Operational Capability Assessment of Fluid Warmers

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INTRODUCTION

Hypothermia contributes to morbidity and mortality in trauma and prolonged field care. Portable fluid warmers used in En Route Care must operate on battery power, deliver clinically meaningful temperatures, and perform across varied flow conditions. Building on prior military fluid warmer evaluations, including our previous evaluation of fluid warming technology in austere environments, we conducted an operational capability assessment of currently fielded portable fluid warmers.[1,2]

METHODS

Three portable fluid warmers (Figure 1) were evaluated. Two units per device underwent two runs per condition (fluid type, flow, power supply). 24°C normal saline and iced packed red blood cells (PRBCs) were infused at nonemergent (125 mL/hr) and emergent (300 mmHg pressure bag) flow rates at sea level. All devices were tested on battery and AC power. Inlet and outlet temperatures (T) were recorded using J-type thermocouples at 1 Hz. Outcomes evaluated included mean outlet T, T change from inlet to end of outlet tubing (ΔT), and initial warmup based on ΔT over first 30 sec for emergent flow and over first 300 sec for non-emergent flow. We first compared all devices (Kruskal-Wallis test) and then performed pairwise comparisons of Buddy Lite to M Warmer or Warrior.

Figure 1. Fluid Warmers evaluated.

Belmont Buddy Lite | MEQU M Warmer | QinFlow Warrior

RESULTS

Table 1 summarizes outlet T, ΔT (full run duration), and ΔT (initial warmup) across matched fluid, flow, and power conditions. M Warmer consistently delivered higher T and ΔT. During emergent flow, M Warmer and Warrior delivered higher T and ΔT, and faster initial warming than Buddy Lite. During non-emergent flow, Buddy Lite and M Warmer delivered higher T and ΔT, and faster initial warming than Warrior. All devices had a higher ΔT with PRBCs during emergent flow conditions. All devices performed similarly on battery versus AC power. Emergent flow was ~ 150 ml/min with saline and ~ 75 ml/min with PRBCs.

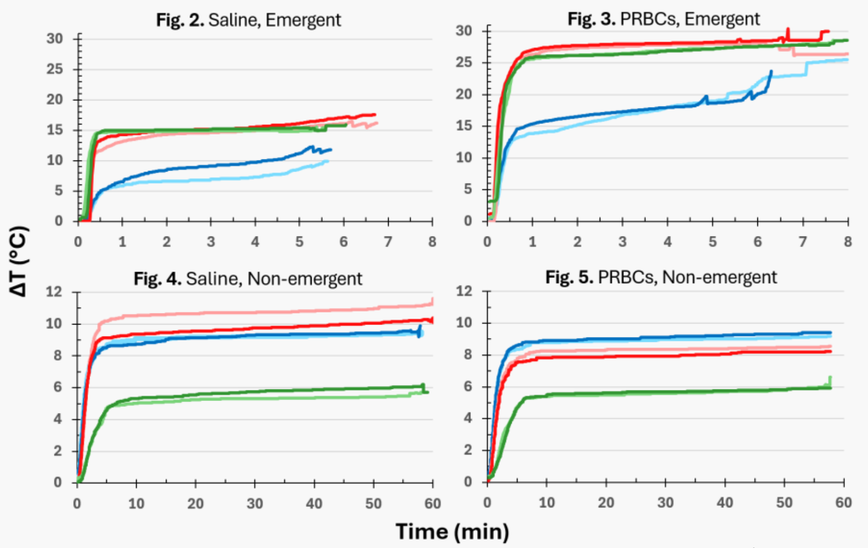
Figures 2-5 show representative ΔT-time profiles.
Figures 6-9 summarize ΔT distributions across all runs.

Table 1. Thermal performance by condition.
Outlet T, inlet-to-outlet ΔT, and initial warming ΔT are shown by warmer, fluid, flow, and power source.

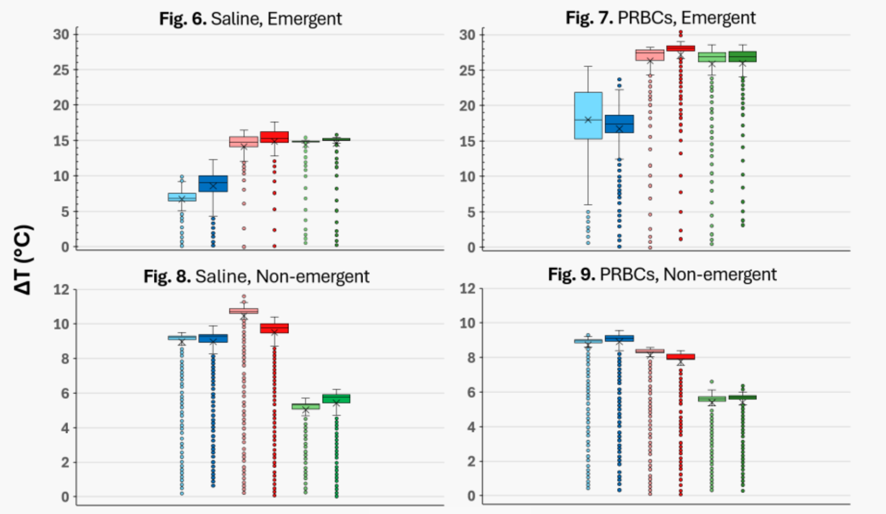
Fluid	Flow	Power	Buddy Lite	M Warmer	Warrior
Outlet T (°C)					
PRBC	Emergent	AC	27.7(1.8)*	38.3(1.4)	36.4(2.0)*
		Battery	28.3(3.4)*	38.6(1.1)	36.6(1.9)*
	Non-emergent	AC	32.4(1.0)	32.8(1.5)	29.1(1.2)*
		Battery	32.1(1.0)	32.6(1.5)	29.0(0.9)*
Saline	Emergent	AC	32.0(2.3)*	37.7(1.4)	37.8(1.8)
		Battery	29.9(1.5)*	37.3(1.5)	37.8(2.1)
	Non-emergent	AC	31.9(1.3)	32.3(0.9)	28.8(1.0)*
		Battery	32.4(1.2)*	33.2(1.2)	28.1(1.0)*
Inlet-to-Outlet ΔT (°C)					
PRBC	Emergent	AC	16.9(2.4)*	27.2(3.2)	26.0(3.9)
		Battery	17.8(4.1)*	27.0(2.8)	26.0(3.8)
	Non-emergent	AC	8.9(1.1)*	7.6(1.5)	5.4(1.2)*
		Battery	8.8(1.0)*	7.9(1.6)	5.5(0.8)*
Saline	Emergent	AC	8.5(2.3)*	15.3(1.4)	14.8(2.0)
		Battery	6.7(1.6)*	14.5(1.5)	14.4(2.2)
	Non-emergent	AC	8.9(1.3)*	9.6(1.0)	5.4(1.1)*
		Battery	8.9(1.3)*	10.6(1.1)	5.1(0.9)*
Initial Warming ΔT (°C)†					
PRBC	Emergent	AC	10.0(4.0)*	19.6(5.9)	18.9(6.4)
		Battery	9.8(4.8)*	20.2(6.3)	17.4(7.5)
	Non-emergent	AC	6.3(2.7)*	5.0(2.5)	2.3(1.6)*
		Battery	6.2(2.6)	5.3(2.6)	2.5(1.5)*
Saline	Emergent	AC	3.9(1.6)*	12.6(3.0)	13.1(3.7)
		Battery	3.8(1.6)*	12.3(2.7)	12.4(3.9)
	Non-emergent	AC	6.4(2.6)	6.5(3.2)	2.4(1.6)*
		Battery	6.4(2.7)	6.9(3.5)	2.4(1.5)*

Data are presented as mean(SD); N = 4 per condition.
† mean ΔT over first 30 s for emergent flow and first 300 s for non-emergent flow.
*p<0.05 vs other two warmers within matched conditions.

Figures 2-5. Representative ΔT–time plots.
One representative run is shown for each warmer and power source under each fluid/flow condition.



Figures 6–9. ΔT distributions across all runs.
Box-and-whisker plots summarize ΔT distributions by warmer, power source, and condition. Boxes indicate IQR, lines indicate medians, and X markers indicate means.



Legend for Figs. 2-9. Warmer, power source

Buddy Lite, Battery; Buddy Lite, AC; M Warmer, Battery; M Warmer, AC; Warrior, Battery; Warrior, AC

DISCUSSION

All tested fluid warmers increase the T of infused fluid; however, the ΔT may be influenced by the fluid type, fluid T, and flow. The highest ΔT for each device was with emergent PRBCs. Higher ΔT seen with emergent PRBCs compared to saline resulted from a lower inlet T and not warmer function. The lowest ΔT for each device was with non-emergent flow conditions due to the extended exposure time of the fluid in the disposable outlet tubing. This effect is more pronounced with the Warrior due to its longer disposable outlet tubing. Buddy Lite had the lowest ΔT under emergent flow, possibly due to fluid-heater interface.

CONCLUSION

Measurable differences in fluid warmer performance were observed. The M Warmer performed better overall and was more consistent across tested conditions. M Warmer and Warrior performed better during emergent flow than Buddy Lite. M Warmer and Buddy Lite performed better during non-emergent flow than Warrior. When using the Buddy Lite or Warrior, clinicians should be aware of the effect of flow on delivered temperature relative to therapy goals.

REFERENCES

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2. Blakeman T, Fowler J, Branson R, Petro M, Rodriquez D Jr. Performance characteristics of fluid warming technology in austere environments. J Spec Oper Med. 2021;21(1):18-24.

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