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The Effect of Sodium Chloride Concentration on Solution Pressure Inside Dialysis Tubing

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Summary

High blood pressure causes significant medical problems around the world such as strokes, blindness and even death. Many people with high blood pressure are asked to lower their intake of salt in their diet which led us to wonder how blood pressure changes with more salt in the body and how the kidney diffuses water in response to salt concentration in the blood. Chemically, the salt outside of the blood vessels affects the pressure inside of the blood vessels due to the movement of water across the vessel walls. We used dialysis tubing containing a 0.9% salt-water solution to simulate the standard concentration of sodium chloride in the blood vessels. These simulated blood vessels were then placed in high and low salt solutions and a gas pressure sensor was used to monitor pressure changes in the dialysis tubing. The results showed that when the dialysis tubing was immersed in a solution that contained less salt, the pressure increased, and when it was immersed in a solution that contained more salt, the pressure decreased. Almost no change was recorded in the 0.9% solution. These findings suggest that salt concentration in the blood would impact the rate of osmosis, changing the pressure within the blood vessels.

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Introduction

High blood pressure has often been associated with the excessive consumption of sodium chloride, or salt. The American Heart Association recommends that the average salt intake should be approximately 2,300 mg per day. In reality, most Americans consume around 3,400 mg per day (1). With a decrease in sodium chloride intake from the average amount consumed to the recommended amount, most people see a 1% to 2% decrease in blood pressure (1).

The kidneys work to remove sodium chloride (salt) from the bloodstream using active transport (2). High sodium chloride intake can cause blood pressure to increase when the kidneys become unable to filter out the large amount of sodium chloride in the blood (3). As the sodium chloride concentration increases in the blood, water from the kidneys is moved into the blood vessels through osmosis (2). As water moves into blood vessels, pressure is increased. Although having too much water in your blood vessels may cause high pressure, having too little can potentially cause weak brain function and weak muscles (4). When people become dehydrated, they are in desperate need of water and may seem confused and experience weakness. They may be given an intravenous solution, which is 0.9% sodium chloride, to act like the body's own fluids since it is the same sodium chloride concentration as blood (5).

Dialysis tubing mimics the function of a blood vessel. This material acts as semipermeable membrane, prohibiting the movement of some particles while allowing access to others (6). Flowing different solutions through this tubing drives a change in osmotic pressure that results in the movement of water across the membrane.

How does the concentration of sodium chloride solution affect the pressure in dialysis tubing when it is placed in a different concentration of sodium chloride solution? The change in pressure observed in dialysis tubing should be similar to the change in pressure in blood vessels after an individual has eaten a salt filled meal. We hypothesized that increasing the concentration of salt in the external solution should result in an increase in pressure within the dialysis tubing, as particles move from where there are more particle collisions to where there are less particle collisions. Similarly, if the concentration of salt is decreased, we should observe a decrease in pressure. We also predicted that a 0.9% isotonic solution, identical to body fluid, will result in no change in pressure.

Results

In order to determine how the concentration of sodium chloride solution would affect the pressure inside of dialysis tubing, we measured the pressure change when dialysis tubing filled with a 0.9% sodium chloride solution was submerged into a hypotonic 0% sodium chloride solution, an isotonic 0.9% sodium chloride solution, and a hypertonic 1.8% sodium chloride solution. We calculated the rate of diffusion by finding the linear regression of the pressure-time graph.

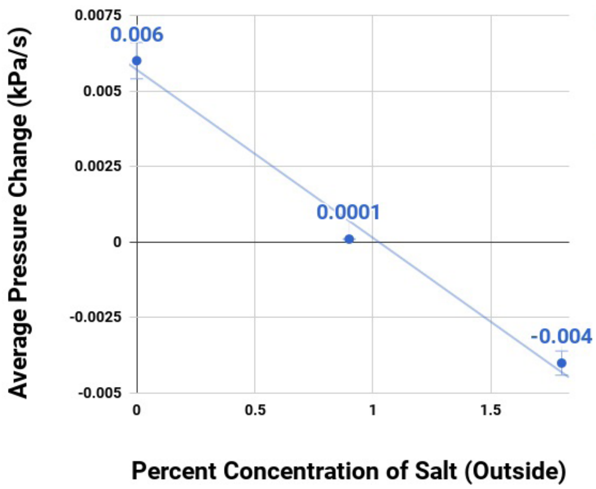

Figure 1. Average rate of change of pressure across dialysis tubing. Pressure across dialysis tubing is inversely proportional to the concentration of sodium chloride outside the tubing. The relationship is described by a linear regression (y = -5.56E-03 + 5.7E-03) with R^2 = 0.989.

In the hypotonic solution of 0% sodium chloride, pressure increased by 0.006 kPa per second (**Figure 1**). In the isotonic 0.9% sodium chloride solution, the pressure change was a negligible 0.0001 kPa per second (**Figure 1**). Lastly, when we tested the hypertonic 1.8% sodium chloride solution, the pressure decreased by 0.004 kPa per second (**Figure 1**). We observed a proportional relationship between the percent concentration of a salt in the solution and the rate of movement of water across dialysis tubing (**Figure 1**). We observed that the standard deviation is small so, we conclude that the variation between replicates is low and trials were close to the mean (**Table 1**).

We have determined the change in the pressure inside of dialysis tubing is predictable as the concentration of salt outside of the dialysis tubing changes. As the concentration of salt outside of the dialysis tubing decreases, the pressure inside the tubing will increase. Conversely, as the concentration of salt increases, the pressure will decrease.

Discussion

High blood pressure is a common medical condition around the world. When an individual eats a high sodium chloride meal, the concentration of sodium chloride in the blood increases. The concentration of sodium chloride in the kidneys is lower than in the blood, causing water to move into the blood. The pressure within the blood vessels consequently increases (1). In this experiment, we compared changes in pressure in dialysis tubing submerged in three solutions containing different percentages of sodium chloride. Altering the concentration of sodium chloride solution surrounding the dialysis tubing simulated the blood vessels in the body changing pressure due to different intakes of salt. We hypothesized that the higher salt concentrations outside the dialysis tubing would result in higher pressure inside the tubing. We expected salt movement to cause this effect, but this was incorrect. The dialysis tubing is semipermeable, allowing the movement of water across the membrane (6).

When the sodium chloride concentration inside the dialysis tubing was higher than outside of the dialysis tubing, then the pressure increased due to water moving from where there was less solute to where there was more solute. On the other hand, the pressure decreased when the sodium chloride concentration was lower compared to the surrounding solution. The pressure remained the same when the sodium chloride solution was the same on the inside compared to the outside.

Our results support the idea that blood pressure will increase when salt concentration in the blood increases. The blood pressure increase is caused by the movement of water into the blood vessel. Although active transport in the kidneys adds a layer of complexity not replicated by dialysis tubing, increased salt concentration in the blood can affect blood pressure (7). These results support the recommendation of reducing dietary salt for patients with high blood pressure.

Percent of Sodium Chloride in the Solution	Rate of Dialysis (kPa/s)				
	Trial 1	Trial 2	Trial 3	Mean	Standard Deviation
0.0	0.0060	0.0075	0.0049	0.0061	0.0013
0.9	0.0001	0.0001	0.0001	0.0001	0
1.8	-0.0230	-0.0031	-0.0078	-0.0044	0.0030

Table 1. Inter-trial variation between dialysis rates for varying percent sodium chloride concentrations.

Materials and Methods

Sodium chloride solutions were made in concentrations of 0% salt, 0.9% salt, and 1.8% salt (8). Dialysis tubing was opened in water and one end was tied and secured with dialysis clamps then filled with a 0.9% sodium chloride solution. Once it was filled with the solution, the rubber stopper connected to the Gas Pressure Sensor (GPS), was inserted into the top of the dialysis tube. This was secured by wrapping the stopper and tubing with parafilm. The beaker was filled with 1000 mL of the variable solution: 0%, 0.9% or 1.8% salt. Each solution was tested three times, while the dialysis tubing remained the same (0.9%) in all trials. The GPS and pressure monitor collected data for 5 minutes in order to observe a pressure change (9). The diffusion rate was calculated by finding the linear regression of the most linear region of the pressure time graph using the pressure monitor.

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