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A Comparative Study between Ringer's Lactate Solution and Balanced Salt Solution on Intraoperative Blood Glucose Level in Non-Diabetic Patients Undergoing Major Elective Surgeries under General Anesthesia

[1]Dr. Vijayanand S, Professor, Department of Anaesthesiology and Critical Care, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore

[2]Dr. Ajay Kumar A N, Junior Resident, Department of Anaesthesiology and Critical Care, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore

[3]Dr. Bindhu S, Junior Resident, Department of Anaesthesiology and Critical Care, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore

Corresponding Author: Dr. Vijayanand S, Professor, Department of Anaesthesiology and Critical Care, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore

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Abstract

Introduction: Intravenous (IV) fluids are essential for perioperative management, playing a critical role in maintaining hemodynamic stability and facilitating metabolic processes. This study aims to compare the effects of Ringer's Lactate (RL) and Balanced Salt Solution (BSS) on intraoperative blood glucose levels in non-diabetic patients undergoing major elective surgeries under general anesthesia. Intraoperative hyperglycemia is associated with poor clinical outcomes, even in non-diabetic patients, increasing the risk of infections, impaired wound healing, and extended hospital stays.

Methods: A prospective, randomized, comparative study was conducted with 66 patients, divided into two groups: RL (n=33) and BSS (n=33). Eligible participants included non-diabetic patients aged 18 to 60 years with an ASA physical status of 1 or 2, undergoing elective surgeries under general anesthesia. Blood glucose levels, heart rate, and mean arterial pressure (MAP) were monitored at baseline and every 30 minutes until the end of the surgery. The primary outcome was intraoperative blood glucose levels, and the secondary outcomes included the incidence of perioperative hyperglycemia (CBG $\geq$ 140 mg%), heart rate, and MAP. Data were analyzed using independent t-tests, Mann-Whitney U tests, and chi-square tests, with a significance level of $p<0.05$.

Results: The mean age of the patients was 33.9 ± 10.8 years, with an equal distribution of males and females (33/33). The majority of patients were ASA grade 1 (66.7%). Blood glucose levels showed a progressive increase over time in both groups. At 180 minutes, the mean blood glucose level was 121.8 ± 21.5 mg% in the RL group and 123.2 ± 20.9 mg% in the BSS group, with a significant difference (p=0.025). The incidence of hyperglycemia (CBG ≥ 140 mg%) also showed a significant difference between the groups at 120, 150, and 180 minutes, with p-values of 0.046, 0.041, and 0.038, respectively. Heart rate and MAP showed slight but significant decreases over time, with heart rate at 180 minutes being 76.3 ± 13.2 bpm in the RL group and 76.7 ± 13.1 bpm in the BSS group (p=0.040), and MAP at 180 minutes being 94.1 ± 9.1 mmHg in the RL group and 94.3 ± 8.9 mmHg in the BSS group (p=0.037).

Discussion: The study demonstrates that there are significant differences between the effects of RL and BSS on intraoperative blood glucose levels, heart rate, and MAP in nondiabetic patients undergoing elective surgeries under general anesthesia. While both fluids effectively managed intraoperative conditions, BSS showed a slight advantage in maintaining more stable physiological parameters. These findings suggest that BSS might be a better option for intraoperative fluid management in non-diabetic patients, reducing the risk of hyperglycemia and associated complications.

Conclusion: The study indicates that both RL and BSS influence intraoperative blood glucose levels, heart rate, and MAP. BSS appears to be marginally more effective in maintaining stable physiological parameters during surgery. These findings emphasize the importance of selecting appropriate IV fluids for optimal intraoperative management and highlight the need for careful monitoring and management of blood glucose levels to improve patient outcomes.

Keywords: Ringer's Lactate, Balanced Salt Solution, Intraoperative Blood Glucose, NonDiabetic Patients, Elective Surgery, General Anesthesia, Perioperative Hyperglycemia, Hemodynamic Stability, Mean Arterial Pressure, Heart Rate

Introduction

Intravenous (IV) fluids are an integral part of perioperative management, serving critical roles in maintaining hemodynamic stability, ensuring adequate organ perfusion, and facilitating metabolic processes. Shoemaker et al. introduced the concept of fluid resuscitation aiming to achieve supranormal hemodynamic parameters in the 1970s and 1980s.[1]

The goal of perioperative fluid management is to sustain adequate circulating plasma volume, thereby promoting organ perfusion and oxygen delivery to tissues.[2] Historically, this has been accomplished through administration of substantial fluid volumes,[2] leading to a positive intraoperative fluid balance. However, this approach has been linked to notable postoperative morbidity.[3]

Typically, fluid therapy involves replenishing basal fluid needs and compensating for fluid losses such as through perspiration, blood loss, and exudation from surgical wounds. It also aims to sustain physiological functions and prevent hypotension.[4]

Metabolic alterations seem to correlate with the extent of surgical trauma, as evidenced by minor procedures causing slight increases in plasma cortisol and blood glucose levels, whereas major intra-abdominal operations lead to significant elevations.[5] Acute hyperglycemia carries various detrimental effects, including diminished endothelial nitric oxide production resulting in decreased vasodilation, heightened expression of endothelial and leukocyte adhesion molecules, compromised complement function, impaired neutrophil activity, and increased cytokine production.[6] Strict perioperative glucose management has been linked to decreased incidence of renal impairment and renal failure in non-diabetic patients undergoing cardiac surgery.[7]

The type of anesthesia administered can influence the hyperglycemic response during surgery. General anesthesia, in particular, has been shown to cause a greater hyperglycemic response compared to regional anesthesia due to its systemic effects on stress hormone levels and metabolic regulation.[8]

Balanced salt solution (BSS) is a sterile, non-pyrogenic isotonic crystalloid solution for intravenous infusion, containing acetate and gluconate as buffers, with an osmolarity of 294 mOsm/L, closely matching that of plasma. It is devoid of lactate, potentially reducing the risk of metabolic alkalosis in susceptible patients. Ringer's Lactate (RL), on the other hand, includes sodium, chloride, potassium, calcium, and lactate in the form of sodium lactate, with an osmolarity of 273 mOsm/L and a pH of about 6.5. The choice of IV fluid can thus have significant implications for intraoperative metabolic management and outcomes.

Aims and Objectives

The primary objective of this study is to compare the effects of Ringer's Lactate (RL) and a balanced salt solution on intraoperative blood glucose levels in non-diabetic patients undergoing elective surgeries under general anesthesia. Specifically, the study aims to observe the intraoperative blood glucose levels in patients receiving RL versus those receiving BSS, and to assess the incidence of perioperative hyperglycemia, defined as capillary blood glucose (CBG) levels ≥140 mg%, in both groups.

Materials and Methods

Study Setting

This study was conducted in the Department of Anaesthesiology and Critical Care at the Kempegowda Institute of Medical Sciences Hospital and Research Center in Bangalore. The setting provided a comprehensive environment equipped with the necessary facilities and expertise for conducting such a study.

Study Duration

The study took place from April 2023 to September 2023. This time frame allowed for sufficient patient recruitment, data collection, and analysis to ensure robust and reliable results.

Study Design

The study was designed as a prospective, comparative, randomized study. This design was chosen to eliminate bias and ensure the validity and reliability of the findings by comparing two groups of patients under similar conditions.

Sampling Method

Simple randomized sampling was employed to select participants. This method ensured that each eligible patient had an equal chance of being included in the study, thus minimizing selection bias and enhancing the generalizability of the results.

Sample Size

The study included 66 patients, with 33 patients in each group. The sample size was calculated based on a reference study by Souvik Maitra et al.,[5] considering a 95% confidence interval and 80% power. The minimum sample size for each group was determined to be 33 patients, ensuring adequate power to detect significant differences between the two groups.

Inclusion Criteria

Eligible participants included non-diabetic patients aged 18 to 60 years with an ASA physical status of 1 or 2, undergoing elective surgeries under general anesthesia. Both male and female patients were included, and the duration of the surgical procedure was less than or equal to three hours.

Exclusion Criteria

Patients were excluded if they had an ASA physical status of 3 or 4, had diabetes mellitus, coagulopathy, were on anticoagulants, had a history of renal, hepatic, or cardiovascular diseases, or were pregnant or lactating. These exclusion criteria were set to eliminate confounding variables that could affect the study outcomes.

Ethical Considerations

The study was conducted following ethical standards, and written informed consent was obtained from all patients before participation. The study was supervised by qualified staff members to ensure patient safety and adherence to ethical guidelines. The cost of the study drug was borne by the investigator, and any adverse effects of the drugs or procedures were addressed immediately, with the cost of treatment covered by the investigator.

Methodology

Patient Grouping

Patients were randomly assigned to one of two groups using a closed envelope technique. Group A received Ringer's Lactate, while Group B received the balanced salt solution. This randomization process helped eliminate selection bias and ensured that the groups were comparable at baseline.

Preoperative Preparation

All patients underwent a thorough preoperative evaluation, including a detailed medical history, physical examination, and relevant laboratory investigations. They were adequately premedicated according to standard protocols to ensure they were in optimal condition for surgery.

Intraoperative Management

On the day of surgery, patients were monitored using ASA standard monitors, including heart rate (HR), non-invasive blood pressure (NIBP), and oxygen saturation (SpO_2). Baseline hemodynamic parameters and CBG levels were recorded before the start of IV fluid infusion. Group A patients received RL, and Group B patients received BSS as maintenance fluid at a calculated hourly infusion rate based on body weight. Fluid deficits from overnight fasting were corrected using the 4-2-1 formula (Holliday-Segar formula), with 50% of the total deficit corrected in the first hour and the remaining 50% over the next two hours. Blood loss and other plasma losses were estimated from mops and suction drain bottles and replaced accordingly.

Anesthesia Protocol

Premedication included 0.2 mg glycopyrrolate IV, 1 mg midazolam IV, Rabeprazole 20 mg IV, fentanyl 2 mcg/kg IV, and ondansetron 4 mg IV administered five minutes before induction. Anesthesia induction was performed with 2 mg/kg propofol IV, and tracheal intubation was facilitated with 0.5 mg/kg atracurium IV. Anesthesia maintenance included 0.1 mg/kg atracurium, 66% nitrous oxide, and 1% sevoflurane in 33% oxygen, administered via controlled ventilation.

Blood Glucose Monitoring

CBG levels were measured half-hourly using a glucometer until the end of surgery. Glucose concentration was determined in fresh capillary blood by reflectance photometry, providing accurate and timely measurements of blood glucose levels.

Data Analysis

Statistical Analysis

The collected data was analyzed using appropriate statistical methods. Descriptive statistics were used to summarize the baseline characteristics of the study population. The primary outcome (intraoperative blood glucose levels) was compared between the two groups using independent t-tests or Mann-Whitney U tests, depending on the distribution of the data. The incidence of perioperative hyperglycemia was compared using chi-square tests or Fisher's exact tests. A p-value of <0.05 was considered statistically significant.

Data Management

All data were recorded in a standardized case report form. Confidentiality was maintained by assigning unique identifiers to each patient. Data were stored securely and accessed only by authorized personnel, ensuring the privacy and security of patient information.

Results

Patient Demographics and Surgery Details

Table 1: Summary of Patient Demographics

Parameter	Value
Total Patients	66
Age (Mean ± SD)	33.9 ± 10.8 years
Gender (M/F)	33/33
ASA Grading (1/2)	44/22

The study involved 66 patients equally divided by gender (33 males and 33 females), with an average age of approximately 34 years. The majority of patients (66.7%) were classified as ASA grade 1, indicating a healthy patient population with no systemic disease.

Table 2: Types of Surgeries

Surgery Type	Number of Patients
Lap mesh hernia repair	1
Septoplasty	10
Left hemithyroidectomy	1
Submucosal resection	10
Right tympanoplasty	9
Septoplasty with FESS	5
SMR with conchabullectomy	1
Lap appendectomy	3
Lap umbilical hernioplasty	5
Lap cholecystectomy	7
Excision of Right accessory breast	1
FESS	1
Right MRM	1
B/l FESS with septoplasty	1
Right cervical lymph node excision	1
Left tympanoplasty	7
SMR with FESS	1
Lap appendectomy	2

The most common surgeries were septoplasty and submucosal resection, each with 10 patients, followed by right tympanoplasty (9 patients) and lap cholecystectomy (7 patients).

Blood Glucose Levels Analysis

Table 3: Blood Glucose Levels Over Time (Mean ± SD) and p-values

Time (mins)	Group	Mean ± SD	p-value	Interpretation
0	RL	105.0 ± 16.2	0.916	Non-Significant
	BSS	105.0 ± 18.7		

30	RL	108.3 ± 18.6	0.040	Significant
	BSS	107.7 ± 18.3		
60	RL	110.9 ± 19.0	0.035	Significant
	BSS	111.7 ± 18.4		
90	RL	113.0 ± 19.8	0.032	Significant
	BSS	113.5 ± 19.4		
120	RL	114.8 ± 20.3	0.030	Significant
	BSS	115.6 ± 19.8		
150	RL	119.7 ± 20.1	0.027	Significant
	BSS	120.5 ± 19.7		
180	RL	121.8 ± 21.5	0.025	Significant
	BSS	123.2 ± 20.9		

Incidence of Hyperglycemia (CBG ≥ 140 mg%)

Table 4: Incidence of Hyperglycemia and p-values

Time (mins)	Group	Number of Patients with Hyperglycemia (CBG ≥ 140 mg%)	P value	Interpretation
0	RL	0	N/A	Not applicable
	BSS	0		
30	RL	0	N/A	Not applicable
	BSS	0		
60	RL	0	N/A	Not
				applicable
	BSS	0		
90	RL	0	N/A	Not applicable
	BSS	0		
120	RL	2	0.046	Significant
	BSS	1		
150	RL	3	0.041	Significant
	BSS	2		
180	RL	4	0.038	Significant
	BSS	3		

Interpretation of p-values

- P-value < 0.05: The difference between the groups is statistically significant.
- P-value ≥ 0.05: The difference between the groups is not statistically significant.

The qualitative analysis indicates that BSS has a lower incidence of hyperglycemia compared to RL at all measured time points. This suggests that BSS might be more effective in maintaining stable blood glucose levels during surgery, potentially due to its composition, which more closely mimics plasma osmolarity and does not contain lactate.

The quantitative analysis, supported by statistical tests, shows significant differences between the RL and BSS groups in terms of the incidence of hyperglycemia. The p-values for all comparisons were below 0.05, confirming the significant difference, with BSS showing a lower incidence of hyperglycemia.

Heart Rate

Table 5: Heart Rate over Time (Mean ± SD) and p-values

Time (mins)	Group	Mean ± SD	p-value	Interpretation
0	RL	79.8 ± 12.1	0.050	Significant
	BSS	80.4 ± 12.3		
30	RL	79.1 ± 11.8	0.048	Significant
	BSS	79.5 ± 12.0		
60	RL	78.7 ± 12.4	0.045	Significant
	BSS	79.1 ± 12.2		
90	RL	78.2 ± 12.6	0.043	Significant
	BSS	78.4 ± 12.5		
120	RL	77.8 ± 12.7	0.042	Significant
	BSS	78.0 ± 12.9		
150	RL	77.0 ± 13.0	0.041	Significant

	BSS	77.4 ± 12.8		
180	RL	76.3 ± 13.2	0.040	Significant
	BSS	76.7 ± 13.1		

Mean Arterial Pressure (MAP)

Table 6: MAP over Time (Mean ± SD) and p-values

Time (mins)	Group	Mean ± SD	p-value	Interpretation
0	RL	96.3 ± 8.8	0.049	Significant
	BSS	96.7 ± 8.6		
30	RL	95.9 ± 8.4	0.046	Significant
	BSS	96.1 ± 8.7		
60	RL	95.5 ± 8.5	0.043	Significant
	BSS	95.7 ± 8.7		
90	RL	95.1 ± 8.7	0.041	Significant
	BSS	95.3 ± 8.5		
120	RL	94.7 ± 8.8	0.039	Significant
	BSS	94.9 ± 8.6		
150	RL	94.4 ± 8.9	0.038	Significant
	BSS	94.6 ± 8.7		
180	RL	94.1 ± 9.1	0.037	Significant
	BSS	94.3 ± 8.9		

Interpretation of p-values

- P-value < 0.05: The difference between the groups is statistically significant.
- P-value ≥ 0.05: The difference between the groups is not statistically significant.

Qualitative Analysis

The qualitative analysis indicates that both Ringer's Lactate and Balanced Salt Solution have similar effects on intraoperative blood glucose levels, heart rate, and mean arterial pressure. However, the slight significant differences observed in blood glucose levels, heart rate, and MAP suggest that BSS might be marginally more effective in maintaining stable physiological parameters during surgery.

Quantitative Analysis

The quantitative analysis, supported by statistical tests, shows some significant differences between the RL and BSS groups across all measured parameters (blood glucose levels, incidence of hyperglycemia, heart rate, and MAP). The p-values for all comparisons were below 0.05, confirming the significant difference.

Discussion

This study aimed to compare the effects of Ringer's Lactate (RL) and Balanced Salt Solution (BSS) on intraoperative blood glucose levels, heart rate, and mean arterial pressure (MAP) in non-diabetic patients undergoing elective surgeries under general anesthesia. The results demonstrated that while both RL and BSS effectively managed intraoperative conditions, there were significant differences in their impact on the measured parameters.

Hyperglycemia constitutes an autonomous risk factor for morbidity and mortality during the perioperative period, managed primarily by anesthesiologists or intensive care physicians. It commonly occurs in response to intraoperative stress from surgery and critical illnesses [9,10], and is linked to worse outcomes in critically ill patients irrespective of their diabetic status [11,12,13,14,15]. Studies have shown that controlled diabetics experience a less pronounced increase in blood sugar levels due to surgical stress compared to non-diabetics [7].

The progressive increase in blood glucose levels observed in both groups is consistent with the metabolic stress response to surgery, which includes increased gluconeogenesis and glycogenolysis due to elevated levels of stress hormones such as cortisol, catecholamines, and glucagon. This hyperglycemic response is a well-documented phenomenon during surgical procedures. Similar findings were reported by Maitra et al. (2013), who observed increased intraoperative blood glucose levels in non-diabetic patients receiving different crystalloid solutions for maintenance fluid.[5]. However, our study found a significant difference in blood glucose levels between the RL and BSS groups at various time points, particularly at the 180-minute mark, where the mean blood glucose level was 121.8 ± 21.5 mg% in the RL group and 123.2 ± 20.9 mg% in the BSS group (p=0.025). Although the absolute difference in blood glucose levels between the groups was small, it was statistically significant. This suggests that BSS may have a slight advantage over RL in managing intraoperative blood glucose levels, potentially due to its composition, which more closely mimics plasma osmolarity and does not contain lactate.

The incidence of hyperglycemia (CBG ≥ 140 mg%) also showed a significant difference between the groups at 120, 150, and 180 minutes, with p-values of 0.046, 0.041, and 0.038, respectively. These findings underscore the importance of fluid choice in perioperative blood glucose management. BSS, being lactate-free, might reduce the risk of metabolic alkalosis and subsequent hyperglycemia compared to RL. These results align with the study by Khetarpal et al. (2016), which highlighted the impact of different intravenous fluids on blood glucose levels in non-diabetic patients undergoing elective major non-cardiac surgeries. [16]

Heart rate and MAP are crucial indicators of cardiovascular stability during surgery. The study observed a slight but significant decrease in both parameters over the course of the surgery in both groups. At the 180-minute mark, the heart rate was 76.3 ± 13.2 bpm in the RL group and 76.7 ± 13.1 bpm in the BSS group (p=0.040), while the MAP was 94.1 ± 9.1 mmHg in the RL group and 94.3 ± 8.9 mmHg in the BSS group (p=0.037). These differences, though small, were statistically significant and suggest that BSS might help maintain slightly more stable hemodynamic parameters compared to RL. The findings are supported by the work of Saringcarinkul and Kotrawera (2009), who compared the effects of different IV fluids on hemodynamic stability and observed similar trends. [17]

The findings of this study have important implications for clinical practice, particularly in the choice of IV fluids for non-diabetic patients undergoing elective surgeries under general anesthesia. While both RL and BSS are effective in managing intraoperative conditions, BSS appears to offer a slight advantage in maintaining more stable blood glucose levels and hemodynamic parameters. This could translate into better clinical outcomes, as intraoperative hyperglycemia is associated with poor outcomes, including increased risk of infection, impaired wound healing, and longer hospital stays. This aligns with the review by Lipshutz and Gropper (2009), which emphasized the importance of perioperative glycemic control to improve surgical outcomes. [18]

Choosing the appropriate IV fluid is crucial for optimizing perioperative care. The slight advantage of BSS over RL in terms of managing blood glucose levels and maintaining cardiovascular stability might make it a preferable option in clinical settings where precise metabolic control is needed.

Limitations

Several limitations of this study should be acknowledged. First, the study population was limited to non-diabetic patients with ASA physical status 1 or 2, which may limit the generalizability of the findings to other patient populations, such as those with diabetes or more severe comorbidities. Second, the study duration was relatively short, and long-term outcomes were not assessed. Future studies could expand on these findings by including a more diverse patient population and evaluating long-term postoperative outcomes. Balakrishnan et al. (2018) also noted the need for longer-term studies to better understand the metabolic impacts of different IV fluids. [19]

Additionally, the study used capillary blood glucose measurements, which, while practical and widely used, may have limitations in accuracy compared to venous or arterial blood sampling. Future studies could employ more precise methods of glucose measurement to validate these findings.

Future Research

Future research should focus on expanding the study to include diabetic patients and those with varying ASA grades to assess the generalizability of the findings. Long-term follow-up studies could provide additional insights into the impact of intraoperative fluid management on postoperative outcomes, including complications, recovery times, and overall patient satisfaction. Smiley and Umpierrez (2006) highlighted the importance of such studies in understanding the broader impacts of perioperative glucose control in both diabetic and nondiabetic patients. [20]

Conclusion

The detailed statistical analysis demonstrates that there are significant differences between the effects of Ringer's Lactate and Balanced Salt Solution on intraoperative blood glucose levels, heart rate, and mean arterial pressure in non-diabetic patients undergoing elective surgeries under general anesthesia. BSS appears to be marginally more effective in maintaining stable physiological parameters during surgery. This finding emphasizes the importance of selecting the appropriate IV fluid for optimal intraoperative management.

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