

The Effect of Microwave Heating on the Acidity of 0.9% Saline in 1 Litre and 100 mL Polyvinyl Chloride Packaging

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ABSTRACT

Objective: Microwave warming of intravenous crystalloid solutions is an accepted practice in operating suites and emergency departments. These intravenous solutions are stored in polyvinyl chloride (PVC) and are known to be acidic. Some of this acidity may be from PVC packaging. We asked if microwave heating affected the acidity of 0.9% saline solution in 1 litre and 100 mL PVC bags.

Methods: Seven 1 litre bags were heated in an 800 Watt microwave for 2 minutes each and seven 100 mL bags were heated for 30 seconds each. After overnight cooling to room temperature, pH and temperature were measured and compared with two control groups of 7 unheated bags.

Results: There was no significant difference between the pH of heated and unheated solutions of saline. The median pH of the 1 litre bags were 5.01 (control) and 5.02 (heated). The median pH of the 100 mL bags were 4.58 (control) and 4.59 (heated). Post hoc, we found the 100 mL bags were more acidic than the 1 litre bags by a median difference of 0.43 pH units ($P = 0.002$).

Conclusions: Microwave heating does not change the acidity of 0.9% saline in 1 litre or 100 mL PVC packaging. (*Critical Care and Resuscitation 2000; 2: 19-21*)

Key words: Microwave heating, polyvinyl chloride, sodium chloride, acids

Microwave heating of intravenous crystalloid solutions is an established clinical practice¹⁻³ in the prevention and management of hypothermia.² Intravenous crystalloid solutions are known to be acidic.⁴⁻¹² Baxter 0.9% saline bags (Baxter Healthcare, Old Toongabbie, NSW, Australia) are marked with a pH range of 4 to 7. A frequently cited reason for this acidity is the formation of carbonic acid after absorption of atmospheric carbon dioxide.⁴⁻⁵ Polyvinyl chloride (PVC) packaging may also increase the acidity of the solutions.¹³ We asked if microwave heating affects the acidity of 0.9% saline solution in 1 litre and 100 mL PVC bags.

MATERIALS AND METHODS

Fourteen Baxter 1 litre bags of 0.9 % saline from the same batch (L08F0 expiry date September 2001) and fourteen Baxter 100 mL bags of 0.9% saline from the same batch (L05F7 expiry date January 2001) were collected from the operating room store at our hospital.

These bags of saline were all packaged in PVC (Viaflex™).

The 1 litre bags were randomly divided into two groups of seven. The outer packaging was removed from all bags. One group was heated individually for 2 minutes on high setting in an 800-watt microwave (Samsung Timesaver 1996 with turn table, Samsung, Malaysia). The control group was kept at room temperature.

After overnight storage at room temperature the pH of all the 1 litre bags of 0.9% saline was measured in a random order - using a random number table - with a pH meter (Orion 420A pH meter, Orion Research, MA, USA). The temperature of these samples was measured using a Hewlet Packard thermistor probe (HP 21075A, MA, USA).

The following day, the 100 mL bags were divided into two groups of seven. One group was heated individually for 30 seconds on high in the same microwave, while the control group stayed at room

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temperature. After overnight storage at room temperature the pH and temperature of the 100 mL bags of saline were tested in the same manner as the 1 litre bags.

Statistical Analysis

Data were expressed using the median and range. The groups were compared using the Mann-Whitney *U* test using statistics software (SPSS). The 95% confidence intervals for median difference were calculated using the method of Gardner and Altman.¹⁴ Significance was assumed at $p < 0.05$. As an important pH difference between the 1 litre and 100 mL groups was observed, we conducted a post hoc comparison of the pH of saline in unheated 1 litre and 100 mL bags.

RESULTS

The control group of 1 litre bags of 0.9% saline had a median pH of 5.01 (range 4.95 to 5.04) and the heated group had a median pH of 5.02 (range 5.01 to 5.04). The median difference in the pH between the 1 litre groups was 0.01 pH units (95% CI = -0.01 to 0.03 pH units, $p = 0.15$). The median temperature of both groups was 22.8°C.

The control group of 100 mL bags of 0.9% saline had a median pH of 4.58 (range 4.53 to 4.59) and the heated group had a median pH of 4.59 (range 4.45 to 4.62). The median difference was 0.01 pH units (95% CI = -0.01 to 0.04 pH units, $p = 0.36$). The median temperature of the two groups was 22°C.

The median difference of the pH of the 1 litre and 100 mL non-heated bags of 0.9% saline between these groups was 0.43 pH units (95% CI = 0.42 to 0.47 pH units, $p = 0.002$).

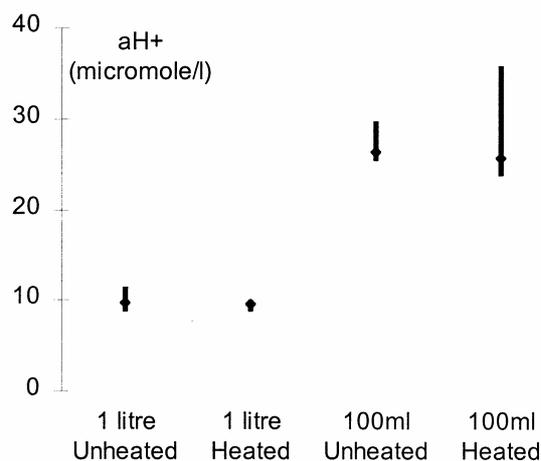


Figure 1. Hydrogen ion activity (aH+) micromoles per litre, of the four saline groups. Dots = Median, Bars = Range.

Hydrogen ion activity was calculated from the equation $\text{pH} = -\log_{10} a[\text{H}^+]$. The hydrogen ion activity for the four groups is shown in figure 1.

DISCUSSION

Microwave heating is an established way to warm intravenous crystalloid solutions.¹⁻³ Our study found that microwave heating did not increase acidity of these solutions. We studied 1 litre bags as they are the most commonly used bags in intravenous therapy and therefore most likely to be used for the prevention and management of hypothermia. The 100 mL bags were also studied as they have a high surface area to volume ratio, so if the microwave heating did result in the formation of acids from the PVC packaging this would be more easily detected.

Microwaves are electromagnetic waves of relatively low frequency (10^9 to 10^{10} Herz). They produce heat by giving quantum amounts of energy to the substances through which they pass.¹⁵ Leaman and Martyak found that the temperature of 1 litre crystalloid solutions had a linear relationship to the warming time between 1.5 and 2.5 minutes.² The regime for microwave heating of the 1000 mL bags (120 seconds on high for an 800-watt oven) is used clinically.³ The regime for microwave heating of the 100 mL bags (30 seconds on high) was created for this study in an aim to exaggerate any problems with the PVC and microwave heating.

The heated saline bags were allowed to cool to room temperature before pH measurement. Altered temperature changes carbon dioxide solubility (Henry's law) and dissociation constants for carbonic acid and other acids that may be present. To avoid these confounding factors we measured the pH of control and heated solutions at room temperature.

In 1985, Anshus, Endahl and Mottley¹ studied three 1 litre bags of normal saline and found a median pH of 5.9 preheating and a median pH of 6.0 post heating. The temperature of the solutions at the time of pH measurement was not reported. We also found no change in pH. Our study, however, used two different volumes of saline, larger samples, and had control groups. The solutions that we tested were considerably more acidic, pH 5.01 pre heating and 5.02 post heating. The reasons for the greater acidity than Anshus's study are unclear but we assume are related to differences in the manufacture of the bags.

We made the incidental finding of a lower pH in the 100 mL bags compared to the 1 litre bags. The unheated 100 mL bags had a median pH of 4.58, which is a hydrogen ion activity of 26.3×10^{-6} mol/L and the unheated 1 litre bags had a median pH of 5.01, which is a hydrogen ion activity of 9.8×10^{-6} mol/L.

The 100 mL bags are over two and a half times more acidic than the 1 litre bags. Given the increased surface area to volume ratio of the 100 mL bags compared with the 1 litre bags, it is possible that the PVC packaging is the source of the extra acid. Possible acids include formic and acetic acids from PVC degradation during post-filling sterilisation,¹⁶ and additives such as derivatives of phthalic acid. One derivative is diethylhexyl phthalate (DEHP) a plasticizer that makes plastic more malleable.¹³ Ausman, however, found in 1981 that there is no increase in DEHP after microwave thawing of parental nutrition solutions in PVC packaging.¹⁷

Our study suggests that no further acids are released in intravenous saline after microwave heating and cooling to room temperature. The difference in pH between the 100 mL and 1 litre bags of saline is not easily explained. Further research is required to determine the source of the extra hydrogen ions and their clinical importance.

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