CASE STUDY

Active Cooling During Transport of Neonates with Hypoxic-Ischemic Encephalopathy

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Introduction

Hypoxic ischemic encephalopathy (HIE) attributable to perinatal asphyxia continues to be a major cause of neonatal morbidity and mortality. Limited therapeutic interventions for HIE are available. Infants who survive HIE often have long-term developmental disabilities, including mental retardation, seizures, and cerebral palsy.[1] Total body cooling has emerged as a therapy for these affected infants. Three multicenter trials demonstrated that treatment with mild hypothermia results in improved neurodevelopmental outcomes in infants of 36 weeks' gestation or greater who have suffered a hypoxic-ischemic event.[2-5]

Prompt initiation of hypothermia is critical and must occur within 6 hours of birth. This 6-hour window is easily achieved when infants are born in a tertiary care center with all the necessary active cooling equipment and personnel. However, infants born at hospitals not able to provide this level of care require transport to a neonatal intensive care unit (NICU) offering hypothermia therapy.

Passive cooling during neonatal transport involves withholding external heat sources and monitoring the neonate's temperature frequently. Active cooling involves using gel packs to achieve target temperatures.[6,7] Neither of these methods provides a continuous-feedback temperature loop. As a result, keeping the temperature within a target range is difficult, and babies often arrive to the tertiary NICU with temperatures outside of the target range. In a recent review, 35 babies were transported to a regional hypothermia center using both passive cooling and active cooling with gel packs. On arrival, only 23 of the babies had temperatures within the desired range of 32 to 35°C.[8]

The CritiCool is a microprocessor-controlled temperature management unit manufactured by MTRE (Southampton, PA). The system uses a control algorithm that monitors skin and core temperature to make adjustments to the circulating water temperature to maintain the patient's core temperature at a target of 33.5°C. Although not specifically designed for transports, the device is small enough to use on transports.

Our program currently serves as a referral area for hypothermia treatment, and transport times may last as long as 6 hours round trip. Therefore, we wished to implement a method to actively provide cooling in a reliable, controlled manner during transports. To accomplish this goal, we employed a CritiCool during transport in our ambulance, fixed-wing aircraft, and helicopter. In this report, we describe the transport of three neonates using the CritiCool during all three modalities of transport.

Case Report

Case 1: Fixed-Wing Aircraft Transport

B.D. was a term infant born to a 20-year-old gravida 2 para 2, O+, human immunodeficiency virus– and hepatitis B–negative, GBS-positive mother at an outside hospital. The mother presented to her obstetrician for a scheduled blood pressure check. On examination, the fetal heart tones were 60 beats per minute (bpm). An emergent Cesarean section was performed under general anesthesia. The baby was unresponsive at delivery and had a heart rate less than 60 bpm. B.D. required intubation and endotracheal tube epinephrine administration. The infant's APGAR scores were 1^1, 3^5, and 4^{10}. He was stabilized and moved to the NICU, where the NICU staff initiated passive cooling. The outside physician immediately called for transport to our NICU. We dispatched our fixed-wing aircraft with the CritiCool equipment so that active cooling could be performed en route (Figure 1A, B). On arrival at the referring NICU, the neonate's temperature was noted to be 31.5°C by the transport team. Passive cooling was continued en route from the referring facility to the aircraft. Once inside the aircraft, the neonate was placed on the CritiCool, and active temperature management began with gradual rewarming (Figure 2). On arrival in Gainesville, the CritiCool and neonate were transferred into an ambulance for ground transport to Shands Teaching Hospital (STH). Active cooling was provided throughout the ground transport. The neonate was then transferred from the ambulance to the NICU, using passive cooling. On arrival to the NICU, active cooling therapy was restarted. The patient's admission temperature was 33.5°C. On initial

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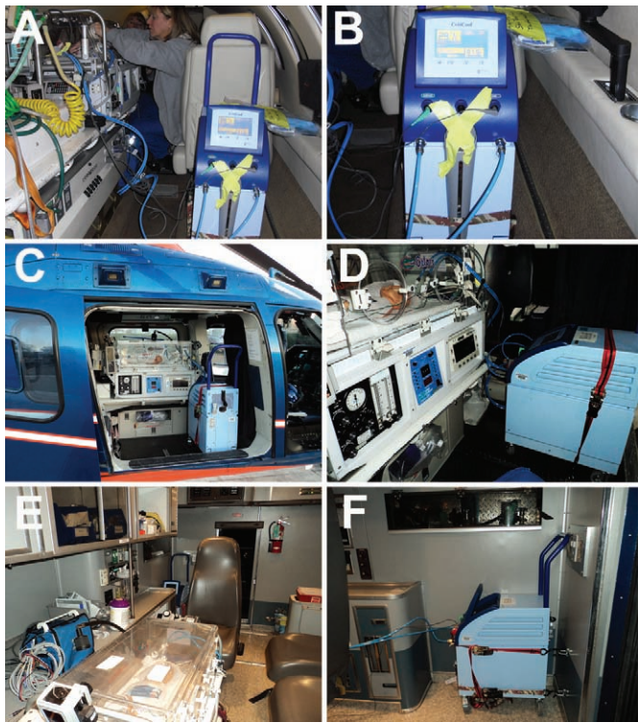
Figure 1. The CritiCool in the ambulance, fixed-wing, and helicopter. A and B demonstrate the CritiCool in our Cessna Citation. Note the yellow tape that covers the cap. C and D show the CritiCool in our Agusta A109 Power helicopter. E and F show the CritiCool in the ambulance; note in panel E the CritiCool is in the back left corner of the photograph. Note the red prototype cap in F (arrow).



physical examination, he was classified as Sarnat stage III, given his history of seizures and absent reflexes. His magnetic resonance imaging (MRI) showed decreased brain volume and restricted diffusion in the thalami, bilateral frontal white matter, splenium of the corpus callosum, and globus pallidus, consistent with HIE. His health stabilized during his hospitalization, but he continued to have diminished reflexes, seizures, and general decreased responsiveness. He was discharged home with hospice care.

Case 2: Helicoptor Transport

B.K. was a 35-week late preterm male, born at a referring medical center to a 21-year-old gravida 4 para 3 mother with negative serologies. The infant was born via emergent C-section secondary to placental abruption with absent fetal heart tones. The infant's APGAR scores were 1^{1}, 2^{5}, 4^{10}, and 7^{15}. The initial arterial pH at 30 minutes of life was 6.60, with a base deficit of 26. The infant was mechanically ventilated and resuscitated. Physicians classified his encephalopathy as Sarnat stage II. The infant's neurologic status and blood gas values qualified him for systemic hypothermia therapy for neuroprotection. The referring facility passively cooled him by removing all external heat sources. When the transport team arrived at the referring facility, the infant's rectal temperature was 31.8°C. The transport team placed the infant on the CritiCool device and transported him via helicopter to our facility without complications (Figure 1C, D). The transit time was approximately 50 minutes, and the infant's rectal temperature was 34.1°C on arrival to our facility (Figure 2). B.K. had a relatively stable hospital course, with complications limited to a mild coagulopathy and mild to moderate cardiac dysfunction. During the 72 hours of systemic hypothermia, his neurologic status continued to improve, he was void of any seizure activity, and a brain MRI on day 4 of life did not demonstrate evidence of neurologic injury.

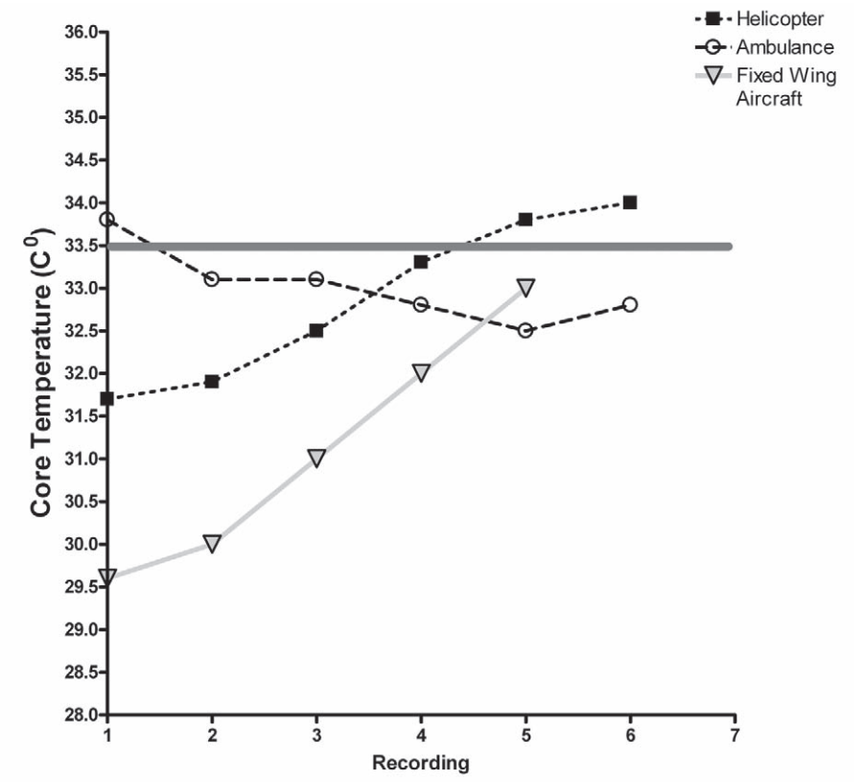
Case 3: Ground Transport

B.T. was a term female infant born to a 28-year-old gravida 1 mother with negative serologies at an outside hospital. The baby was born via emergent Cesarean section secondary to fetal bradycardia. Initial Apgar scores were 1^{1}, 3^{5}, and 5^{10}. The baby was initially intubated but then self-extubated and was left extubated because of improving respiratory status. However, she developed seizure activity, was re-intubated, and phenobarbital was administered. During transport to a referral hospital, passive cooling was initiated. On arrival at the referral hospital, physicians confirmed the need for hypothermia therapy and contacted STH for transfer. We dispatched an ambulance equipped with a CritiCool device (Figure 1E, F). Our ambulance team placed the neonate on the CritiCool and actively cooled her throughout the transport. The CritiCool maintained her temperature between 32.5 and 33.1°C during the entire transport (Figure 2). Her temperature on arrival to STH was 33.3°C. While she was transferred from the ambulance to the NICU, the transport team passively cooled the neonate. Active cooling was reinitiated on her arrival to the NICU. Physicians in the STH NICU classified her as Sarnat stage III with a history of seizure activity and without a gag reflex. She was actively cooled for 72 hours. Her clinical course improved, with eventual extubation and improved neurologic status. Her MRI was normal.

Discussion

Therapeutic hypothermia has emerged as state-of-the-art treatment for neonates with HIE. As a result, clinicians must have a reliable and controlled method to cool these neonates during transport to centers with hypothermia programs. Often these neonates are inadvertently overcooled because of the resultant changes in metabolism and heat production from HIE. Both passive cooling and active cooling with gel packs[9] can cause this overcooling. Overcooling has the potential to increase serious side effects associated with cooling, such as: arrhythmias, electrocardiogram changes, electrolyte abnormalities, thrombocytopenia, and coagulopathies.[10] In this report, we demonstrate that the servo-controlled CritiCool is feasible for use during both ground and air transports.

Figure 2. Comparison of patient temperatures as recorded during the ambulance, fixed-wing, and helicopter transports. The gray line represents the ideal target temperature of 33.5°C. During the ambulance transport, the patient's temperature stayed very consistent and within the target range during the entire transport. In both the fixed-wing and helicopter transports, the patients were below the target temperature on arrival at the referring facilities. The CritiCool device rewarmed both patients with user inputs so that they were within the target range on arrival to Shands Teaching Hospital. The recording time intervals for the ambulance and fixed-wing transports were 15 minutes; for the helicopter the interval was 10 minutes because of the shorter duration of the transport.



The CritiCool device is not designed specifically for transports, but the size of the device makes it a viable transport option. On the first transport, the water cap loosened with road bumps. This complication was remedied with tape. The company, based on our feedback, produced a modified cap that did not leak during our subsequent helicopter transport. The device performs with remarkable ease if the patient's temperature is at or above 33.5°C. However, if the patient is below the target temperature of 33.5°C, the health care professional must manipulate the device's program to safely bring the temperature up to the target level. Based on feedback from our experience, the company is actively attempting to improve the ease of use in neonates below the target temperature.

Based on our experience, we have learned several practical lessons. First, the CritiCool device lacks a battery backup. Second, the device weighs approximately 70 lbs when completely filled with water. Therefore, transport team members cannot practically move the device from the fixed wing aircraft or helicopter once secured. Third, an alternative temperature monitoring method must be used during long transfers between the facility and fixed-wing aircraft to avoid temperature fluctuations associated with passive cooling. Originally, we placed the neonate on the cooling wrap and placed the rectal and skin probes used by the CritiCool before transfer to the transport incubator. This procedure worked well for the ambulance and helicopter, which involved short transports from the referring NICU to the transport vehicle. However, during fixed-wing air transports, ground transport times from referring NICU to the airport can approach 30 minutes. During our ground transport from the hospital to the airport for the fixed-wing transport, we used the same technique as the ambulance case report and placed the neonate on the wrap and applied the rectal and skin CritiCool probes in the referring NICU. However, the neonate's temperature was noted on arrival to the aircraft to be below 33.5°C. To monitor the temperature during prolonged ground transit for air transports, we have since changed our practice and opt to place a separate continuous rectal probe monitor and provide passive cooling. If the neonate's temperature is below 33.5°C, the incubator should be turned on to 0.5°C above the neonate's current temperature. On arrival to the

aircraft the rectal probe is then replaced with the rectal probe for the CritiCool.

This report demonstrates the first use of a servo-controlled cooling device during multiple modes of transport. The device enables the user to tightly regulate and control the neonate's temperature in a controlled and tightly monitored fashion.

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