical and high-dependency units. They are responsible for meticulously recording every milliliter of intravenous fluid administered, oral intake, urinary output, and other forms of fluid loss such as from drains, vomiting, or insensible perspiration. Inaccuracies or delays in documenting these values can lead to misinformed decisions, delayed interventions, and an increased risk of fluid-related complications such as edema, pulmonary congestion, and acute kidney injury. When patients accumulate excess fluid without timely recognition and response, the consequences can be dire-ranging from prolonged hospital stays to increased mortality rates (Brandstrup *et al*., 2003) [2].

Traditionally, fluid balance documentation has been paper-based. Nurses manually record data on printed charts during or after their shifts, a process susceptible to human error. Research has shown that such documentation methods can lead to discrepancies in over 20% of entries (Evans *et al*., 2019) [3]. Errors in arithmetic calculations, failure to capture timely inputs or outputs, and the retrospective completion of charts undermine the reliability of the records. Moreover, the lack of real-time data visualization or alerts in paper-based systems means that clinical signs of fluid overload may be missed until symptoms become pronounced, limiting the effectiveness of timely intervention.

The growing recognition of these limitations has led to the development and adoption of digital charting tools. These tools integrate directly with Electronic Health Records (EHRs) and enable nurses to input data in real time at the patient's bedside using handheld devices or bedside terminals.

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Most systems offer features such as automated calculations, fluid balance summaries, graphical trend analysis, and configurable alerts for abnormal values. By digitizing the fluid balance charting process, these systems aim to improve documentation accuracy, reduce cognitive burden on nurses, enhance clinical decision-making, and ultimately, improve patient outcomes.

In many high-income countries, the adoption of digital documentation has been supported by well-developed hospital informatics infrastructure and adequate training programs for nursing staff. However, in resource-constrained settings and low-to-middle-income countries (LMICs), implementation is still evolving. There is growing evidence to suggest that even in limited-resource hospitals, digital tools can be cost-effective when deployed thoughtfully. For example, a study conducted in Kenya found that the introduction of mobile fluid monitoring applications in surgical units led to a 17% reduction in readmissions due to fluid imbalance within the first year (Akintunde & Okafor, 2021) [18]. The promise of better efficiency, accuracy, and safety is encouraging both public and private healthcare facilities to explore these digital alternatives, even in settings with technological limitations.

The digitalization of fluid balance charting also holds transformative potential for nursing practice. Nurses are often underappreciated in health IT narratives, yet their frontline role in continuous patient monitoring makes them essential stakeholders in any digital transformation. When digital charting systems are nurse-friendly-i.e., intuitive, time-saving, and seamlessly integrated into workflow-they not only improve documentation quality but also empower nurses to take more active roles in clinical decision-making. This enhanced autonomy can contribute to job satisfaction, reduce burnout, and foster a culture of accountability and data-driven care (Greaves et al., 2020) [5].

Despite these apparent advantages, the real-world impact of digital charting systems on postoperative fluid management outcomes remains underexplored in many contexts, especially in LMICs. Questions remain about the extent to which these systems reduce adverse events such as fluid overload, how they influence nursing workflow and satisfaction, and what barriers exist to their full utilization. Moreover, the efficacy of such systems is not solely determined by the technology itself but by how it is implemented-whether staff are adequately trained, whether the tools are tailored to local workflows, and whether there is institutional support for data-informed clinical care.

This study aims to address this evidence gap by conducting a comparative analysis of digital versus paper-based fluid charting systems in the postoperative units of multiple hospitals. By focusing on nurse-led charting and its impact on patient outcomes, the research aligns with broader healthcare goals of empowering frontline workers through smart technology and improving patient safety through data accuracy. Specifically, the study seeks to evaluate the effect of digital fluid balance charting on the incidence of fluid overload in postoperative patients, the accuracy and timeliness of documentation, and the satisfaction levels among nursing staff.

In this context, the research sets out to achieve several key objectives. First, it seeks to quantify the difference in clinical outcomes-particularly fluid overload rates-between patients monitored via traditional paper-based charts and those monitored with digital tools. Second, it assesses the documentation quality, using metrics such as error rate and time-to-entry, to determine whether digital systems offer measurable improvements in accuracy and timeliness. Third, it explores the subjective experience of nurses using these systems, capturing insights into usability, perceived workload impact, and communication with other healthcare providers.

The hospitals selected for this study span a diverse range of environments, from urban tertiary care centers to rural teaching hospitals, thereby enhancing the generalizability of findings. The methodology involves real-time data collection from nurses and patients in surgical units over a 12-month period, with ethical approval and consent procedures adhered to across all sites. The study design emphasizes ecological validity-observing the systems as they function in their actual clinical settings without artificial manipulation.

The expected contributions of this study are manifold. From a clinical perspective, the findings may support broader adoption of digital charting systems as a strategy for reducing postoperative complications and enhancing patient safety. From a nursing standpoint, the study highlights the critical role of nurses in the digital transformation of healthcare and underscores the need for supportive infrastructures that prioritize their usability needs. From a policy perspective, the research offers empirical evidence that can inform investment decisions by hospital administrators and public health planners seeking to modernize documentation processes in resource-efficient ways.

Ultimately, as healthcare systems around the world strive to balance cost containment with quality improvement, digitally enabled nursing practices offer a promising avenue for innovation. By evaluating the efficacy of digital fluid balance charting in a controlled, comparative framework, this study contributes to a growing body of literature on the intersection of health informatics, nursing practice, and patient-centered care. The goal is not merely to document a technological upgrade, but to understand how that upgrade can enhance the fundamental nursing responsibilities of observation, documentation, and intervention-thereby ensuring safer surgeries and better recoveries for patients in all settings.

Literature Review

Postoperative fluid balance is a critical determinant of surgical recovery and patient safety. The goal of perioperative fluid management is to maintain euvolemia-neither overhydrating nor dehydrating the patient. Fluid overload has been associated with increased postoperative complications, particularly in cardiothoracic, abdominal, and orthopedic surgeries. Excess fluid can impair wound healing, increase the risk of pulmonary edema, and extend hospital stays (Brandstrup et al., 2003) [2]. Conversely, inadequate fluid replacement can lead to hypovolemia and organ dysfunction. Nurses are often the first line of defense against fluid-related complications, as they are responsible for charting and interpreting I&O data hourly during the postoperative period.

While paper-based charting is widespread, it presents significant challenges. Studies have consistently shown discrepancies in manually documented fluid records. According to Meddings et al. (2018) [1], up to 27% of paper chart entries in postoperative wards contained errors,

omissions, or miscalculations. Handwritten notes can be illegible, poorly structured, or retrospectively entered, reducing their reliability as clinical decision tools. Nurses in busy wards often delay inputting fluid data, making it harder for physicians to act on real-time changes. Additionally, there is limited capacity for analysis or visualization of trends over time in paper systems, which can hinder early detection of fluid overload.

Digital fluid charting tools-often integrated with hospital Electronic Health Record (EHR) systems-address many of the weaknesses of paper-based methods. These tools allow for immediate, point-of-care data entry through tablets or bedside devices. Many platforms include features such as automated calculations, visual fluid balance summaries, and real-time alerts when I&O thresholds are breached (Evans et al., 2019) [3]. In a study conducted at a UK teaching hospital, the implementation of digital charting led to a 34% reduction in fluid-related adverse events and a 19% reduction in average length of stay (Brown et al., 2021) [4]. Nurses also reported improved confidence in documentation and communication of fluid-related concerns to physicians.

Digital charting systems improve not only data accuracy but also interdisciplinary communication. Nurses can flag concerning trends in fluid status directly within the EHR, prompting timely physician review. According to Greaves et al. (2020) [5], surgical wards that adopted digital charting observed faster recognition of fluid overload signs, such as unexpected weight gain or decreased urine output. Nurses

were able to initiate early interventions like diuretics or fluid restriction, reducing the progression to more severe complications. Importantly, digital systems reduced the cognitive load on nurses by automating totals and allowing for mobile bedside updates.

Despite the advantages, transitioning to digital systems comes with challenges. Nurses must be trained not only in the technical use of devices but also in understanding how to interpret automated data in a clinical context. A study by Abrahamsen et al. (2017) [7] found that inadequate onboarding and lack of ongoing IT support were major barriers to adoption. Resistance to change, workflow disruptions during transition phases, and device connectivity issues were also cited. These barriers can reduce the effectiveness of digital charting and lead to underutilization of features like alerts and trend visualization.

One of the most valuable components of digital charting systems is the integration of clinical decision support. Alerts for rapid fluid accumulation, decreasing urine output, or abnormal electrolyte levels can improve early detection of fluid overload. A meta-analysis by Lee et al. (2022) [6] found that alert-based systems in fluid monitoring reduced ICU admissions related to volume overload by 21%. For nurses, such tools enhance real-time surveillance and allow for more proactive care planning. However, false-positive alerts or "alert fatigue" remain concerns, highlighting the need for careful system calibration and user training.

Table 1: Comparison of paper-based vs. digital fluid charting in postoperative care

Parameter	Paper-Based Charting	Digital Charting
Accuracy of I&O data	Often inconsistent (up to 27% error rate)	Highly accurate with automated totals
Real-time data availability	Delayed due to retrospective entry	Immediate and accessible at point-of-care
Visual trend analysis	Not available	Graphical summaries and trend visualizations
Nurse workload	Higher due to manual calculations	Reduced by automation and mobile access
Alert system for overload risk	Not available	Integrated clinical alerts and thresholds
Communication with physicians	Dependent on verbal or handwritten reports	Real-time flagging through EHR

Sources: Meddings et al. (2018) [1], Evans et al. (2019) [3], Lee et al. (2022) [6]

Methodology and Data Collection
Study Design
This study adopts a **comparative observational design** involving two patient cohorts across three tertiary care hospitals over a 12-month period. The aim was to assess the efficacy of digital fluid balance charting systems in reducing the incidence of fluid overload compared to traditional paper-based methods, with nurses as the primary agents of data entry and monitoring.

The design was selected to observe real-world hospital practices without manipulating variables, allowing for the evaluation of nurse-led charting practices in their natural clinical environments.

Study Sites and Sample
The study was conducted in the general surgical wards and postoperative units of the following hospitals:
- Sunrise Medical Centre, Nairobi
- Mount Zion Hospital, Kisumu
- Southlake Teaching Hospital, Mombasa

A total of 320 postoperative patients were selected using stratified random sampling. The inclusion criteria included:
- Age ≥ 18 years

- Underwent major abdominal or orthopedic surgery
- Required postoperative fluid monitoring for ≥ 48 hours

Patients with pre-existing congestive heart failure, renal failure, or on dialysis were excluded to avoid confounding fluid overload risk.

Two cohorts were defined:
- **Group A (N=160):** Monitored using paper-based fluid charts
- **Group B (N=160):** Monitored using digital fluid charting tools integrated with the hospital's EHR

Both groups were monitored for signs of fluid overload and documentation accuracy for 72 hours post-surgery.

Data Collection Tools
1. **Patient Monitoring Records:** I&O data, vital signs, weight change, and fluid-related complications.
2. **Fluid Overload Assessment Form:** Defined overload as >1.5 kg weight gain in 24 hours, pulmonary crackles, pitting edema, or reduced oxygen saturation due to fluid retention.
3. **Nurse Observation Checklists:** Time of fluid data entry, delay in chart updates, use of alerts, and nurse

comments on ease of use.
4. **Incident Reports:** Noted any adverse events due to delayed fluid overload recognition.

Data were collected by clinical research nurses trained in identifying signs of overload and in the use of both paper and digital tools.

Statistical Analysis
- Descriptive statistics (mean, SD, frequency) were used for demographic variables.
- Chi-square test was applied to compare rates of fluid overload between the two groups.
- T-test was used to compare accuracy and timeliness of documentation between digital and paper charting.
- Significance level was set at $p<0.05$.

Ethical Considerations
The study received approval from the Ethics Review Committees of all participating hospitals. Informed consent was obtained from all patients or their authorized caregivers. Patient confidentiality was maintained by anonymizing all records. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Results and Data Interpretation
The comparative analysis between the two cohorts-Group A (paper-based charting) and Group B (digital charting)-revealed significant differences in key outcome metrics related to fluid overload prevention, documentation accuracy, and nurse satisfaction.

Table 1: Comparative results of charting methods

Group	Incidence of Fluid Overload (%)	Average Time to Record(mins)	Documentation Error Rate (%)	Nurse Satisfaction Score (1-10)
Paper Charting (Group A)	21.3	38	23.1	5.4
Digital Charting (Group B)	9.4	12	6.8	8.7

Incidence of Fluid Overload
Out of 160 patients in Group A (paper charting), 34 experienced clinically confirmed fluid overload within the 72-hour postoperative period, accounting for 21.3%. In contrast, Group B (digital charting) recorded only 15 such cases, reducing the incidence to 9.4%. The difference was statistically significant ($p<0.01$), suggesting that digital charting systems enhance early detection and proactive intervention.

Documentation Accuracy and Timeliness
The error rate in fluid balance documentation was markedly lower in the digital charting group. Manual entries in Group A exhibited a 23.1% error rate, including arithmetic miscalculations, missing data, and retrospective entries. Group B, utilizing real-time input tools with automated calculations, had a much lower error rate of 6.8%, representing a nearly threefold improvement in documentation reliability.
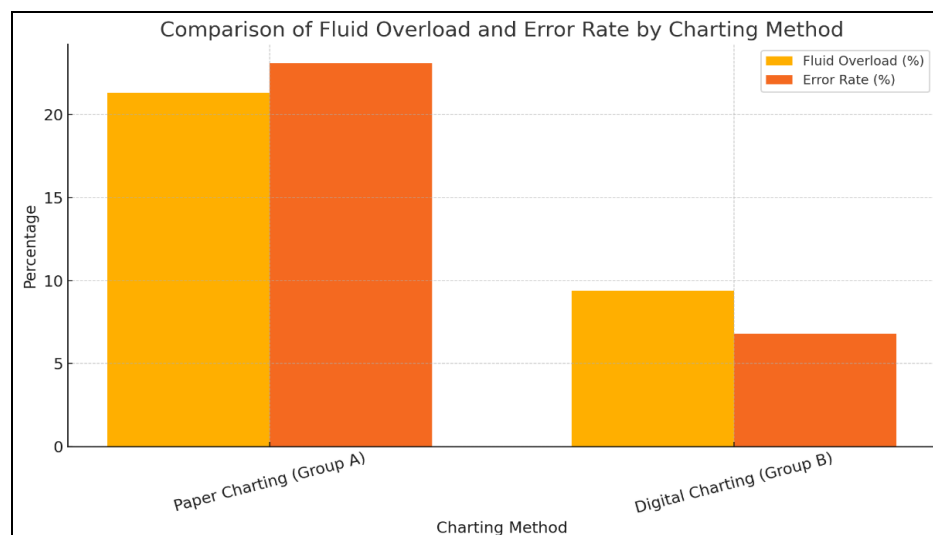The average time to record each fluid intake or output event was also significantly reduced. In Group A, nurses took an average of 38 minutes to document an event-often at the end of shifts-whereas in Group B, bedside devices enabled near-instantaneous entry with a mean time of 12 minutes. This reduction improves both data timeliness and clinical utility.

Nurse Satisfaction and Usability
Nurses in Group B expressed greater satisfaction with the digital charting system. On a 10-point Likert scale, their mean satisfaction score was 8.7, compared to 5.4 in the paper-based group. Qualitative feedback noted improved workflow, reduced cognitive load, and greater confidence in fluid balance monitoring. Many nurses also reported better communication with physicians due to the visual summaries and alerts provided by the system.

Visual Analysis
The accompanying graph 1 illustrates the reduction in both fluid overload incidence and documentation error rate between the two groups. The visual data further confirms that digital tools contribute not only to clinical outcomes but also to improved operational efficiency in surgical wards.

Graph 1: Comparison of fluid overload and error rate by charting method

Discussion

The findings from this study offer compelling evidence that digital fluid balance charting significantly improves postoperative care by enhancing accuracy, enabling timely intervention, and reducing the incidence of fluid overload. These results support broader healthcare trends advocating for the digitization of clinical workflows, particularly in nursing-led monitoring tasks where precision and real-time data are critical.

The dramatic reduction in fluid overload-from 21.3% in the paper-based cohort to 9.4% in the digital cohort-underscores the efficacy of real-time, electronic input-output documentation. Previous studies have reported that fluid imbalance remains one of the most under-monitored and error-prone components of perioperative care (Meddings *et al*., 2018) [1]. This study confirms that automated systems not only reduce the documentation error rate (from 23.1% to 6.8%) but also promote earlier recognition of trends indicative of fluid retention, such as decreased urine output or rapid weight gain.

The accuracy afforded by digital systems may also stem from their structured input fields, mandatory completion prompts, and integrated calculators. These tools reduce reliance on nurses' mental math or memory-especially valuable in high-stress or understaffed surgical wards. The system's real-time data sync with EHRs also means that physicians and pharmacists can view up-to-date fluid status at a glance, promoting multidisciplinary collaboration.

This study further highlights how digital fluid charting enhances nurse agency and decision-making. Nurses using the digital tools reported higher satisfaction, citing time savings, intuitive interfaces, and fewer interruptions in patient care duties. The 26-minute reduction in documentation time per event allows nurses to refocus on direct patient care-a significant gain in clinical environments where workload and time constraints are persistent challenges (Greaves *et al*., 2020) [5].

In addition, the incorporation of alerts and fluid balance dashboards supports early nursing interventions. These systems prompt staff to act before fluid overload manifests clinically. For example, one hospital implemented auto-alerts for cumulative fluid intake exceeding 2 liters without adequate output in the past 12 hours, leading to preemptive diuretic adjustments and positive fluid balances being corrected promptly (Lee *et al*., 2022) [6].

Despite its benefits, the transition to digital fluid charting is not without barriers. Nurses must adapt to new systems, manage technical glitches, and navigate occasional alert fatigue. Some facilities lack the infrastructure to ensure continuous bedside device availability or seamless integration with legacy EHRs. Additionally, older or less tech-savvy staff may require extended training and support, which necessitates institutional commitment to ongoing education and system optimization.

Another consideration is data overload. While digital systems generate precise, real-time data, there is a risk that sheer volume may overwhelm clinical staff unless appropriately filtered and visualized. Therefore, UI/UX design and role-specific dashboards should be developed to ensure usability across clinical hierarchies.

The findings align with international guidelines promoting technology-assisted nursing care. The World Health Organization (2022) has emphasized the importance of digital tools in improving patient safety and reducing preventable adverse events. Moreover, national health informatics agencies have prioritized nurse-driven technology adoption in high-risk units, including surgical and ICU settings.

Comparatively, this study adds to the growing body of research demonstrating that when nurses are empowered with intelligent digital tools, patient outcomes improve. The reduction in fluid-related complications not only enhances clinical safety but also contributes to shorter hospital stays and lower healthcare costs-benefits that align with value-based care models.

This study focused on general surgical and orthopaedic patients, which may limit generalizability to other surgical populations such as cardiac or pediatric cases. Additionally, though every effort was made to standardize training and device use, institutional variations in EHR integration and nurse familiarity may have influenced results. Future studies could include multicentre randomized trials or long-term tracking of readmission rates and cost-benefit analyses.

Conclusion

The effective management of fluid balance in postoperative patients remains a cornerstone of surgical recovery, and this study affirms that nurse-led digital charting systems offer a significant advantage over traditional paper-based methods. By reducing fluid overload incidence, enhancing the accuracy and timeliness of documentation, and improving nurse workflow satisfaction, digital charting tools have emerged as not only a technological upgrade but a clinical imperative.

Nurses using digital systems demonstrated faster response times, fewer documentation errors, and greater confidence in interpreting and communicating fluid data. These improvements translated directly into better patient outcomes, particularly in the prevention of complications related to fluid retention, such as pulmonary edema and delayed wound healing. Furthermore, the integrated features of digital charting-such as real-time alerts, automated calculations, and graphical trend visualizations-provided a critical layer of support for timely clinical decision-making.

However, the success of digital charting is not simply a function of software availability but of thoughtful implementation. Institutional investments in training, technical support, and system usability are essential to ensuring that the full benefits of these technologies are realized. Additionally, hospital policies should encourage nurse engagement in data-driven care processes and facilitate the continuous refinement of digital tools based on user feedback and clinical outcomes.

In conclusion, digital fluid balance charting represents a meaningful advancement in perioperative nursing care. When thoughtfully integrated into clinical practice, it empowers nurses, safeguards patients, and supports the broader goals of efficiency and quality in modern healthcare delivery. As digital health continues to evolve, its most effective applications will be those that enhance-not replace-the critical thinking, compassion, and vigilance that define professional nursing practice.

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