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SCIENTIFIC ARTICLE

Is There Risk of Emboli during Infusion with Line Type Blood-Liquid Warmers?

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Abstract
Introduction: Line type blood-liquid warmers are used widely due to their low expense, practical use and nondependence on sets. We aimed to investigate the relationship of bubbles in line type warmers with two different warming properties.
Materials and methods: Two groups were designed with S-line and Astoflo® brand blood-liquid warmers. By using 10 medisets for each group (n = 20), we infused 1,000 mL 0.9% NaCl solutions at 350 mL.hour^{-1} speed for one hour in the operating room. Temperatures at the proximal, midway and distal parts of lines, temperature of experiment environment, temperature of liquid used and temperature of liquid reaching the cannula after warming were measured. Time to visually observable bubble formation was recorded. We compared findings statistically using the Mann-Whitney U test.
Results: There were no differences between the groups with respect to temperatures at the proximal, midway and distal parts of lines, temperature of experiment environment, temperature of liquid used and temperature of liquid reaching the cannula ($p > 0.05$). Bubbles were observed with both warmers and time to bubble formation was similar in the two study groups ($p = 0.143$).
Conclusions: In the experimental setting, we have designed conditions similar to our clinical environment. Both types of warmers provided similar warming levels and formed visible bubbles. Considering that low amounts of emboli can be fatal in infants and children, bubble formation should be taken seriously into account for emboli and further studies should be carried out to determine the amount, the reasons and the contents of bubble formation.

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Introduction

Blood-liquid warmers developed for blood and liquids infusion protect the patients from hypothermia and hypothermia-related side effects. Various blood-liquid warmers are being used to inhibit hypothermia which is one of the most important causes of mortality-morbidity in patients undergoing general anesthesia.[1-3]

Fast infusion systems, microwave systems and warming reservoir systems have been developed for the purpose of warming blood and serum products. Since these systems are expensive and require sets, more convenient and cheaper systems were sought after. The most widely used systems today are line type warming devices due to their low expense, practical use and nondependence on sets.[1,4] Two types of line type warming devices manufactured by two companies are used in Dokuz Eylül University School of Medicine Hospital. Lately, we have noted bubbles in serum sets during infusion via line type warmers. Embolism during anesthesia is a serious complication requiring urgent intervention. It can lead to fatal events if unnoticed or left without treatment.[4-6] Since embolism has such dangerous results, we aimed to investigate the relationship of bubbles in line type warmers with two different warming properties and whether these bubbles would cause emboli. We have seen studies report air emboli in fast infusion devices; however, we could not find any information in line type systems with formation of bubbles similar to air.

Materials and methods

After approval of Dokuz Eylul University Local Ethical Committee on Experimental Studies, we designed two groups: *S-line* (Barkey, Germany) and *Astoflo*® (Futuremed America Inc.,U.S.A.) brand blood-liquid warmers, by using 10 medisets (Eczacıbaşı-Baxter, Ayazağa/İstanbul,Turkey) for each group (n = 20).

Group *S-line* (n = 10): In the operating room, we performed infusion of 1,000 mL 0.9 % NaCl solutions (Eczacıbaşı-Baxter, Ayazağa/İstanbul, Turkey) by using *S-line* blood-liquid warmer at 350 ml/hour speed for one hour (Fig. 1).
Group *Astoflo*® (n = 10): In the operating room, we performed infusion of 1,000 mL 0.9 % NaCl solutions (Eczacıbaşı-Baxter, Ayazağa/İstanbul, Turkey) by using *Astoflo*® blood-liquid warmer at 350 ml/hour speed for one hour (Fig. 2).

Experiment setup

S-line and *Astoflo*® brand serum warmers were mounted on two serum hangers at equal high levels. Before the study, temperatures at the proximal, midway and distal parts of lines, temperature of experiment environment, temperature of liquid used and temperature of liquid reaching the cannula after warming were measured in order to determine the warming level of liquid warmers (Fluke 87 V, USA). We recorded time to visually observable bubble formation. We prepared a 1,000 mL 0.9% NaCl solution for infusion with the same brand serum sets (Mediset). After filling the serum set reservoirs equally with liquid, we filled serum sets with 0.9 % NaCl taking care to avoid any bubbles. In order to mimic the clinical scenario and to stabilise flow rates, we mounted a "drop adjusting set" (Lacus, Ankara) and 18-gauge cannula (Bıçakçılar, İzmir) at the end of the serum set. We repeated these procedures 10 times in each group.

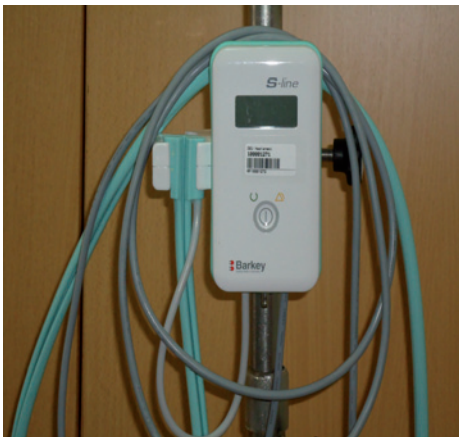

Figure 1 *S-line* blood-liquid warmer.

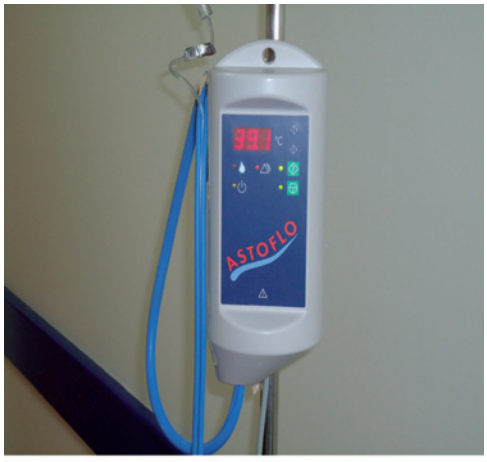

Figure 2 *Astoflo*® blood-liquid warmer.

Statistical methods

We analyzed all data obtained from the study using SPSS 15.0 for Windows (Chicago, Illinois, USA) program. We used non parametric tests (*Mann-Whitney U* for statistical comparison. Data are given as mean ± standard deviation (mean ± SD) and $p < 0.05$ was considered statistically significant.

Results

Temperature of experiment environment, temperature of liquid before infusion, temperature of adjusted warmer, temperatures of warming lines' proximal, midway and distal parts, temperature of liquid exiting from the cannula were similar among the two study groups, and there were no statistically significant differences ($p > 0.05$ for all) (Table 1).

Visually apparent bubbles were determined at 9.7 ± 0.94 minues in Group *S-line* (Fig. 3), and at 9.00 ± 1.05 minutes in Group *Astoflo*® (Fig. 4). Time to bubble observation was statistically similar between the two study groups ($p = 0.143$).

Table 1 Comparison of temperature measurements between the two study groups.

Measured Temperatures	Group *S-line* (°C) (mean ± SD)	Group *Astoflo*® (°C) (mean ± SD)	p value
Temperature of experiment environment	22.40 ± 1.37	21.33 ± 0.34	0.271
Temperature of liquid before infusion	21.85 ± 1.47	20.93 ± 0.57	0.123
Temperature of adjusted warmer	39.19 ± 0.25	39.33 ± 0.17	0.143
Temperature of warming line's proximal part	40.16 ± 1.27	41.06 ± 0.83	0.143
Temperature of warming line's midway part	39.80 ± 1.33	40.16 ± 061	0.393
Temperature of warming line's distal part	39.62 ± 0.49	39.80 ± 0.32	0.280
Temperature of liquid exiting from the cannula	33.71 ± 1.59	34.04 ± 0.52	0.163

Discussion

Warming of liquids during surgical operations provide the main contribution for maintaining normothermia of the patients. In order to maintain normovolemia and normothermia, pressurised infusion tools are widely used for patients expected to experience excessive volume loss, predicted to undergo surgey for more than two hours and requiring high volumes of intravascular liquid replacement.[1] There are different liquid warmers available since the mid 1980s and these are utilized to infuse liquids to the patients at 37°C. Most of the available tools today utilize either water baths or warming plates for warming the liquids before applying to the patients.[2,3]

The development of blood warmers help anesthesiologists to avoid morbidity and mortality related to hypovolemia and hypothermia in patients at high risk. Nevertheless, the use of these tools are not totally free of risks.[1,5,6]

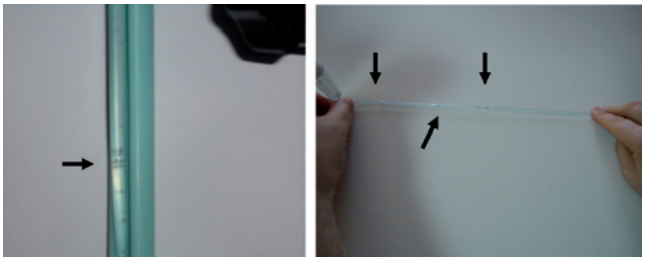

Figure 3 Bubbles formed at set of the *S-line* brand warmer.

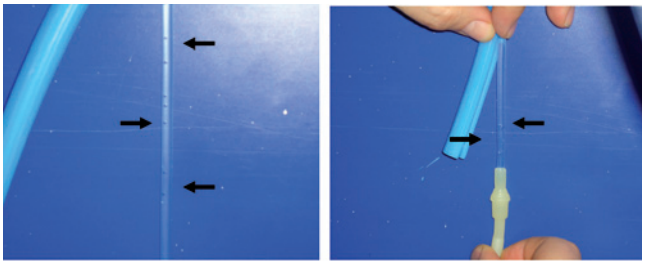

Figure 4 Bubbles formed at set of the *Astoflo*® brand warmer.

Liquid bags and other bags used to augment intravenous volumes contain air volumes sufficient to cause serious emboli. Blood-liquid warmers used for prevention of hypothermia also carry risks of air emboli irrespective of the brand and infusion rate. There have been reports of air emboli originating from serum bags used with tools capable of infusion by pressure and warming.[4-6] However, there are no reports on the occurrence of air emboli with the use of line type warming devices used only for warming purposes.

Emboli occurring during anesthesia are serious complications requiring urgent intervention. Emboli can appear in gas, fat or amniotic fluid form. Air embolism is described as an iatrogenic problem caused by the entrance of gases like air, nitrouse oxide and carbon dioxide into the vascular system. The most frequent type is venous air embolism (VAE). In arterial air embolism (AAE), air passes into the systemic circulation via heart defects or transpulmonary shunts, being named paradoxical air emboli (PAE). VAE and AAE have different clinical scenarios and effects. If unnoticed or left untreated, they can lead to fatal events.[7,8]

Since subclinical emboli are not always noticed and major emboli are rare, one should not readily assume that "embolism is rarely encountered"; the incidence is not as low as is supposed. The exact incidence of air embolism related with intravenous treatment is unknown. Although the occurrence of symptomatic air emboli is believed to be less than 2%, mortality is seen in up to 30% of cases. In order for air to enter into the venous system, there must be a connection between the gas and the vein and there should be a pressure gradient for the gas to move. The result depends on the amount of air entering the system, entrance rate and the position of the patient at that moment. Species and body frame are also known to be important. Air given at a rate of 7.5 $mL.kg^{-1}$ can cause death in dogs, while 0.55 $mL.kg^{-1}$ suffices for rabbits. In children, the same volume would cause more serious effects compared to adults due to smaller volume of the ventricle. Since air entering the system by slow infusion is simultaneously absorbed, dogs for example tolerate 1,400 mL air entrance over a few hours.[9,10] It is not easy to estimate the amount of air emboli humans can tolerate. In PAE, small amounts of air cause cardiovascular and/or neurological symptoms. The amount of air thought to be sufficient for fatal venous air emboli ranges between 10 to 480 mL; however, this is still a matter of discussion. Considering that the filling rate for the right side of the heart is approximately 100 mL, this

volume can lead to fatal emboli. While classical textbooks state that air more than 5 mL.kg^{-1} is sufficient for shock and cardiac arrest, even small amounts of air (such as the 20 mL empty chamber volume in the lumen of intravenous sets) can also cause complications.[10,11] When venous emboli occurr in patients under general anesthesia, use of nitrous oxide can increase the size of the bubble and lead to worsening effects of emboli. For this reason if air embolism is suspected, nitrous oxide should be promptly discontinued.[12]

The *S-line* brand warmer that we used in this study uses a warming plate, and the *Astoflo*® brand uses a warm bath to warm the set. Since we did not use pressure and fast infusion in our model, the amount of air emboli originating from the liquid bag can be ignored. In the experimental setting we have designed similar to our clinical environment, the two types of warmers with different warming properties provided similar warming levels (33.71 ± 1.59ºC in Group *S-line*, 34.4 ± 0.52ºC in Group *Astoflo*®). We determined visible bubbles appearing at 9.7 ± 0.94 minutes in Group *S-line* and at 9.00 ± 1.05 in Group *Astoflo*®. Pressurised infusion systems are generally blamed for allowing entrance of air into the set[1,4,11]). However, the systems we use do not have pressurised infusion systems. In this setting, the reason for bubble formation may have been caused by the warming of the set and/or warming of 0.9% NaCl in the set. Due to technical inadequacies, we could not calculate the total volume of bubble formation, amount of bubble exiting the set while warm liquid passed and the content of the bubbles had we continued infusion at 350 mL of volume in one hour and had given the total of 1,000 mL serum. For this reason, we do not know how much air we might have given to a patient in clinical setting. We could not show whether this amount would reach levels to cause fatal emboli. Yet studies have reported that an 11-week healthy boy who had undergone elective hernia repairment and required revision surgery on the 5th postoperative day experienced cardiac arrest due to iatrogenic emboli. Postmortem autopsy showed that the child did not have any heart defects but had fatal air emboli in the arterial and venous systems.[13] By considering that lower amounts of emboli can be fatal.

In infants and children, bubble formation should be seriously considered for emboli. We believe that further studies are needed using different sets, liquid and blood products in order to determine the reasons, the amount, the contents and the consequences of bubble formation.

Conflicts of interest

The authors declare no conflicts of interest.

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