

Evidence Supporting the Safety of Rapid Patient Cooling

Robert B. Schock, Ph.D.

*From the Department of Research and Development, The Sid Wolvek Research Center,
[Life Recovery Systems](#) HD LLC, Kinnelon, NJ USA*

As the applications for targeted temperature management are evolving, an increasing body of evidence supports the rationale for more rapid achievement of target therapeutic temperatures. This report examines the safety of a new technique for achieving rapid patient cooling (LRS Technical Report, January 2012).

In the wake of the latest patient care guidelines from the American Heart Association¹, therapeutic hypothermia is quickly gaining acceptance as a standard of care. A growing body of evidence is suggesting that the use of more rapid patient cooling methods is desirable in this application, as this may reduce the side effects of hypothermia induction, such as shivering and metabolic disorders². The use of rapid cooling techniques has been questioned by some on the basis of safety considerations related to high cooling rates and risks of overcooling. These issues are discussed below.

High Cooling Rates

Therapeutic patient cooling has been actively studied for over half a century. One of the more prominent applications has been the use of cooling to prevent brain and other organ injury during prolonged periods of cardiac arrest, as typically occur in open heart surgery. The typical “on-pump” cardiac bypass procedure involves the use of a heart lung machine, which cools the patient by approximately 20C° in 30 minutes³, a cooling rate of 40C°/hour. This procedure has been safely administered to millions of patients. Complications which result from this invasive method are typically the result of bleeding, embolic episodes, or blood damage.

The most rapid noninvasive cooling method known is ice water immersion. This has been shown to generate a cooling rate of approximately 0.35C°/min (21C°/hour) in hyperthermic awake volunteers⁴, with no adverse side effects. A desirable characteristic of the ice water immersion treatment is that shivering is generally suppressed at the lowest water temperatures (~2C°). A second important observation is that the cooling rate during ice water immersion is so rapid that a rectal temperature inaccurately reflects core temperature during the cooling process; an esophageal temperature probe more accurately reflects true core temperature during this rapid cooling⁵.

Ice water immersion cooling has also been studied in normothermic anesthetized volunteers who have been cooled to hypothermic levels⁶. In these studies, the subjects were typically cooled from normothermia to 34°C as a result of a 20 minute period of immersion, a cooling rate of 9.7C°/hour. This was approximately six times as fast as the cooling provided by conventional cooling blankets. As in the prior studies of hyperthermic volunteers, this rapid cooling rate did not cause any adverse effects.

Exertional heatstroke is a deadly condition that requires the most aggressive treatment measures. This condition can kill or permanently disable even young, well-conditioned athletes. Ice water immersion is well recognized as the standard of care for treatment of exertional heatstroke⁷. This treatment has been applied in hundreds of well-documented cases, with extremely high cooling rates and a lack of adverse side effects.

The application of rapid cooling methods for the induction of therapeutic hypothermia has recently seen increased interest. A study of 24 patients treated with the Life Recovery Systems ThermoSuit System, a product which cools with convective ice water immersion, reported patient cooling rates averaging 3.5C°/hour (range, 1.8 to 8.8C°/hour)⁸. The clinical safety profile of the ThermoSuit treatment as reported in this and in a subsequent larger study⁹ compares very favorably with that reported in a similar study of 64 patients, in which conventional cooling blankets and the Medivance Arctic Sun (a system that employs adhesive-faced cooling pads) were used; these cooling methods demonstrated cooling rates approximately five times slower than those of the ThermoSuit approach¹⁰. A comparison of hypothermia induction times reported for these studies is provided in Figure 1.

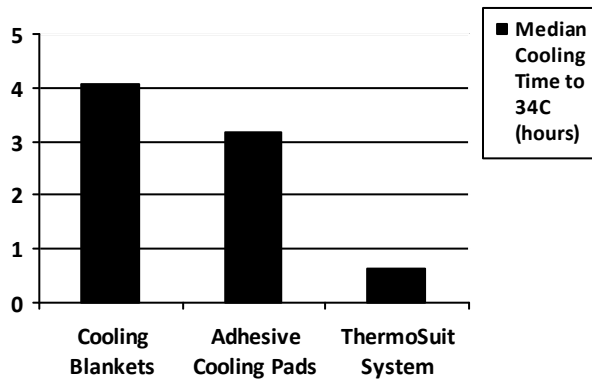


Figure 1. Median cooling times for induction of therapeutic hypothermia (from *Resuscitation* 2011^{8,10})

Another clinical study of therapeutic hypothermia investigated the use of an invasive rapid cooling protocol which included the use of cold intravenous saline infusion and an intravascular cooling catheter¹¹. This approach produced a typical cooling rate of 3.6 C°/hour, a rate similar to that of the noninvasive ThermoSuit method. Aside from a 33% incidence of infections that resulted from this invasive approach, there were no clinical complications of the rapid cooling induction. Overall, there were fewer complications in the cooled patients than in a control group of normothermic patients.

Further clinical evidence supporting the safety of rapid patient cooling was provided by a four-year study that showed that even delays of one hour in initiating cooling or 30 minutes in achieving target therapeutic temperatures significantly reduced the chances of a good brain recovery with certain types of patients^{12,13}. These results validated those of a previously published German study, which also reported a strong benefit of earlier achievement of target temperature¹⁴.

The advantages of faster achievement of target temperature are most apparent when adjustments are made for patient comorbidities as part of the data analysis; patients who have suffered more severe cerebral injury tend to lose the ability to conserve their own body heat and are more easily cooled¹⁵. Previous studies which have not made such adjustments have sometimes failed to demonstrate a benefit of faster achievement of target temperature^{16,17}.

Numerous laboratory studies have shown that fast, early cooling minimizes ischemic injury^{18,19,20,21,22,23,24,25}. Temperature dependent adverse biochemical reactions are inhibited by hypothermia. Early intervention clearly minimizes the time that these reactions have to accumulate adverse byproducts. While additional clinical studies investigating the relationship between

cooling speed and outcomes would be helpful, studies conducted thus far support the hypothesis that the use of faster cooling methods is beneficial to patients. Likewise, these studies have shown no significant evidence that the use of faster cooling methods is harmful.

Overcooling

All surface cooling methods have some potential to overcool patients, as has been reported for cooling blankets and the Medivance Arctic Sun device; overcooling by approximately 4C° has been reported to occur with both of these methods¹⁰. Humans subjected to ice water immersion have been reported to continue to drop in temperature by an additional 0.56°C to nearly 2°C after being removed from the water^{5,6}. The ThermoSuit System, which is the only available product which uses ice water immersion to cool patients, anticipates this “afterdrop” and a message on the display instructs the user to purge the water from the suit at 1.5°C above the target temperature. The water is automatically purged if the temperature drops within 1°C of the target. To assure an accurate assessment of core body temperature during rapid cooling, the Instructions for Use of the ThermoSuit System specify the use of esophageal or nasopharyngeal temperature monitoring, as opposed to bladder or rectal temperature monitoring; this further reduces the probability of overcooling. As an additional measure to avoid overcooling, the Instructions for Use recommend that the user immediately remove the patient from the ThermoSuit upon completion of the purge process, and place the patient on a conventional cooling/warming blanket to assure that the patient remains within the targeted range of temperatures. These approaches have proven successful in the achievement of safe, rapid and accurate cooling of hundreds of patients with the ThermoSuit System.

Conclusions

New evidence supports the clinical value of rapid patient cooling in a number of applications. Cooling by ice water immersion, as provided by the Life Recovery Systems ThermoSuit® System, offers potentially significant clinical benefits. By using an accurate core temperature monitoring method (esophageal or nasopharyngeal monitoring) and feedback-controlled cessation of cooling induction, this simple noninvasive approach is capable of providing safe, rapid, and accurate patient cooling. It offers an important new clinical option for the treatment of severe hyperthermia, as well as for the rapid induction of therapeutic hypothermia.

FDA-Cleared Indications for The LRS ThermoSuit System:

Temperature reduction in patients where clinically indicated, e.g. in hyperthermic patients.

CE and Health Canada – Cleared Indications for the LRS ThermoSuit System:

Temperature reduction in patients where clinically indicated, e.g., to induce hypothermia in patients to preserve cardiac and brain function in victims of cardiac arrest, stroke, heart attack, traumatic brain injury.

References

¹ ECC Committee, Subcommittees and Task Forces of the American Heart Association, “2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care”, *Circulation* 2010;122:S768-S786.

² Polderman K and Herold I, “Therapeutic hypothermia and controlled normothermia In the intensive care unit: Practical considerations, side effects, and cooling methods”, *Crit Care Med* 2009; 37(3): 1101-1120.

³ Stone G et al, “Do Standard Monitoring Sites Reflect True Brain Temperature When Profound Hypothermia is Rapidly Induced and Reversed?”, *Anesthesiology* 1995; 82(2): 344-351.

⁴ Proulx CI et al, "Effect of water temperature on cooling efficiency during hyperthermia in humans", *J Appl Physiol* 2003; 94(4):1317-1323.

⁵ Proulx CI et al, “Safe cooling limits from exercise-induced hyperthermia”, *Eur J Appl Physiol* 2006; 96:434-445.

⁶ Plattner, O et al, " Efficacy of Intraoperative Cooling Methods", *Anesthesiology* 1997; 87(5):1089-1095.

⁷ Casa DJ, McDermott EC, Le SW et al, “Cold Water Immersion: The Gold Standard for Exertional Heatstroke Treatment”, *Exerc Sport Sci Rev* 2007, 35; 3:141-149.

⁸ Howes D, Ohley W, Dorian P, et al, “Rapid Induction of Therapeutic Hypothermia using Convective-Immersion Surface Cooling: Safety, Efficacy, and Outcomes”, *Resuscitation* 2010 Vol. 81, no .4, 388-392.

⁹ McMullan P, Howes D, Ohley W, et al, “41 - Liquid Convection Surface Cooling Leads to High Rate of Recovery of Post-VT/VF Patients”, *Circulation* 2011 (Abstract);124:A41.

¹⁰ Heard KJ, Peberdy MA, Sayre MR et al, “A randomized controlled trial comparing the Arctic Sun to standard cooling for induction of hypothermia after cardiac arrest”, *Resuscitation* 2010 Vol 81, No. 1, 9-14.

¹¹ Götzberg M, Olivecrona GK, Koul S et al, “A Pilot Study of Rapid Cooling by Cold Saline and Endovascular Cooling Before Reperfusion in Patients With ST-Elevation Myocardial Infarction”, *Circ Cardiovasc Interv* 2010;3:400-407.

¹² Mooney MR, Unger BT, Boland LL et al, “Therapeutic Hypothermia After Out-of-Hospital Cardiac Arrest: Evaluation of a Regional System to Increase Access to Cooling”, *Circulation* 2011, 124:206-214.

¹³ Sendelbach S, Hearst MO, Johnson PJ, Unger BT, Mooney MR, “Effects of Variation in Temperature Management on Cerebral Performance Category Scores in Patients Who Received Therapeutic Hypothermia Post Cardiac Arrest”. *Resuscitation* (2012), doi:10.1016/j.resuscitation.2011.12.026

¹⁴ Wolff B et al, “Early achievement of mild therapeutic hypothermia and the neurologic outcome after cardiac arrest”, *International Journal of Cardiology* 2009.

¹⁵ Felberg RA et al, “Hypothermia After Cardiac Arrest – Feasibility and Safety of an External Cooling Protocol”, *Circulation* 2001; 104: 1799-1804.

¹⁶ Haugk M et al, “Relationship between time to target temperature and outcome in patients treated with therapeutic hypothermia after cardiac arrest”, *Critical Care* 2011, 15:R101.

¹⁷ Sawyer KN et al, “The Impact of Time to Target Temperature on Survival to Hospital Discharge for Patients Undergoing a Comprehensive Postresuscitation Program Following Out-of-Hospital Cardiac Arrest”, *Circulation* 2011 (Abstract); 124: A7.

¹⁸ Busto R, Dietrich WD, Globus MY, Ginsberg MD, “Postischemic moderate hypothermia inhibits CA1 hippocampal ischemic neuronal injury”, *Neurosci Lett.* 1989 Jul 3; 101(3): 299-304.

¹⁹ Kuboyama K et al, “Delay in cooling negates the beneficial effect of mild resuscitative cerebral hypothermia after cardiac arrest in dogs: a prospective, randomized study”, *Crit Care Med* 1993; 21:1348-58.

²⁰ Janata A, Weihs W, Bayegan K et al, “Therapeutic hypothermia with a novel surface cooling device improves neurologic outcome after prolonged cardiac arrest in swine”, *Crit Care Med* 2008 ;36(3): 895-902.

²¹ Zhao H, Steinberg G, “Limited Therapeutic Time Windows of Mild-to-Moderate Hypothermia in a Focal Ischemia Model in Rat”, *Stroke Research and Treatment* 2011, Article ID 131834.

²² Markgraf CG, Clifton GL, Moody MR, “Treatment window for hypothermia in brain injury”, *J Neurosurg.* 2001; 1995(6):979-83.

²³ Carroll M, Beek O, “Protection against hippocampal CA1 cell loss by post-ischemic hypothermia is dependent on delay of initiation and duration”, *Metab Brain Dis.* 1992;7(1):45-50.

²⁴ Alam HB, Chen Z, Honma K et al, "The rate of induction of hypothermic arrest determines the outcome in a Swine model of lethal hemorrhage", *J Trauma.* 2004 ;57(5):961-9.

²⁵ Shao Z-H, Chang W-T, Ki, Chan KC et al, “Hypothermia-induced cardioprotection using extended ischemia and early reperfusion cooling”, *Am J Physiol Heart Circ Physiol* 2006.