Economic Evaluation of the TherMax Blood Warmer For Reducing Hypothermia Episodes During CRRT

Michael J. Blackowicz[1], Max Bell[2,3], Jorge Echeverri[1], Kai Harenski[1], Marcus E. Broman[4]

[1] Baxter Healthcare Corporation, Deerfield, Illinois, USA; [2] Department of Perioperative Medicine and Intensive Care, Karolinska University Hospital, Solna, Stockholm, Sweden; [3] Department of Physiology and Pharmacology, Karolinska Institutet, Stockholm, Sweden; [4] Perioperative and Intensive Care, Skåne University Hospital, Lund, Sweden

Background

- Hypothermia is common in patients with acute kidney injury (AKI) when treated with continuous renal replacement therapy (CRRT).
- Hypothermia is associated with increased risk of mortality and longer ICU stay.[1]
- The TherMax blood warmer (Baxter Healthcare) has been shown to reduce the occurrence of hypothermia.[2]
- The TherMax blood warmer directly warms the blood with heating plates; its control software is integrated into the PrisMax system (Baxter Healthcare) for delivery of CRRT.
- With a bi-direction connection to the PrisMax system, the TherMax blood warmer responds to changing treatment parameters; prescribed temperature targets are maintained by adjustments based on return blood temperature and CRRT prescription parameters.

Objectives

- Estimate and compare the risk of hypothermia during use of the TherMax blood warmer on the PrisMax system versus a standalone CRRT blood warmer.
- Estimate and compare costs and cost-effectiveness of the TherMax blood warmer versus a standalone CRRT blood warmer.

Methods

- The study included patients with AKI who were treated with CRRT (≥ 1 hour) in the Adult ICU at Skåne University Hospital between December 2006 and September 2020. All patients had normal body temperature (36.5°C–37.5°C) at the start of CRRT. Patients were excluded if they had undergone induced/therapeutic hypothermia or had received CRRT with more than one type of device (or the device brand could not be ascertained).
- Patients were treated with the Barkey S-Line standalone blood warmer (Barkey GMBH & Co KG) and the Prismaflex system (Baxter Healthcare) prior to November 2018, and with the TherMax blood warmer integrated into the PrisMax system after November 2018.
- Warmer blood temperatures and patient body temperatures were recorded hourly and stored automatically in the Intellispace Critical Care and Anesthesia (ICCA) system, along with any relevant notes regarding patient status and therapy. Hypothermia was defined as body temperature < 36°C.
- A Markov model was developed in which relevant health states for each treatment were normothermia, hypothermia, discharged alive, and death.
- Itemized and total costs included ICU costs per admission, CRRT treatments per admission, and average expected costs per admission for the CRRT and blood warmer devices over their expected lifetimes.
- Total life-years remaining after discharge was calculated among patients discharged alive.
- The incremental cost-effectiveness ratio (ICER) was calculated as follows:

$$ICER = (Diff.\ in\ total\ inpatient\ costs)/(Diff.in\ LYG\ from\ preventing\ hypothermia)$$

- All costs were calculated in $USD adjusted to 2020 consumer price index.
- All economic model inputs are reported in Table 1.

Table 1. Model Inputs

Parameter	TherMax Warmer	Standalone Warmer	Reference
Patient age (yr)	65.4	65.4	Data on file, Baxter Healthcare
Life-years remaining	17.5	17.5	USRDS 2020[3] – Average life-years remaining, general US population age 65
Life-years remaining	7.8	7.8	USRDS 2020[3] – Average life-years remaining, ESRD patients age 65
Chronic dialysis	21.8%	21.8%	Wald 2013[4] – Dialysis dependence at 90 days following CRRT for AKI
Hypothermia	34.5%	71.9%	Data on file, Baxter Healthcare
Mortality – normothermic	40.0%	40.0%	Ethgen 2015[5] - ICU mortality among AKI patients on CRRT
Mortality – hypothermic	59.2%	59.2%	Erkens 2019[1] - ICU mortality (RR = 1.48) among patients with hypothermia
ICU days – normothermic	12.0	12.0	Uchino 2007[6] - ICU length of stay among patients with AKI treated with CRRT
ICU Days – hypothermic	13.7	13.7	Inaba 2009[7] - Mean difference in LOS between hypothermia and normothermia
CRRT duration (days)	7.0	7.0	Ethgen 2015[5] - Days on CRRT
Inpatient cost per day	$5,611	$5,611	Kramer 2015[8] - Mean total cost / mean ICU LOS in the US, 2012-2016
RRT cost per day	$961	$961	Ethgen 2015[5] - Acute CRRT cost per day
Device cost	$50,000	$38,000	Baxter 2020[9] – US List price, PrisMax and PrismaFlex, respectively

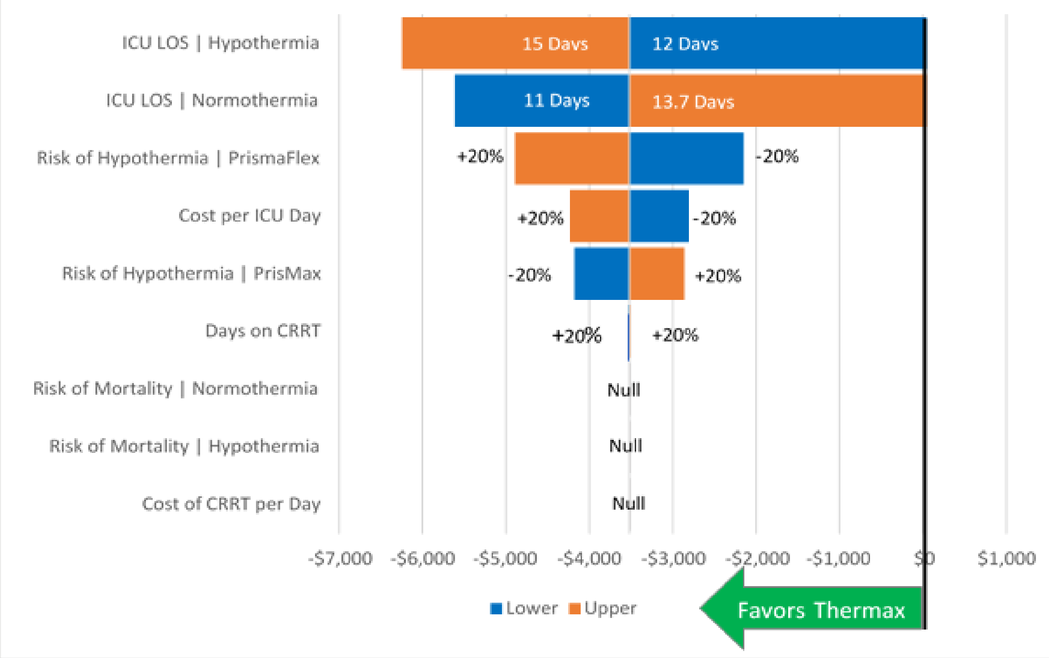
Results

- Data were obtained from 526 patients treated with the standalone blood warmer and 29 patients treatment with the TherMax blood warmer.
- Hypothermia occurred in 34.5% of patients with the TherMax blood warmer and 71.9% of patients with the standalone warmer (Table 2).
- Total life-years gained by avoiding mortality related to hypothermia was 9.0 in the TherMax blood warmer group and 8.0 in the standalone warmer group (Table 2).
- The total cost difference (–$3,562) and the cost difference of ICU stay (–$3610) favored the TherMax blood warmer, while cost of CRRT treatments was assumed to be the same for both warmers at $7,344 per admission. The list price for the PrisMax system is higher than for the Prismaflex system, but the per-patient cost difference was negligible (Table 2).
- Cost per life-year gained was lower for the TherMax blood warmer compared to the standalone warmer ($8,615 for the TherMax warmer and $10,115 for the standalone warmer (Table 2).
- The incremental cost-effectiveness ratio was negative (–$3,619), indicating superior cost-effectiveness for the TherMax blood warmer compared to the standalone warmer (Table 2).
- Sensitivity analysis demonstrated that ICU length of stay is the most impactful variable, but results still favor the Thermax blood warmer over the standalone warmer even at conservative values for ICU length of stay (Figure 1).

Table 2. Model Results*

	TherMax Warmer	Standalone Warmer	Difference
Clinical Characteristic			
ICU length of stay (days)	12.0	13.7	-1.7
Risk of hypothermia	35%	72%	-37%
Risk of mortality	47%	54%	-7%
Life-years gained	9.0	8.0	1.0
Total Costs	$77,590	$81,152	-$3,562
CRRT treatment	$6,727	$6,727	$0
ICU length of stay	$70,664	$74,274	-$3,610
Device	$200	$152	$48
Cost-effectiveness			
Total cost per life-year gained	$8,615	$10,115	-$1,501
ICER	-$3,619	-	-

Figure 1. Deterministic Sensitivity Analysis for Cost-Effectiveness*



Bars represent cost-effectiveness model results at lower and upper values of each relevant model input to demonstrate the impact of uncertainty around each model input.

Length of stay for normothermia and hypothermia was set to vary by either by ±1 day from the mean or set equal; percentage increases (multiplicative) are used where informed values are not available.

Conclusions

Switching from a standalone blood warmer to the TherMax blood warmer with the PrisMax system for CRRT is associated with less risk of hypothermia and less risk of mortality associated with hypothermia, which led to more life-years gained and greater cost-effectiveness.

*Additional information on cost-effectiveness can be found in: Blackowicz, et al. *PLoS One*. 2022;17(2):e0263054.

References

1. Bell M, Ronco C, Hansson F, Broman M. Hypothermia during CRRT, a comparative analysis. Acta Anaesthesiol Scand. 2020;64(8):1162-1166.
2. Erkens R, Wernly B, Masyuk M, Muessig JM, Franz M, Schulze PC, et al. Admission body temperature in critically ill patients as an independent risk predictor for overall outcome. Med Princ Pract. 2020;29(4):389-395.
3. United States Renal Data System. 2020 USRDS Annual Data Report: Epidemiology of kidney disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD, 2020.
4. Wald R, Shariff SZ, Adhikari NK, Bagshaw SM, Burns KE, Friedrich JO, et al. The association between renal replacement therapy modality and long-term outcomes among critically ill adults with acute kidney injury: a retrospective cohort study. Crit Care Med. 2014;42(4):868-877.
5. Ethgen O, Schneider AG, Bagshaw SM, Bellomo R, Kellum JA. Economics of dialysis dependence following renal replacement therapy for critically ill acute kidney injury patients. Nephrol Dial Transplant. 2015;30(1):54-61.
6. Uchino S, Bellomo R, Kellum JA, Morimatsu H, Morgera S, Schetz MR, et al. Patient and kidney survival by dialysis modality in critically ill patients with acute kidney injury. Int J Artif Organs. 2007;30(4):281-292.
7. Inaba K, Teixeira PG, Rhee P, Brown C, Salim A, DuBose J, et al. Mortality impact of hypothermia after cavitary explorations in trauma. World J Surg. 2009;33(4):864-869.
8. Kramer AA, Dasta JF, Kane-Gill SL. The impact of mortality on total Costs within the ICU. Crit Care Med. 2017;45(9):1457-1463.
9. Healthcare B. Baxter Product Catalog. 2020.