

Original Research Article

Effect of blood storage on electrolyte levels

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ABSTRACT

Background: Blood transfusion can be an immediate life saving measure in several acute conditions such as hemorrhage and anemia. However, various post transfusion complications are observed in patients which may be associated with the storage conditions of the collected blood. Electrolytes play a major role in maintaining homeostasis within the cells. Potassium is the most important extracellular cation responsible for maintenance of the cell integrity. Prolonged and improper storage of blood can lead to leakage of electrolytes, thus changing the cell morphology. This can adversely affect the patients who receive such blood. This study helps us analyze the effect of blood storage on electrolyte levels.

Methods: For the study, 10ml of blood was collected from 30 blood bags containing CPDA-1 at the time of blood donation from 30 different volunteers. This blood containing the CPDA-1 was divided into 5 parts of 2ml and each 2ml sample was stored in plain bulbs. All the samples were stored at 4°C. Samples were tested to check for changes in the electrolyte (Na⁺, K⁺, Cl⁻) levels on day 0, 3, 7, 14 and 21. ANOVA was used to calculate the variance in the electrolyte levels.

Results: Average sodium level on day 0 was 152.9±3.8 mEq/l. There was a significant decrease and it was measured at 139.5±4.8 mEq/l on day 21. Average potassium level on day 0 was 4.2±0.4 mEq/l. A significant spike was observed in potassium levels. The final reading of potassium level on day 21 was 15.2±0.7 mEq/l. Average chloride level on day 0 was 71.9±6.6 mEq/l which significantly declined to 67±5.9 mEq/l.

Conclusions: Though blood is stored in proper conditions, a biochemical change occurs within the cells due to prolonged storage and thus affects its viability.

Keywords: Electrolyte concentration, Stored blood, Hypernatremia, Hypokalemia

INTRODUCTION

Blood transfusion is a life saving measure used often to compensate the components of blood that are deficient in the body and it is used for various pathological conditions. Blood storage is an important and essential step prior to blood transfusion. However, prolonged storage of blood leads to alteration in the biochemistry of RBCs causing structural changes such as decrease in RBC size, rigidity of RBCs and making the fluid more acidotic.¹ Improper and prolonged storage of blood can lead to leakage of electrolytes through the RBCs.

Prolonged contact of plasma with RBCs results in exchange of contents between the plasma and the RBCs. This leads to changes in electrolyte concentrations as well as dilution. Under normal conditions in the body's circulation, these do not occur as optimum temperature, pH, nutrient concentration and waste product removal is maintained.² RBCs stored over a period of time at 4°C lose their viability and this may cause alteration in electrolyte concentration.³

Sodium is an extracellular cation which regulates blood volume and maintains nerve and muscle functions.

Sodium levels above 145 mEq/l will result in hyponatremia, leading to a hyperosmolar state. An increase in extracellular sodium causes cellular dehydration due to movement of intracellular fluid into extracellular spaces. Hyponatremia (sodium level below 135 mEq/l) can cause cellular edema which may affect the central nervous system causing depression and cerebral edema.⁴ Change in potassium levels is one of the most important electrolytic changes in stored blood. Potassium is an intracellular cation which regulates heartbeat, muscle function and is a critical part of neuron transmission. In stored blood, K⁺ slowly, but constantly leaks out of cells into the surrounding plasma. This increase in potassium levels in stored blood can be dangerous when used for transfusion. In cases of severe kidney disease, even a small fluctuation in K⁺ concentration can lead to adverse complications and can prove to be fatal. Chloride is an extracellular anion responsible for maintaining proper balance and pressure of the various fluid compartments.⁵

Imbalance in these electrolyte levels can cause muscle spasms, fatigue, hallucinations, weakness, respiratory difficulty, pH imbalance and can be fatal, causing irregular heartbeat, paralysis of lungs and cardiac arrest.⁶ All the three electrolytes (sodium, potassium and chloride) maintain electrolyte levels and are responsible for maintaining acid base balance.²

Recent reports suggest that transfusion of blood stored in improper and prolonged conditions was seen to be associated with increased risk of post transfusion complications, as well as postoperative complications and a higher mortality rate. Studies have also found a correlation between duration of RBC storage and, morbidity and mortality rates post transfusion, suggesting that prolonged storage may be responsible for adverse outcomes. Hence it is of utmost importance to observe the levels of sodium, potassium and chloride during blood storage.

METHODS

This was an observational study conducted at MIMER medical college and Bhausaheb Sardesai general hospital, Talegaon, Dabhade. It was for a duration of 4 months from June 2017 to September 2017.

A total of 30 patients were recruited as part of the study. The participants were volunteers from a blood donation camp, who were healthy and were tested negative for Australia antigen, HIV, HBV, HBC and syphilis.

Inclusion criteria

Healthy volunteers who are tested negative for Australia antigen, HIV, HBV, HBC and syphilis were included in the study.

Procedure

The normal range of the electrolytes were considered as follows; sodium: 135-145 mEq/l, potassium 3.5-5.0 mEq/l and chloride 98-108 mEq/l.^{6,7} 10ml of blood sample was collected each from 30 blood bags with CPDA-1 present in the bag at the time of collection. Each 10ml sample was collected in 5 different plain bulbs labelled as 1, 2, 3, 4 and 5 with 2ml of blood in each bulb (one collection bag contains 63 ml of citrate dextrose phosphate with adenine-1; CPDA-1).

Bulbs labeled as number 1 were processed on the same day for electrolytes and the other four were stored in refrigerator at 4-6°C. Bulbs with number 2 were processed on 3rd day, bulbs with number 3 were processed on 7th day, bulbs with number 4 were processed on 14th day and, bulbs with number 5 were processed on 21st day. Electrolytes levels from the above samples were estimated on the instrument Roche.

Time utilization calendar

Two months from sample collection, data analysis and report preparation.

Statistical analysis

The data was expressed as mean±standard deviation. Mean values were compared with the normal range by the Mann Whitney test. ANOVA was used to calculate the variance in the electrolyte levels with the help of social science statistics software.

RESULTS

The study consisted of a total of 30 healthy participants ranging from 18 to 60 years of age. Out of which 9 were female participants and 21 male participants. Ratio of male to female is showed by pie diagram in (Figure 1). Electrolyte levels in the blood collected from blood bags containing CPDA-1 and stored in 5 plain bulbs was estimated for each participant on day 0, 3, 7, 14 and 21. Electrolyte levels for 0, 3, 7, 14 and 21 days are shown in (Table 1).

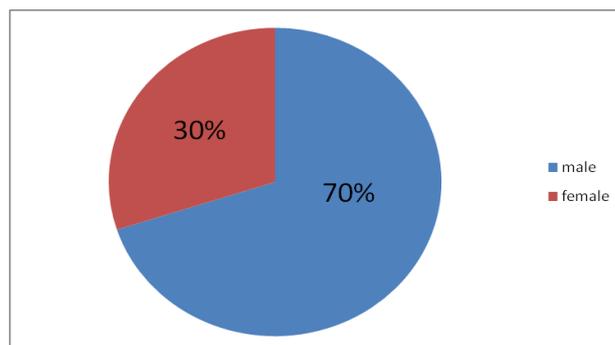


Figure 1: Male to female ratio of the samples collected.

It can be observed that there is a significant decrease in the sodium levels from 152.9±3.8 on day 0 to 139.5±4.8 on day 21 (Figure 2). There was an acclivity in Potassium levels in the blood ranging from 4.2±0.4 on day 0 to

15.2±0.7 on day 21 (Figure 3). Chloride levels in the blood are observed to significantly decrease from 71.9±6.6 on day 0 to 67±5.9 day 21 which is observed in (Figure 4).

Table 1: Electrolyte levels (sodium, potassium and chloride) over 21 days.

Electrolytes	Day wise levels						
Na ⁺	152.9±3.8	153.1±4.1	149.4±3.6	145.3±4.5	139.5±4.8	55.63509	<0.00001
K ⁺	4.2±0.36	5.5±1.0	9.9±1.3	13±1.2	15.2±0.7	701.56798	<0.00001
Cl ⁻	71.9±6.6	71.2±6.4	71.8±5.9	68.1±6.0	67±5.9	4.11411	0.003459

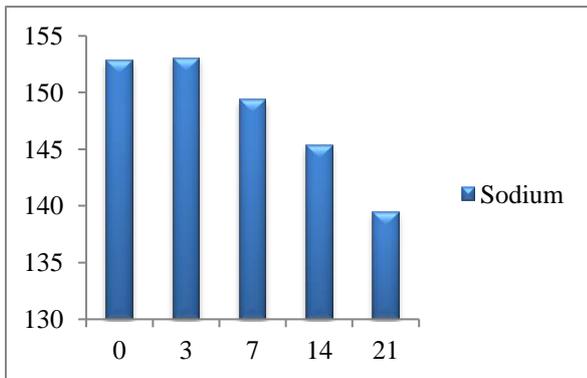


Figure 2: Decrease in sodium levels.

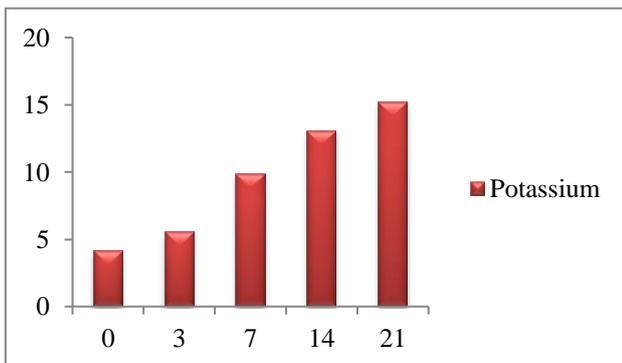


Figure 3: Increase in potassium levels.

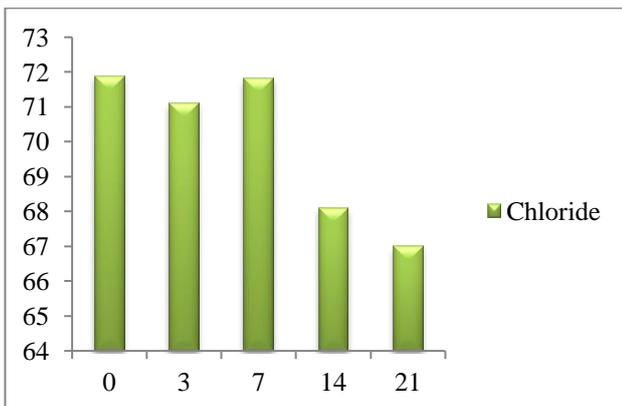


Figure 4: Decrease in chloride levels.

DISCUSSION

Blood transfusion becomes imperative and a life saving measure in many emergency situations. Storage of blood leads to alteration in the cellular integrity. This leads to leakage of potassium outside the cell along with reduction in the sodium levels in the extracellular fluid and a decrease in the chloride levels. The anticoagulant used is CPDA which is present in the blood bag. This will help to emulate the storage environment used in storage of blood prior to blood transfusion. CPDA prevents coagulation and forms an energy source which increases the viability of the cells in the blood.⁸ The study included 30 healthy volunteers and blood samples were collected from the blood bags containing the blood donated by these volunteers and were stored in plain bulbs. The study was conducted over a period of 21 days which aimed at observing changes in electrolyte levels of stored blood.

Potassium is an intracellular cation and the most important electrolyte required for proper homeostasis and maintenance of resting membrane potential. The average level of potassium in the blood is 3.5-5.0mEq/l. Potassium levels above 5.0 mEq/l is termed as hyperkalemia.⁹ The average value observed on the day of collection was 4.2. There was a small rise in the potassium levels on day 3 which reached a value of 5.5 mEq/l. There is gradual increase in the level of potassium. The average level of potassium on day 7 was 9.9 mEq/l. Further increment in the level of potassium was observed and it reached a value of 13 on day 14. The final reading of average potassium on day 21 was observed to a level of 15.2 mEq/l. There is a significant increase in potassium levels (p<0.00001) over the study duration which was similarly observed in Verma et al study.² In severe kidney diseases patients with even minute hyperkalemia can have deleterious effects.¹⁰

Sodium is an extracellular cation with a normal blood value ranging between 135-145 mEq/l. The average value of Sodium on the day of sample collection was 152.9 mEq/l. There is a mild increment in the sodium levels on day 3 and reaches a value of 153.1, followed by a mild decrease in sodium level. Average sodium level on day 7 was 149.4. Sodium levels observed on day 14 were 145.3 mEq/l. The decline of sodium continued and reached a

value of 139.5 mEq/l on day 21 ($p < 0.00001$).⁴ Drastic changes in the sodium levels can have a detrimental effect on the patients. Hyponatremia increases the incidence of edema in patients.⁶

Chloride is an extracellular anion with normal values ranging between 98-108 mEq/l. Average Chloride level observed on the day of collection was 71.9 mEq/l. There was a minimal decrease in chloride values on day 3 reaching to the value 71.2 mEq/l. There is a small increment in the chloride levels on day 7 with the reading observed as 71.8 mEq/l. After day 7 there was a significant decline ($p < 0.003459$) in chloride values which reached to a value of 68.1 mEq/l on day 14 followed by 67 mEq/l on day 21 while in International journal of science and research, the study reflected a steady decline in the Chloride levels.⁵ Many studies show RBC lesions may cause an increase in the duration of stay in hospitals, infections, pro-inflammatory and immunomodulatory effects and multiple organ failure which may lead to an increase in mortality.^{4,11} Hyperkalemia in both adult and pediatric patients is associated with severe cardiac arrhythmias and cardiac arrest after rapid transfusion of banked blood.¹² Minute changes in the electrolyte levels can have the worst outcome in critically ill patients. There is significant rise in postoperative complications in patients undergoing cardiac surgery who have undergone transfusion which may in turn cause reduction of the survival rate.^{13,14} An increase in mortality has been observed in patients receiving older blood.^{15,16} This study helps us analyze the current strategies used for blood storage and help us determine the electrolyte changes in the stored blood which have an effect on the cellular integrity. Changes in the electrolyte levels over time are observed and transfusion of this older blood can affect the patient outcome. Assessment of the duration of blood storage can thus be done to determine safe duration of storage which will help in reduction of transfusion associated co-morbidities.

Limitations

Limitations of the study should be noted, the sample size was small and blood sample storage period can be extended. Secondly subsequent changes in serum electrolytes after blood transfusion were not analyzed, so further studies are needed to support the evidence.

CONCLUSION

A significant change in the electrolyte levels of the blood containing CPDA-1 stored in the plain bulbs was observed over the course of the study. Therefore, care should be taken while determining the age of blood. Complications can occur in patients post transfusion especially in critically ill patients due to changes in the electrolyte levels. Thus, care has to be taken while transfusing older blood. Transfusion of fresher blood will help reduce complications associated with changes in electrolyte levels.

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