Print ISSN: 2321-6379
Online ISSN: 2321-595X

Original Article

Comparative Analysis of Balanced Salt Solution and Ringer's Lactate as Perioperative Fluids for Spinal Fusion Surgery: A Comprehensive Study

Rhythm Mathur[1], Virendra Jain[1], Hari Hara Dash[1],Sandeep Vaishya[2]

[1]Department of Neuroanaesthesiology, Fortis Memorial Research Institute, Gurugram, Haryana, India, [2]Department of Neurosurgery, Fortis Memorial Research Institute, Gurugram, Haryana, India

Abstract

Background: Prolonged spinal fusion surgeries are associated with extensive dissection and instrumentation leading to significant fluid loss. Extensive administration of Ringer's lactate (RL) leads to hyperlactatemia, hyperkalemia, hypervolemia, hyponatremia, and hypercalcemia. To avoid these deleterious effects and to maintain milieu internae, balanced salt solutions were recently developed. The current study aimed primarily to compare the two in spinal fusion surgery patients in view of hemodynamics, serum electrolytes, and acid-base status with the secondary aim being patient recovery from anesthesia and duration of hospital stay.

Materials and Methods: Sixty patients posted for spinal fusion surgery were randomly divided to receive either balanced salt solution (group A) or RL (group B) as intraoperative and post-operative fluid at 2 mL/kg/h. Hemodynamic parameters were monitored continuously at 5-min intervals and were noted at pre-induction, post-induction, after positioning, and then throughout intraoperative and post-operative periods. Arterial blood gas samples were taken before induction and also intraoperatively at 2 h, 4 h, before closure, and postoperatively at 12 and 24 h for blood gases and electrolytes estimation.

Results: The volume of fluid administered intraoperatively and postoperatively was comparable. Arterial blood pH and arterial carbon dioxide remained within the normal physiological range in both groups which were statistically comparable. Serum lactate levels increased significantly ($P < 0.001$) in group B patients receiving RL intraoperatively which returned to normal range after 12 h which was comparable to group A. Duration of intensive care unit and hospital stay were comparable.

Key words: Balanced salt solution, Ringer's lactate, Spinal fusion surgery

INTRODUCTION

Spinal fusion surgery of the lumbosacral region has undergone a paradigm shift due to emaculate refinement in surgical technique, instrumentation, and screw fixation. The complexity of the procedures is continuing to increase and older patients with significant comorbidities are being offered ever more major procedures for which they would have previously been not considered. Major concerns during anesthesia in this type of surgery are prone positioning, protracted surgery, fluid shift, and intraoperative blood loss.[1] Intraoperative infusion of volume and type of intraoperative fluid during surgery play a significant role in minimizing post-operative complications.

The primary goal of intraoperative fluid therapy is to restore and maintain sufficient blood volume to guarantee adequate oxygen and nutrient transport to the tissues by infusing fluid, electrolytes, and buffers directly into the extracellular fluid compartment.[2] Among the crystalloids normal saline and Ringer's lactate (RL) are used commonly in the intraoperative period.

RL has the advantage over normal saline because its calculated osmolality is nearly 273 mOsm/L with measured osmolarity being 254 mOsm/L.[3,4] which is hypo-osmolar to extracellular fluid (275–295 mOsm/kg) and can be given in large volume to correct hypotension effectively. However, major drawbacks with extensive use of RL are a progressive increase in lactate levels, high serum potassium,

Access this article online

www.ijss-sn.com

Month of Submission : 01-2024
Month of Peer Review : 02-2024
Month of Acceptance : 03-2024
Month of Publishing : 03-2024

Corresponding Author: Dr. Rhythm Mathur, Departments of Neuroanaesthesiology, Fortis Memorial Research Institute, Gurugram, Haryana, India.

volume overload, hyponatremia, metabolic alkalosis, and high blood calcium. It cannot be used with blood products as it contains calcium which may bind to the citrate causing clotting of blood products.[5]

In an endeavor to overcome the above issues, balanced salt solutions were developed where the lactate buffer (as in RL) is replaced by acetate, gluconate, or maleate as a buffer that is a precursor to bicarbonate, CO_2, and water. It closely mimics human plasma in its content. The balanced salt solution being isotonic helps in better intravascular compartment expansion. The advantage further includes volume and electrolyte deficit correction, and pH balance while substantially addressing acidosis.[6] Theoretically, excessive balanced salt solution infusion should not affect pH and can be given along with blood and blood products as it does not contain calcium.

To the best of our knowledge, none of the studies has compared RL with the balanced salt solution in spinal fusion. Thus, our study has been designed to compare both these fluids in spinal surgery patients in view of hemodynamics, serum electrolytes, acid-base status, and patient recovery from anesthesia.

MATERIALS AND METHODS

After obtaining the approval of the Institutional Ethical Committee a randomized controlled study was conducted for 12 months. All the patients posted for spinal fusion surgery were explained about the study and their written informed consent was obtained. Patients with renal dysfunction, dyselectrolytemia, dehydration, cardiovascular disease, respiratory dysfunctions, uncontrolled diabetes mellitus, hepatic dysfunction, and patients who may require post-operative ventilation were excluded from the study.

Sample Size

The sample size was calculated with an alpha error of 5% and a power of 90%. It was determined using the statistical software G-power (3.0.10). The sample size was calculated to be 26 patients in each group. However, we enrolled a total of 60 patients and those were randomly divided into two groups according to computer computer-generated random number list at the time of induction of anesthesia.

Anesthesia Technique

All the patients were preoperatively evaluated and their hematological, biochemical, metabolic, and other pertinent investigations were reviewed. In the operating room, all the patients were monitored with standard 5-lead electrocardiography, heart rate (HR), non-invasive blood pressure, and pulse oximeter. Basal parameters were recorded. An 18-gauze cannula was placed in the dorsum of the hand. The patients in group A received balanced salt solution and patients in group B received Ringer's lactate only as the maintenance fluid during the intraoperative period.

Induction was achieved with fentanyl 2 μg/kg followed by Propofol 2–3 mg/kg and rocuronium 1 mg/kg for orotracheal intubation. Anesthesia is maintained with oxygen, air, and sevoflurane with intermittent positive-pressure ventilation. Tidal volume of 6–8 mL/kg with rate of 10–12/min to maintain the $EtCO_2$ around 35 mm of Hg. Intra-arterial pressure monitoring was carried out in all patients. Patients were turned to a prone position on the Allen frame. Eyes and pressure points were adequately covered and padded.

Intravenous Fluids

Fasting fluid requirements were calculated as 2 mL/kg/h. The maximum 8 h of fasting was taken and the patients were infused fluids over 3 h (1/2, 1/4, and 1/4 of the total calculated volume). All the patients received an infusion rate of 2 mL/kg/h as maintenance fluid throughout the intraoperative period. If the patient developed hypotension (systolic blood pressure [SBP] <90 mmHg) and concomitant tachycardia (HR >90/min) 200 mL of fluid boluses were given. Hypotension not responding to 2 boluses of fluid challenge was managed by phenylephrine (0.1 mg). Following completion of the surgery, patients were turned supine and extubated after adequate reversal. All the patients were shifted to neurosurgical intensive care units (ICU) for post-operative management. Depending on group allocation the same fluid regimen was continued at 2 mL/kg/h.

Outcome Variables

Hemodynamic parameters were monitored continuously every 5 min and recorded before induction, after intubation, following positioning, and intraoperatively till reversal. The electrolytes estimated and recorded were serum sodium, serum potassium, serum calcium, and serum chloride along with calculated serum osmolarity. The metabolic parameters included arterial blood pH, arterial bicarbonate, base deficits, lactates, and blood glucose. The immediate post-operative complications were also recorded. The post-operative hospital stay as a surrogate marker of morbidity was the other outcome of the morbidity parameter. The criteria for discharge of patients were neurological stability and minimal post-operative pain.

Statistical Analysis

Data were expressed as frequency, percentage, mean, standard deviation, median, and/or interquartile range.

Quantitative variables with normal distribution were compared between the groups using an independent *t*-test. Skewed variables were compared between the groups using the Mann–Whitney U test. Paired *t*-test was used to compare quantitative variables within a group. Categorical variables were compared using the Chi-square test. The results were compiled using suitable tables, charts, and graphs wherever necessary. $P < 0.05$ is considered significant. Analysis was performed using the Statistical Package for the Social Sciences version 21.0 [Diagram 1].

RESULTS

Among 70 patients assessed for eligibility, 60 patients were enrolled for the study as per the inclusion criteria. The data were analyzed with 30 patients either receiving a balanced salt solution (group A) or RL solution (group B) [Table 1].

Demographic Variables

Demographic parameters (age, sex, weight, and American Society of Anesthesiologists grade) were comparable among patients of both groups [Table 1].

Surgical Procedures, Input, and Output

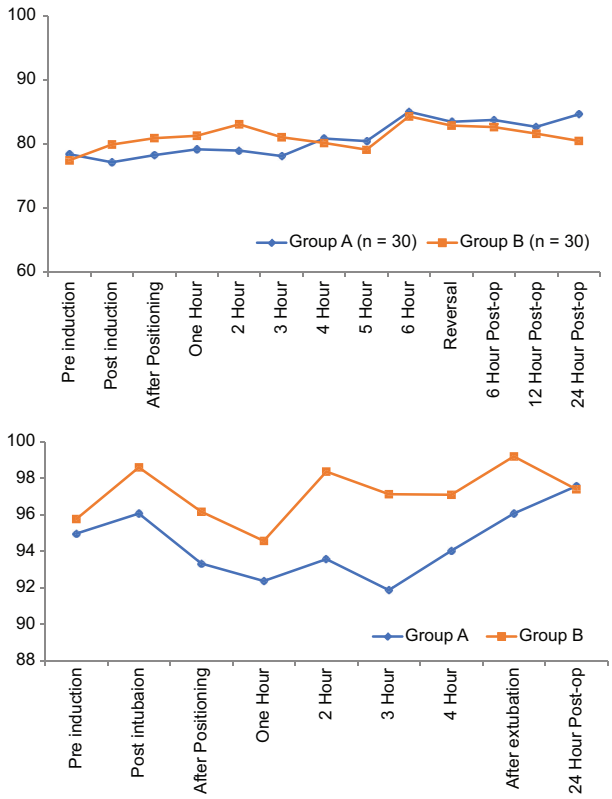
The prolapsed intervertebral disc was the most reported etiopathology. The duration of surgery and the spinal segments involved were comparable. The total volume of crystalloids and colloids infused during the intraoperative period was comparable with the blood loss. Urine output and drain output in the post-operative period were statistically comparable in both groups [Table 2].

Hemodynamic Variables

HR, SBP, diastolic blood pressure, and mean blood pressure (MBP) during the perioperative period were comparable in both groups.

Table 1: Demographic variables

Parameter	Group A (*n*=30)	Group B (*n*=30)	*P*-value
Age (years)	54.43±9.43	56.93±7.44	0.267
Sex; n (%)			
Male	19 (63.3)	16 (53.3)	-
Female	11 (36.7)	14 (47.7)	
Weight (Kg)	86.09±12.14	84.7±10.75	0.645
American Society of Anesthesiologists Grade; *n* (%)			
Grade I	14 (47.7)	17 (56.7)	-
Grade II			
Hypertension	7 (23.3)	8 (26.6)	
Diabetes	5 (1.67)	3 (10)	
Hypothyroidism	4 (13.3)	2 (6.7)	



The line diagram shows a trend in the change of heartbeat and MBP at different time points in group A and group B. Group A=Balanced salt solution; Group B=Ringer's lactate.

Metabolic

Arterial blood pH, arterial carbon dioxide, blood bicarbonate, base excess, and blood sugar remained within

Table 2: Surgical procedures, input, and output

Parameter	Group A (*n*=30)	Group B (*n*=30)	*P*-value
Diagnosis; n (%)			
PIVD	18 (60)	16 (53.3)	-
Lumbosacral listhesis	5 (16.7)	6 (20)	
Lumbar canal stenosis	7 (23.3)	8 (26.7)	
Levels of spinal fusion; *n* (%)	18 (60)	16 (53.3)	-
One segment	12 (40)	14 (46.7)	
Two segments			
Duration of Surgery (minutes)	207.77±14.66	208.5±16.39	0.858
Intra-operative			
Volume of crystalloids	3250±774.04	3316.66±712.97	0.730
Volume of colloids	500	500	-
Blood loss	420.33±136.17	403.67±117.83	0.620
Urine output	779.10±211.70	800.34±223.19	0.707
Post-operative			
Volume of crystalloids	1250±550	1450±530	0.530
Urine output	824.5±179.66	870±176.0	0.325
Drain output	110.37±22.06	115.40±21.46	0.374

Data expressed as mean or mean±standard deviation otherwise indicated; Group A: balanced salt solution; Group B: Ringer's lactate

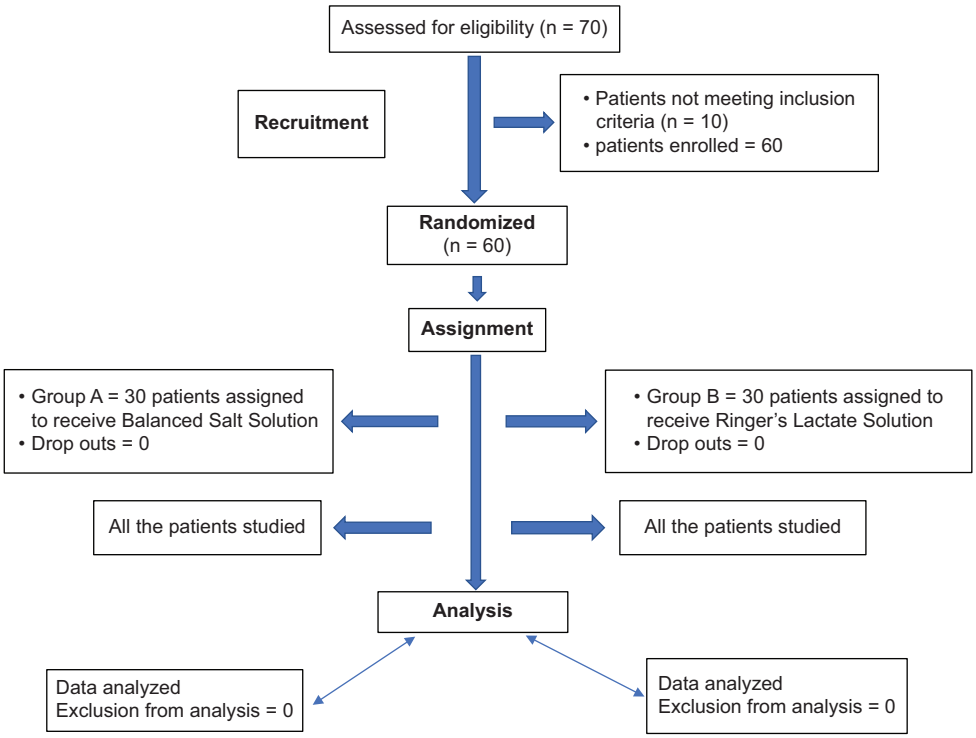


Diagram 1: Consort diagram

the normal physiological range among all cases till 24 h [Tables 3 and 4].

Electrolytes

Serum sodium, potassium, calcium, and chloride levels remained within the physiological range in both groups during intraoperative and post-operative periods [Table 5].

Plasma Osmolarity and Lactate

Plasma osmolarity was within the physiological range in both the groups over time but serum lactate levels increased in patients receiving RL intraoperatively from 4th h up till reversal which was highly significant ($P < 0.001$). However, the lactate level returned to the normal range after 12 h which was comparable to group A patients [Graph 1].

Post-operative Complication

Hypotension was appreciated in 16.7% in group A and 30% in group B. Four and six patients in group A and group B, respectively, had facial puffiness whereas five patients in group A and seven patients in group B had conjunctival edema [Table 6].

ICU Stay and Hospital Stay

The two groups were not significantly different in terms of ICU stay and duration of hospital stay. All the patients remained for 24 h in ICU and stayed for 3 days in the hospital. Duration of ICU stay was 22.92 ± 0.78 in group A and 22.68 ± 1.12 in group B, which was comparable.

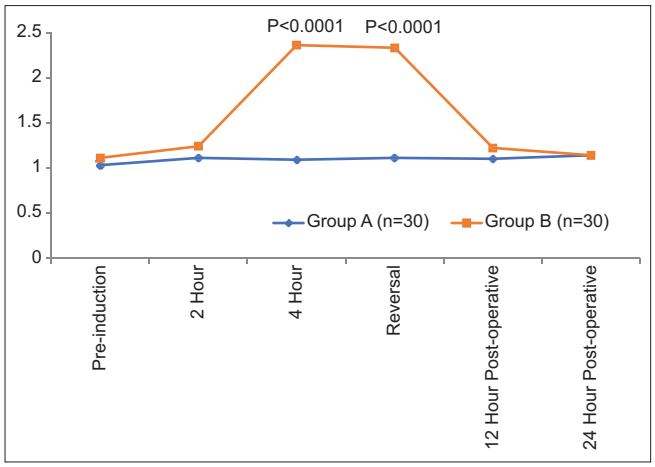
Table 3: pH, $PaCO_2$, Bicarbonate, and base excess

Parameter	Time(Hr)	Group A (*n*=30)	Group B (*n*=30)	*P*-value
pH	Pre-induction	7.41±0.02	7.41±0.01	0.625
	2 h	7.4±0.02	7.4±0.01	0.433
	4 h	7.4±0.02	7.39±0.02	0.411
	Reversal	7.4±0.01	7.4±0.02	0.272
	12 h post-operative	7.4±0.01	7.4±0.02	0.613
	24 h post-operative	7.41±0.02	7.41±0.01	0.860
$PaCO_2$	Pre-induction	40.39±2.42	40.67±2.56	0.678
	2 h	40.48±1.98	40.43±2.26	0.929
	4 h	41.25±2.15	40.33±2.21	0.115
	Reversal	41.22±2.93	40.37±2.37	0.230
	12 h post-operative	41.17±2.88	40.9±2.4	0.696
	24 h post-operative	40.33±2.26	40.5±2.26	0.771
Bicarbonate	Pre-induction	24.55±1.46	24.38±1.56	0.670
	2 h	24.56±1.6	24.73±1.72	0.687
	4 h	24.87±1.56	24.96±1.49	0.816
	Reversal	24.78±1.38	24.76±1.51	0.951
	12-h post-operative	25.72±1.98	24.95±1.78	0.125
	24-h post-operative	24.85±1.5	25.47±1.73	0.154

Table 4: Glucose

Time(Hr)	Group A (*n*=30)	Group B (*n*=30)	*P*-value
Pre-induction	101.7±19.45	96.6±16.45	0.285
2 h	100.17±19.35	95.97±17.04	0.384
4 h	103.83±19.14	95.07±17.33	0.073
Reversal	105.03±22.16	99.43±15.07	0.265
12 h post-operative	109.23±18.71	101.7±18.18	0.125
24 h post-operative	103.67±16.35	97.87±17.94	0.203

Data expressed as mean±standard deviation; Group A: Balanced salt solution; Group B: Ringer's lactate



Graph 1: Line diagram shows trend in change of lactate at different time points in group A and group B. group A: Balanced salt solution; group B: Ringer's lactate

Table 5: Electrolytes

Parameter	Group A (*n*=30)	Group B (*n*=30)	*P*-value
Sodium			
Pre-induction	139±2.93	139.63±3.15	0.431
2 h	138.7±2.72	139.17±3.29	0.558
4 h	139±3.09	140.37±3.46	0.118
Reversal	139.57±3.47	140.23±3.08	0.443
12-h post-operative	138.47±2.96	139.43±3.58	0.268
24-h post-operative	139±3.31	140.47±2.28	0.154
Potassium			
Pre-induction	4.04±0.36	4.2±0.52	0.196
2 h	4.23±0.41	4.43±0.39	0.068
4 h	4.05±0.53	4.23±0.45	0.173
Reversal	4.26±0.5	4.35±0.39	0.448
12 h post-operative	4.21±0.42	4.16±0.46	0.709
24 h post-operative	4.28±0.46	4.33±0.48	0.687
Calcium			
Pre-induction	0.89±0.13	0.92±0.07	0.272
2 h	0.9±0.12	0.9±0.06	0.979
4 h	0.91±0.12	0.92±0.07	0.599
Reversal	0.91±0.1	0.91±0.07	0.765
12 h post-operative	0.91±0.11	0.9±0.07	0.448
24 h post-operative	0.91±0.1	0.92±0.07	0.743
Chloride			
Pre-induction	101.43±3.82	100.13±2.86	0.148
2 h	101.97±3.35	100.53±3.04	0.093
4 h	101.87±3.99	101.47±3.17	0.674
Reversal	100.97±3.99	101.1±2.87	0.884
12 h post-operative	102±3.19	101.63±2.09	0.378
24 h post-operative	101.52±3.4	100.6±2.88	0.276

DISCUSSION

Administration of intravenous fluids during anesthesia is a universal practice for patients undergoing major surgery. This is of utmost importance to maintain intravenous volume and milieu interior.[2]

Hemodynamic variables were minimally significant when a balanced salt solution was compared with RL suggesting that the variation could be attributed to the depressant effect of anesthetic agents and the volume replacement with RL might be less effective than compared to other fluids. These hemodynamic variations were minimal in concordance with Kumar *et al.* study.[7]

Table 6: Adverse events

Parameter	Group A (*n*=30) (%)	Group B (*n*=30) (%)	*P*-value
Hypotension	5 (16.7)	9 (30)	0.222
Restlessness	3 (10)	3 (10)	1
Shivering	0	0	0
Delirium	0	0	0
PONV	6 (20)	10 (33.3)	0.243
Requirement of ventilation	0	0	0
Delayed emergence	0	0	0
Facial puffiness	4 (13.3)	6 (20)	0.488
Conjunctival edema	5 (16.7)	7 (23.3)	0.519

Data expressed as frequency (percentages) otherwise indicated, Group A: Balanced salt solution, Group B: Ringer's lactate, PONV: Post-operative nausea and vomiting

Maintenance of serum electrolytes in the perioperative period is highly essential in surgical patients for the maintenance of homeostasis and better recovery in the post-operative period. Although the balanced salt solution contains a comparatively higher concentration of sodium (140 mmol/L) than RL (131 mmol/L), the end plasma sodium was better in the balanced salt solution group. However, in our study, infusion of a balanced salt solution did not lead to hypernatremia in any patient since it contained normal level of sodium. Similar findings have also been reported by Hassan *et al.*,[8] in pediatric surgical patients.

RL contains 111 mmol/L and a balanced salt solution of 98 mmol/L of chloride ions. Thus, RL infusion leads to a slight increase in serum chloride concentration at the end of our study. However, the increase within the group as well as between the groups was not statistically significant. Our findings are also in agreement with Sharma *et al.*,[9] who reported a consistent rise in chloride with RL as well as Sterofundin during scoliosis surgery.

We observed that administration of both RL and balanced salt solution resulted in a slight increase of potassium up to 24-h post-surgery. However, the increase was statistically insignificant. Our findings also support that neither balanced salt solution nor RL causes a change in serum potassium levels.

Kumar *et al.*,[7] reported that calcium levels were maintained within normal limits following administration of sterofundin which contains calcium whereas other study fluids such as RL, plasmalyte, and kabilyte caused a slight decrease in calcium levels though not clinically significant.

Our study also did not observe a significant increase in calcium during the course of surgery.

Our study result showed that blood glucose levels remained within the normal physiological range in both groups which were statistically comparable in both intraoperative and post-operative periods. Liu *et al*.,[10] compared a balanced salt solution with RL in type 2 diabetes mellitus patients undergoing gastrointestinal surgery. The primary outcome of the study was hyperlactatemia and hyperglycemia in patients receiving RL.

Our study observed that lactate levels in RL group significantly increased up to the reversal phase then started decreasing and normalized 12 h postoperatively. The increased lactate levels did not affect the outcomes of our patients. The liver has a high capacity to metabolize lactate. Prolonged anesthesia for long surgeries with an inhalation agent, prone position within advertent compression over the liver, and blood transfusions can put significant stress over the functional capacity of the liver and can predispose to lactic acidosis. Infusion of large quantities of lactate-containing infusions in healthy volunteers transiently and slightly elevates the serum lactate levels but does not decrease the pH. Our findings are in concordance with Sharma *et al*.,[9] who reported similar observations while studying Sterofundin and Ringer lactate-based infusion in scoliosis correction surgery.

There was no significant difference in surgical blood loss between both groups. In contrast, Sharma *et al*.,[9] reported a significantly higher blood loss in RL group in comparison to Sterofundin group. Moreover, in the present study, both intraoperative and post-operative (surgical drain), blood loss was comparable in both groups. Other intraoperative parameters such as crystalloid volume and duration of surgery were comparable between both groups. Cases with facial puffiness and conjunctival edema subsided within 24 h.

All patients in our study remained for 24 h in ICU and stayed for 3 days in the hospital. There was no difference in post-operative period, ICU stay, or duration of hospital stay with the use of both fluids.

CONCLUSION

Based on our findings, the balanced salt solution can be used for perioperative maintenance and replacement requirements without gross changes in hemodynamics. We, therefore, recommend the use of a balanced salt solution in the intraoperative period in patients undergoing spinal fusion surgery.

REFERENCES

1. Sweeney RM, McKendry RA, Bedi A. Perioperative intravenous fluid therapy for adults. Ulster Med J 2013;82:171-8.
2. Robin ED, Bromberg PA. Claude Bernard's milieu interieur extended: Intracellular acid-base relationships. Am J Med 1959;27:689-92.
3. Reid F, Lobo DN, Williams RN, Rowlands BJ, Allison SP. (Ab)normal saline and physiological Hartmann's solution: A randomized double-blind crossover study. Clin Sci (Lond) 2003;104:17-24.
4. Williams EL, Hildebrand KL, McCormick SA, Bedel MJ. The effect of intravenous lactated Ringer's solution versus 0.9% sodium chloride solution on serum osmolality in human volunteers. Anesth Analg 1999;88:999-1003.
5. Gladden LB. Lactate metabolism: A new paradigm for the third millennium. J Physiol 2004;558:5-30.
6. Langer T, Santini A, Scotti E, Van Regenmortel N, Malbrain ML, Caironi P. Intravenous balanced solutions: From physiology to clinical evidence. Anaesthesiol Intensive Ther 2015;47:78-88.
7. Kumar AK, Pratyusha AC, Kavitha J, Ramachandran G. Comparative study of effect of intra-operative administration of ringer's lactate, sterofundin, plasmalyte-A and kabilyte on ionic and acid base status. MedPulse Int J Anesthesiol 2017;4:59-67.
8. Hassan HM, Hasbullah AN, Ali S, Isa R. Ringer's lactate versus sterofundin ® iso in paediatric surgical patients: The acid base and electrolytes assessment. J Anesthesiol 2018;6:33-9.
9. Sharma A, Yadav M, Kumar BR, Lakshman PS, Iyenger R, Ramchandran G. A comparative study of sterofundin and ringer lactate based infusion protocol in scoliosis correction surgery. Anesth Essays Res 2016;10:532-7.
10. Liu X, Sun L. The influence of PlasmaLyte A on glycometabolism in type 2 diabetic patients during operation. J Med Res 2009;38:36-8.

How to cite this article: Mathur R. Comparative Analysis of Balanced Salt Solution and Ringer's Lactate as Perioperative Fluids for Spinal Fusion Surgery: A Comprehensive Study. Int J Sci Stud 2024;11(12):30-35.

Source of Support: Nil, **Conflicts of Interest:** None declared.