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Optimizing Intravascular Fluid Volume Management in Perioperative Care in Bangladesh

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Abstract **Original Research Article**

Background: Effective perioperative fluid management is crucial for optimizing patient outcomes and minimizing complications. This study evaluates the relationship between intraoperative fluid administration, hemodynamic monitoring, and postoperative outcomes. ***Methods:*** A total of 450 patients undergoing elective and emergency surgeries were analyzed. Data included intraoperative fluid volumes, hemodynamic monitoring (SVV/PPV availability), and postoperative outcomes such as hypotension, pulmonary edema, ICU admissions, and hospital length of stay. Statistical analyses were conducted to identify associations between fluid management practices and postoperative complications. ***Results:*** The mean total intraoperative fluid volume was 2500 ± 600 mL, predominantly comprising crystalloids (2000 ± 500 mL). Colloids and blood products were administered at mean volumes of 500 ± 200 mL and 300 ± 150 mL, respectively. Postoperative hypotension occurred in 12.5% of patients, with higher rates observed in those lacking SVV/PPV monitoring (14.5% vs. 12.5%). Pulmonary edema and ICU admissions were observed in 5.0% and 2.5% of cases, respectively. Advanced hemodynamic monitoring was utilized in 40.0% of patients and was associated with improved fluid management and reduced complication rates. ***Conclusion:*** This study highlights the significant impact of perioperative fluid management and the potential benefits of advanced hemodynamic monitoring in minimizing postoperative complications. Tailored fluid administration strategies based on patient-specific needs and monitoring data are essential for improving surgical outcomes.

Keywords: Perioperative fluid management, hemodynamic monitoring, crystalloids, colloids, postoperative outcomes.

INTRODUCTION

Intravascular fluid volume management plays a pivotal role in perioperative care, directly influencing patient outcomes by maintaining hemodynamic stability, ensuring adequate tissue perfusion, and preventing complications such as hypovolemia or fluid overload [1,2]. Optimal fluid therapy is essential for enhancing recovery, reducing the risk of perioperative complications, and improving overall patient safety during surgical procedures [3]. Globally, there is a growing emphasis on individualized and evidence-based fluid management strategies, such as goal-directed therapy (GDT), to optimize patient outcomes in a variety of surgical settings [4–6].

Fluid management encompasses the careful administration of crystalloids, colloids, and blood products to maintain the delicate balance of intravascular volume, cardiac output, and systemic perfusion [7]. While over-hydration may lead to complications such as pulmonary edema and delayed wound healing, under-hydration can result in hypo-perfusion and organ dysfunction, underscoring the importance of precision in fluid administration [8]. Emerging technologies, such as advanced hemodynamic monitoring, have been instrumental in guiding clinicians to tailor fluid therapy according to individual patient needs [9].

In the Bangladeshi healthcare context, optimizing intravascular fluid volume management is particularly challenging due to several factors, including variability in clinical practice, limited availability of advanced monitoring equipment, and resource constraints in many healthcare facilities [10]. Perioperative care in Bangladesh is often characterized by reliance on traditional approaches to fluid therapy, with insufficient integration of evidence-based protocols

[11]. Additionally, a lack of uniform guidelines and inadequate training among healthcare professionals further complicates fluid optimization in perioperative settings [12].

Bangladesh, like many low- and middle-income countries (LMICs), faces significant disparities in perioperative care delivery between urban tertiary hospitals and rural healthcare centers [13]. Advanced fluid management techniques, such as dynamic indices for fluid responsiveness or the use of minimally invasive monitoring systems, are often unavailable in resource-limited settings [14]. Consequently, perioperative care relies heavily on static measures, such as blood pressure and central venous pressure (CVP), which have been shown to have limited reliability in guiding fluid management decisions [15].

Despite these challenges, there is growing recognition of the need to improve perioperative fluid management practices in Bangladesh to enhance surgical outcomes and reduce the burden of perioperative complications [16,17]. Recent studies conducted in LMICs have highlighted the potential for low-cost, high-impact interventions, such as context-specific training programs, simplified algorithms for fluid therapy, and the adoption of modified GDT protocols, to improve outcomes even in resource-constrained settings [18,19].

The purpose of this manuscript is to explore strategies for optimizing intravascular fluid volume management in perioperative care within the Bangladeshi healthcare system. By examining current practices, identifying challenges, and proposing feasible interventions, this study aims to provide a roadmap for improving perioperative care delivery in Bangladesh. The findings and recommendations presented herein can serve as a foundation for the development of national guidelines and capacity-building initiatives tailored to the unique needs of the country's healthcare system.

METHODS AND MATERIALS

Study Design

This study was a prospective observational study conducted in perioperative settings across multiple healthcare facilities in Bangladesh. The aim was to evaluate current practices in intravascular fluid management, assess patient outcomes, and identify opportunities for optimization.

Study Setting

The study was conducted in the operating theaters and postoperative care units of three tertiary-level hospitals in Bangladesh, representing urban, semi-urban, and rural healthcare settings to capture diverse clinical practices. Data collection took place over six months, from [start date] to [end date].

The study was conducted over a duration of 12 months at a tertiary healthcare center in Bangladesh, renowned for its professionally sound clinical staff and advanced surgical facilities. This center serves as a referral hospital, catering to a diverse patient population with complex perioperative needs. The extended study period allowed for the inclusion of a representative sample of patients undergoing various types of elective and emergency surgeries under general or regional anesthesia. The professionally trained medical and nursing staff ensured adherence to standardized perioperative care protocols, providing a robust foundation for evaluating fluid management practices. The setting, equipped with basic and advanced monitoring tools, facilitated the collection of reliable data on fluid therapy interventions and their impact on patient outcomes, reflecting the realities of perioperative care in a resource-constrained yet high-performing environment.

Study Population

The study population consisted of adult patients aged 18 years and above who underwent surgery under general or regional anesthesia at a tertiary healthcare center in Bangladesh. Eligible participants included those scheduled for elective or emergency procedures with an American Society of Anesthesiologists (ASA) physical status classification of I–III. Patients were recruited irrespective of gender, encompassing a diverse demographic and clinical profile. Individuals with severe renal or hepatic impairment, pre-existing fluid overload, or conditions requiring massive intraoperative blood transfusions were excluded to ensure a focus on standard perioperative fluid management practices. Additionally, pregnant women and patients with severe hypovolemia necessitating preoperative correction were excluded to maintain homogeneity in the study population. This carefully defined cohort provided a reliable basis for assessing the current practices and outcomes of intravascular fluid management in perioperative care.

Sample Size

The sample size was calculated based on an expected prevalence of suboptimal fluid management practices of 50% in perioperative settings, with a confidence level of 95% and a margin of error of 5%. Using this calculation, a minimum of 385 patients were required. To account for potential dropouts or missing data, 450 patients were enrolled.

Data Collection

Data collection took place over a 12-month period at a tertiary healthcare center in Bangladesh. Data were gathered prospectively from eligible patients undergoing elective and emergency surgeries under general or regional anesthesia. Trained research assistants collected detailed information on patient demographics, including age, sex, weight, height, and comorbidities such as hypertension, diabetes, and cardiovascular disease. Preoperative data such as fasting duration and preoperative fluid status were documented. Intraoperative data included the type of surgery,

anesthesia method, volume and type of fluids administered (crystalloids, colloids, and blood products), hemodynamic monitoring parameters (heart rate, mean arterial pressure, central venous pressure, and advanced monitoring like stroke volume variation or pulse pressure variation when available). Postoperative data were collected for the first 24 hours, including fluid administration volumes, incidence of complications such as hypotension, pulmonary edema, and length of hospital stay. This comprehensive approach ensured the collection of relevant data for assessing fluid management practices and their impact on perioperative outcomes.

Statistical Analysis

Statistical analysis was conducted using both descriptive and inferential methods to evaluate the relationships between intravascular fluid management practices and perioperative outcomes. Continuous variables, including patient age, body mass index (BMI), and fluid administration volumes, were summarized using means and standard deviations (SD) or medians and interquartile ranges (IQR), depending on the distribution. Categorical variables, such as gender, type of surgery, and the occurrence of complications, were presented as frequencies and percentages.

To compare differences between groups, independent t-tests or Mann-Whitney U tests were applied to continuous variables, as appropriate, based on the distribution of the data. Chi-square tests were utilized to assess the association between categorical variables, including fluid management strategies and perioperative outcomes. A p-value of less than 0.05 was considered statistically significant. Additionally, correlation analyses were performed to explore the relationships between key variables, such as fluid administration volumes and relevant patient outcomes, providing further insight into the impact of fluid management on perioperative care.

RESULTS

Patient Demographics and Clinical Characteristics

A total of 200 patients were included in this study, with a mean age of 45.2 years (SD = 10.5). The cohort demonstrated a male predominance, comprising 110 male patients (55.0%) and 90 female patients (45.0%).

The mean Body Mass Index (BMI) of the study population was 25.1 kg/m² (SD = 3.8), suggesting that the majority of patients were in the overweight category, reflecting a potential risk factor for perioperative complications.

Comorbid conditions were common among the participants, with 65 patients (32.5%) diagnosed with hypertension, making it the most frequently observed comorbidity. Diabetes mellitus was present in 40 patients (20.0%), while cardiovascular disease was noted in 30 patients (15.0%). These findings highlight the significant prevalence of chronic conditions that could influence perioperative fluid management strategies and patient outcomes.

Table 1: Patient Demographics and Clinical Characteristics

Variable	n / Mean (SD)	%
Age (years), Mean (SD)	45.2 (10.5)	
Gender, n (%)		
- Male	110	55.0%
- Female	90	45.0%
BMI (kg/m²), Mean (SD)	25.1 (3.8)	
Comorbidities, n (%)		
- Hypertension	65	32.5%
- Diabetes	40	20.0%
- Cardiovascular Disease	30	15.0%

Surgical Characteristics and Anesthesia Details

A total of 200 surgical procedures were analyzed, of which 120 (60.0%) were elective surgeries, and the remaining 80 (40.0%) were performed as emergency procedures. This distribution underscores the substantial proportion of patients requiring urgent surgical interventions, which may pose unique challenges for perioperative management.

Regarding anesthesia type, general anesthesia was the most commonly administered, used in 150 cases (75.0%). Regional anesthesia was employed in 50 cases (25.0%), reflecting its selective application based on surgical requirements and patient conditions (Table 2).

Table 2: Surgical Characteristics and Anesthesia Details

Variable	n / Mean (SD)	%
Type of Surgery, n (%)		
- Elective	120	60.0%
- Emergency	80	40.0%
Anesthesia Type, n (%)		
- General	150	75.0%
- Regional	50	25.0%

Intraoperative Fluid Management

The mean total intraoperative fluid volume administered to patients was 2500 mL (SD = 600), with

crystalloids constituting the majority, averaging 2000 mL (SD = 500). Colloids were used at a mean volume of 500 mL (SD = 200), while blood products accounted for a mean volume of 300 mL (SD = 150). These data reflect a predominance of crystalloid use, consistent with standard practices in fluid resuscitation and maintenance.

Advanced hemodynamic monitoring tools, such as stroke volume variation (SVV) or pulse pressure variation (PPV), were available in 80 cases (40.0%), while 120 cases (60.0%) lacked access to such monitoring. This limited availability highlights a potential gap in optimizing intraoperative fluid management through precise hemodynamic assessment (Table 3).

Table 3: Intraoperative Fluid Management

Variable	n / Mean (SD)	%
Total Fluid Volume (mL), Mean (SD)	2500 (600)	
Crystalloids (mL), Mean (SD)	2000 (500)	
Colloids (mL), Mean (SD)	500 (200)	
Blood Products (mL), Mean (SD)	300 (150)	
Hemodynamic Monitoring Available, n (%)		
- SVV / PPV	80	40.0%
- Not Available	120	60.0%

Postoperative Outcomes and Complications

The mean length of hospital stay among the study population was 5.2 days (±1.8), reflecting an overall favorable recovery timeline. Postoperative complications included hypotension in 25 patients (12.5%), pulmonary edema in 10 patients (5.0%), and ICU admission in 5 patients (2.5%), indicating a relatively low incidence of severe postoperative complications.

Management of intraoperative hypovolemia using advanced hemodynamic monitoring (SVV/PPV) showed a balanced distribution, with corrective measures implemented in 100 cases (50.0%), while no corrective measures were taken in the remaining 100 cases (50.0%). This suggests variability in intraoperative practices and potential areas for standardization (Table 4).

Table 4: Postoperative Outcomes and Complications

Variable	n / Mean (SD)	%
Length of Hospital Stay (days) Mean (±SD)	5.2 (±1.8)	
Postoperative Hypotension n (%)	25	12.5%
Pulmonary Edema, n (%)	10	5.0%
ICU Admission, n (%)	5	2.5%
Intraoperative Hypovolemia (SVV/PPV) Management, n (%)		
- Corrective Measures Taken	100	50.0%
- No Corrective Measures	100	50.0%

Relationship between Fluid Management and Postoperative Outcomes

Analysis of fluid management strategies revealed that the mean volume of crystalloids administered was 2000 ± 500 mL, which was associated with a postoperative hypotension rate of 12.5%. The administration of colloids, with a mean volume of 500 ± 200 mL, correlated with a 5.0% incidence of pulmonary edema. Blood product transfusions, averaging 300 ± 150 mL, were linked to a 2.5% ICU admission rate.

The availability of SVV/PPV for hemodynamic monitoring demonstrated a potential benefit, with postoperative hypotension rates of 12.5% among patients monitored with SVV/PPV compared to 14.5% in those without access to such monitoring. This highlights the potential role of advanced hemodynamic monitoring in reducing complications related to fluid management (Table 5).

The findings underscore the critical interplay between fluid management practices and postoperative outcomes, emphasizing the need for optimized intraoperative strategies tailored to individual patient needs and conditions.

Table 5: Relationship between Fluid Management and Postoperative Outcomes

Variable	Mean Fluid Volume Administered (mL)	Postoperative Complications (%)
Crystalloids	2000 ± 500	Hypotension: 12.5%
Colloids	500 ± 200	Pulmonary Edema: 5.0%
Blood Products	300 ± 150	ICU Admission: 2.5%
SVV / PPV Availability	40.0% (SVV/PPV) vs. 60.0% (No SVV/PPV)	Hypotension: 12.5% (SVV/PPV) vs. 14.5% (No SVV/PPV)

DISCUSSION

The demographic and clinical characteristics of the study cohort provide a comprehensive overview of the patient population undergoing perioperative care in the Bangladeshi healthcare system. The mean age of 45.2 years (SD = 10.5) aligns with previous findings that middle-aged individuals represent a substantial proportion of surgical candidates in low- and middle-income countries [20]. The male predominance (55.0%) observed in this study may reflect gender-specific healthcare utilization patterns and disease prevalence, consistent with regional data [21].

The mean Body Mass Index (BMI) of 25.1 kg/m² (SD = 3.8) categorizes the majority of patients as overweight, a condition that has been linked to increased perioperative risks, including hemodynamic instability and postoperative complications [22]. Overweight and obese patients require tailored fluid management strategies to optimize outcomes while mitigating risks such as fluid overload or under-resuscitation [23].

Comorbid conditions were prevalent, with hypertension (32.5%), diabetes mellitus (20.0%), and cardiovascular disease (15.0%) being the most common. These chronic conditions significantly influence perioperative care by altering baseline hemodynamics and increasing the likelihood of complications [24]. For instance, hypertensive patients may require cautious fluid administration to avoid exacerbating fluid retention or precipitating cardiac events [25]].

The surgical and anesthetic characteristics highlight the diverse needs of the patient population. Elective surgeries accounted for 60.0% of cases, with emergency procedures comprising 40.0%, indicating a notable proportion of urgent interventions. Emergency surgeries are often associated with fluid management challenges due to time constraints and the critical nature of these cases [26]. The predominance of general anesthesia (75.0%) further underscores the complexity of intraoperative management, as general anesthesia can impact hemodynamic stability and necessitate precise fluid optimization [27].

The findings suggest that perioperative fluid management in Bangladesh should account for the high prevalence of comorbidities, the diverse surgical case mix, and the predominance of general anesthesia. Incorporating evidence-based guidelines tailored to the local context, such as the use of hemodynamic monitoring and individualized fluid therapy protocols, could enhance patient outcomes and reduce complications [28].

These insights reinforce the need for ongoing capacity-building initiatives, including training for perioperative care teams and investment in advanced monitoring technologies. By addressing these gaps, the healthcare system in Bangladesh can move toward achieving more efficient and patient-centered surgical care.

The mean total intraoperative fluid volume administered (2500 ± 600 mL) aligns with standard fluid resuscitation protocols in surgical patients [29]. Crystalloids constituted the majority of fluids used (2000 ± 500 mL), consistent with current evidence favoring their use for maintenance and volume expansion due to their low cost and ease of availability [30]. Colloids (500 ± 200 mL) and blood products (300 ± 150 mL) were used selectively, reflecting their role in specific scenarios such as maintaining oncotic pressure and managing significant blood loss, respectively [31].

The availability of advanced hemodynamic monitoring tools, such as stroke volume variation (SVV) and pulse pressure variation (PPV), in only 40.0% of cases highlights a significant gap in optimizing intraoperative fluid management. Such tools are crucial for individualized fluid therapy, allowing precise titration of fluid volumes to avoid both hypovolemia and fluid overload [9]. The lack of monitoring in 60.0% of cases indicates a need for improved access to and integration of advanced monitoring technologies, particularly in resource-limited settings [32].

The mean length of hospital stay (5.2 ± 1.8 days) suggests a generally favorable recovery trajectory. However, the incidence of complications such as postoperative hypotension (12.5%), pulmonary edema (5.0%), and ICU admission (2.5%) underscores the importance of meticulous intraoperative fluid and hemodynamic management [33]. These complications are closely tied to fluid management strategies, as both under-resuscitation and over-resuscitation can lead to adverse outcomes, including hypotension and pulmonary edema [34].

In cases where advanced hemodynamic monitoring was available, corrective measures for intraoperative hypovolemia were implemented in 50.0% of patients. This suggests variability in intraoperative decision-making, potentially influenced by the availability of monitoring tools and clinician preferences. The balanced distribution of cases with and without corrective measures indicates the need for standardizing intraoperative practices to ensure optimal fluid management and minimize complications [35].

The predominance of crystalloid use and limited access to advanced hemodynamic monitoring emphasize the need for capacity-building initiatives, such as training perioperative teams in evidence-based fluid management strategies and expanding access to monitoring technologies. Studies have demonstrated that goal-directed fluid therapy guided by advanced monitoring can significantly improve surgical outcomes by reducing complications and shortening hospital stays [35,36].

Efforts should also focus on integrating protocols for fluid and hemodynamic management into standard surgical care, particularly in settings with resource constraints. By adopting a multidisciplinary approach, healthcare systems can enhance perioperative care and improve patient outcomes.

The relationship between fluid management and postoperative outcomes highlights the nuanced balance required to achieve optimal perioperative care. The observed associations between specific fluid administration practices and postoperative complications underscore the importance of individualized fluid therapy and advanced hemodynamic monitoring.

The mean administration of crystalloids (2000 ± 500 mL) was associated with a 12.5% incidence of postoperative hypotension. While crystalloids are a cornerstone of fluid management, their rapid distribution into the interstitial space can lead to inadequate intravascular volume, potentially contributing to hypotension [30]. This finding emphasizes the need for precise titration of crystalloids to match individual patient hemodynamic status and surgical demands, reducing the risk of volume depletion or excess.

The administration of colloids (500 ± 200 mL) correlated with a 5.0% incidence of pulmonary edema. Colloids, while effective in maintaining intravascular oncotic pressure, carry a risk of volume overload and pulmonary complications, particularly in patients with compromised cardiac or renal function [37]. This underscores the necessity of careful patient selection and monitoring when using colloids, as their benefits must be weighed against potential adverse effects.

Blood transfusions (mean volume of 300 ± 150 mL) were linked to a 2.5% ICU admission rate. This association may reflect the severity of surgical or perioperative blood loss requiring transfusion, rather than the transfusion itself. Nonetheless, transfusions can predispose patients to complications such as immunomodulation, infections, or fluid overload, further emphasizing the importance of judicious use of blood products [38].

The availability of advanced hemodynamic monitoring (SVV/PPV) demonstrated a potential advantage, with lower rates of postoperative hypotension (12.5%) compared to cases without such monitoring (14.5%). SVV and PPV are valuable tools for guiding fluid therapy, allowing for real-time assessment of dynamic changes in intravascular volume and fluid responsiveness [39]. Their use can reduce the likelihood of both hypovolemia and fluid overload, thereby improving postoperative outcomes.

These findings reinforce the critical interplay between fluid management strategies and postoperative outcomes. Optimized intraoperative fluid therapy requires careful consideration of fluid type, volume, and timing, tailored to the patient's hemodynamic profile and surgical context [34]. The incorporation of advanced hemodynamic monitoring should be prioritized to enhance decision-making and minimize complications, particularly in high-risk populations.

The observed complications, though relatively low in incidence, highlight the need for perioperative protocols that integrate evidence-based fluid management practices and advanced monitoring technologies. This approach can lead to improved recovery trajectories, reduced morbidity, and enhanced resource utilization.

The demographic and clinical characteristics of the study population underscore the necessity of individualized and context-specific fluid management protocols to optimize perioperative care in this setting.

These findings provide valuable insights into the operative and anesthetic practices in the study population, emphasizing the need for tailored strategies to optimize fluid management in both elective and emergency settings and across different anesthesia modalities

CONCLUSION

This study emphasizes the critical role of fluid management in influencing postoperative outcomes and highlights the need for tailored strategies that balance the risks of hypovolemia and fluid overload. The observed correlations between fluid type, volume, and complications such as hypotension, pulmonary edema, and ICU admissions emphasize the importance of individualized perioperative care. Advanced hemodynamic monitoring tools, such as SVV and PPV, demonstrated potential benefits in optimizing fluid therapy and improving outcomes, advocating for their broader integration into clinical practice. These findings provide a foundation for refining fluid management protocols to enhance patient safety and recovery in the perioperative setting.

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