Active Intravascular Rewarming for Hypothermia Associated with Traumatic Injury

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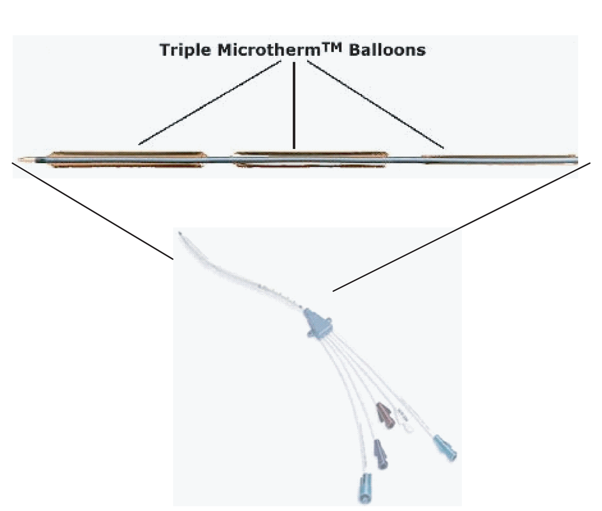
BACKGROUND

Hypothermia (core temperature less than 35°C) is a significant contributor to mortality in severely injured patients. Rewarming is an enormous challenge, especially in those who require operative or angiographic intervention. In this patient population, external warming methods are only capable of reducing further heat loss, whereas active rewarming adds heat to the body's core but is invasive. The purpose of this project was to analyze our initial experience with a minimally invasive, continuous, automated, and easily portable intravascular rewarming technique using the Alsius Corporation's CoolGard system.

METHODS

IRB approved retrospective chart review of severely injured patients with hypothermia treated by intravascular rewarming at a level 1 trauma center over a 6 month period. Demographic information, initial physiologic and laboratory findings, injury patterns, rewarming data, and treatment outcomes were evaluated.

Severely injured patients had femoral vein resuscitation catheters placed as indicated. Alternatively, those with moderate to severe hypothermia had the balloon resuscitation catheters placed. Target patient temperature was set at 37°C and the rewarming rate was set to MAX. The machine and catheter are shown below.



RESULTS

Eleven hypothermic trauma patients were treated with the intravascular rewarming device. The mean patient age was 39 years and the mean ISS was 40. Although the patients' mean ED arrival temperature was 35°C, they continued to lose heat at an average rate of 0.6°C/h, despite aggressive implementation of standard hypothermia precautions and warming measures, and had a mean temperature at the start of intravascular rewarming of 33.6°C. The delay interval between ED arrival and start of rewarming correlated strongly with mortality (Pearson $r = 0.66$).

Seven patients went from the ED directly to either the OR or angiography to control internal bleeding, with additional risk of heat loss in these relatively cold environments. They lost an average of 2.4°C and incurred a mean delay of 282 minutes of lost rewarming time during the acute injury period. Four patients went directly from the ED to the ICU, three of whom died of unsurvivable traumatic brain injury. Of the five survivors, four had rewarming initiated early in the course of treatment, either in the ED or OR. The two patients with the lowest ED arrival temperatures, both with extensive penetrating injuries, had intravascular rewarming begun immediately and survived.

The mean warming rate of the 11 patients was 1.5°C/h (SD, 1.0; range, 0.67–4.00), which correlated strongly with the degree of hypothermia ($r = 0.67$). The degree of hypothermia also showed significant correlation to acidosis (for pH $r = -0.77$), base deficit ($r = 0.48$), and coagulation factor deficit (for temperature-corrected prothrombin time, $r = 0.53$), which are also known to negatively influence survival in trauma patients. Starting temperatures and warming rates did not correlate well with ISS, total transfusion amounts, or survival (all $r < 0.30$) in our small sample.

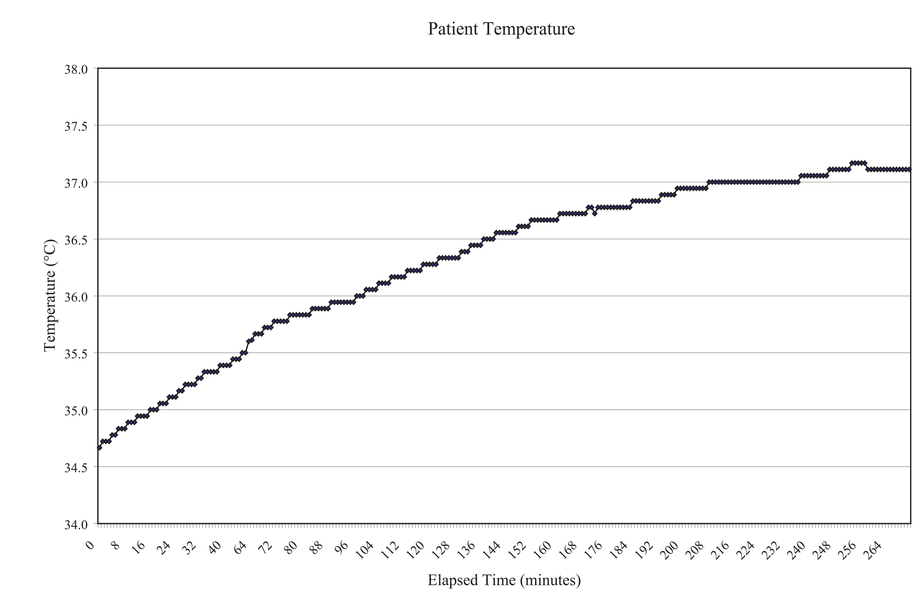
Sample data graphs depict a patient's warming progress, and how the device senses temperature changes and adjusts the balloon temperature to maintain the set target (37°C in our patients).

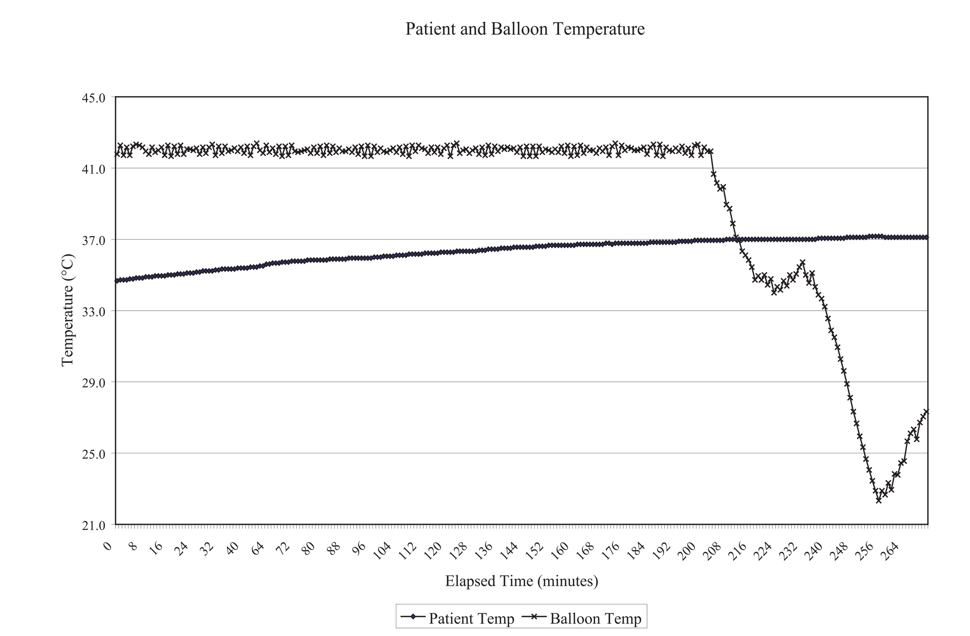
RESULTS

Demographic Information (n = 11)	Mean +/- SD (Range) or Quantity
Age (yrs)	39.3 +/- 21.6 (16-84)
Male:Female	7:4
Blunt:Penetrating	7:4
Emergency Dept to Operating Room	5
Emergency Dept to IR	2
Emergency Dept to ICU	4
Mean Injury Severity Score	39.6 +/- 15.7 (12-75)
Mean Revised Trauma Score	6.5 +/- 4.5 (0-12)
Mean Systolic BP	91.1 +/- 60.2 (0-210)
Mean ED arrival Temp (°C)	35.2 +/- 1.1 (33.3-36.8)
Mean rewarming start temp (°C)	33.6 +/- 1.0 (31.8-35.3)
Mean pH	7.05 +/- 0.21 (6.69-7.33)
Mean base deficit	9.0 +/- 6.3 (1-18)
Mean prothrombin time	23.0 +/- 12.2 (11.5-50.8)
Mean units all blood products	24.5 +/- 21.0 (0-73)

Patient	ED Temp (°C)	Procedure	Start Location	Delay Interval (min)	Start Temp (°C)	Warming Rate (°C/h)
1	36.1	IR	ICU	577	33.3	1.24
2	36.1	OR	ICU	210	34.4	1.37
3	35.1	OR	ICU	180	33.5	1.09
4	35.3	OR	OR	49	32.2	1.93
5	34.8	None	ICU	114	33.1	0.76
6	33.3	OR	OR	79	33.6	0.77
7	33.7	None	ED	85	34.7	0.67
8	36.8	None	ICU	88	31.8	4.00
9	34.9	IR	ICU	160	33.1	2.74
10	34.3	None	ED	130	34.3	1.08
11	36.5	OR	OR	119	35.3	1.11
Mean	**35.2**			**163**	**33.6**	**1.53**

IR = Interventional Radiology Angiography Suite





CONCLUSIONS

Hypothermia in severely injured patients may result from environmental exposure, loss of heat production due to shock, or both. At best, standard superficial rewarming methods reduce the rate of heat loss. Extracorporeal rewarming with external circuits is effective at rewarming, and reduces transfusion requirements and mortality. However, external techniques have additional risks, and limitations due to personnel requirements.

Intravascular rewarming delivers heat directly to the body core at a rate similar to external circuits, but with minimal risk and supervision requirements. Temperature control is automatic and portable; therefore, rewarming can be initiated in the ED and continued in the OR, interventional radiology suite, and ICU, occurring simultaneously with resuscitation and hemorrhage control efforts.

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