5-2015

# Serum sodium levels and associated mortality rates and length of stay in surgical ICU patients

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**Serum Sodium Levels and Associated Mortality Rates and**

**Length of Stay in Surgical ICU Patients**

An honors thesis in partial fulfillment

Of the requirements for the degree of

Honors Baccalaureate in Nursing

By

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Honors Nursing Student

April, 2015

University of Arkansas

This honors undergraduate thesis is approved for recommendation to the

College of Education and Health Professions Honors Council.

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## ABSTRACT

Dysnatremia in the intensive care unit (ICU) is a common problem among ICU patients and has been associated with an increase in mortality rates (Sakr et al., 2013). Dysnatremia upon admission to the ICU, in comparison with ICU acquired dysnatremia, has also been linked with higher mortality rates (Sakr et al., 2013). In this quality improvement project, a retrospective medical record review was used to evaluate cohorts of normonatremic and dysnatremic patients upon admission to the surgical ICU and compare their length of stay and mortality rate. The study setting was in an intensive care unit within an urban hospital in Northwest Arkansas. Study results were then compared to previously published studies focusing on length of stay and mortality rates of dysnatremia patients in surgical ICU. The study included 103 surgical patients, 75 normonatremic and 28 dysnatremic patients, admitted to an ICU in whom sodium levels were drawn within 24 hours upon admission. The results of this study showed no statistically significant difference between normonatremic and dysnatremic patients in the length of stay or mortality rates.

# Serum Sodium Levels and Associated Mortality Rates and Length of Stay in Surgical ICU Patients

## BACKGROUND

Sodium is the major extracellular cation that exists in the body. It is maintained within a normal level, 135-145 mEq/L, by the sodium potassium pump and renal excretion. The body's total water volume can be adjusted by the manipulation of sodium (Tisdall, Crocker, Watkiss & Smith, 2006). A serum sodium content outside the range of 135-145 mEql/L can be defined as a dysnatremia. This value is a reflection of how much sodium is in the body compared to the total body water content (Stieglmair, Linder, Lassnigg, Mouhiddine, Hiesmayr, & Schwarz, 2013). Dysnatremia has a major impact in the intensive care unit (ICU) affecting between 25%-45% of all patients admitted, and thus is a large focus of the ICU nurse's responsibilities. (Sakr, Rother, Ferreira, Ewald, Dunish, Riedemmann, & Reinhard, 2013). Dysnatremias are common in the ICU due to the severity and complexity of the patients admitted. For example, in an unconscious patient, the physician must control all fluid administration and water balance levels (Lindner, Kneidinger, Holzinger, Druml, & Schwarz, 2009).

Dysnatremias have been associated with an increase in mortality rate in both instances in which the patient was admitted with dysnatremia or developed dsynatremia during their ICU stay (Sakr et al., 2013). Studies have shown that dysnatremias seen in the ICU are largely preventable and reflect largely upon the quality of care given (Stelfox, Ahmed, Zugun, Khandwala & Laupland, 2010). Mortality rates in such patients range from 42% to 62% (Stelfox, Ahmed, Khandwala, Zygun, Shahpori, & Laupland, 2008). As the serum sodium level continues to rise, it has a prognostic impact justifying that once a dysnatremia has been detected, prompt treatment is needed (Darmon Diconne, Souweine, Ruckly, Adrie, Azoulay, Cle'h, Garrouste-Oregas, Schwebel, Goldgran-Toledano, Khallel, Dumenil, Jamali, Cheval, Allaouchiche, Zeni, and Timist, 2013). Although both forms of dysnatremia development have been linked to increased mortality, dysnatremia present upon admission has been linked to higher mortality rates as compared to dysnatremia development during the ICU stay (Sakr et al., 2013; Funk, Lindner, Druml, Metnitz, Schwarz, Bauer, & Metnitz, 2010). In one study of all patients admitted to an ICU with a dysnatremia, 81.4% of the patients had hyponatremia while 18.6% had hypernatremia (Sakr et al., 2013).

**Hypernatremia**

Hypernatremia is defined as a serum sodium level greater than 145 mEq/L. This electrolyte disturbance was once thought to only affect the elderly and infants with diarrhea but has also been found upon ICU admission in 2%-9% critically ill patients (Lindner, Funk, Schwarz, Kneidinger, Kaider, Schneeweiss, Dramer, and Druml, 2007; Funk et al., 2010; Lindner & Funk, 2013). However, it is more common for hypernatremia to develop within the first week of the ICU stay rather than be present at admission (Lindner, Kneidinger, Holzinger, Druml, and Schwartz, 2009; Lindner & Funk, 2013). Symptoms of hypernatremia include lethargy, thirst, irritability, hyperreflexia, ataxia, seizures, and coma (Tisdall, Crocker, Watkiss, & Smith, 2006).

Hypernatremia will often develop due a variety of conditions that impair renal function, the inability to communicate thirst, mechanical ventilation, fever, nasogastric feeding, large amounts of saline administration, administration of sodium rich antibiotics such as fosfomycin, osmotic therapy, administration of mannitol, hypovolemia, diabetes mellitus, and diabetes insipidus (Lindner et al., 2009; Stelfox et al., 2008; Lindner & Funk, 2013; Aiyagari, Deiber, & Diringer, 2006). These situations lead to the development of free water loss and/or sodium gain (Lindner et al., 2009). In a study conducted by Lindner et al., (2009) a negative fluid balance was more common and found in two thirds of hypernatremic patients. The clinical manifestations associated with a negative fluid balance hypernatremia include polyuria and diarrhea (Lindner et al., 2009). The loss of free water can be due to renal excretion or extrarenal acts such as a fever (Lindner & Funk, 2013). Fever has thought to be responsible for 20% of hypernatremic cases (Lindner & Funk, 2013). In patients with multi-organ failure where large amounts of saline were administered throughout the course of their illness, it was found that hypervolemic hypernatremia was more common (Lindner & Funk, 2013).

No matter the cause, hypernatremia can lead to decreased left ventricular contractility, cerebral shrinkage with risk of vascular rupture, restlessness, cramps, rhabdomyolysis, impaired gluconeogenesis, hyperventilation, and disturbed glucose utilization, and coma all which will negatively impact the health of the patient (Lindner & Funk, 2013). When hypernatremia develops, there is also a shift of free water from the intracellular space into the extracellular space. This can lead to the shrinkage of brain cells, vascular rupture, and permanent neurologic damage (Lindner & Funk, 2013). Hypernatremia upon admission upon to the ICU can also be due to a neurological impairment that is preventing the patient from having adequate water uptake (Funk et al., 2010). Thirst is the body’s major defense mechanism against hypernatremia. When there is even a slight increase in the osmolality it leads to the feeling of thirst and the secretion of antidiuretic hormone. When there is an impairment of this mechanism, as when a patient is unconscious, intubated, or sedated, there is a greater risk of the development of increased serum sodium levels (Lindner & Funk, 2013).

Mortality rates are greater for patients with hypernatremia when compared with normonatremic patients. Mortality rates are also higher in patients with hypernatremia upon admission to the ICU (Lindner et al., 2007; Waite, Fuhrman, Badawi, Zuckerman, & Franey, 2013). In neurologic/neurosurgical intensive care units, patients with hypernatremia also had lower mean Glasgow Coma Scale scores and higher Acute Physiology and Chronic Health Evaluation (APACHE II) scores- indicating a greater probability of death (Aiyagari et al., 2006). Studies have demonstrated even small increases in serum sodium levels are correlated with an increase in risk for mortality (Funk et al., 2010). For example, in a study by Aiyagari, Deibert, & Diringer (2006), the mortality rate in mild hypernatremia (155-160 mEq/L) was 33%, moderate hypernatremia (151-155 mEq/L) was 29%, and the mortality rate in severe hypernatremia (>160 mEq/L) was 52%. Developing hypernatremia has also been linked to increased intensive care unit length of stay (Lindner et al., 2007; Stelfox et al., 2008; Waite et al., 2013). In summary, increases in serum sodium levels are associated with an increasing severity of disease, length of ICU length of stay and mortality (Lindner et al., 2007).

**Hyponatremia**

Hyponatremia is defined as a serum sodium level less than 135 mEq and is present in 13.7%-15% of patients upon admission to the ICU (Tisdall et al., 2006; Funk et al., 2010). Symptoms of hyponatremia include lethargy, nausea, vomiting, irritability, headache, muscle weakness/cramps, drowsiness, confusion, depressed reflexes, seizures, coma, and death (Tisdall et al., 2006). Hyponatremia commonly develops because of a negative solute balance, positive fluid balance, or a combination of the two. For example, hyponatremia can occur when the sodium loss occurs in a patient without the corresponding water loss. Hyponatremia can often be caused by the syndrome of inappropriate secretion of antidiuretic hormone (SIADH) (Tisdall et al., 2006). With SIADH, there is the retention of free water even though there is a low serum osmolality leading to a dilutional hyponatremic state (DeVita, Gardenswartz, Konecky, & Zabetakis, 1990).

A negative sodium balance is more often the cause of hyponatremia as opposed to a positive fluid balance. Hyponatremia has also been linked to receiving hypotonic fluids postoperatively (Stelfox et al., 2010). It is the most common electrolyte disorder and occurs more frequently in patients following cardiothoracic surgery, trauma, acute myocardial infarction, bacterial endocarditis, or a neurologic disorder (Darmon et al., 2013; Funk et al., 2010; Stelfox et al., 2008; DeVita, Gardenswartz, Konecky, & Zabetakis, 1990; Tisdall et al., 2006). In a study by Stelfox et al. (2010), 12 of 52 patients developed postoperative hyponatremia following cardiovascular surgery due to an increased secretion of vasopressin. Hyponatremia can be caused by a reduced cardiac output prior to surgery as well as post-surgery due to related pain and stress (Stieglmair et al., 2013). Increased urinary excretion and intracellular shifts caused by intraoperative hypothermia and extracorporeal circulation also contribute to development of post-cardiothoracic surgery hyponatremia (Stelfox et al., 2010). However, Stieglmair et al. (2013) found the main factor for hyponatremia post cardiothoracic surgery was due to renal sodium loss and water retention.

Hyponatremia has also been linked to heart failure and liver cirrhosis (Funk et al., 2010). Hyponatremia is estimated to occur in 10% of patients with heart failure. It is most commonly caused by a greater proportion of water than sodium due to the increased water retention seen in heart failure. The decrease in cardiac output, as seen in heart failure patients, also plays an important role in the development of hyponatremia. The reduction in cardiac output leads to less blood flow to the kidneys which in turn decreases the glomerular filtration rate. This reduces the rate of blood flow delivery to the diluting segment in the kidney and diminishes the ability of the body to excrete dilute urine causing a dilutional hyponatremia. Other causes of hyponatremia in heart failure are the results of extensive use of diuretics (Sica, 2005). Additional causes of hyponatremia are diarrhea, vomiting, and blood loss (Tisdall et al., 2006). Prevention of hyponatremia is mainly accomplished by the kidney with its ability to dilute the urine (Achinger, Moritz, & Ayus, 2006).

Patients with hyponatremia have been linked to an increased mortality rate as compared to those without hyponatremia (Stieglmair et al., 2013). It has also been found that even small decreases in serum sodium levels upon ICU admission can result in an increase in mortality rates (Funk et al., 2010).

## STUDY AIMS

The goal of this project to determine if there were differences in length of stay and mortality rates between normonatremic and dysnatremic surgical patients admitted to the ICU in the study hospital between March 2013 and March 2014.

The aims of this descriptive study were to 1) compare the length of stay between normonatremic and dysnatremic surgical patients admitted to the ICU and 2) to examine the mortality rate between normonatremic and dysnatremic surgical patients admitted to the ICU.

## HYPOTHESES

Based on the literature review, the following hypotheses were constructed:

(1) There will be a statistically significant difference in ICU length of stay between normonatremic and dysnatremic surgical ICU patients.

(2) There will be a statistically significant difference in mortality rates between normonatremic and dysnatremic surgical ICU patients.

## METHODS

This study was implemented following the approval of the University of Arkansas Institutional Review Board and the Quality Improvement Department of the hospital in which the study was performed.

### Design

This retrospective cohort study was designed to assess the incidence of dysnatremia in surgical ICU patients admitted at the study hospital. This quality improvement project used a retrospective medical record review surgical patients admitted to the ICU between March 2013 and March 2014.

### Data Source and Sample

Informed consent was not required as all data was de-identified in compliance with the Health Insurance Portability and Accountability Act guidelines (“Research”, 2013). All surgical patients admitted to the ICU who were $\geq$ of 18 years old were included in the study. Patients were excluded from the study if serum levels were not drawn within 24 hours of admission to the ICU, were pregnant, had a primary or secondary diagnosis of end stage renal disease (ESRD), or were admitted as a non-surgical patient. The data collected was extracted from the hospital’s electronic medical records system and included the patient’s age, sex, admitting diagnosis, comorbidities, surgical procedure performed, serum sodium levels, length of stay, and survival status.

**Procedure**

This study consisted of a medical records review of all surgical ICU patients admitted from March 2013 to March 2014. A random sample of charts was selected to provide two groups of patients. The sample was selected by using a random number generator. Group 1 (N=75) consisted of surgical patients admitted to the ICU with documented normonatremia on admission, and Group 2 (N=28) consisted of surgical patients admitted to the ICU with a documented dysnatremia. Sampling issues experienced during the study resulted in unequal sample sizes between the two groups. Data collected from each group included the patient's age, sex, admitting diagnoses, comorbidities, and surgical procedures. The mortality rate of patients for each group was also examined.

A univariate analysis was performed using all variables aforementioned. Values of categorical variables are reported as percentages and values of continuous variables as mean. To examine mortality rate of patients a Chi Square was performed. To determine if there was a difference between lengths of stay in the ICU, an independent-samples t-test was performed. A level of significance of alpha=0.05 was used to establish statistical significance. All analyses were done using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY).

## RESULTS

A total of 103 patients were included in this study. The mean age for patients in the study was 64 years of age (SD $\pm$13.60). The frequency and percentage by age range by group is provided (Table 1). The majority of participants were over the age of 61 in both Group 1 (54.7%) and Group 2 (64.3%).

*Table 1.*

*Patient Age by Group*

| | | | Group | |
|---|---|---|---|---|
| | | | Group 1 Normonatremia | Group 2 Dysnatremia |
| Patient Age | <= 28 | Count | 1 | 0 |
| | | % within Group | 1.3% | 0.0% |
| | 29 - 36 | Count | 1 | 0 |
| | | % within Group | 1.3% | 0.0% |
| | 37 - 44 | Count | 5 | 1 |
| | | % within Group | 6.7% | 3.6% |
| | 45 - 52 | Count | 8 | 5 |
| | | % within Group | 10.7% | 17.9% |
| | 53 - 60 | Count | 19 | 4 |
| | | % within Group | 25.3% | 14.3% |
| | 61 - 68 | Count | 16 | 4 |
| | | % within Group | 21.3% | 14.3% |
| | 69 - 76 | Count | 11 | 8 |
| | | % within Group | 14.7% | 28.6% |
| | 77 - 84 | Count | 11 | 4 |
| | | % within Group | 14.7% | 14.3% |
| | 85+ | Count | 3 | 2 |
| | | % within Group | 4.0% | 7.1% |
| Total | | Count | 75 | 28 |
| | | % of Total | 72.8% | 27.2% |

The mean number of comorbidities for Group 1 was 2.65 (SD $\pm$ 1.82) and for Group 2 was 2.93 (SD $\pm$ 2.05). (Table 2). The three most frequent admitting diagnoses in the total population included cardiology (43.7%, n=45), gastrointestinal (25.2%, n=26), and cancer (10.7%, n=11) as shown in Figure 1. There was not a statistically significant difference between groups in regard to the number of comorbidities by group. The most frequent comorbidities noted in Group 1 were hypertension and dyslipidemia (15.29% and 9.09% respectively) followed by an "Other" category (36%) which included comorbidities that did not appear frequently enough in the population to have their own category. The most frequent comorbidities noted in Group 2 were coronary artery disease (6.93%) and dyslipidemia (6.93%) followed by other disease processes of small frequency which were included in the "Other" category (27.72%). Cardiothoracic surgery was the most frequently performed operation at 47%.

*Table 2.*

*Frequency of Comorbidities by Group*

| | **Group 1- Normonatremic Patients** | | **Group 2- Dysnatremic Patients** | |
|---|---|---|---|---|
| **Number of Comorbidities** | **Frequency** | **Percent** | **Frequency** | **Percent** |
| 0 | 6 | 8.0 | 1 | 3.6 |
| 1 | 17 | 22.7 | 6 | 21.4 |
| 2 | 18 | 24.0 | 8 | 28.6 |
| 3 | 13 | 17.3 | 5 | 17.9 |
| 4 | 8 | 10.7 | 3 | 10.7 |
| 5 | 5 | 6.7 | 1 | 3.6 |
| 6 | 6 | 8.0 | 1 | 3.6 |
| 7 | 2 | 2.7 | 2 | 7.1 |

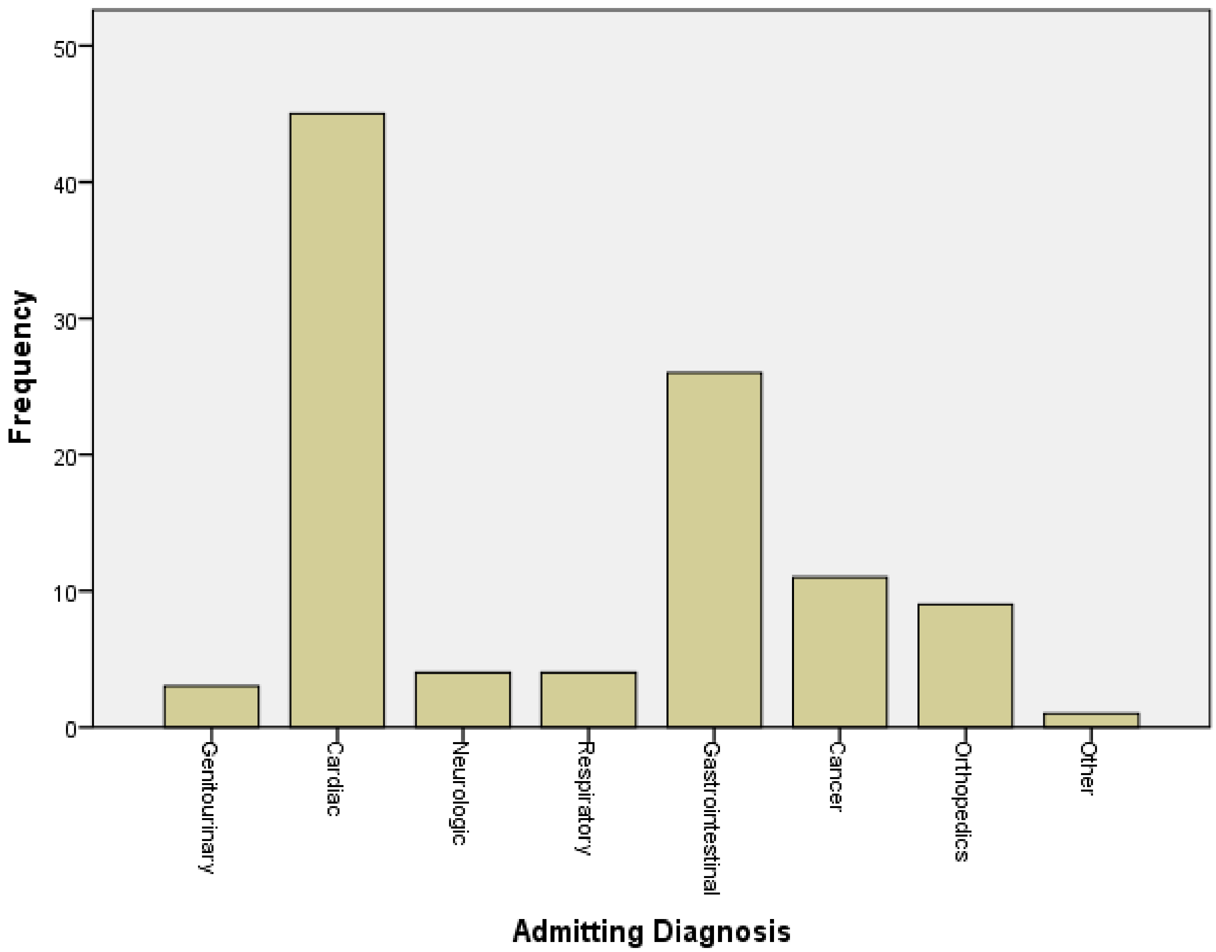


*Figure 1. The frequency of admitting diagnoses in study patients (Group 1 and 2).*

**Length of Stay in the ICU**

Total ICU length of stay ranged from 1 day to 41 days for patients in the study. The mean ICU length of stay was for Group 1 was 8.3 days (SE ± .642) and for Group 2 8.46 days (SE ± 1.43). An independent-samples t-test to determine if there were differences in the ICU length of stay did not reveal any significant results.

**Mortality Rate for the Study**

There were two deaths of patients in the study. Both deaths occurred in Group 1- normonatremic patients. No deaths were noted in Group 2, dysnatremic patients providing an overall mortality rate of 1.9% for the study groups.  A Fisher's Exact Test did not note statistical significance between Group 1 and Group 2 in terms of mortality rate.

**Sodium Levels**

In Group 1, 72.8% (n=75) of patients had sodium levels within the normal parameters of 135-145 mEq/L, while 27.2% of patients (n=28) had sodium levels which fell outside the normal parameters (< 135 mEq/L or > 145 mEq/L) (Figure 2). Within Group 2, dysnatremic patients, there were two readings of hypernatremia upon ICU admission and 26 readings of hyponatremia upon ICU admission.

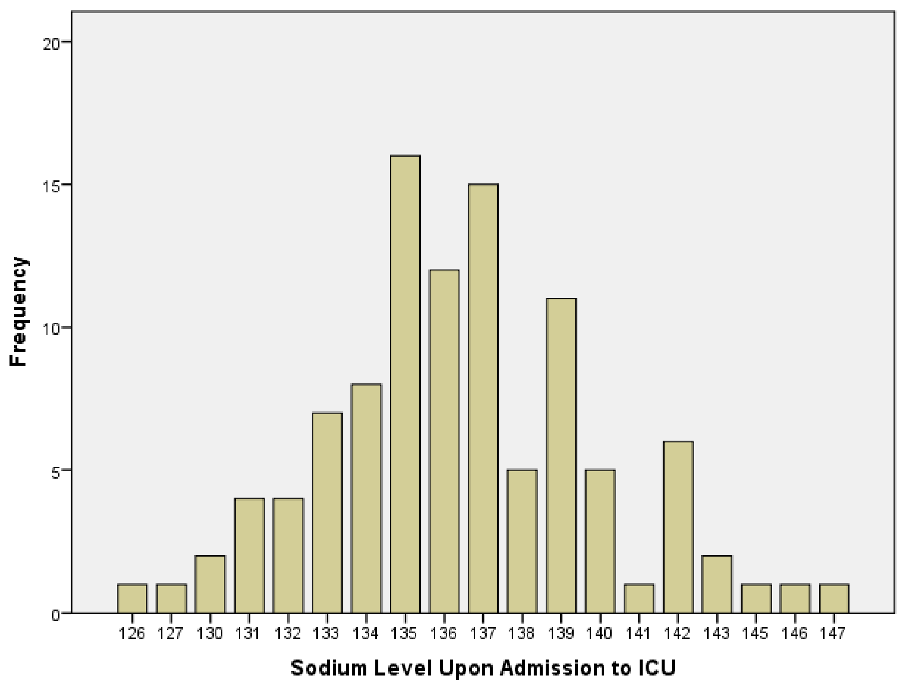


*Figure 2. Sodium levels of all study participants upon admission to ICU*

## DISCUSSION

Dysnatremia, which affects 25%-45% of all admitted patients, is common in the critically ill due to the underlying severity of illness seen in these patients (Sakr et al., 2013). Within the dysnatremic patients, hypernatremia was seen in 2 patients upon ICU admission and hyponatremia in the remaining 26 patients. This was consistent with previous research by Sakr and colleagues (2013) also noted a higher percentage of hyponatremia (81.9%) developing in patients than hypernatremia (18.6%) upon admission to the ICU. A limitation of this study was the sample size of the dysnatremic group (n=26) due to a clerical problem obtaining all the patient records.  When the total study population was taken into consideration, dysnatremia accounted for a 1.9% incidence of hypernatremia, which corresponds with a 2-9% incidence noted in Funk et al. (2010) study. In this same study, hyponatremia was stated to occur in 13.7%-15% of all critically ill patients. Findings from the current study reveal hyponatremia occurred in 23.3% (n=26) our study patients. This could be related to the great number of cardiothoracic surgical patients admitted in this study. Findings from this study are consistent with those of Stelfox et al. (2010) in which there was an increased incidence of hyponatremia in cardiothoracic surgery patients.

The exact cause of the hypernatremia or hyponatremia upon admission was not evaluated as part of this study. A pattern of comorbidities associated with the dysnatremic patients as compared to the normonatremic patients emerged with a slightly higher average number of comorbidities in the dysnatremic patients (2.93) versus the normonatremic patients (2.65). Although the difference in comorbidities between the two groups were not statistically significant, it may reflect the underlying severity of disease in the dysnatremic patient (Sakr et al., 2013). There was a higher number of patients with a cardiac diagnosis with nearly half of the surgeries performed in the entire study population (47%) being cardiothoracic surgeries. Fifty percent of the 28 dysnatremic patients had cardiothoracic surgeries performed with 12 of these found to be hyponatremic and two found to be hypernatremic upon admission into the ICU. This corresponds well to the studies by Stelfox et al. (2010) who found an increased correlation between patients who have had cardiothoracic surgery and hyponatremia. The main contributing factor post cardiothoracic surgery was renal sodium loss and water retention as seen in heart failure, although it can also be due to these patients having an increased secretion of vasopressin, reduced cardiac output, pain, or stress (Stieglmair et al., 2013). Medications that the patients were on at the time of surgery were not analyzed, but there has been an association of hyponatremia seen in heart failure due to the overuse of diuretics (Sica, 2005). With cardiovascular problems such as hypertension and heart failure, consisting of 15.8% of comorbidities, it can be assumed that a percentage of these patients would have been on a diuretic and four of the patients exhibiting dysnatremia. Diabetes, which was seen in 6.9% (n=7) of Group 2, also has a contributing factor in dysnatremia. Hyperglycemia can cause the movement of water from the intracellular space into the extracellular space- leading to hyponatremia (Saker et al., 2013). Of the 6.9% presenting with diabetes in the dysnatremic group, all had hyponatremia. Although serum glucose levels were not drawn as a part of this study, hyperglycemia can result in subsequent hyponatremia levels (Saker et al., 2013). A second frequent admitting diagnosis seen in the total patient group was gastrointestinal problems- which occurred in 15.6% of the dysnatremic population with hyponatremia presenting upon admission to the ICU. This could be related to diarrhea, vomiting, or blood loss that is often seen with gastrointestinal disorders (Tisdall et al., 2006).

Developing hyponatremia and hypernatremia has been linked to ICU length of stay, although this was not reflected in this study (Stelfox et al., 2008). Group 1 had a mean ICU length of stay at 8.53 and Group 2 had a mean ICU length of stay 8.46. The lack of statistical significance between the two groups could reflect appropriate and aggressive treatment provided by the healthcare team to rapidly correct any sodium disturbance. Aggressive therapy and correction of dysnatremias could therefore impact the ICU length of stay in patients.

Previous studies concluded that patients with hypernatremia or hyponatremia upon ICU admission had a greater incidence of mortality as compared to those not having a dysnatremia upon ICU admission (Lindner et al., 2007; Stieglmair et al., 2013). This could be attributed to the possible impact of comorbidities, age of the patient, or the severity of the surgical procedure performed prior to admission to the ICU (Saker et al., 2013). These results were not reflected in this study as there was an overall survival rate of 98% (n=101). The two deaths that occurred were within the normonatremic patient population. Although small fluctuations in serum sodium levels have been associated with increases in mortality, this was not reflected in the study (Funk et al., 2010). This discrepancy could be associated with aggressive treatment by the healthcare team which may include fluid administration during surgery or the small patient population sample.

The primary limitation of this study was small sample size. The small sample size was due to two main reasons. First, a number of charts were not available for review due to a clerical mistake. Second, the time when the serum sodium level was drawn also had to be adjusted once the study began. Originally, the study established a three hour time lapse maximum for drawing the serum sodium from when the patient reached the ICU from surgery. This criteria may have been too stringent as serum sodium levels were not promptly drawn upon arriving to the ICU. With this original time restriction it provided only a limited number of patients that met the criteria to be included in the study. To be able to obtain more data, the time allowed from arrival to blood draw was adjusted from three hours to 24 hours. Previous studies that were referenced also included up to 7 years' worth of patient data- allowing thousands of patients to be included in their analysis, while this study only contained 103 due to previously stated circumstances. The small sample size may have had an impact on the results by not having a large enough sample to demonstrate statistical significance in the length of stay and mortality rate when comparing a normonatremic and dysnatremic surgical ICU patient population.

## CONCLUSION

Dysnatremias continue to be prevalent in the surgical ICU patient and may reflect upon the complexity of the medical status of the patient as well as the quality of care given to the patient (Stelfox et al., 2010). This study did not correlate well with previous studies performed. Although we did see the same trend in the percentage of hyponatremic patients in our dysnatremic patients, our sample size was limited. Other reasons for not having other similar findings may include differences in timing of initial serum sodium levels, and early assessment and medical management of dysnatremias by the healthcare team. The study did not demonstrate a statistically significant difference in length of stay or mortality between normonatremic and dysnatremic patients. This quality improvement project allowed the hospital to reflect upon the effectiveness and timeliness of their management of sodium disturbances in surgical ICU patients by comparing results of this study with previous larger studies.

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