Original Article

Acid–base and hemodynamic status of patients with intraoperative hemorrhage using two solution types: Crystalloid Ringer lactate and 1.3% sodium bicarbonate in half-normal saline solution

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Abstract

Background: Intraoperative hemorrhage is one of the problems during surgery and, if it happens in a high volume without an immediate action to control, it can be fatal. Nowadays, various injectable solutions are used. The aim of this study was to compare the acid–base and hemodynamic status of the patient using two solutions, Ringer lactate and 1.3% sodium bicarbonate, in half saline solution.

Materials and Methods: This clinical trial was performed at the Al-Zahra Hospital in 2013 on 66 patients who were randomly selected and put in two studied groups at the onset of hemorrhage. For the first group, crystalloid Ringer lactate solution and for the second group, 1.3% sodium bicarbonate in half-normal saline solution was used. Electrocardiogram, heart rate, O2 saturation non-invasive blood pressure and end-tidal CO2 were monitored. The arterial blood gas, blood electrolytes, glucose and blood urea nitrogen were measured before serum and blood injection. After the infusion of solutions and before blood transfusions, another sample was sent for measurement of blood parameters. Data were analyzed using SPSS software.

Results: The mean arterial pressure was significantly higher in the second group than in the first group at some times after the infusion of solutions. pHh levels, base excess, bicarbonate, sodium, strong ion differences and osmolarity were significantly greater and potassium and chloride were significantly lower in the second group than in the first group after the infusion of solutions.

Conclusion: 1.3% sodium bicarbonate in half-normal saline solution can lead to a proper correction of hemodynamic instability. By maintaining hemodynamic status, osmolarity and electrolytes as well as better balance of acid–base, 1.3% sodium bicarbonate solution in half-normal saline solution can be more effective than Ringer lactate solution during intraoperative bleeding.

Key Words: 1.3% sodium bicarbonate in half-normal saline solution, intraoperative hemorrhage, Ringer lactate

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INTRODUCTION

Intraoperative hemorrhage is one of the life-threatening events in surgery. In one study, hemorrhage was reported as the most common cause of cardiac arrest in the operating room.[1] If the incidence of hemorrhage and lack of due treatment happened, blood loss results in hypotension, subsequent hypotension, hypothermia, coagulation disorders, shock and cardiac arrest.[2,3] Fluids administration is the cornerstone of treatment in hemorrhagic shock. The entrance of fluid into blood circulation leads to higher cardiac output and blood pressure.[4]

Fluids are used in various forms, including crystalloid, isotonic, hypertonic or colloid.[5] Crystalloid solutions can be associated with different effects on the acid–base status of the patient in the way that, in some circumstances, it can lead to severe metabolic acidosis.[6]

Normal saline is a common solution in the treatment of hemorrhage that may lead to hyperchloremic acidosis in patients.[6-8] Ringer lactate solution is a crystalloid solution with an osmolarity of 273 and pH of 6.5, which is commonly applied in intraoperative hemorrhage and in the treatment of hemorrhagic shock.[9] It is said that lactate is converted to bicarbonate by the liver dealing with lactate acidosis by hypoperfusion in hemorrhages.[10] Because of decreased perfusion of the liver during hemorrhagic shock or some underlying diseases in the liver, the conversion of lactate to bicarbonate may not happen.[11,12] On the other hand, acidic Ringer lactate solution can theoretically hamper dealing with the metabolic acidosis in these patients .Ringer lactate is a solution that has less osmolarity than plasma, and its use can lead to unresponsiveness and complications in hypovolumic patients.[13] Recently, immunological and apoptosis of liver, lung and gastrointestinal cells complications have been reported due to the use of this solution.[14] Through properties such as alkaline on one hand and hyperosmolarity on the other, 1.3% sodium bicarbonate solutions in half-normal saline with osmolarity of 430 may deal with hypovolume cause by hemorrhage and lactic acidosis. 1.3% isotonic sodium bicarbonate solution is used to treat metabolic acidosis and prevent contrast-induced nephropathy.[15-17] The solution is suitable for tackling the metabolic acidosis due to lack of chloride ion. The existence of chloride ion in crystalloid solutions leads to worsening acidosis caused by hemorrhages.[18] Ringer lactate solution contains 110 mmol chlorine per liter while 1.3% isotonic sodium bicarbonate solution is chlorine-free and 1.3% sodium bicarbonate solution in half-normal saline solution contains 65 mmol chlorine per liter. The present study was designed and performed to determine and compare the acid–base status and hemodynamics of patients suffering from intraoperative hemorrhage following the use of two different types of crystalloid solutions: Ringer lactate and 1.3% crystalloid sodium bicarbonate in half-normal saline.

MATERIALS AND METHODS

After receiving approval by the vice chancellor and the Ethics Committee of the Isfahan University of Medical Sciences with project number of 392230, providing verbal explanations to patients and obtaining informed consent, this randomized controlled clinical trial study was performed at the Al-Zahra Medical Center in Isfahan, Iran, in 2013. The study population consisted of those patients who had undergone surgery at this center.

Inclusion criteria included patients aged between 18 and 70 years, ASA = I, II, III under general anesthesia who were at risk of intraoperative hemorrhage surgery and lack of history of gastrointestinal and urinary disease leading to pre-operative acid–base disorders and lack of taking pre-operative diuretics and hemoglobin (Hb) ≥12. If hemorrhagic, resulting in cardiac arrest and hemorrhage less than the maximal allowable blood loss (MABL) with Hb levels <9, the patient was excluded from the study.

The sample size was estimated using the formula of the estimation of sample size to compare the means and considering the confidence level of 95% ($Z_{1-a}/2 = 1.96$), test power of 80% ($Z_{1-b} = 0.84$), mean intraoperative hemorrhage as in other studies; the sample size was estimated at approximately 1.17 and the least significant difference between the study groups was considered as 0.8 for 35 patients in each group.

Patients undergoing general anesthesia and meeting the inclusion criteria were selected and randomly assigned to one of the two studied groups when hemorrhage started. For the first group, crystalloid Ringer lactate solution and for the second group 1.3% sodium bicarbonate solution in half-normal saline was used. If the prediction for hemorrhage in patients was over MABL, according to the type of surgery, pathology and surgical description and with the onset of hemorrhage in patients, crystalloid solutions were started as infusion three times the rate of the volume of hemorrhage. The volume of hemorrhage was estimated as 30 cc for each wet gas, 15 cc for each semi-gas wet, 200 cc for Longaz wet and 50 cc for semi-wet Longaz.

General anesthesia was induced using thiopental 5 mg/kg, neuromuscular 0/5 mg/kg and fentanyl 2 μg/kg, and anesthesia after endotracheal intubation and mechanical ventilation with a tidal volume 10 mL/kg and RR = 10/min by 1–1.2% isoflurane and 50% nitrous oxide and oxygen mixture was undertaken. All patients underwent monitoring electrocardiogram (ECG), heart rate (HR), O_2 saturation (SpO_2), non-invasive blood pressure and end-tidal CO_2. The mean arterial blood pressure, heart rate and SpO_2 before treatment and then every 15 min were measured and recorded in the questionnaire. After induction of anesthesia and before the intervention, blood samples for arterial blood gas (ABG) and a sample from each patient to measure blood glucose, blood urea nitrogen (BUN) and chloride were collected and sent to the laboratory. If the amount of hemorrhage was more than the MABL, after the infusion of solutions and before blood transfusions, another sample was sent to the laboratory for measurement of blood parameters. Then, the values of pH, base excess (BE) and HCO3 were calculated from the blood gas sheet and the values of strong ion differentiation (SID), osmolarity and MABL were calculated according to the following formulas and recorded in the patient questionnaire.

SID = (Na + K + Mg + Ca) - CL

Osmolarity = [2Na] + CL/18 + BUN/2.8

MABL: (weight) × 0.7 male, 0.6 female × (Hb patient) – (Hb 9)/Hb patient

In the MABL formula, the calculation of target hemoglobin was equivalent to 9 g/dL. The purpose of the amount of hemoglobin higher than 12 mg/dL as inclusion criterion and also hemoglobin 9 mg/dL as the target hemoglobin is that the range of acceptable hemorrhage in patients enjoys a greater volume (at least 25% of blood volume); therefore, the volume of the provided infusion fluids will accordingly become higher. The preparation method of 1.3% sodium bicarbonate solution in half-normal saline solution was as follows: Three vials of 50 cc of 5.4% sodium bicarbonate were added to 850 cc half-normal saline solution such that 1.3% sodium bicarbonate in half-normal saline solution could be obtained.

Data were analyzed using SPSS software version 20. Statistical tests used included T Student (for comparison of quantitative data of the two groups), Chi-square (for comparison of qualitative data of the two groups) and analysis of variance with repeated measures (for comparison of changes in hemodynamic parameters between the two groups).

RESULTS

A total of 66 patients were enrolled in the study and six patients were excluded from the study, resulting in 60 patients being examined in the study. For 30 patients, Ringer lactate solution and for the other 30 patients, 1.3% sodium bicarbonate solution was used in half-normal saline solution. Table 1 shows the distribution of basic and demographic variables of the patients in both groups. On performing the T test, Chi-square test and Fisher exact tests on the mentioned data, it was revealed that the distribution of age, sex, type of operation and ASA had no significant differences between the two groups ($P > 0.05$).

Table 2 presents the means and standard deviations of the hemodynamic variables of the two groups. According to this table and to the T test, the mean HR from the 45th minute and later had a significant difference between the two groups, such that it was higher in the group receiving Ringer lactate. Also, the mean arterial pressure (MAP) from the 45th minute and after that had a significant difference between both groups, and it was lower in the group receiving Ringer lactate. Analysis of variance with repeated measures on the mentioned data also showed that the mean changes in HR had a significant difference between the two groups ($P = 0.016$). However, changes in MAP were not significantly different between the groups ($P = 0.33$). Changes in HR and MAP between the two groups have been shown in Figures 1 and 2.

The mean and standard deviation of the level of blood elements before the injection of the solution and before transfusion in both groups receiving Ringer lactate and 1.3% sodium bicarbonate solution in half-normal

Table 1: Distribution of basic and demographic variables in both groups

Variable	Group level	Ringer lactate	1.3% sodium bicarbonate in half-normal saline solution	*P*
Age	Year	56.6±13.4	6±16.4	0.88
Sex	Male	14 (46.7)	14 (46.7)	1
	Female	16 (53.3)	16 (53.3)	
Operation type	Prostatectomy	8 (26.7)	8 (26.7)	0.99
	Cystoprostatectomy	7 (23.3)	8 (26.7)	
	THA	10 (33.3)	11 (36.7)	
	EP	2 (6.7)	1 (3.3)	
	Laparatomy	3 (10)	2 (6.7)	
ASA	I	15 (50)	14 (46.7)	0.99
	II	13 (43.3)	13 (43.3)	
	III	2 (6.7)	3 (10)	

ASA: American Society of Anesthesiologist, THA: Total hip arthroplasty, EP: Ectopic pregnancy

Table 2: Mean and standard deviation of arterial pressure and heart rate from pre- to post-operation in both groups

Groups Time	Heart rate (beats/min)			Mean arterial pressure (mmHg)		
	1.3% sodium bicarbonate in half-normal saline solution	Ringer	*P*	1.3% sodium bicarbonate in half-normal saline solution	Ringer	*P*
Before hemorrhage	99.5±17.8	103.5±12.3	0.32	101.2±7.1	102.7±11.8	0.21
Min 15	101.8±20.2	103.4±12.9	0.71	101.2±10.6	95.9±9.9	0.58
Min 30	100.3±18.7	106.1±12.7	0.17	97.2±7.1	93.8±6.5	0.24
Min 45	100.3±18.2	111.4±11.5	0.007	97.3±8.3	92.5±9.2	0.002
Min 60	104.2±18.2	118.1±12.6	0.001	90±5.8	86.2±6.4	<0.001
Min 75	104.5±19.5	120.9±14.1	<0.001	86.5±5.9	83.7±6	<0.001
Min 90	103.1±17.7	116.1±15	0.003	87.2±10.8	83±6	0.3
P	0.07	<0.001	0.016	0.001	<0.001	0.33

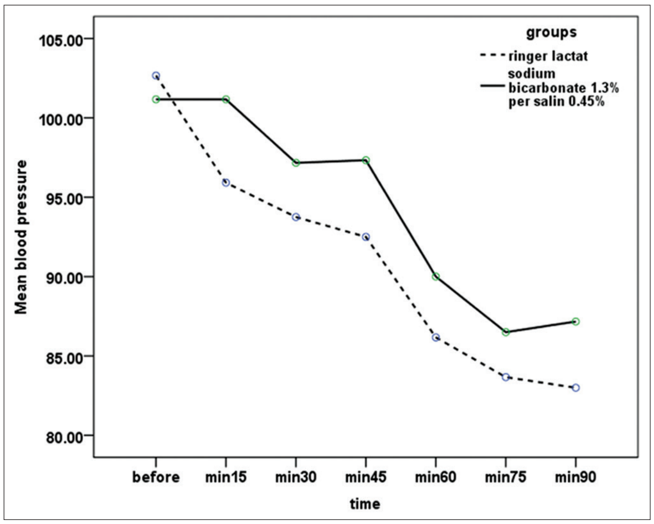

Figure 1: Pre-operative heart rate changes to min 90 in both groups

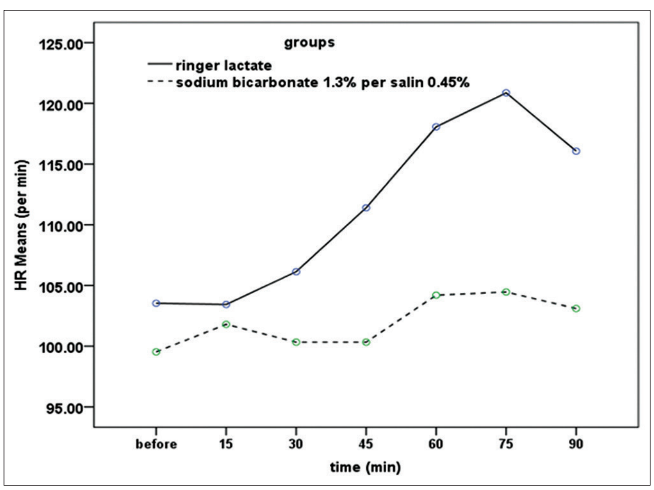

Figure 2: Pre-operative mean arterial pressure to min 90

saline solution are shown in Table 3. According to this table, none of the studied variables had statistically significant differences between the two groups before the treatment. But, before transfusion, the pH levels, BE, bicarbonate, sodium, potassium, chloride, SID and osmolarity were significantly different between the two groups.

DISCUSSION

The objective of this study was to determine and compare the acid–base, electrolytes and hemodynamic status in surgical patients following hemorrhage using Ringer lactate solution and 1.3% sodium bicarbonate in half-normal saline solution.

In this study, two groups of patients undergoing surgery were studied and evaluated in terms of basic variables such as age, gender, type of surgery and ASA physical class differences, which had no significant differences; therefore, the intervening effect of these factors were neutralized and the obtained results were most likely related to the effect of the solution type used for the patients. According to the obtained results, the MAP had a significant difference between both groups at some times during surgery. In this regard, the mean HR was different in both groups in most times and patients receiving Ringer lactate had a higher HR and the difference was more clear specially after the 45th minute. Therefore, patients receiving 1.3% sodium bicarbonate in the half-normal saline solution had more optimal hemodynamic stability than patients receiving Ringer lactate. Hemodynamic study until the 90th minute was performed because the administration of fluids was continued to this time but the comparison was not conducted after this time due to blood administration in both groups. In a study conducted in Tehran in 2008, it was determined that in hemorrhagic shock by applying both Ringer lactate and 5% saline solutions, there was a significant difference between MAP and HR at the beginning and ending times of each group while there was no significant difference in the improvement of hemodynamic status. As previously mentioned, in the present study, the group receiving 1.3% sodium bicarbonate in half-normal saline solution has had lower HR compared with the Ringer lactate group.[19] 1.3% sodium bicarbonate solution in half-normal saline solution is considered as a hypertonic liquid, but its tonicity is less than 5%

Table 3: Mean and standard deviation of the level of blood elements during pre-injection of the solution and transfusion in the two groups

Groups Variable	Before serum injection			Before blood injection			Two time different		
	Ringer lactate	1.3% sodium bicarbonate in half-normal saline solution	*P*	Ringer lactate	1.3% sodium bicarbonate in half-normal saline solution	*P*	Ringer lactate	1.3% sodium bicarbonate in half-normal saline solution	*P*
pH	7.37±0.01	7.37±0.01	0.93	7.3±0.05	7.42±0.06	<0.001	0.05±0.04	0.05±0.06	<0.001
BE (mEq/L)	−2.1±1.4	−1.37±0.81	0.06	−4.5±2.23	0.67±2.7	<0.001	−4.5±2.4	−2.03±2.7	<0.001
HCO_3 (mEq/L)	21.6±1.35	22.4±0.97	0.05	19±1.9	23.9±2.31	<0.01	2.57±1.4	−1.5±2.5	<0.001
Na (mEq/L)	138.2±2.09	138.2±2.8	0.99	136.6±3.08	142.3±5.2	<0.001	1.53±0.48	−4.17±0.67	<0.001
Ca (mg/dL)	8.94±1.1	9.27±0.62	0.16	9.12±0.39	9.1±1.4	0.99	−0.18±1	0.15±1.28	0.26
Mg (mg/dL)	1.88±0.15	1.94±0.14	0.14	1.93±0.16	1.97±0.15	0.32	−0.05±0.15	−0.03±0.2	0.69
K (mEq/L)	3.91±0.32	3.85±0.28	0.42	3.92±0.32	3.73±0.37	0.036	−0.004±0.19	0.12±0.06	0.07
Cl (mEq/L)	101.2±2.5	103.7±4.9	0.08	106.5±4.3	102.2±5.1	0.001	−5.33±0.61	1.5±0.39	<0.001
Glucose (mg/dL)	135.8±34.4	127.3±36.4	0.36	140.3±30	139.4±41.2	0.93	−4.53±2	−12.2±4.4	0.12
BUN (mg/dL)	19.5±4.6	21.4±6.2	0.19	20.6±4	22.4±6	0.17	−1.03±0.5	−1±0.63	0.97
SID	51.7±3.3	49.6±5.3	0.063	45.1±5.9	55±6.1	<0.001	6.63±4.5	−5.4±3.9	<0.001
Osmolarity (mOsm/L)	288.9±4.6	289.5±6.3	0.69	274.7±6.3	286.4±9.8	<0.001	14.2±5.4	3±7.3	<0.001

BUN: Blood urea nitrogen, SID: Strong ion differentiation

in hypertonic saline solution. Thus, it seems likely that, compared with 5% hypertonic saline solution, the improvement of hemodynamic status resulted from 1.3% sodium bicarbonate solution is related to its alkalinity property and dealing with acidosis from hemorrhage.

In a research performed by Noritomi *et al*. in 2011, using normal saline in the treatment of hemorrhagic shock induced in animals caused reduction in BE and created hyper-chlormic acidosis.[20] In the present study, patients receiving 1.3% sodium bicarbonate in half-normal saline solution had more stability on changes in BE, SID, Cl and pH. Thus, it seems likely that in the presence of bicarbonate ion and also having fewer ions to normal saline, the serum does not lead to hyperchlormic acidosis and reducing SID. Also, results of other studies have shown that crystalloid solutions differently affect the acid–base status of patients so that they can lead to intensifying metabolic acidosis in some circumstances.[6]

In a study conducted in 2003, Reid *et al*. reported that even in healthy patients receiving 2 L of normal serum saline also causes hyperchloraemia.[7] In addition, in a study performed by Scheingraber *et al*. in 1999 on patients undergoing major intraabdominal gynecologic surgery, it was found that the use of normal saline serum causes metabolic hyperchlormic acidosis and reduction of SID, but these disorders were not seen in patients receiving Ringer lactate solution.[21] However, in this study, severe hemorrhage is not mentioned. Thus, it seems likely that the relative disorder of SID, pH and Cl in those receiving Ringer lactate serum in the present study is because of the inability of Ringer lactate in the improvement in these variables during severe hemorrhage than 1.3% sodium bicarbonate solution in the half-normal saline solution.

SID is the difference between cations of Na, K, Mg and Ca and anions of Cl so that any change in SID leads to a change in the ions of $[OH]^-$ and $[H]^+$. Reducing SID causes acidity and increasing SID causes alkalinity. Its normal rate is 40–44. SID is an independent variable and ions of $[OH]^-$ and $[H]^+$ are dependent variables, wherein changes in ions of $[OH]^-$ and $[H]^+$ are the only changes and without changes the associated ions will not effect the pH.[22] Also, in the present study, SID changes have been consistent with changes in pH, and this has greatly resulted from the lack of increasing strong anion of chloride following use of 1.3% sodium bicarbonate in half-normal saline solution. In a study conducted by Fukuta *et al*. in 1998, it was determined that after blood loss, pH and bicarbonate of arterial blood decreases and lactate rate increases, such that following the use of Ringer solution with bicarbonate and then Ringer lactate, these parameters were clearly improved. The same results were also observed in the present study, with the difference that 1.2% sodium bicarbonate solution in half-normal saline solution was used instead of using bicarbonate Ringer.[23] During a survey conducted by Kees *et al*. in 2005 on Ringer solution produced in a company, it was reported that the measured osmolarity was 208 mosmol/L, unlike the osmolarity written on the solution (276 mosmol/L). According to the author of the article, using such a solution can even be dangerous in certain clinical circumstances.[24] It seems likely that other solutions such as Ringer lactate serum enjoys real lower osmolarity than what is written on the solution. With regard to the issue on the one hand and osmolarity equivalent to 273 mosmo/L related to the Ringer lactate on the other hand, it shows more hypotonicity than the Ringer solution. Therefore, it likely causes a greater decrease in blood osmolarity, while 1.3% sodium bicarbonate in half-normal saline solution leads to more stability in blood osmolarity, as has been shown in the present study.

As noted earlier, the comparison of blood elements in the two studied groups revealed that changes in the rate of serum pH, BE, bicarbonate, sodium and also strong ions including potassium, chloride, SID and the osmolarity have significant differences between the two groups before blood transfusion. Therefore, in comparison with Ringer lactate, using the mentioned solution has been consistent with the stability of blood elements and electrolytes in patients. Therefore, in order to cope with ensuing complications of blood loss and hemorrhagic shock, the use of the mentioned solution will have more favorable outcomes.

Impossible use of 1.3% isotonic sodium bicarbonate solution that is obtained by adding 150 mL of 8.4% sodium bicarbonate to 850 mL of distilled water because of non-availability for comparing with current solutions, difficulty in measuring ABG serial and electrolytes and also impossibility of simulation of hemorrhagic shock in this study can be considered as limitations of the study. Finally, it is concluded that in the hemorrhage conditions, the use of Ringer lactate solution can lead to the lack of proper correction of hemodynamic disorders, intensification of lactic acidosis, increasing chloride ion and reduction in osmolarity and SID and, correspondingly, using 1.3% sodium bicarbonate in half-normal saline solution can be useful in maintaining hemodynamic, osmolarity and electrolytes; also, better balance of acid–base in a more favorable way to cope with the effects resulting from hemorrhages.

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Conflicts of interest

There are no conflicts of interest.

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