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Analysis of the Impact of the Infusion Volume of Intraoperative Intravenous Solutions on the Length of Hospital Stay

LAURA CAMPOS SANTOS¹ , CLARA BICALHO LOURENÇO¹ , BRUNO CAMPOS SANTOS² , NILSON FERREIRA DE OLIVEIRA JUNIOR² , CAROLINA TRANCOSO DE ALMEIDA² .

¹FACULDADE CIÊNCIAS MÉDICAS DE MINAS GERAIS, BELO HORIZONTE, MINAS GERAIS, BRAZIL.

²DEPARTMENT OF SURGERY OF FACULDADE CIÊNCIAS MÉDICAS DE MINAS GERAIS, BELO HORIZONTE, MINAS GERAIS, BRAZIL.

CORRESPONDING AUTHOR: LAURA CAMPOS SANTOS – ALAMEDA EZEQUIEL DIAS, 275 - CENTRO, BELO HORIZONTE - MG, 30130-110 - BRAZIL (+55) 31983712312

EMAIL: LAURAA_CAMPOS@HOTMAIL.COM

HIGHLIGHTS

What is already known?

- Protocols for surgical patient management improve care and outcomes.
- It is necessary to individualize patient care in the perioperative period.
- Overhydration in a patient can lead to worse clinical outcomes.

What has been shown?

- Volume infused ranged from 600 to 2,400 mL.
- 80% of herniorrhaphy and cholecystectomy patients were discharged on day one.
- No significant link was found between hospital stay length and infused volume.

How can the study contribute to the literature?

- Pioneering study on infused volume in herniorrhaphy and cholecystectomy.
- The study encourages multicenter research on factors affecting stay length.
- Focuses on proper surgical patient management to enhance care.

ABSTRACT

Introduction: The infusion of intraoperative intravenous solutions aims to optimize hemodynamic stability and correct deficits in the patient's clinical condition. However, the infused volume often diverges from the recommendations of protocols like Enhanced Recovery After Surgery (ERAS) and Aceleração da Recuperação Total Pós-Operatória (ACERTO) due to the subjectivity involved. Excessive fluid replacement is associated with renal hypoperfusion, tachyarrhythmia, and worsening respiratory patterns, increasing the risk of progression to sepsis and multiple organ failure. **Objective:** To assess the relationship between the volume of intraoperative intravenous fluid infusion and the length of hospital stay in individuals undergoing elective herniorrhaphy and laparoscopic cholecystectomy at a quaternary care hospital. **Methods:** A retrospective cross-sectional study reviewed 400 medical records of patients who underwent surgeries between January and December 2022. Two groups with different infused volumes (500-1100mL vs. 1150-2600mL) were compared, excluding cases with complications or requiring intensive care. **Results:** The median age was 57 years; 47% of patients were men and 54% women. Comorbidities such as hypertension and diabetes were present in 37.5% of cases, and 66% of patients were classified as ASA 2. The most common procedures were cholecystectomies (50%) and inguinal herniorrhaphies (26%). The predominant infusion was normal saline, with a median volume of 1,100 mL. About 80% of patients were discharged on the first postoperative day. **Conclusion:** There was no significant correlation between the infused volume and the length of hospital stay. Multicenter studies are needed to understand the effects of this intervention in medium-sized procedures.

Keywords: Surgery Department; Enhanced Recovery After Surgery; Intraoperative Period; Monitoring Intraoperative; General Surgery.

INTRODUCTION

The first reports on the administration of perioperative volume date back to 1832.¹ Since then, the understanding of its physiological effects has advanced. More recent studies have questioned the criteria for indication and the infused volume. It is known that restoring circulating plasma volume aims to ensure hemodynamic stability while preventing fluid accumulation in the interstitial space.² Thus, factors such as surgical technique, nutrition, medications, mental health, patient physiology, anesthetic drugs, and infusion volume influence recovery and, if properly managed, can minimize hospitalization time.³

The volume infused during the perioperative period has the main objectives of maintaining blood volume, optimization of preload and oxygen transport capacity, ensuring hemodynamic stabilization, and preserving electrolyte and acid-base balance.⁴ However, in practice, volume replacement tends toward hyperhydration, especially in patients undergoing epidural analgesia. Moreover, hypotension is often interpreted as hypovolemia and treated with aggressive fluid replacement.⁵ The consequences of excessive fluid replacement include prolonged ileus, reduced blood flow, renal cortical hypoperfusion, and tachyarrhythmia. Additionally, it is associated with myocardial dysfunction, acute pulmonary edema, and acute respiratory failure.² Thus, despite its theoretical benefits, large-volume infusion may lead to adverse effects, especially when intravenous fluid administration does not align with the patient's individual needs. A review of perioperative care is necessary, and protocols such as Enhanced Recovery After Surgery (ERAS) and Aceleração da Recuperação Total Pós-Operatória (ACERTO) are used for this purpose.

The ERAS protocol was first developed in 2001 and includes recommendations to reduce postoperative morbidity, promote faster recovery, and facilitate earlier hospital discharge. It covers preoperative care, in-

cluding nutritional support, fasting, prophylaxis, and analgesia. Intraoperative care involves surgical access routes, anesthetic techniques, and volume and electrolyte replacement. Postoperative care focuses on re-feeding and patient mobilization.⁵ It was designed to reduce surgical stress, preserve physiological functions, and optimize recovery in surgical patients.⁶ Its authors emphasize that the primary goal of the protocol is to enhance patient recovery quality, rather than merely accelerating surgery and recovery time.⁷ Similarly, in 2005, the Júlio Muller University Hospital developed the ACERTO project based on the ERAS protocol. Its focus is on reducing hospital length of stay, minimizing the use of blood products, lowering rates of surgical site infections and operative complications, and ultimately decreasing mortality.⁸ This is a multimodal perioperative care program grounded in evidence-based medicine, contrasting with traditional empirical approaches.⁹ These protocols enhance patient recovery by addressing both physiological and psychological aspects of care, ensuring greater comfort throughout the surgical process.¹⁰

The implementation of protocols for intravenous fluid prescription offers benefits in preventing postoperative complications. In the ACERTO experience, clinical outcomes before and after protocol implementation showed a reduction of approximately 35% in intravenous fluid volume during the immediate postoperative period and 47% on the first postoperative day.¹¹ Recent studies on restrictive fluid management in the postoperative period have also shown a reduced need for blood transfusions and lower urinary output, along with shorter hospital stays and fewer postoperative complications.⁷ Therefore, an in-hospital analysis is needed to assess adherence to these protocols. Given the relationship between perioperative infusion volume and hospital length of stay, its applicability and potential benefits for public health systems should be evaluated. Thus, this study aims to assess the rela-

tionship between intraoperative infusion volume and hospital length of stay in patients undergoing elective laparoscopic abdominal wall herniorrhaphy and cholecystectomy.

METHODS

Study design

This article presents a retrospective cross-sectional study investigating the relationship between intraoperative infusion volume and hospital length of stay in patients undergoing elective abdominal wall herniorrhaphy and laparoscopic cholecystectomy at a university hospital. Data collection was conducted via medical record review and the acquisition of relevant clinical information. Data were collected from medical records of patients without intraoperative complications, such as circulatory instability, blood transfusions, ICU referrals, or prior ICU bed reservations. Medical records from January 1st to December 31st, 2022, were reviewed until the minimum sample size of 385 patients was reached. The sample calculation considered a 5% significance level and a conservative approach for the estimated proportion, set at 50%, yielding a minimum required sample size of 385 patients.

Sample:

The study sample included patients who underwent elective abdominal wall herniorrhaphy and laparoscopic cholecystectomy. The minimum sample size of 385 medical records was determined using the formula proposed by Bolfarine and Bussab (2005), based on the following inclusion and exclusion criteria:

Inclusion criteria:

- Patients who underwent elective abdominal wall herniorrhaphy or laparoscopic cholecystectomy at a university hospital between January 1st and December 31st, 2022;
- Patients who followed the institution's prescribed fasting protocol (solid and liquid);

- Medical records with data on postoperative hospital length of stay and total intraoperative infusion volume.

Exclusion criteria:

- Patients who underwent surgeries without anesthesiological assistance;
- Patients who underwent emergency surgeries;
- Patients who did not adhere to the prescribed fasting period or failed to follow the university hospital protocol;
- Patients who had intraoperative complications involving circulatory instability;
- Patients who received blood components;
- Patients who were referred to the Intensive Care Unit or had prior ICU bed reservations;
- Incomplete medical records lacking data on postoperative hospital length of stay and total intraoperative infusion volume.

Instruments and Procedures:

A data collection form was developed on the REDCap platform (Research Electronic Data Capture, Vanderbilt University, USA) to gather relevant information from medical records. The collected variables included medical record number, patient age, procedure month, pre-existing comorbidities, surgical classification, type of surgery performed, postoperative hospital length of stay, intraoperative infusion volume, and occurrence of postoperative complications. Each variable was individually entered into the data management platform with categorical and numerical records. The medical record number was used as the primary identifier to prevent duplicates, as each patient is assigned a unique ID. Platform validation rules were continuously applied to detect anomalies in numerical trends, helping identify potential data entry errors.

Statistical analysis

Statistical analysis was performed using R software version 4.0.3. Numerical variables were analyzed using the Anderson-Darling normality test. The t-test or Mann-Whitney test was applied for comparison of means or medians. Potential associations between categorical variables were assessed using the Chi-square test or Fisher's Exact test. A significance level of 5% was established.

RESULTS

The study included 400 patient records, with 186 (47%) males and 214 (53%) females, and a median age of 57 years. Of these, 250 (63%) patients had pre-existing comorbidities, while the remaining 150 (37%) were healthy. The most common comorbidities included hypertension in 228 (57%) patients, diabetes mellitus in 61 (15%), and hypothyroidism in 27 (6.8%) patients. Other comorbidities in the sample are presented in the following table (Table 1).

Table 1. Comorbidities in the Overall Sample

Comorbidities	N = 400
Presence of Comorbidities	250 (63%)
Systemic Arterial Hypertension	172 (43%)
Coronary Artery Disease	3 (0.8%)
Cardiac Arrhythmia	3 (0.8%)
Diabetes Mellitus	61 (15%)
Chronic Obstructive Pulmonary Disease	15 (3.8%)
Other Pneumopathies	
Smoking	2 (0.5%)
Alcoholism	25 (6.3%)
Hypothyroidism	4 (1.0%)
Current Neoplasia	27 (6.8%)
Obesity	1 (0.3%)
Congestive Heart Failure	11 (2.8%)
Dialytic Chronic Kidney Disease	2 (0.5%)
Non-dialytic Chronic Kidney Disease	3 (0.8%)
Mood Disorders	3 (0.8%)
Dementias	23 (5.8%)
Autoimmune Diseases	6 (1.5%)
	3 (0.8%)

In terms of preoperative classification by the American Society of Anesthesiology (ASA), which predicts potential perioperative risks, 132 (33%) patients were classified as ASA 1, 263 (66%) as ASA 2, and 5 (1.3%) as ASA 3.

The surgeries performed included 104 (26%) unilateral inguinal hernioplasties, 21 (5.3%) incisional hernioplasties, 59 (15%) umbilical hernioplasties, 11 (2.8%) bilateral inguinal hernioplasties, and 22 (5.5%) epigastric herniorrhaphies. Furthermore, 199 (50%) of the analyzed medical records pertained to patients who underwent laparoscopic cholecystectomy. In terms of anesthetic modality, 210 (53%) patients received general anesthesia, 152 (38%) received spinal anesthesia, 33 (8.3%) had an epidural block, and 5 (1.3%) received local anesthesia with sedation.

Regarding fluid infusion, some patients received both 0.9% Sodium Chloride (Normal Saline) and Ringer's Lactate, while others received only 0.9% Sodium Chloride. In all 400 analyzed medical records (100%), 0.9% Sodium Chloride was infused in quantities ranging from 600 to 2400 ml, with a median of 1,100 ml. Ringer's Lactate was infused in only 4 patients (1.0%), with volumes ranging from 500 ml in 3 patients to 1000 ml in 1 patient.

Of the sample, 56 patients were discharged on the day of surgery, accounting for 14% of the total. The majority, 319 patients (80%), were discharged on the first day after surgery. The remaining patients were discharged between the second and fifteenth days after surgery.

A total of 25 patients (6.3%) experienced postoperative complications: 2 patients (0.5%) had bleeding, 16 patients (4%) had infectious complications, and 2 patients (0.5%) experienced prolonged ileus. Six patients (1.5%) required reoperation. No deaths were reported.

Analysis of the sample categorization by cross-referencing the ASA variable shows that all patients were classified as ASA 1, 2, or 3, with a median total infused volume of 1,100 mL across all three classes. No pa-

tients classified as ASA 4, 5, or 6 were included in the study due to the exclusion criteria. In terms of hospital stay, among ASA 1 patients, 17 (13%) were discharged on the day of surgery, while 108 (82%) were discharged the following day. Among ASA 2 patients, 38 (14%) were discharged on the day of surgery, and 208 (79%) were discharged the following day. For ASA 3 patients, 1 (20%) was discharged on the day of surgery, while 3 (60%) were discharged the next day.

Cross-referencing the length of hospital stay with the type of anesthesia revealed that 31 (55%) of the patients discharged on the day of the procedure received general anesthesia, while 16 (29%) received spinal anesthesia ($p<0.001$). On the first day post-surgery, 163 (51%) of the patients received general anesthesia, and 131 (41%) received spinal anesthesia ($p<0.001$). Among patients who stayed for two days or more, 16 (64%) received general anesthesia, while 5 (20%) received spinal anesthesia ($p<0.001$). The remaining patients received local anesthesia with sedation or an epidural block. The median total volume infused across all categories for the length of hospital stay variable was 1,100 mL.

To enhance data interpretation, a cross-tabulation was performed based on total volume, dividing the sample into two main groups: the first group with a total volume of 500 to 1,100 mL and the second group with a total volume of 1,150 to 2,600 mL. The median total volume of saline infused ranged from 1,100 mL in the first group to 1,600 mL in the second group ($p<0.001$). In the lower volume infused group, 32 (13%) patients were discharged on the day of surgery, 193 (81%) on the following day, and 5 (2.1%) on the second day after the procedure ($p>0.001$). In the higher volume infused group, 24 (15%) patients were discharged on the day of surgery, 126 (78%) on the following day, and 4 (2.5%) on the second postoperative day ($p>0.001$). In group 1, 13 patients (5.5%) experienced surgical complications, compared to 12 patients (7.4%) in group 2 ($p>0.001$). Additional comparative data between the two groups are presented in Table 2.

Table 2. Cross-tabulation by Volume Class

Characteristics	Volume Class			Value p ²
	Total, N = 4001	Between 500 e 1100, N = 2381	Between 1150 e 2600, N = 1621	
ASA				>0.9
1	132 (33%)	79 (33%)	53 (33%)	
2	263 (66%)	156 (66%)	107 (66%)	
3	5 (1.3%)	3 (1.3%)	2 (1.2%)	
Anesthetic Modality				0.092
Geral anesthesia	210 (53%)	114 (48%)	96 (59%)	
Local anesthesia with sedation	5 (1.3%)	4 (1.7%)	1 (0.6%)	
Epidural block	33 (8.3%)	19 (8.0%)	14 (8.6%)	
Spinal anesthesia	152 (38%)	101 (42%)	51 (31%)	
0,9% Saline Solution				
Yes	400 (100%)	238 (100%)	162 (100%)	
Ringer Lactate				0.3
Yes	4 (1.0%)	1 (0.4%)	3 (1.9%)	
Total amount of 0,9% Saline Solution	1,100 (1,100, 1,600)	1,100 (1,100, 1,100)	1,600 (1,500, 1,600)	<0.001
Total amount of Ringer Lactate				>0.9
500	3 (75%)	1 (100%)	2 (67%)	
1000	1 (25%)	0 (0%)	1 (33%)	
Length of hospital stay				0.6
0	56 (14%)	32 (13%)	24 (15%)	
1	319 (80%)	193 (81%)	126 (78%)	
2	9 (2.3%)	5 (2.1%)	4 (2.5%)	
3	3 (0.8%)	2 (0.8%)	1 (0.6%)	
4	4 (1.0%)	1 (0.4%)	3 (1.9%)	
6	4 (1.0%)	3 (1.3%)	1 (0.6%)	
7	1 (0.3%)	0 (0%)	1 (0.6%)	
8	1 (0.3%)	0 (0%)	1 (0.6%)	
9	1 (0.3%)	0 (0%)	1 (0.6%)	
10	1 (0.3%)	1 (0.4%)	0 (0%)	
15	1 (0.3%)	1 (0.4%)	0 (0%)	
Post-surgical complications				0.4
Yes	25 (6.3%)	13 (5.5%)	12 (7.4%)	
Reoperation				0.7
Yes	6 (1.5%)	3 (1.3%)	3 (1.9%)	
Death				
	400 (100%)	238 (100%)	162 (100%)	

Characteristics	Volume Class			Value p ²
	Total, N = 4001	Between 500 e 1100, N = 2381	Between 1150 e 2600, N = 1621	
Bleeding				0.2
Yes	2 (0.5%)	0 (0%)	2 (1.2%)	
Infections				0.4
Yes	16 (4.0%)	8 (3.4%)	8 (4.9%)	
Prolonged Ileus				0.5
Yes	2 (0.5%)	2 (0.8%)	0 (0%)	
Time classes				0.7
Zero days	56 (14%)	32 (13%)	24 (15%)	
One day	319 (80%)	193 (81%)	126 (78%)	
>= Two days	25 (6.3%)	13 (5.5%)	12 (7.4%)	

DISCUSSION

Current literature shows that implementing perioperative care protocols is directly associated with improved patient outcomes. Aguilar-Nascimento et al. (2020) demonstrated that the ACERTO protocol used in hernioplasties not only reduces morbidity and hospitalization time but also significantly decreases hospital costs. These findings indicate that the guidelines outlined in the protocol promote greater efficiency in patient care. For instance, shorter hospitalization times contribute to reduced potential costs associated with patient care.¹³ Teixeira et al. (2019) illustrate that in Brazilian tertiary centers, patients subjected to the ERAS protocol had a reduction in hospitalization time of up to two days compared to those who were not, also highlighting the resulting cost savings without affecting morbidity and mortality rates.¹⁴

The analysis of the data collected in this study reveals a reduction of approximately 2% in the surgical complication rate between the groups with lower total infusion volume compared to the group with higher total infusion volume (5.5% versus 7.4%; p 0.4). The analyzed complications included reoperation, death, bleeding, infections, and prolonged ileus. However, the significance level found in this study does not support the confirmation of the data illustrated in the current literature, which indicates a direct relationship between fluid restriction measures and a lower incidence of metabolic alterations.⁷

Regarding the choice of solution for surgery, 100% of the patients received saline solution, which contributes to lower rates of hyperglycemia during and after surgery, thereby reducing surgical complications.¹⁵ Other studies indicate that the choice between Ringer Lactate and saline solution does not affect postoperative outcomes in elective and non-cardiac surgeries, allowing for discretion by the anesthetist.¹⁶

In this study's sample, the predominant anesthetic modality was general anesthesia, used by 53% of patients, compared to 38% for spinal anesthesia, 8.3% for epidural block, and 1.3% for local anesthesia with sedation. Studies examining anesthesia in inguinal herniorrhaphies indicate that patients receiving local anesthesia experienced a higher incidence of pain during the perioperative period but spent less time in the recovery room.¹⁷ Therefore, the chosen anesthetic modality may be closely linked to longer hospital stays.

Netto et al. (2008) compared the outcomes of local versus regional anesthesia in inguinal herniorrhaphy, finding a 16-hour difference in the average length of hospital stay between the two anesthetic modalities. Patients receiving regional anesthesia had an average hospital stay of 43 hours, while those receiving local anesthesia stayed for 27 hours.¹⁸

Regarding the anesthetic modality in laparoscopic cholecystectomy, studies comparing general anesthesia to spinal anesthesia have found that spinal anesthesia offers better pain control and lower hospital costs for patients, although this modality is rarely used in clinical practice for this procedure.¹⁹ There was no difference in length of stay, as all patients were discharged after 24 hours, nor in terms of patient satisfaction.¹⁹ In the present study, all patients undergoing laparoscopic cholecystectomy received general anesthesia.

The intraoperative infusion regimen classified as restrictive by anesthesiology involves administering 10-15 ml/kg/h, while the liberal regimen can reach 30-40 ml/kg/h.⁴ There is disagreement about the overall superiority of one regimen over the other. Literature suggests that the liberal regimen may be superior in medium-sized surgical procedures, while the restrictive regimen appears to offer advantages, such as lower morbidity and shorter hospital stays, in large abdominal surgeries.⁴ Lorentz (2010) further emphasizes that, in healthy patients, the elimination of excess fluids of 22 ml/kg (approximately 1.5 L) may take on average, two days. As discussed in his study, the peak fluid translocation occurs 5 hours postoperatively and may persist for up to 72 hours. Comparing different infusion therapies is limited by the lack of standardization in studies on the limits of restrictive and liberal therapies. Samples from the same surgical center, as in the present study, tend to show minimal significant variability in the total infused volume, making it diffi-

cult to conduct a statistically significant analysis of the relationship between total volume and length of hospital stay. The variability in the studied sample ranged from 500 to 2600 mL, values that, despite potentially following different intraoperative infusion regimens, align with the perioperative averages recommended by various studies.

Aguilar-Nascimento et al. (2022) compared outcomes before and after the implementation of the ACERTO protocol in university hospitals for patients undergoing major digestive surgeries, finding results that highlight the benefits of care standardization. Patients treated under the ACERTO protocol had a median hospital stay three days shorter than those operated on before the protocol was adopted.²⁰ In terms of mortality, the study found similar rates in both groups. Regarding the risk of postoperative complications and surgical site infections, benefits were observed following the adoption of the ACERTO protocol.²⁰ Thus, while there is a substantial body of literature supporting the effectiveness of protocols for major surgeries, research on small or medium-sized surgeries is limited, highlighting the need for further studies to fully assess their impact.

Moreover, it is important to note that this study was one of the first to compare hospital length of stay with total infused volume. The results support the need for further studies to evaluate the implementation of protocols such as ERAS and ACERTO in Brazilian healthcare centers. To conduct a comprehensive analysis of factors contributing to prolonged hospital stays, it is essential to consider additional determinants such as the patient's cognitive function, age, level of dependence in daily living activities, mobility capacity, and available social support - factors that extend beyond the total volume infused during the intraoperative period.²¹

Notably, about 99% of the sample in this study had a preoperative ASA I or ASA II classification. This tool is used to classify patients and predict the risk of peri-

operative complications. Only 1% of the sample had an elevated risk of unfavorable outcomes and, consequently, longer hospital stays.²²

Future discussions regarding the additional benefits of reducing hospital length of stay are extensive and deserve attention. The established relationship between length of stay, malnutrition, and postoperative outcomes should drive targeted care for surgical patients, emphasizing the need to understand the factors that may contribute to shorter hospital stays. Literature suggests that protocols like ACERTO implement effective measures for patients undergoing elective gastrointestinal surgeries, such as those analyzed in the present study.

Limitations

The lack of statistical significance in certain variables, such as hospital length of stay when comparing the two groups with different total volumes infused, reflects the limitations found in studies with restricted sampling - typically conducted at a single surgical center or involving few surgical modalities. Current literature indicates, for instance, the failure of ERAS implementation in emergency settings in low-income centers, raising doubts about whether the same benefits exist in resource-limited environments.²³ Therefore, new multicenter studies are needed to further validate the effectiveness of perioperative management protocols.

CONCLUSION

The volume of intraoperative intravenous solution infusion did not have a statistically significant impact on hospital length of stay in the present study. Surgical complication rates were lower in the group with lower total volume infused compared to the group with higher total volume (5.5% versus 7.4%; p 0.4). Multicenter studies are needed to gain a better understanding of the effects of the intervention in medium-sized procedures.

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THE AUTHORS DECLARE THAT THEY HAVE NO KNOWN COMPETING FINANCIAL INTERESTS OR PERSONAL RELATIONSHIPS THAT COULD HAVE APPEARED TO INFLUENCE THE WORK REPORTED IN THIS PAPER.