A NEW BLOOD WARMER

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SUMMARY
The Medimpact electronic in-line blood warmer has been assessed experimentally. It was found to be capable of warming cold stored blood (4°C) to 32°C at a flow of 560 ml/hr and of being positioned very near to the intravenous cannula. It is suitable and safe for massive blood transfusion in infants weighing up to 14 kg or for neonatal exchange transfusion.

The methods available for warming blood have been classified by Besseling et al. (1965). Churchill-Davidson (1968) describes them as “source heating” or “in-line heating”.

Source heating is a slow process unless radio frequency induction is used (Besseling et al., 1965), although this method may cause significant haemolysis if the bottle of blood is not full (Staples and Griner, 1971). The main disadvantage of source heating is that blood cools as it passes down the giving-set tubing (Hey, Kohlinsky and O’Connell, 1969).

In-line heaters involve the use of coils in water-baths. Preparation is time-consuming and most types have a deadspace of 50–75 ml. They may be placed near to the patient, but not closer than about 1 metre, so heat loss may still occur from the tubing.

In paediatric surgery small gains and losses of blood volume may be important, and blood loss can be unexpected and severe. The blood warmer described here may be placed close to the intravenous cannula; it is reasonably efficient and it is safe.

DESCRIPTION
The Medimpact blood warmer consists of a metal base plate 24.5 cm long with a hairpin-shaped groove on its lower surface which can hold a loop of 6-mm diameter tubing from a transfusion giving-set (fig. 1).

The block temperature may be adjusted from 37°C to 40°C, by a variable thermostat and a mercury thermometer is fitted at the side of the block to monitor this temperature (fig. 2). The facility for adjustment is perhaps superfluous; the setting was maintained at 40°C throughout this assessment.

If the block reaches a temperature of 41°C the power supply becomes disconnected from the warmer by an override safety thermostat and an alarm sounds. The power requirement (12.6 ± 1V, d.c.) is provided by a mains-operated power pack remote from the warmer itself (fig. 3), and electrical safety is ensured by an isolation transformer. The unit develops 31.5 W (at peak current of 2.5 A) which is equivalent to about 7.5 calories/second.

METHOD OF EVALUATION
Bottles of “time expired” blood were removed from the storage refrigerator and suspended 1 metre above the cannulae to which they were connected with BR-20 giving-sets (Baxter Division, Travenol Ltd). Each bottle was agitated gently to ensure mixing of plasma and red cells. Needle thermocouple probes were inserted into the bottle and into the injection rubber between the cannula and blood warmer. The temperature of the blood bottle was noted, and the temperature of the blood emerging from the warmer (measured with a Comark Electronic thermometer) was recorded with a Devices pen-recorder. Four cannulae commonly used during paediatric surgery were investigated, and the performance of the blood warmer at maximum flow through each was assessed. The ambient temperature was usually 27.6°C (table I) and the haematocrit of the blood used was 32%. Flows were calculated by timing the passage of a measured volume of blood.

RESULTS
With no active warming and at an ambient temperature of 27.6°C and a flow of 1300 ml/hr (18-gauge
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Medicut) blood temperature increased from 4°C in the bottle to 11°C at the cannula.

With active warming at mean flow rates through the administration apparatus ranging from 560 to 427 ml/hr blood temperature was increased by 78% to 86% of the initial difference between the temperature of the warming block and the temperature of the blood in the storage bottle. At greater flows the efficiency of the warmer decreased; for example, at 1300 ml/hr blood temperature increased by only 31% of the difference (table I).

DISCUSSION

There have been several reviews of the hazards of massive blood transfusion (Baue, Herman and Shaw, 1961; Bennett, 1968; Besseling et al., 1965; Bunker, Bendixen and Murphy, 1962; Burton, 1968; Churchill-Davidson, 1968; Dybkjaer and Elkjaer, 1964; Hey, Kohlinsky and O'Connell, 1969; Ludbrook and Wynn, 1958; Mollison, 1972; Schroeder and Forbes, 1969). Cold stored blood (4–8°C) should never be transfused rapidly as this may cause a serious decrease in the temperature of the recipient, particularly in the anaesthetized infant (Dybkjaer and Elkjaer, 1964; Harrison, Bull and
The dangers of this hypothermia have been emphasized by Bower, Jones and Weeks (1960), Farman (1962), and Mann and Elliot (1957). Additionally it may cause selective cooling of the heart (Dunn, 1966).

In clinical practice many factors affect the performance of a blood warmer. These include initial blood temperature, ambient temperature, length of giving-set tubing and blood flow rate.

In this study, ideal warming to 37°C was never achieved at the flows used, although cold blood at maximum flow through the Butterfly 21 was warmed to 34.6°C. In practice, warming to 32°C at the cannula is considered by many to be adequate. This is the temperature to which blood is warmed at flows of about 100 ml/min in the warmers described both by Bennett and Alladine (1967) and by Dybkjaer and Elkjaer (1964), and which is found to be satisfactory for such rapid transfusion in adults. Thus the Medimpact blood warmer can raise the temperature of cold blood to acceptable levels at flow rates up to approx. 560 ml/hr. If the definition of massive blood replacement as the replacement of one-half of the patient’s blood volume in 1 hour is accepted (Stewart, 1962), then this is suitable for warming blood for such transfusion in patients weighing up to about 14 kg. For larger children the warmer is acceptable when blood replacement is not massive.

Hey, Kohlinsky and O’Connell (1969) found that at flows of 100 ml/hr along a standard 150-cm giving-set, the temperature of blood warmed 10–15°C above room temperature decreased by 50% of the initial blood/ambient temperature difference. Thus at an ambient temperature of 25°C and blood warmed to 40°C, the temperature of the blood decreases by 7.5°C, or 0.5°C per 10 cm of tubing. The Medimpact blood warmer does not require a coil or waterbath, and can be placed within 10 or 20 cm of the intravenous cannula, thereby minimizing this problem. Lagging the output line, which increases its bulk and reduces its flexibility (Russell, 1969), is not required.

It is usual in exchange transfusion to withdraw and transfuse blood intermittently in 10-ml aliquots. If the initial temperature of the blood were 4°C (which is unlikely in a warm environment) the Medimpact warmer, placed distal to the injecting syringe, would warm the blood adequately provided that the syringe contents were not discharged in less than 2 min.
## Table I.

<table>
<thead>
<tr>
<th>Cannula</th>
<th>Mean blood flow (ml/hr)</th>
<th>Initial temperature of blood in storage bottle (°C)</th>
<th>Final temperature of blood leaving warming block (°C)</th>
<th>Ambient temperature (°C)</th>
<th>Temperature change t°F - t°I × 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butterfly 21 ext. diam. 21 s.w.g.</td>
<td>427</td>
<td>4.2°</td>
<td>34.6°</td>
<td>27.6°</td>
<td>85%</td>
</tr>
<tr>
<td>int. diam. 22 s.w.g.</td>
<td>462</td>
<td>11.2°</td>
<td>35.8°</td>
<td>27.6°</td>
<td>86%</td>
</tr>
<tr>
<td>Venflon ext. diam. 19 s.w.g.</td>
<td>560</td>
<td>4.1°</td>
<td>32°</td>
<td>27.6°</td>
<td>78%</td>
</tr>
<tr>
<td>int. diam. 23 s.w.g.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-gauge Medicut ext. diam. 20 s.w.g.</td>
<td>755</td>
<td>4.0°</td>
<td>19.8°</td>
<td>27.6°</td>
<td>44%</td>
</tr>
<tr>
<td>int. diam. 22 s.w.g.</td>
<td>780</td>
<td>7.6°</td>
<td>22.5°</td>
<td>27.6°</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>877</td>
<td>14.0°</td>
<td>25.8°</td>
<td>27.6°</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>1085</td>
<td>25.0°</td>
<td>32.2°</td>
<td>25.0°</td>
<td>48%</td>
</tr>
<tr>
<td>18-gauge Medicut ext. diam. 18 s.w.g.</td>
<td>1300</td>
<td>4.2°</td>
<td>15.2°</td>
<td>27.6°</td>
<td>31%</td>
</tr>
<tr>
<td>int. diam: 20 s.w.g.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The thermostat setting was 40°C.
2. The temperature change is expressed as a percentage of the initial temperature difference between the warming block and the blood in the storage bottle.
3. Note how the flow improves with increasing temperature as the blood viscosity falls (Knight, 1968).

Complete haemolysis of red cells occurs when blood is warmed to 50°C (Bennett, 1968), but Howland and Schweitzer (1965) found only slight haemolysis after warming to 40°C although the red cell survival time may be reduced (Mollison, 1972). Dybkjaer and Elkjær (1964) state that 40–41.5°C is “above the permissible maximum”, but Knight and Wellard (1962) found no detectable haemolysis at such temperatures even at slow blood flows. Karle (1969) found that “incubation” of blood at 41.5°C in the pyrexial rabbit did produce 20% haemolysis in the first hour, with only 60% red cell survival after 4.5 hours and a reduced half-life of 8.5 days when the temperature had been maintained for 8 hours.

Chalmers and Russell (1973) have incubated stored human blood (from 1 to 21 days old) for up to 1 hour at 41°C, 43°C, 45°C and 50°C, and their preliminary results indicated that progressive haemolysis occurred only at 50°C. Though the red cell survival may be reduced in vivo, they found no evidence of haemolysis after incubation at 45°C in vitro. They observed that the temperature limit on warming blood has been extremely conservative to date.

In view of the relatively short time that the blood remains in the baseplate tubing at any flow, the Medimpact warmer is unlikely to haemolyse any blood even if the block temperature were to rise to the maximum 43°C (this should never happen unnoticed if the block monitoring thermometer is used properly).

The Department of Health has tested the warmer and approved its safety.

**Editor's Note.** This instrument is now known as the “Lenton” blood warmer. The red light referred to in figure 2 has been replaced by an amber light.

## Acknowledgements

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## References


ROYAL COLLEGE OF SURGEONS OF ENGLAND

The 1974 Annual Meeting of Fellows and Members will take place at the University of Exeter on Friday and Saturday, December 13 and 14, 1974. The symposia on topics of interest to surgeons, dental surgeons, anaesthetists and general practitioners are open to all medical and dental practitioners, whether or not they are diplomates of the College. Full particulars may be obtained from the Secretary, Royal College of Surgeons of England, 35/43 Lincoln's Inn Fields, London WC2A 3PN (Tel. 01-405 3474, ext. 163).