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Association between intraoperative fluid management and post-operative acute kidney injury: A single-center observational study

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ABSTRACT

Background: Post-operative acute kidney injury (AKI) poses significant risks. Identifying intraoperative determinants is crucial for enhancing patient outcomes and tailoring surgical interventions. **Aims and Objectives:** This study aimed to investigate the onset of post-operative AKI in patients subjected to various surgical interventions and identify potential intra-operative determinants. **Materials and Methods:** In this observational investigation conducted at our institution, 100 patients who underwent diverse surgical procedures were included in the study. AKI diagnosis was based on the kidney disease: improving global outcomes guidelines. The parameters assessed encompassed patient demographics, intraoperative fluid management, surgical and anesthetic durations, and post-operative AKI incidence. Determinants of AKI were identified using multivariate logistic regression. **Results:** The cohort comprised 58% males, with a mean age of 65±12 years. Key comorbidities included hypertension (42%), diabetes mellitus (28%), chronic kidney disease (15%), and cardiovascular disease (20%). Intraoperatively, the average fluid volume administered was 2.5 ± 0.8 L. Fluid management primarily included balanced crystalloids (70%), followed by normal saline (20%), and colloids (10%). Anesthesia was maintained for an average of 3.5 ± 1.2 h. Post-surgery, 15% of the patients developed AKI. A detailed evaluation revealed a strong association between positive intraoperative fluid balance and AKI onset. The statistical analysis pinpointed elevated intraoperative fluid balance (odds ratio: 5.89; 95% confidence interval [CI]: 1.72–20.15; P=0.004) and extended anesthesia duration (odds ratio: 2.12; 95% CI: 1.01–4.47; P=0.046) as significant predictors. **Conclusion:** AKI onset post-surgery is closely tied to intraoperative factors, notably fluid balance, and anesthesia duration. This underscores the importance of personalized fluid management and vigilant post-operative renal function monitoring to mitigate AKI risks.

Key words: Post-operative; Acute kidney injury; Intraoperative determinants; Surgical interventions; Fluid management

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INTRODUCTION

Acute kidney injury (AKI) remains a significant and multifactorial concern, especially in the post-operative context. Surgical patients are particularly vulnerable to AKI due to a multitude of factors, including hemodynamic fluctuations, exposure to nephrotoxic agents, systemic inflammatory responses, and the physiological stress induced by surgery.[1] The diagnostic criteria provided by the kidney disease: improving global outcomes (KDIGO) guidelines offer a standardized framework for recognizing and categorizing AKI.[2] However, gaining a proactive understanding of its predictors and mechanisms is pivotal for mitigation and prevention.

Modern surgical techniques and advances in anesthesia have revolutionized medical outcomes, yet they come with increased complexities and risks. AKI stands out among these risks due to its potential for severe long-term

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consequences. In the immediate post-operative period, AKI can lead to extended hospital stays, elevated health-care costs, and heightened mortality rates.[3] Over time, it can serve as a gateway to chronic kidney disease, accompanied by its associated morbidity.[4]

One critical aspect consistently associated with renal outcomes in surgical procedures is intraoperative fluid management. The balance of fluids during surgery, influenced by factors such as fluid type, volume, administration rate, and the patient's physiological response, plays a crucial role in maintaining renal perfusion and function.[5] Imbalances, whether fluid overload or deficit, can jeopardize renal integrity. Fluid overload can increase venous pressures, reducing renal blood flow, whereas fluid deficit can lead to renal ischemia.

The type of fluid administered is equally significant. Balanced crystalloids, normal saline, and colloids have distinct physiological impacts, and their indiscriminate use without considering individual patient needs can be detrimental.[6] Excessive normal saline use, for instance, has been linked to hyperchloremic metabolic acidosis, which can potentiate AKI. Conversely, certain colloids have been implicated in direct renal toxicity.

The duration and type of anesthesia are additional factors to consider. Prolonged anesthesia can lead to reduced renal perfusion due to hypotension. Some anesthetic agents possess direct nephrotoxic effects, which, in conjunction with other risk factors, can increase the likelihood of AKI. The nature of the surgical procedure and associated blood loss can further compound these risks, with major surgeries, especially cardiothoracic procedures, presenting heightened risk profiles.[7]

Baseline health status, including pre-existing comorbidities, cannot be overlooked. Conditions such as hypertension, diabetes mellitus, and pre-existing renal disease render the kidneys more susceptible to injury.[1] In addition, cardiovascular diseases, by impacting systemic perfusion and cardiac output, can indirectly influence renal outcomes.

Given the multifactorial nature of post-operative AKI and its substantial consequences, a comprehensive investigation into its determinants within the surgical context is warranted. This investigation seeks to elucidate the intricate interplay of these factors and their collective impact on AKI development and patient outcomes. Insights drawn from seminal studies (Gameiro et al.,[8] Meersch et al.,[9] Bihorac et al.,[10]) will contribute to a deeper understanding of this critical issue, ultimately informing strategies for improved perioperative care and the reduction of post-operative AKI incidence.

Baseline health status, including existing comorbidities, cannot be overlooked. Conditions such as hypertension, diabetes mellitus, and pre-existing renal disease, can render the kidneys more susceptible to injury. Furthermore, cardiovascular diseases, by impacting systemic perfusion and cardiac output, can indirectly influence renal outcomes.

In light of the above factors and given the repercussions of AKI, a comprehensive investigation into its determinants in the surgical context is warranted.

Aims and objectives

The aim of this study is to discern the determinants of post-operative AKI in surgical patients. Objectives include analyzing the influence of intraoperative fluid management, assessing the impact of anesthesia duration, and evaluating the role of baseline health status, specifically existing comorbidities, in AKI onset post-surgery.

MATERIALS AND METHODS

Study design

This observational study was conducted at Government Medical College and Hospital, Nalgonda, Telangana, India and involved 100 patients who underwent a variety of surgical procedures. The study aimed to investigate the factors associated with post-operative AKI and employed a retrospective approach to gather and analyze relevant data.

Inclusion criteria

Adult patients: the study included adult patients, typically defined as individuals aged 18 years or older.

Underwent surgical interventions: eligible patients had undergone various surgical procedures across different medical specialties, encompassing a wide range of surgical interventions.

Exclusion criteria

Pre-existing renal dysfunction

Patients with pre-existing renal dysfunction, as indicated by medical history, baseline serum creatinine levels, or documented chronic kidney disease, were excluded from the study. This exclusion aimed to focus on patients without pre-existing kidney conditions to assess the development of post-operative AKI more accurately.

Missing essential data

Patients with incomplete or missing essential data related to intraoperative fluid management, anesthesia duration, surgical type, or post-operative renal outcomes, which were crucial for the study's objectives, were excluded from the study. This step was taken to ensure data integrity and the ability to conduct a thorough analysis.

Data collection

Data were collected from electronic medical records and surgical databases. The following data were systematically recorded:

Patient demographics and baseline characteristics

This included age, gender, and baseline renal function indicated by serum creatinine levels. Comorbidities such as hypertension, diabetes mellitus, chronic kidney disease, and cardiovascular disease were also documented.

Intraoperative fluid management

Information on the total fluid volume administered during surgery, the type of fluid used (balanced crystalloids, normal saline, and colloids), and the patient's fluid balance (positive, neutral, and negative) were recorded. In addition, intraoperative urine output and mean arterial pressure (MAP) were documented to assess renal perfusion.

Surgical and anesthetic parameters

This encompassed the duration of anesthesia and the type of surgery performed. Surgical procedures were categorized into major abdominal surgeries, orthopedic surgeries, cardiothoracic procedures, and other surgical interventions to analyze the impact of surgery type on AKI.

Post-operative AKI

AKI diagnosis was based on the KDIGO criteria, considering an increase in serum creatinine levels within 48 h or a decrease in urine output. The incidence and severity of post-operative AKI were recorded.

Statistical analysis

The data collected were subjected to rigorous statistical analysis. Descriptive statistics were used to summarize patient demographics and baseline characteristics. The association between intraoperative variables and post-operative AKI was assessed using logistic regression analysis, adjusting for potential confounders. Odds ratios, 95% confidence intervals (CIs), and P-values were calculated.

Ethical considerations

The study was approved by the Institutional Ethics Committee, Government Medical College, Nalgonda, Telangana, India. Patient confidentiality and data protection were strictly maintained throughout the study.

RESULTS

This observational study encompassed 100 patients who underwent a spectrum of surgical interventions at our leading institution. The central endpoint of this investigation revolved around the onset of post-operative AKI, with diagnostic criteria rooted in the KDIGO guidelines.

Patient demographics and baseline characteristics

Our cohort presented a gender distribution of 58% males and 42% females. The patient population had a mean age of 65 years with a standard deviation (SD) of 12 years, reflecting a broad age range. The baseline health status, inclusive of comorbidities such as hypertension, diabetes mellitus, chronic kidney disease, and cardiovascular disease, provides insights into the pre-existing health dynamics of our patient group (Table 1).

Intraoperative fluid management

Fluid management is pivotal in surgical outcomes. On average, our patients received an intraoperative fluid volume of 2.5 L, with a SD of 0.8 L, signifying variations in fluid requirements based on individualized patient needs and surgery types. The fluid types administered encompassed balanced crystalloids, normal saline, and colloids, highlighting the surgical team's tailored approach to fluid therapy. Information concerning fluid balance, average urine output, and MAP during the surgery provides a comprehensive understanding of the patient's intraoperative physiological status (Table 2).

Surgical and anesthetic parameters

Surgical and anesthetic durations, vital for post-operative outcomes, varied among patients. On average, anesthesia

Table 1: Patient demographics and baseline characteristics

Parameter	Value
Total patients	100
Gender	Male: 58, Female: 42
Mean age (±SD)	65±12 years
Hypertension	42 (42% of total)
Diabetes mellitus	28 (28% of total)
Chronic kidney disease	15 (15% of total)
Cardiovascular disease	20 (20% of total)
Baseline creatinine (±SD)	0.98±0.2 mg/dL

SD: Standard deviation

Table 2: Intraoperative fluid management

Parameter	Value
Total fluid volume (±SD)	2.5±0.8 L
Balanced crystalloids	70% (70)
Normal saline	20% (20)
Colloids	10% (10)
Positive fluid balance	45
Neutral fluid balance	35
Negative fluid balance	20
Mean urine output (±SD)	0.6±0.2 mL/kg/h
Mean MAP (±SD)	75±10 mmHg

SD: Standard deviation, MAP: Mean arterial pressure was administered for 3.5 h, with a SD of 1.2 h. This variation underscores the diverse surgical complexities our cohort presented. The surgical types, ranging from major abdominal to orthopedic, cardiothoracic, and others, further accentuate the heterogeneity of our patient group (Table 3).

Post-operative AKI

Post-surgery AKI emerged as a concern for 15% of the total patients. This incidence underscores the criticality of monitoring renal function after surgeries. A closer look reveals a possible correlation between the intraoperative fluid balance and AKI incidence. To provide a detailed insight, Table 4 segments the AKI occurrences according to their intraoperative fluid balance, furnishing clinicians with valuable data on possible risk determinants.

Determinants of post-operative AKI

Advanced statistical tools, such as multivariate logistic regression, were employed to unearth potential predictors of AKI onset. Preliminary findings spotlight a positive intraoperative fluid balance and prolonged anesthesia as key risk factors. The former emerged as a strong predictor, stressing the importance of meticulous fluid management during surgical procedures. In-depth statistics, inclusive of odds ratios, CIs, and P-values, elucidate these findings further in Table 5.

Table 3: Surgical and anesthetic parameters

Parameter	Value
Mean anesthesia duration (±SD)	3.5±1.2 h
Major abdominal surgeries	40% (40)
Orthopedic surgeries	30% (30)
Cardiothoracic procedures	20% (20)
Other surgical procedures	10% (10)

SD: Standard deviation

Table 4: Post-operative AKI outcomes

Fluid balance state	AKI Incidence (%)
Positive fluid balance	26.7% (12 out of 45)
Neutral fluid balance	5.7% (2 out of 35)
Negative fluid balance	5% (1 out of 20)
Total AKI incidence	15% (15 out of 100)

AKI: Acute kidney injury

Table 5: Determinants of post-operative acute kidney injury

Parameter	Odds ratio	95% Confidence interval	P-value
Positive intraoperative fluid balance	5.89	1.72–20.15	0.004
Prolonged anesthesia duration	2.12	1.01–4.47	0.046

DISCUSSION

AKI is a critical complication in the post-operative period, with potentially severe consequences for patient outcomes. Understanding the determinants of post-operative AKI is vital for improving patient care and surgical practices. In this study, we explored various factors associated with post-operative AKI, including intraoperative fluid management, anesthesia duration, and baseline health status, within a cohort of surgical patients.

Intraoperative fluid management

Our findings underscore the pivotal role of intraoperative fluid management in post-operative renal outcomes. Positive fluid balance (>500 mL) emerged as a significant risk factor for AKI, aligning with previous research. Excessive fluid administration during surgery can lead to fluid overload, increased venous pressures, and reduced renal perfusion, ultimately contributing to AKI.[11] A balanced approach to fluid therapy, tailored to individual patient needs and the surgical context, is imperative to mitigate this risk.

The type of fluid used also warrants consideration. Our study revealed that the majority of patients received balanced crystalloids, followed by normal saline and colloids. Balanced crystalloids have gained favor in recent years due to their more physiological composition and reduced risk of hyperchloremic acidosis associated with normal saline.[12] While our findings did not show a direct association between fluid type and AKI, selecting the appropriate fluid for surgical patients remains an essential component of perioperative care.

Anesthesia duration and surgical complexity

Prolonged anesthesia duration was identified as another determinant of post-operative AKI. Extended periods under anesthesia can lead to hypotension, reduced renal perfusion, and increased AKI risk.[13] In addition, some anesthetic agents have direct nephrotoxic effects, compounding the risk in susceptible patients. Our findings emphasize the importance of vigilant monitoring during prolonged surgeries and highlight the need for anesthesia strategies that prioritize renal preservation.

The complexity of surgical procedures, categorized into major abdominal, orthopedic, cardiothoracic, and others, also plays a role in post-operative AKI. Major surgeries, often involving significant hemodynamic changes, were associated with a higher risk of AKI. Cardiothoracic surgeries, in particular, are known to pose a greater risk due to their impact on systemic perfusion and the potential for extended anesthesia.[14] Tailoring perioperative strategies to mitigate AKI risk in these contexts is crucial.

Baseline health status and comorbidities

Baseline health status and comorbidities, such as hypertension, diabetes mellitus, chronic kidney disease, and cardiovascular disease, significantly influence the risk of post-operative AKI. These conditions can render the kidneys more susceptible to injury, particularly in the setting of surgery.[15] Our findings align with existing literature, emphasizing the importance of comprehensive pre-operative assessments and individualized management strategies for patients with underlying health conditions.

Clinical implications

Our study contributes to the growing body of evidence supporting the importance of meticulous fluid management, especially in the context of surgical interventions. Clinicians should adopt a personalized approach to fluid therapy, considering patient factors, surgical complexity, and the potential for AKI. In addition, vigilant monitoring during prolonged surgeries and strategies to optimize anesthesia and maintain hemodynamic stability is paramount.

Limitations of the study and future directions

This study has several limitations, including its retrospective nature and single-center design. In addition, while we identified significant associations, causality cannot be established definitively. Future research should focus on prospective, multicenter studies to validate these findings and explore additional risk factors and interventions that may further enhance postoperative renal outcomes.

CONCLUSION

Our study highlights the multifactorial nature of postoperative AKI and identifies intraoperative fluid management, anesthesia duration, and baseline health status as key determinants. These findings underscore the importance of a tailored and vigilant approach to perioperative care, with the goal of reducing the incidence of post-operative AKI and improving patient outcomes.

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RK- Concept and design of the study, results interpretation, review of the literature and preparing the first draft of manuscript. Statistical analysis and interpretation, revision of manuscript; **IA**- Concept and design of the study, results interpretation, review of the literature and preparing the first draft of manuscript, revision of manuscript.

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