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Original Article

Evaluation of the Correlations Between Sodium Fluctuations and Clinical Outcomes in Children Undergoing Cardiopulmonary Bypass

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ABSTRACT

Introduction: Sodium abnormalities constitute some of the most common electrolyte disorders during cardiopulmonary bypass (CPB), and they exhibit a rise for various reasons during CPB. The use of CPB for correcting congenital heart diseases in infants has profound physiological effects on most organs. The devastating effects of CPB are often more pronounced in infants. This study aimed to determine the relationship between sodium fluctuations and clinical outcomes in infants undergoing CPB.

Methods: This cross-sectional study (correlational) was conducted on 473 children who underwent CPB in 2016 according to our inclusion criteria. The samples were divided into 2 groups according to sodium fluctuations with a cutoff point of 15 mEq/L, and the clinical outcomes were compared between the 2 groups. The data were analyzed by SPSS, version 16, and presented as descriptive and inferential statistics.

Results: The incidence of cardiac (P<0.001), pulmonary (P=0.005), renal (P=0.02), neurologic (P=0.001), and hemorrhagic (P=0.02) outcomes were significantly different between the 2 groups. Gastrointestinal outcomes, infection outcomes, intubation time, intensive care unit stay, hospital stay, and mortality were not significantly different between the 2 groups.

Conclusions: Sodium fluctuations of 15 mEq/L or higher, as an independent factor, exacerbated cardiac, pulmonary, neurologic, renal, and hemorrhagic outcomes. ***(Iranian Heart Journal 2021; 22(2): 27-37)***

KEYWORDS: Sodium oscillations, Pediatric cardiac surgery, Cardiopulmonary bypass, Clinical outcomes

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Heart diseases are considered epidemic disorders in the present age. These diseases are responsible for the increase in mortality, disability, and medical costs. [9]

By 2016, in the United States, 37 000 000 coronary artery bypass grafting procedures and 14 000 000 valve surgeries had been performed. [2, 3] Thanks to advances in pediatric cardiac and thoracic surgery, approximately 85% of infants with congenital heart disease currently survive to adulthood. [1]

Cardiopulmonary bypass (CPB) for pediatrics often requires changes in temperature, hematocrit, and flow rates over a very wide range. [5, 9] As a result, the use of CPB to correct congenital heart diseases in children has profound physiological effects on most organs. [10, 11] The devastating effects of CPB are often more remarkable in infants by comparison with adults. One reason is that many organs such as the brain, the lung, the coagulation system, and the endocrine system are still immature and have not developed sufficiently. In addition, newborns and infants have higher metabolic needs and, therefore, require a greater flow rate for perfusion per unit area of their body. [12]

Sodium abnormalities are one of the most common electrolyte disorders during CPB, and they exhibit elevations for various reasons during CPB. The reasons for this include high intakes of fluids during CPB (preparation solutions, cardioplegic solutions, and product injections), the use of diuretics, impaired antidiuretic hormone secretions, and cardiac natriuretics during CPB. [14-16]

Sodium is the first determinant of osmolarity and the main regulator of the extracellular fluid volume. The absorption or excretion of sodium is usually associated with the absorption and excretion of water. In addition, sodium is active in maintaining electrochemical states and essential for muscle contraction and nerve transmission. Sodium imbalance often occurs during clinical trials due to simple or complex causes, and sodium deficiency and sodium excess are among the most common disorders of sodium imbalance. [17]

In a retrospective, descriptive study, symptoms and clinical outcomes of severe sodium disorders were assessed at the time of admission in the emergency department. The results showed that 38% of patients with severe hypernatremia and 68% of patients with severe hyponatremia had neurologic symptoms. The most common symptom of hypernatremia was a lack of awareness of time and place, and the most common symptoms of hyponatremia were weakness and nausea. The results of that study demonstrated that sodium level disorders were the most common incidence in the emergency department. [18] Another study also showed that 10% of patients after open-heart surgery in the intensive care unit (ICU) had elevated serum sodium levels and longer hospital stays with a mortality rate of 19%. Sodium deficiency was closely associated with the patients' body surface area, the duration of surgery, preoperative sodium levels, and postoperative lactate levels. [19]

Studies on electrolyte disorders, especially sodium and its oscillations, show significant complications from the cardiac surgery process, especially in patients undergoing CPB surgery. Because of the relatively high incidence of postoperative clinical outcomes, research is needed to reduce and control these adverse outcomes. In addition to surgical and technical interventions, anesthesiologists, practitioners, and ICU nurses with pharmacological interventions and physiological management strategies can alleviate these symptoms in patients.

Despite the importance of this electrolyte, no special protocol has been defined to treat its disorder during surgery. The results of the previous studies vary in different centers and conditions. Given the discrepancies among the few investigations in this regard, we examined the relationship between fluctuations in sodium levels and clinical outcomes in infants (aged 0–24 mon) undergoing CPB.

METHODS

This study was a cross-sectional study (correlational). The study population comprised children between 0 and 2 years old with congenital heart diseases undergoing CPB in 2016. The continuous sampling method was used in the present study. The total sample size was 473 according to the inclusion criteria. The patients' data, including demographic, hospitalization, and surgical information, were recorded at 3 time points (preoperative, intraoperative, and postoperative). The samples were divided into 2 groups in terms of sodium oscillations with a cutoff point of 15 mEq/L. Clinical outcomes were compared between the 2 groups. The outcome was defined as the incidence of at least 1 outcome in each outcome group. The relationships between outcomes and demographic information were also examined. Data were collected and recorded from the patients' medical, anesthesia, CPB, and ICU sheets.

The inclusion criteria were comprised of not having a history of neurological disorders, not having a history of chromosomal abnormalities, having undergone CPB, not having had preoperative cardiopulmonary resuscitation, not having been intubated before surgery, surviving the surgery for at least 24 hours, and having complete medical record information.

Data were collected using data collection forms, whose validity and reliability were confirmed before the study. The data included demographic characteristics such as age, sex, height, weight, and the body surface area, as well as hospitalization and surgical information. Hospitalization and surgical data contained 3 parts. Preoperative information consisted of disease diagnosis, surgical reassessment, and laboratory tests (sodium, hemoglobin, platelet, and creatinine). Intraoperative information encompassed the duration of surgery, the duration of CPB, the duration of the aortic clamp, blood transfusion, intraoperative blood product transfusions, and sodium levels during surgery. Postoperative information comprised sodium levels during the first 24 hours of ICU stay (at 2-4, 6-8, 10-12, 14-16, 18- 20, and 22-24 hours after ICU entrance) and the transfusion of blood and blood products.

Cardiac outcomes were defined as arrhythmias (atrial fibrillations, premature ventricular contractions, premature atrial contractions, paroxysmal supraventricular tachycardias, and ventricular fibrillations), myocardial infarction, cardiac tamponade, cardiac arrest, pacemaker dependence, receiving more than 2 inotropes, and deep vein thrombosis. Neurologic consequences were considered to be dizziness, drowsiness, seizure, blindness, and motor impairment. Respiratory outcomes consisted of pneumothorax, hemothorax, pleural effusion (need for tubal ligation), atelectasis, pulmonary edema, a drop in the partial pressure of oxygen of below 60 mm Hg, reintubation, and pneumonia (sputum culture positive). Renal outcomes encompassed a 50% increase in baseline creatinine; dialysis; hematuria; infection including wound infection (purulent discharge and wound culture with positive results); sepsis (positive blood culture); and a fever of greater than 37.5 °C. Gastrointestinal outcomes were defined as ascites (need for peritoneal catheter insertion) and gastrointestinal bleeding. Other outcomes were bleeding greater than 100 mL/kg of body weight at ICU admission. The length of hospitalization and ICU stay, intubation, and mortality up to 30 days after discharge were also assessed.

Statistical Analysis

The data were analyzed with SPSS, version 16. Descriptive (frequencies and the mean ± the standard deviation [SD]) and inferential (the independent *t*-test, the χ^2 test, and the Pearson correlation analysis) statistics were used to report the findings.

Ethical Considerations

The study protocol was approved by the Research Ethics Committee of Iran University of Medical Sciences (ethics code: IR.IUMS.REC 1396.9311584006).

RESULTS

The present study investigated the relationship between sodium fluctuations and clinical outcomes in infants undergoing CPB (473 patients) aged 0 to 24 months in 2 groups with sodium fluctuations (345 patients) and without sodium fluctuations (127 patients).

The results demonstrated that 213 infants (45%) were girls and 260 (55%) were boys. The frequency distribution of age showed that 102 infants (21.6%) were included in the age group of 0 to 6 months, 114 (24.1%) in the age group of 7 to 12 months, 120 (25.4%) in the age group of 13 to 18 months, 137 (29%) in the age group of 19 to 24 months. The mean age was determined to be 13.02 months (SD=7.25).

The frequency distribution of the numerical index of the body surface area of the infants using CPB showed that 77 (16.3%) ranged from 0 to 0.29 m^2, 128 (27.1%) ranged between 0.3 and 0.39 m^2, 219 (46.3%) ranged from 0.4 to 0.49 m^2, and 49 (10.4%) were greater than 0.5 m^2. The mean body surface area was 0.30 m^2 (SD=0.09).

The frequency distribution of children with congenital malformations showed 125 (26.4%) with ventricular septal defect, 105 (22.2%) with tetralogy of Fallot, 60 (12.7%) with ventricular septal defect + atrial septal defect, 39 (8.2%) with dextro-transposition of the great arteries, 30 (6.3%) with valve abnormality, 24 (5.1%) with total anomalous pulmonary venous return, and 90 (19.1%) with other diagnoses such as atrial septal defect, Glenn shunts, pulmonary valve commissurotomy, patent ductus arteriosus, anomalous left coronary artery from the pulmonary artery, atrioventricular canal defect, and hypoplastic left heart syndrome.

The frequency of surgery duration showed that 50 patients (10.6%) had a surgery duration of less than 179 minutes, 170 (35.9%) between 180 and 239 minutes, 114 (24.1%) between 240 and 299 minutes, 105 (22.2%) between 300 and 359 minutes, and 34 (7.2%) more than 360 minutes. The mean duration of surgery was 257.84 minutes (SD=4.40). In the present study, 58 patients (12.3%) had a bypass duration of less than 60 minutes, 255 (53.9%) between 60 and 119 minutes, 110 (23.3%) between 120 and 179 minutes, and 50 (10.6%) more than 180 minutes. The mean bypass time was determined 108.25 minutes (SD=52.32).

The aortic cross-clamp time was 0 minutes (without cross-clamp) in 24 patients (5.1%), less than 30 minutes in 58 (12.3%), between 30 and 59 minutes in 190 (40.2%), between 60 and 89 minutes in 90 (19%), between 90 and 119 minutes in 60 (12.7%), and more than 120 minutes in 51 (10.8%). The mean aortic cross-clamp time was 62 minutes (SD=4.34). The preoperative hemoglobin level in 217 infants (45.9%) was less than or equal to 12 g/dL and 256 (54.1%) had hemoglobin levels greater than 12 g/dL. The mean hemoglobin level before surgery was 12.69 g/dL (SD=2.22). The preoperative hematocrit level was below 36% in 227 patients (48%) and greater than 36% in 246 (52%). The mean preoperative hematocrit level was 37.31% (SD=6.22). The preoperative creatinine frequency in 385 cases (81.4%) was less than or equal to 0.5 mg/dL. Furthermore, 88 patients (18.6%) had creatinine levels more than 0.5 mg/dL. The mean creatinine level before surgery was 0.42 mg/dL (SD=0.14). The preoperative platelet count in 75 patients (15.9%) was less than or equal to 200 000 µL, and 398 cases (84.1%) had a platelet count of over 200 000 μL. The mean preoperative platelet count in the children was 293370 μL (SD=88430).

The frequency of sodium fluctuations in the children showed that 345 cases (72.9%) had sodium fluctuations (cut point=15 mEq/L) and 128 (27.1%) had no sodium fluctuations. The results of the χ^2 test showed that the incidence of cardiac, pulmonary, renal, neurologic, and hemorrhagic outcomes was statistically significant in the 2 groups, and the prevalence of these effects was higher in the group with sodium fluctuations (Table 1).

The intubation time in the majority of the patients in the 2 groups was less than or equal to 48 hours. The mean duration of intubation in the group with sodium oscillations was 54.46 minutes (SD=105.73), while this value was 45.07 minutes in the group with no oscillations (SD=86.08). The independent *t*-test results revealed that the 2 groups had no significant difference in the mean intubation time (*P*=0.36).

Evaluation of the ICU stay revealed that the highest rate was 3 to 6 days in the sodium oscillation group and less than 3 days in the group without sodium oscillations. The mean length of the ICU stay was 6.34 days (SD=6.82) in the group with sodium fluctuations and 5.42 days in the other group (SD=8.22). The independent *t*-test demonstrated no significant difference between the 2 groups in the mean length of the ICU stay (*P*=0.22).

Assessment of hospitalization showed that the highest rate ranged between 10 and 20 days in the group with sodium oscillations and less than 10 days in the group without sodium oscillation. The mean length of hospital stay was determined 15.13 days (SD=9.36) in the group with sodium oscillations and 13.71 days (SD=8.28) in the other group. The results of the independent *t*-test showed no significant difference between the 2 groups in the mean length of hospital stay (*P*=0.13).

Table 1: Evaluation of clinical outcomes in the infants undergoing cardiopulmonary bypass in the 2 groups

Sodium Oscillations (mEq/L) / Consequences		Ye s(n=345)		No (n=128)		χ^2 Test Results
		Frequency	Frequency Percentage	Frequency	Frequency Percentage	
Heart	Yes	185	53.6	43	33.6	χ^2=15 df=1 *P*<0.001
Pulmonary	Yes	214	62	61	47.7	χ^2=7.92 df=1 *P*=0.005
Infection	Yes	170	49.3	52	40.6	χ^2=2.80 df=1 *P*=0.09
Gastrointestinal	Yes	92	26.7	31	24.2	χ^2=0.29 df=1 *P*=0.59
Death	Yes	33	9.6	15	11.7	χ^2=0.47 df=1 *P*=0.49
Hemorrhagic (>100 mL/kg)	Yes	29	8.4	3	2.3	χ^2=5.43 df=1 *P*=0.02
Nephrological	Yes	152	44.1	42	32.8	χ^2=4.88 df=1 *P*=0.02
Neurological	Yes	108	31.3	20	15.6	χ^2=11.62 df=1 *P*=0.001

Table 2: Examination of the clinical outcomes with gender

Sex / Consequences		Male (n=260)		Female (n=213)		χ2 Test Results
		Frequency	Frequency Percentage	Frequency	Frequency Percentage	
Heart	Yes	123	47.3	105	49.3	χ^2=0.18 df=1 *P*=0.66
Pulmonary	Yes	158	60.8	117	54.9	χ^2=1.64 df=1 *P*=0.20
Neurological	Yes	69	26.5	59	27.7	χ^2=0.08 df=1 *P*=0.77
Infectious	Yes	133	51.2	89	41.8	χ^2=4.12 df=1 *P*=0.04
Gastrointestinal	Yes	72	27.7	51	23.9	χ^2=0.85 df=1 *P*=0.35
Nephrological	Yes	101	38.8	93	43.7	χ^2=1.12 df=1 *P*=0.28
Hemorrhagic (>100 mL/kg)	Yes	14	5.4	18	8.5	χ^2=1.74 df=1 *P*=0.18
Death	Yes	30	11.5	18	8.5	χ^2=1.22 df=1 *P*=0.26

Table 3: Assessment of the duration of postoperative intubation with the sex parameter

Sex / Intubation Time (h)	Male (n=260)		Female (n=213)	
	Frequency	Frequency Percentage	Frequency	Frequency Percentage
≤ 48	193	74.2	167	78.4
49–96	31	11.9	17	8
97–144	22	8.5	11	5.2
145–192	2	8	0	0
≥193	12	4.6	18	8.5
SD ± Mean	43.08±58.80		62.71±134.84	
Independent *t*-test results	*t*=2.11 df=471 *P*=0.03			

Examination of the clinical outcomes with the gender parameter showed that the incidence of the infection outcome was 89 infants for the female gender (41.8%) and 133 for the male gender (51.2%). The results of the χ^2 test demonstrated a significant difference between the 2 groups of boys and girls in the incidence of the postoperative infection outcome (*P*=0.04). Statistically, there was no significant difference between the boys and girls (Table 2).

Comparison of the duration of post-surgical intubation with sex showed that most of the studied units in both male and female groups were within or less than 48 hours. The mean duration of intubation was 43.08 (58.80) in the boys and 62.71 (134.84) in the girls. The results of the independent *t*-test showed that the 2 groups had a statistically significant difference in the mean duration of intubation and were heterogeneous (*P*=0.03) (Table 3).
Assessment of the length of the ICU stay showed that the highest percentage of the

studied units was in the range of 3 to 6 days in the male group and less than 3 days in the female group. The mean length of stay in the ICU was 6.14 days in the boys (SD=5.89) and 6.04 days in the girls (SD=8.59). The results of the independent *t*-test demonstrated that the 2 groups had no significant difference in the mean length of the ICU stay and were homogeneous (*P*=0.87).

Examination of hospitalization after surgery with the sex parameter showed that the highest percentage of the studied units was 11 to 20 days in the male group and less than 10 days in the female group. The mean length of hospital stay was 14.70 days (SD=8.97) for the boys and 14.80 days for the girls (SD=9.26). The results of the independent *t*-test showed that there was no statistically significant difference in the length of stay in the hospital (*P*=0.906).

Assessment of each of the clinical outcomes with the body surface area in the infants undergoing cardiac surgery showed a statistically significant relationship between the body surface area and the clinical outcomes of pulmonary, neurological, renal, infection, and death (Table 4).

The results of this study showed an inverse correlation between the quantitative variables of age and the intubation time, the ICU length of stay, and the hospital length of stay, such that an increase in age was associated with a decrease in the intubation time, the ICU length of stay, and the hospital length of stay. There was also an inverse correlation between the quantitative variables of the body surface area and the intubation time, the ICU length of stay, and the hospital length of stay. An increased body surface area was associated with a decrease in the intubation time, the ICU length of stay, and the hospital length of stay (Table 5).

Assessment of the incidence of each clinical outcome with the age demographic parameter showed a statistically significant relationship between age and the incidence of all clinical outcomes except the cardiac outcome (Table 6).

Table 4: Assessment of the incidence of each clinical outcome with the demographic parameter of the body surface area

Body Surface Area (m^2) / Consequences		Mean ± SD	Independent *t*-Test Results
Heart	Yes	0.39 ± 0.10	*t*=0.81 df=471 *P*=0.41
	No	0.39 ± 0.08	
Pulmonary	Yes	0.38 ± 0.10	*t*=3.18 df=471 *P*=0.002
	No	0.41 ± 0.07	
Infectious	Yes	0.37 ± 0.10	*t*=4.40 df=471 *P*<0.001
	No	0.41 ± 0.07	
Gastrointestinal	Yes	0.38 ± 0.10	*t*=1.59 df=471 *P*=0.11
	No	0.39 ± 0.08	
Death	Yes	0.30 ± 0.10	*t* =7.38 df=471 *P*<0.001
	No	0.40 ± 0.08	
Hemorrhagic (>100 mL/kg)	Yes	0.41 ± 0.08	*t*= -1.22 df=471 *P*=0.22
	No	0.39 ± 0.09	
Nephrological	Yes	0.36 ± 0.09	*t*=5.79 df=471 *P*<0.001
	No	0.41 ± 0.08	
Neurological	Yes	0.36 ± 0.11	*t*=4.27 df=471 *P*<0.001
	No	0.40 ± 0.08	

Table 5: Relationship between the quantitative demographic variables and the intubation time, the ICU length of stay, and the hospital length of stay in the infants undergoing cardiopulmonary bypass

Quantitative Variables / Consequences	Age	Body Surface Area
Intubation time	*r*= -0.335 *P*<0.001	*r*= -0.333 *P*<0.001
ICU stay Hospital stay	*r*= -0.214 *P*<0.001	*r*= -0.179 *P*<0.001
Hospital stay	*r*= -0.114 *P* 0.013	*r*= -0.100 *P*=0.029

ICU, Intensive care unit

Table 6: Examination of the incidence of each clinical outcome with the age demographic parameter

Age (month) / Consequence		Mean ± SD	Independent *t*-Test Results
Heart	Yes	12.62 ± 7.70	*t*=1.15 df=471 *P*=0.24
	No	13.39 ± 6.79	
Pulmonary	Yes	11.54 ± 7.39	*t*=5.39 df=471 *P*<0.001
	No	15.08 ± 6.52	
Infection	Yes	11.83 ± 7.55	*t*=3.40 df=471 *P*=0.001
	No	14.08 ± 6.81	
Gastrointestinal	Yes	11.67 ± 7.84	*t*=2.40 df=471 *P*=0.01
	No	13.49 ± 6.97	
Death	Yes	6.08 ± 7.1	*t*=7.37 df=471 *P*<0.001
	No	13.8 ± 6.83	
Hemorrhagic (>100 cc/kg)	Yes	16.47 ± 7.15	*t*=-2.80 df=471 *P*=0.005
	No	12.77 ± 7.20	
Nephrological	Yes	10.93 ± 7.69	*t*=5.38 df=471 *P*<0.001
	No	14.48 ± 6.55	
Neurological	Yes	11.02 ± 8.30	*t*=3.69 df=471 *P*<0.001
	No	13.76 ± 6.68	

DISCUSSION

CPB is associated with numerous physiological changes. Extracorporeal perfusion properties also contribute to endocrine, metabolic, and electrolyte changes.[20, 21] Patients on the pump have extensive electrolyte changes. Practically, these patients have heart diseases, and they are treated with a variety of medications, which must be considered. On the other hand, if patients have a history of heart failure, sodium accumulation, an increase in the extracellular fluid, or a decrease in the body's total potassium, their condition can be exacerbated by previous diuretics. With the onset of the pump and especially with hemodilution, large amounts of fluid and sodium are pumped into the extracellular space and blood potassium levels decrease.[22, 23]

The present study aimed to investigate the relationship between sodium fluctuations and clinical outcomes in infants undergoing CPB.

The results showed that 345 of 473 patients had sodium oscillations, which comprised 72.9% of the studied units. This percentage is different in the mentioned studies and is significantly less than the percentage obtained in this study. The cause can be the difference in the length of time taken to record the lowest and highest sodium levels. In addition, the present study was performed in infants, whose body surface area is smaller than the CPB circuit. Moreover, compared with adults, the prevalence of hemodilution in infants is higher and their body systems are not well developed in regulating and equilibrating water and electrolyte during and after surgery. In the present study, there was a statistically significant difference between the 2 groups with and without sodium oscillations in cardiac, pulmonary, neurological, renal, and hemorrhagic outcomes. Moreover, the 2 groups were homogeneous in terms of the intubation time, the ICU length of stay, and the hospital length of stay.

Consistent with the results of our study, Crestanello et al [6] investigated the impact of hyponatremia on the increase in mortality and morbidity after CPB surgery in the United States. They found that patients who had experienced a period of hyponatremia had a lower left ventricular cardiac output and a lower glomerular filtration rate. In their study, however, postoperative hypothermia was evaluated and the patients were divided into 2 groups. Lee et al [14] examined changes in sodium concentrations in children undergoing CPB surgery and its clinical results. The preoperative period was associated with more clinical problems than the postoperative period. The most common problems with acute renal failure were acute pneumonia and pulmonary congestion.

Consistent with the results of the neurologic outcome in our investigation, a study by Munoz III et al [18] investigated the effect of low sodium levels during CPB on the incidence of stroke after coronary artery bypass surgery in Texas. It was observed that a mean sodium level of less than 130 mEq/L during CPB was a risk factor for stroke in patients. Hyponatremia (sodium<135 mEq/L) increased the incidence of stroke in the patients by twofold. Another study was also conducted to investigate the relationship between sodium solutions, sodium changes, and postoperative seizures. The results showed that sodium change was strongly associated with postoperative seizures. Further, sodium changes during CPB had adverse effects on the nervous system. [18] A study in 2013 investigated the relationship between sodium and potassium changes during surgery and postoperative complications in CABG. The result of that study showed that the prevalence of coronary heart disease was not statistically significantly different between the 2 study groups, which is inconsistent with the result of our study. [4] This may be due to the nature of the study population insofar as the mentioned study was performed on adults and the present study on infants, who have not yet developed the coagulation system.

We also investigated the simultaneous use of sodium and potassium electrolytes, which precludes an accurate attribution of postoperative complications to changes in 1 or both electrolytes.

We observed a statistically significant difference in the incidence of infection between the 2 groups of boys and girls, with the incidence being higher in the male group. There were homogeneous differences in other outcomes with no statistically significant difference. There was a statistically significant difference in the duration of intubation between the 2 groups of boys and girls, with the female group having a longer duration of intubation. There was no statistically significant difference concerning the lengths of ICU and hospital stay.

Our results showed a significant relationship between the body surface area and the clinical outcomes of pulmonary, neurological, renal, infection, and death. There was also an inverse correlation between age and the body surface area, the duration of intubation, the length of ICU stay, and the length of hospital stay with a statistically significant difference. With an increase in age and the body surface area, the duration of intubation and the length of the ICU and hospital stay decreased. Other findings of this study revealed a statistically significant relationship between age and the incidence of all clinical outcomes except the cardiac outcome, indicating that the prevalence of clinical outcomes decreased with age. Overall, the findings of the present study showed that sodium oscillations could worsen postoperative outcomes. These results are consistent with the results of previous studies.

CONCLUSIONS

It can be concluded that sodium fluctuations greater than or equal to 15 mEq/L as an independent factor are implicated in cardiac, pulmonary, neurological, renal, and hemorrhagic outcomes. Indeed, these outcomes are exacerbated by such fluctuations.

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