Simple Cost-Effective Alternative to Fluid and Blood Warming System to Prevent Intraoperative Hypothermia

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Fluid and blood warming devices are useful in situations of massive transfusions and in pediatric patients. However, the initial cost and disposable nature of many of these devices are a major hindrance in their efficient utilization. We report a simple cost-effective means of warming blood and other fluids, consisting of intravenous tubing coiled around the hose of a convective body warmer before its connection to the patient. A simple experiment using normal saline as fluid and a plastic bottle as a receptacle was also conducted to quantitate and validate the temperature rise by our technique. Overall temperature increase was a mean (± SD) of 6.11°C ± 3.17°C. The rise in temperature was highest (7.57°C ± 3.88°C) with flow rates below 10 mL/min and a higher temperature setting of 42°C. Such low-cost techniques help overcome resource deficits in developing countries and improve patient care.

Keywords: Blood warming method, cost-effective, innovation.

Low-cost, high-impact techniques are the way to overcome resource deficits in developing countries. We describe a novel yet simple technique to prevent intraoperative hypothermia as an alternative to costlier fluid-blood warming units.

Methods

• Technique. Our technique uses a readily available forced-air warming unit to prewarm the blood and fluid before infusion during the intraoperative period. Intravenous (IV) tubing (including an extension tubing of approximately 150 cm) was coiled around the convective warming hose that delivers the forced air to a warming blanket, before connection to the IV cannula on the patient (Figure 1A). A digital noncontact infrared thermometer was used to verify the temperature at the proximal and distal ends of the infusion tubing (Figure 1B, 1C). A significant change in the temperature was observed between the 2 points where temperatures were measured (Figure 1B, 1C).

• Experiment. A simple experiment was conducted to validate this finding. An input fluid (0.9% normal saline [NS]) was connected via an IV and extension tubing to a 20-gauge IV cannula, which was allowed to drain into an empty plastic bottle made of the same material as the input bottle. The tubing was coiled around the circumference of the convective hose of the body warmer 5 times before draining into the empty bottle. The temperature of the body warmer was set at 1 of 2 levels (42°C and 38°C) during the experiment. The flow rate of the input fluid was kept at 2 arbitrary levels: slow (< 10 mL/min) and fast (> 50 mL/min). The temperature of the input fluid (Tin) was varied from a minimum of 12°C to a maximum of 23°C (ambient room temperature). The input fluid was precooled in a refrigerator to 12°C and then attached to the tubing. Strict input fluid temperatures could not be maintained because of spontaneous warming of the fluid at room temperatures, and hence concurrent paired readings of input and output fluids were obtained to provide a range of values. For one output fluid temperature.

Figure. Coiling of Intravenous Tubing to Forced-Air Warmer Hose (A). Temperature Difference at Proximal (B) and Distal (C) End of Blood/Fluid Delivery Tubing
ture reading (T O), 100 mL of output fluid was allowed to collect before we took concurrent paired temperature readings of both input and output fluids. Then the 100 mL was discarded, and the procedure was repeated with a different flow rate and/or different hose temperature. Each reading was taken 3 consecutive times to account for imprecision of the recording thermometer. Ambient temperature was maintained at 23°C throughout the experiment. Blood as input fluid was not used because it would be unethical to waste blood for such purposes and NS was considered a suitable surrogate (although real-time flow rates of blood might be slower than NS because of higher viscosity).

• Statistical Analysis. Statistical analysis was done using the Wilcoxon signed rank test for input vs output temperatures and the Mann-Whitney (U) test for comparison of difference of temperatures (T O − T i = T diff) between different flow rates and different hose temperatures. The Spearman correlation test was done to establish a relationship between T i and T O. Results are displayed as means ± standard deviations, and a P value below .05 was taken as significant.

Results
The mean T i and T O were 19.09°C ± 3.7°C and 25.21°C ± 1.66°C, respectively, and the difference was statistically significant (Table). There was a linear increase in T O as a function of T i with a correlation coefficient of 0.628. Without controlling for hose temperature, T diff was significantly higher at a low flow rate compared with a high flow rate (7.22 ± 2.31 vs 4.73 ± 1.85, P = .008). However, the effect of the 2 different hose temperatures (without controlling for flow rates) on T diff was not significant (6.11 ± 3.17 vs 6.11 ± 3.17, P = .57).

The output temperatures achieved were higher than ambient room temperature and were achieved even when the input fluid T i was 12°C. The nonsignificant difference in T diff between different hose temperatures was probably because the difference between the body warmer’s target temperatures (42°C and 38°C) was too small to cause much change in output temperatures. Overall, the experiment shows that this simple technique is capable of consistently increasing the temperatures of input fluid to a clinically useful degree, and that warming is better at low flow rates.

Discussion
Even mild hypothermia in the perioperative period has been associated with adverse outcomes, including impaired drug metabolism, prolonged recovery from anesthesia, cardiac morbidity, coagulopathy, wound infections, and postoperative shivering.1 Effective methods of active warming are forced-air warming or conductive warming. Despite these active warming measures or when these measures cannot be effectively applied, patients can become hypothermic from administration of IV fluids and blood at room temperature. Hence, infusion fluid and blood warming, increasing the operating room temperature, and warming of irrigation fluids are used as adjunctive therapies.2

One study documented that each liter of IV fluid infused into adult patients at ambient temperature decreases the mean body temperature by approximately 0.25°C.3 Warming of the blood transfusion and IV fluids to body temperature has been associated with significantly reduced occurrence of perioperative hypothermia.4 Several blood-fluid warming units are available in the market to actively warm blood and fluids. Equipment such as the Nuova/05 Blood and Infusion warmer (Nuova GmbH), Hotline Blood and Fluid Warmer (Smiths Medical International Ltd), or enFlow IV fluid and blood warming system (CareFusion, now Becton, Dickinson and Co) use either a counter-current waterbath or a dry heat technology. Turner et al5 compared 4 different fluid heating systems and found that with input fluid temperature of 23°C, the Bair Hugger (Bair Hugger 241, Augustine Medical) warming system had output temperatures of 26°C at a flow rate of 68 mL/min, whereas Hotline, Standard Ranger (Bair Hugger Ranger System, Augustine Medical) and Fluido (Datex-Ohmeda Inc, now GE Healthcare) systems had output temperatures of 31.1, 35.2, and 35.3°C at flow rates of 152, 153, and 141 mL/min, respectively. Our technique compares favorably with the Bair Hugger fluid warming system but falls short of the other warmers.5 These machines are generally costly; require single-use disposable tubings or

<table>
<thead>
<tr>
<th>Flow rate/hose temperature</th>
<th>Input temperature (T i)</th>
<th>Output temperature (T o)</th>
<th>Difference of temperatures (T diff = To – Ti)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low flow/38°C</td>
<td>18.35 (0.84)</td>
<td>25.57 (0.16)</td>
<td>7.22 (2.31)</td>
<td>0.027</td>
</tr>
<tr>
<td>Low flow/42°C</td>
<td>18.33 (4.49)</td>
<td>25.89 (1.09)</td>
<td>7.57 (3.88)</td>
<td>0.002</td>
</tr>
<tr>
<td>High flow/38°C</td>
<td>21.33 (0.21)</td>
<td>23.53 (0.25)</td>
<td>2.20 (0.20)</td>
<td>0.109</td>
</tr>
<tr>
<td>High flow/42°C</td>
<td>19.88 (4.20)</td>
<td>24.61 (2.46)</td>
<td>4.73 (1.85)</td>
<td>0.008</td>
</tr>
<tr>
<td>Overall</td>
<td>19.09 (3.7)</td>
<td>25.21 (1.66)</td>
<td>6.11 (3.17)</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

Table. Mean (Standard Deviation) Input and Output Temperatures at Different Hose Temperatures and Flow Rate Settings
cartridges, thus incurring recurrent costs; carry a risk of contamination from infected waterbath; and require additional time for setup, hence, acting as an impediment to their routine use. A no-cost or low-cost technique using the available resources, although not optimal, can serve as an effective alternative to or supplement of the existing warming system.

Conclusion
A simple coiling of IV tubing around the existing warming unit hose can prewarm the fluids and blood before administration. However, because of diminished effectiveness in scenarios requiring high flows, such as resuscitation during intraoperative hemorrhage, conventional warmers with better warming efficacy should probably be used. A prospective comparison between this new technique and one of the well-established fluid and blood warming systems is likely to validate its utility in the intraoperative setting.

REFERENCES

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DISCLOSURES
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did discuss off-label use within the article.