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Original research article

Comparison of acid–base and electrolyte imbalances between normal saline and 1.4% sodium bicarbonate intravenous fluids therapy during cervical and lumbar laminectomy

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ARTICLE INFO

Article history:
Received 22 February 2016
Received in revised form
15 March 2016
Accepted 30 March 2016
Available online 5 May 2016

Keywords:
Crystalloid solutions
Fluid therapy
Laminectomy
Sodium Bicarbonate
Water-electrolyte balance

ABSTRACT

Introduction: Large amounts of normal saline infused in surgeries can cause hyperchloremic metabolic acidosis.
Aim: This study was designed to evaluate electrolyte and acid–base imbalances in the common fluid therapy method (normal saline) and the use of 1.4% sodium bicarbonate with normal saline fluid therapy during surgical laminectomy.
Material and methods: In this double-blind randomized clinical trial patients from 35 to 70 years in age, having American Society of Anesthesiologists physical status class I–II, candidation for cervical and lumbar laminectomy in Baqiyatallah Hospital (Tehran, Iran) in 2015 were enrolled. Patients were randomized into either two groups receiving 1.4% sodium bicarbonate and normal saline intravenous solutions for deficit fluid therapy during the surgery. Hemodynamics, arterial blood gases, and electrolytes levels were measured before and after surgery. Data were compared between the groups by SPSS.
Results and discussion: Forty patients with a mean age of 49.9 ± 12.7 years were evaluated. There were no significant differences in demographic data, mean surgery duration, blood loss, urine output, and infused fluid volumes between the two groups ($P > 0.05$). The mean PCO_2 and HCO_3 values significantly increased in the bicarbonate group, whereas they decreased significantly in the normal saline group. The mean serum lactate increased significantly in the bicarbonate group while the mean serum Cl^- increased significantly in the normal saline group ($P < 0.05$).

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http://dx.doi.org/10.1016/j.poamed.2016.03.005

Conclusions: The results of this study showed the superiority of 1.4% sodium bicarbonate fluid in controlling acid–base and electrolyte imbalances during this kind of surgery, but it should be verified by further studies.

1. Introduction

Fluid therapy is an essential part of surgeries[1] and nearly all patients with general anesthesia should receive some intravenous (IV) fluids.[2] Evidence shows that fluid therapy during surgeries has a dramatic effect on surgery results in the long-run.[1] In general, two groups of serums, crystalloid and colloid, are more commonly used for fluid therapy during surgeries.[3]

Achieving an appropriate effective circulating volume and assuring oxygen delivery to tissues are the goals of fluid therapy which are provided by a high volume of crystalloid, usually ringer and normal saline. Required fluids in patients include maintenance and deficit fluids like bleeding and third space.[1]

Acid–base balance is of great importance as the life of patients depends on it.[4] In patients undergoing general anesthesia, acid–base disorders followed by cardiovascular, muscular, and respiratory dysfunctions as well as central nervous system disorders are highly prevalent.[1] Electrolyte disorders damage cells by changing intra- and extra-cellular fluids balance. They occur repeatedly, especially in surgeries of long duration.[5]

During long surgeries, patients receive a high amount of normal saline which may result in hyperchloremic metabolic acidosis with perfusion alteration and end organ dysfunction.[4,6] Sodium-bicarbonate 7.5%, a hypertonic solution, is usually used for treatment which is associated with intracellular acidosis as a complication.[7,8]

This prospective study was done to evaluate electrolyte and acid-base imbalances in the common fluid therapy method (normal saline) and the use of 1.4% sodium bicarbonate with normal saline in cervical and lumbar laminectomy surgeries in order to decrease the incidence of metabolic acidosis and achieving an improvement in fluid therapy.

2. Material and methods

2.1. Study subjects

This double-blind clinical trial was carried out of patients of age ranging 35–70 years old referring to Baqiyatallah Hospital (Tehran, Iran) in 2015 with American Society of Anesthesiologists (ASA) physical status class I-II that were considered candidates for elective cervical and lumbar spinal laminectomy by the same neurosurgeon. Patients with chronic kidney disease (CKD), hepatic failure, electrolytes imbalance, changes in blood pressure more than 30% of basal amount, need for blood transfusion before and during operation, intestinal preparation before operation, and need for lower $PaCO_2$ less than 35 mmHg were excluded from the study. The included and excluded patients are described in Fig. 1. No patient was excluded during the study.

2.2. Study design

Patients were visited the night before operation and randomized into two groups by a computer-generated randomization list. After entrance to the operation room, demographic data and patients' numbers were written on each checklist. A blood sample was taken from IV line before IV fluid was infused and an arterial blood sample was taken for arterial blood gases' analysis. Premedication was done using midazolam (1–2 mg) and fentanyl (75–150 μg). The patients were oxygenated by 100% O_2 gas; then 5 mg/kg sodium thiopental for anesthesia and 0.5 mg/kg atracurium were administered for facilitating intubation. Laryngoscopy was done and the patients' tracheas were intubated using 8-mm and 7.5-mm high-volume/low-pressure SUPA endotracheal tubes (SUPA, Tehran, Iran) for male and female patients. After fixation, endotracheal tube was connected to a mechanical ventilator (Drager, Lubeck, Germany) with tidal volume of 10 cc/kg and respiratory rate of 12 per minute setting. For anesthesia maintenance, 60 $\mu g\,kg^{-1}\,min^{-1}$ propofol was prescribed and analgesia was done using 5–10 mg IV morphine. A Foley catheter was inserted for all patients and urine output was measured. Fluids needed were calculated in checklists. Maintenance fluid therapy was done using normal saline and deficit fluid therapy was carried out using 1.4% sodium bicarbonate in the first group, whereas maintenance and deficit fluid therapies were done using normal saline in the second group. The 1.4% sodium bicarbonate was produced using 150 mL sodium bicarbonate 7.5% added to 850 mL infusible distilled water identical in shape and size to normal saline fluid by another anesthesiologist. Drug prescriber, who filled the checklists in all stages as well as the person who performed the analysis were unaware of the infused fluid in both groups. All patients were evaluated in terms of arterial blood gases, electrolytes, and hemodynamic factors before and after the operation (on arrival in the PACU). During the suturing time, propfol was discontinued; then 100% oxygen was prescribed. After finishing the surgery, with observation of respiration, reverse drugs, such as 0.04 mg/kg neostigmine and 0.02 mg/kg atropine, were infused.

2.3. Measurements

Arterial blood gases were analyzed using GEM Premier 3000 (Instrumentation Laboratory, Bedford, MA, USA) and all other laboratory findings were measured using Pars Azmoon lab kits (Pars Azmoon Co., Tehran, Iran) at the Central Laboratory of Baqiyatallah Hospital.

Systolic and diastolic blood pressures were continuously measured by an advanced practice nurse in anesthesia using an automatic monitoring system (Cardioset FX7, SaIRAN Medical Industry-Iran) during the operation.

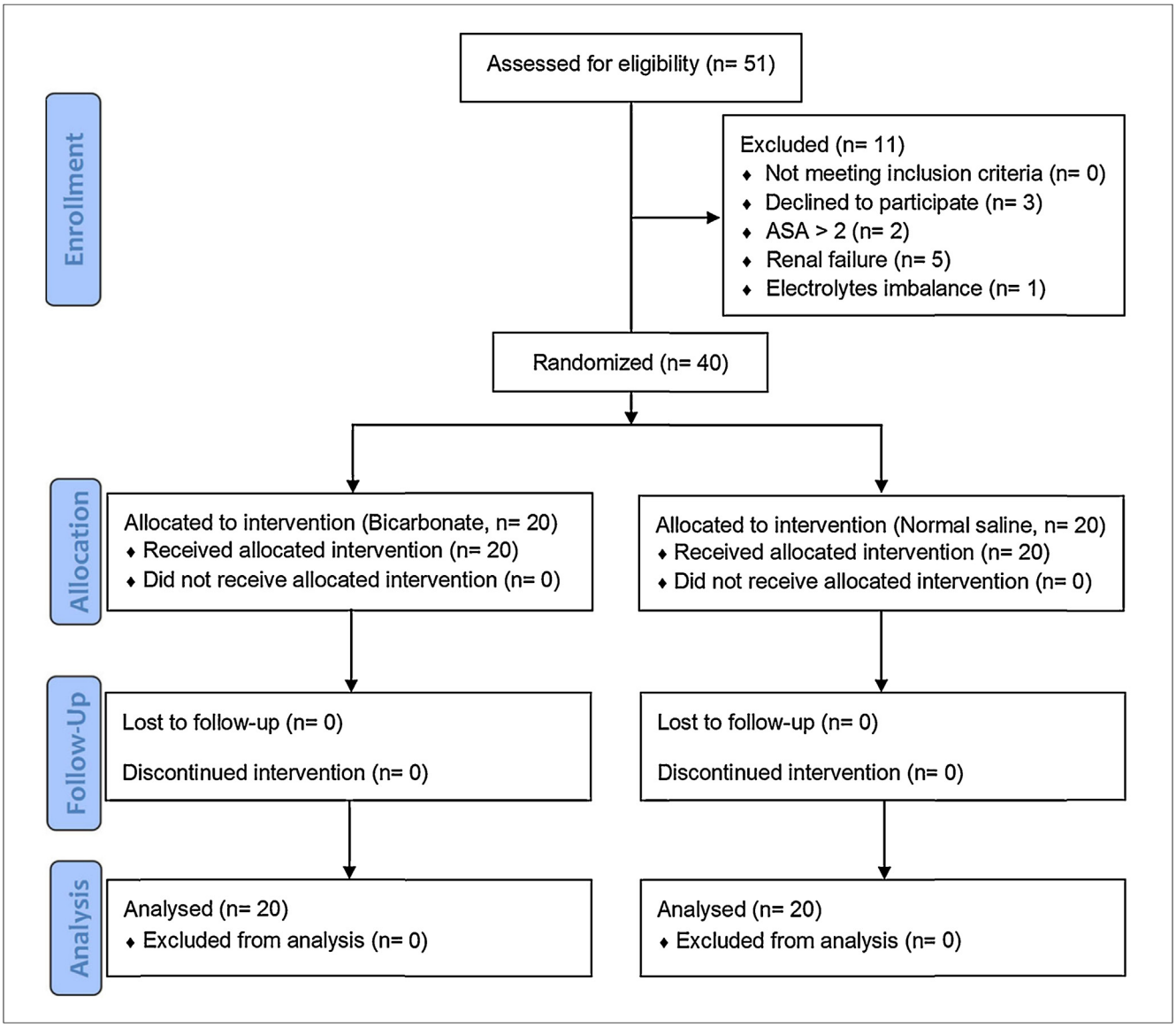

Fig. 1 – Study flow chart.

Surgery time was noted from the first incision until suturing was done.

2.4. *Ethical consideration*

This research study followed the tenets of the Declaration of Helsinki and written informed consent was obtained from all patients. The study was approved by the Ethics Committee of Baqiyatallah University of Medical Sciences with Iranian registry code of clinical trials of IRCT2014061717413N4.

2.5. *Statistical analysis*

Data were analyzed using the statistical package for social sciences (SPSS) version 21 (IBM Corp, Armonk, NY) for Microsoft Windows. At first, the patients were described using mean descriptive statistics, standard deviation, and frequency and the two groups were compared before the surgery initiation by independent sample *t*-test and its nonparametric equivalent (Mann–Whitney) for quantitative variables. Then χ^2 and Fisher's exact tests were run for evaluating the qualitative variables. After surgery, the groups were compared using these tests. Before and after surgery, changes in the obtained values were first calculated in each group and then compared between the two groups using independent sample *t*-test and its nonparametric equivalent. Before and after treatment values were compared in each group using paired sample *t*-test and its nonparametric equivalent (Wilcoxon) with $P < 0.05$ considered significant.

3. Results

Forty patients (15 male and 25 female patients) with the mean age of 49.9 ± 12.7 years and the mean weight of 71.9 ± 9.2 kg were evaluated. The mean operation time was 168.8

Table 1 – Patients' characteristics.

Variables	Study Group		P value
	Bicarbonate (n = 20)	Normal saline (n = 20)	
Age, years	48.0 ± 13.5	51.8 ± 11.9	0.359
Male gender, No. (%)	7 (35)	8 (40)	0.774
Weight, kg	75.0 ± 11.2	70.9 ± 6.6	0.166
Surgery time, minutes	172.9 ± 40.4	165.0 ± 33.5	0.524

Table 2 – The mean volume needed and infused in the study groups.

Variables	Study Group		P value
	Bicarbonate (n = 20)	Normal saline (n = 20)	
Blood loss, mL	410.5 ± 166.3	355.0 ± 209.5	0.367
Urine volume, mL	426.3 ± 179.8	335.0 ± 106.5	0.065
Needed fluid, mL			
Volume expander	375.5 ± 54.6	352.5 ± 32.3	0.113
Maintenance	341.3 ± 33.1	329.1 ± 19.5	0.215
Deficit	910.0 ± 88.2	877.6 ± 51.9	0.215
Third space	728.4 ± 237.1	701.9 ± 176.9	0.722
Infused volume, L	3.58 ± 0.83	3.44 ± 0.89	0.641

± 36.6 min. There were no significant differences in demographic data and operation time between the two groups ($P > 0.05$). Patients' demographic data are shown in Table 1.

The mean blood loss was 382.1 ± 189.4 mL and the mean urine volume was 379.5 ± 152.1 mL. There were no significant differences between the two groups in blood loss, urine volume, and fluid volume needed ($P > 0.05$). The mean fluid infused volume was 3.51 ± 0.85 L; this volume was 3.58 ± 0.83 L in the bicarbonate group and 3.44 ± 0.89 L in the normal saline group ($P = 0.641$). Needed and infused volumes are described in Table 2.

There was not a significant difference in mean pH before the operation between the two groups ($P = 0.605$). Mean pH significantly decreased after operation in the normal saline group ($P < 0.001$). Before operation, there were also no significant differences in PCO_2 and HCO_3 values between the two groups ($P > 0.05$). Mean PCO_2 and HCO_3 values significantly increased in the bicarbonate group, whereas they presented significant decreases in the normal saline group ($P < 0.05$).

There were no significant differences in preoperative lactate, sodium, potassium, and Cl^- values between the groups ($P > 0.05$). The mean lactate value significantly increased after operation in the bicarbonate group ($P = 0.002$), whereas the mean Cl^- amount significantly increased in the normal saline group ($P = 0.003$). Changes in arterial blood gases and electrolytes in the two groups are shown in Table 3.

Table 3 – Changes in arterial blood gases and electrolytes during operation.

Variables	Study Group		P value
	Bicarbonate (n = 20)	Normal saline (n = 20)	
pH			
Before operation	7.46 ± 0.06	7.45 ± 0.04	0.605
After operation	7.45 ± 0.08	7.40 ± 0.06	0.043
Changes	−0.006 ± 0.08	−0.046 ± 0.05	0.050
Trend P value	0.726	<0.001	–
PCO_2, mmol/L			
Before operation	31.1 ± 7.72	30.55 ± 6.37	0.807
After operation	34.75 ± 7.81	27.25 ± 4.49	0.001
Changes	3.7 ± 6.4	−3.3 ± 5.8	0.001
Trend P value	0.021	0.019	–
HCO_3, mmol/L			
Before operation	21.88 ± 3.34	21.04 ± 3.25	0.428
After operation	24.14 ± 3.32	17.83 ± 3.12	<0.001
Changes	2.27 ± 2.8	−3.22 ± 2.3	<0.001
Trend P value	0.002	< 0.001	–
Lactate, mmol/L			
Before operation	1.18 ± 0.45	1.34 ± 0.49	0.401
After operation	1.50 ± 0.58	1.35 ± 0.43	0.344
Changes	0.318 ± 0.4	0.013 ± 0.3	0.011
Trend P value	0.002	0.856	–
Sodium, mmol/L			
Before operation	142.6 ± 4.1	142.3 ± 2.5	0.818
After operation	143.9 ± 4.2	142.4 ± 1.9	0.132
Changes	1.4 ± 3.8	0.05 ± 2.6	0.198
Trend P value	0.119	0.931	–
Potassium, mmol/L			
Before operation	3.39 ± 0.51	3.23 ± 0.45	0.317
After operation	3.46 ± 0.67	3.30 ± 0.42	0.370
Changes	0.08 ± 0.66	0.07 ± 0.50	0.978
Trend P value	0.615	0.356	–
Cl^-, mmol/L			
Before operation	104.6 ± 2.2	106.3 ± 4.6	0.133
After operation	103.7 ± 5.4	109.1 ± 4.4	0.344
Changes	−0.9 ± 5.8	2.8 ± 3.5	0.021
Trend P value	0.494	0.003	–

4. Discussion

The results of this study showed that 1.4% sodium bicarbonate serum has a superiority in controlling acid-base imbalance compared to the current fluid therapy method with normal saline in patients undergoing cervical and lumbar laminectomy surgeries.

Waters et al., evaluating 22 patients with surgeries lasting for more than four hours, reported that mean serum lactate and chloride levels increased 1.8 and 106 units, respectively, which indicated a significant relationship with base excess. Also, plasma volume did not show significant changes after operation, but there was a significant association between base excess changes and infused normal saline and chloride.[9]

In another study by Hofmann et al., 24 gynecologic surgery patients were categorized as ringer lactate serum and serum with acetate basis receivers. They concluded that there were no significant differences between the two groups in hemodynamic results, while pH and HCO_3 levels had significant reductions in the ringer lactate group which showed more pH changes.[10]

In a systematic review, Burdet et al. assessed 14 clinical trials in which prescribing buffer and non-buffer solutions during surgeries were compared. In this study, buffer and non-buffer solution groups had mortality rates of 2.5% and 1.5%, respectively. Urine volume, serum creatinine, and incidence of

nausea and vomiting indicated no significant differences between the two groups after surgery. Arterial CO_2 pressure was significantly lower in the non-buffer group, while there was not a significant difference between the two groups in blood products transfusion requirement during surgery and hospitalization period. In comparison with the non-buffer group, the buffer group had lower mean pH for 0.06 units and a higher base deficit.[11]

Vanzyl et al. compared the effect of ringer lactate and sodium chloride 0.9% serums on treating diabetic ketoacidosis. They reported a significantly longer required time for achieving normal pH in the sodium chloride group, while plasma glucose normalization time was significantly longer in the ringer lactate group. Required time for managing diabetic ketoacidosis did not indicate a significant difference between the two groups.[12]

In another systematic review on assessing various crystalloids by Cortes et al., more pH reductions, higher acidosis incidence, and lower bicarbonate levels were reported for normal saline compared to ringer lactate and ringer acetate.[13]

Shimada et al. divided 20 abdominal aorta aneurysm (AAA) patients into ringer bicarbonate and ringer acetate groups. They reported clamping of aorta as a factor lowering pH and base excess. There was not a significant difference between the two groups in preventing this decrease, however. They concluded that ringer bicarbonate has no effect on correcting low pH due to AAA restoration surgery.[7]

In another study by Leverve et al., ringer lactate and half molar sodium lactate serums were compared in 208 patients undergoing coronary artery bypass grafting. In this study, mean arterial blood pressure was not significantly different between the two groups, while mean infused serum was significantly lower in half-molar sodium lactate group which is an indicator of better cardiac index after surgery.[14]

Tie et al. assessed five clinical trials and observed that sodium bicarbonate prescription had no significant effect on the hospitalization duration, mortality rate, and incidence of atrial fibrillation following coronary artery bypass graft surgery. However, ventilator requirement, ICU admission time, and incidence of alkalosis significantly increased by prescribing bicarbonate. This study did not indicate that prescription of bicarbonate prevented the incidence of renal failure due to cardiothoracic surgeries.[8] In a similar study by Turner et al., sodium chloride and sodium bicarbonate serums were compared. Overall, 24% of sodium chloride and 27% of sodium bicarbonate groups were afflicted by post-surgical acute kidney injury. In this study, sodium bicarbonate did not have a decreasing effect on the incidence of acute kidney injury following cardiothoracic surgeries.[15]

The importance of renal failure prevention in hospitalized patients, especially severely ill ones, has been emphasized by Schiffl. He observed that applying sodium bicarbonate was not effective in preventing renal failure because of increased mortality risk. Schiffl suggests more clinical trials for better decision making.[16]

Nakayama et al. categorized 40 laparatomy surgery patients into ringer bicarbonate and ringer acetate groups. Serum bicarbonate level and base excess significantly decreased in the ringer acetate group after operation, but they were significantly higher in the second and forth hours after surgery in the ringer bicarbonate group.[17]

In another study by Tellen et al., the incidence of metabolic acidosis after left hemi-colectomy surgery was compared when using saline 0.9%, ringer lactate and a combination of these serums. They concluded that a combination of saline 0.9% and ringer lactate has a better effect on fluid therapy and management of metabolic acidosis after left hemi-colectomy.[18]

Haase et al. studied 100 coronary artery bypass grafting patients and reported sodium bicarbonate (4 mmol/kg) to significantly increase plasma bicarbonate level, base excess, and urine pH in comparison with sodium chloride (4 mmol/kg). Increases in plasma creatinine and urea were significantly lower in the sodium bicarbonate group.[19]

In a study by McGuinness et al., patients undergoing elective heart surgery were divided into sodium bicarbonate and sodium chloride serum receivers with 0.5 mEq kg^{-1} h^{-1} and 0.2 mEq kg^{-1} h^{-1} for the first hour and the 23 remaining hours, respectively. In this study, 47% of sodium bicarbonate and 44% of sodium chloride patients had post-surgical acute kidney injury in the first five days after operation. There were no significant differences in ventilator requirement, ICU, and hospital admission time between the two groups.[20]

Andou et al. evaluated 16 wide hysterectomy patients in two groups: ringer lactate and ringer acetate. They observed a significantly higher bicarbonate level and base excess in the ringer bicarbonate group and reported ringer bicarbonate to be a more appropriate fluid in wide hysterectomy surgeries.[21]

5. Conclusions

Based on the results of this study, it can be concluded that the incidence of acid–base imbalance following lumbar laminectomy surgery significantly decreases by applying 1.4% sodium bicarbonate serum. Considering the limited sample size in this pilot study, more clinical trials are needed for confirming its results. Future studies can also compare this fluid with ringer lactate, acetate, and bicarbonate serums in other surgeries. It is also suggested that in future studies prescription of different doses of bicarbonate be assessed before, during, and after surgery.

Authors' contribution

Idea developing: Seyed Jalal Madani; study design: Seyed Jalal Madani, Fariba Araste Fard, Abbasali Delavari; data collection: Fariba Araste Fard, Seyed Jalal Madani, Abbasali Delavari, Hamidreza Karimi-Sari, Mohammad Hossein Khosravi; Statistical analysis: Hamidreza Karimi-Sari; drafting the manuscript: Hamidreza Karimi-Sari, Mohammad Hossein Khosravi; critical revision of paper: Seyed Jalal Madani; study supervision: Seyed Jalal Madani, Abbasali Delavari.

Financial disclosure

All of the authors mentioned no financial disclosure.

Funding source

Baqiyatallah University of Medical Sciences, Deputy of Research.

Conflict of interests

All of the authors mentioned no conflict of interests.

Acknowledgements

The authors would like to thank all physicians, nurses, and staffs at the Operation Room of Baqiyatallah Hospital.

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