The Effect of Strong Ions When Added to Whole Blood or Isolated Plasma

Researchers have found that isotonic saline causes an acidosis in blood.[1,2] In his work, Stewart suggested that the strong ions are responsible for this action.[3] To test this theory, several different anions were used to create salt solutions that were isotonic relative to plasma. Water or blood that had been equilibrated to 40 mm Hg were diluted with these salt solutions and pH was recorded. Sodium chloride or sodium lactate were used for the blood, but sodium chloride alone was used to dilute plasma and red blood cells suspended in lactated Ringer's solution. The decrease in pH when whole blood was diluted with isotonic saline was smaller than all other conditions, suggesting that red blood cells removed chloride allowing plasma bicarbonate to rise.

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Introduction

When infusing isotonic saline in patients, an acidosis occurs, which can cause several problems such as coagulopathy (poor blood clotting), chloride-induced renal vasoconstriction, depression of myocardial functions, decrease in blood pressure, inhibition of membrane calcium channels and inhibition of norepinephrine. Some of these symptoms can also be caused by hypovolemia and can mislead the surgeon or anesthesiologist. An incorrect diagnosis can lead to other complications before, during and after surgery.[1,2]

Strong ions added to a solution cannot be neutralized; they can only be added or removed. Weak electrolytes, however, can remove or add hydrogen ions to solution as needed. To maintain the electrical neutrality of a solution, weak acids must adjust their ionic to non-ionic ratio. Therefore, strong ions are independent variables and weak ions are dependent variables.[3] The purpose of this study was to test the hypothesis that strong ions in solution affect pH levels.

Methods

In the first experiment, 20 mL of distilled water containing carbonic anhydrase was equilibrated with CO_2 (40 mm Hg) and then diluted with 10 mL of isotonic salt solutions. Second, whole blood which was equilibrated with CO_2 was diluted in 50% increments with NaCl, Na-Lactate and lactated Ringer's solution up to 300%. In another experiment, isolated plasma that was also equilibrated with CO_2 was diluted up to 300% with NaCl. Finally, red blood cells were suspended with lactated Ringer's solution, equilibrated with CO_2 and diluted with NaCl. The pH was measured before and after the dilutions. A *t* test was used to compare the data and the level of significance was set at $P<.05$.

Results

Diluting water with isotonic saline produced the lowest pH (4.5); while the highest pH in water was produced by diluting with sodium bicarbonate. Diluting whole blood with sodium chloride did not produce a large fall in pH until the dilution exceeded 150% of the original blood volume. When isolated plasma was diluted with isotonic saline the fall in pH was linearly related to the amount of diluting fluid (Figure 1). Whole blood diluted with Na-Lactate also showed a fall in pH that was similar to the isolated plasma. Whole blood was also diluted with lactated Ringer's solution instead of NaCl, and once again, the results resembled those of isolated plasma. Similarly, red blood cells (RBC) suspended in lactated Ringer's solution, then diluted with isotonic saline, produced results more like isolated plasma than like whole blood.

Discussion

The results from the experiment in which whole blood was diluted with isotonic saline did not produce a severe acidosis until a large amount of NaCl was added. This is most likely the result of the RBC removing some of the

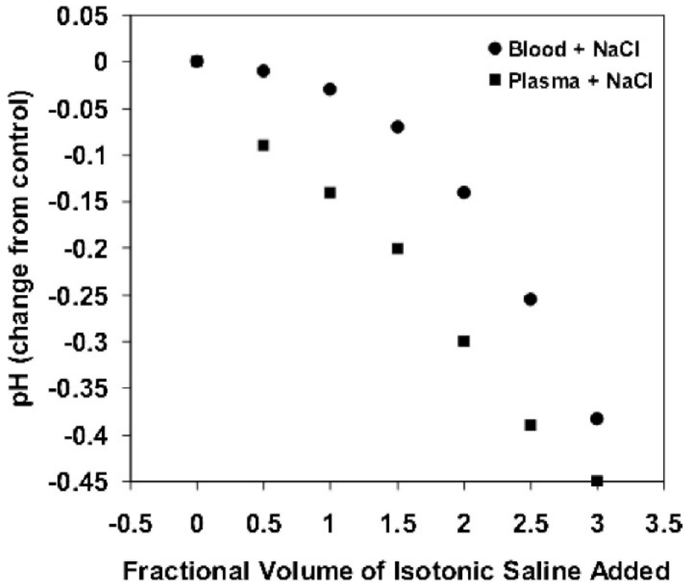

Fig 1. Scatterplot showing the fall in pH with increasing dilutions of plasma or whole blood using isotonic saline. Zero added saline represents the control condition

chloride because of the chloride shift mechanism and releasing bicarbonate. Isolated plasma showed a greater acidosis than that of blood. Since RBC were not present in plasma, the hypothesis that RBC removed chloride was supported. Further support for this assumption is seen by the experiment in which whole blood was diluted with Na-Lactate. The fall in pH was similar to that of plasma. Because RBC have little ability to remove lactate, the lactate added remained in plasma, causing pH to fall as if RBC were not present. When RBC suspended in lactated Ringer's solution was diluted with isotonic saline, the fall in pH was similar to that of isolated plasma. This may be due to several possibilities. One is that the chloride shift mechanism is not working and is somehow inhibited by the suspension. In addition, removing plasma proteins will affect blood buffering.

Although lactate is a strong ion, infusing lactated Ringer's solution in patients does not produce an acidosis. This is likely the result of the liver removing lactate, restoring the proper strong ion difference and raising bicarbonate concentration. Knowing the implications of infusing different solutions in severely dehydrated patients will lead to better patient management.

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