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A New Protocol for First Responders for Hypothermic Pulselessness in Pediatric Patients

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Abstract

In the summer of 1986, a two-and-a-half-year-old girl, named Michelle, was submerged in a creek near Salt Lake City for a total of 62 minutes from initial submersion to removal by rescuers [7]. The young girl showed no signs of life, and was found pulseless, flaccid, cyanotic[1], and with fixed and dilated pupils[2] [7]. Despite the grim presentation of the girl, emergency medical services (EMS) made resuscitative efforts and transported her to Primary Children's Medical Center in Salt Lake City [7]. Fortunately for Michelle, the physicians at Primary Children's quickly placed her on an extracorporeal rewarming and circulation device, and three hours after initial submersion, manual chest compressions were discontinued as she was stable enough to circulate blood independent of the external rewarming machine [7]. Ultimately, after an extended admission to Primary Children's, Michelle was able to function at the appropriate developmental age-level by three-and-a-half years old [7]. Following Michelle's miraculous survival and recovery, the use of extracorporeal membrane oxygenation (ECMO) in pediatric hypothermic cardiac arrest became a focus for pediatric emergency physicians; however, because this condition is so rare, it is often difficult to study. The purpose of this review, in conjunction with several emergency physicians at Primary Children's Medical Center and the University of Utah Hospital in Salt Lake City, is to evaluate the effectiveness of ECMO introduction into pediatric patients suffering from hypothermic cardiac arrest. Ultimately, the research involved in this study was used to modify the Utah State EMS protocol for hypothermic cardiac arrest in children in order to incorporate appropriate treatment and transport decisions for emergency medical technicians (EMTs) and paramedics with the objective of increasing survival and positive outcome rates in these patients. Following implementation of the aforementioned protocol, trainings were conducted for fire and EMS agencies across the Wasatch Front to decrease the number of patients that are incorrectly treated annually.

Keywords: Emergency Medical Services (EMS), Hypothermia, Pediatrics

1. Introduction

1.1 Accidental Hypothermia

Accidental hypothermia is defined as a core body temperature less than 35° C [8]. Within this definition are subcategories: mild hypothermia ranges from 31 to 35° C; moderate hypothermia ranges from 29 to 31° C; and severe hypothermia is less than 29° C. Primary hypothermia, the type addressed henceforth, "occurs when heat production in an otherwise healthy person is overcome by the stress of excessive cold, especially when the energy stores of the body are depleted" [8]. Impairment of the body's consciousness, circulation, and breathing increases as a patient's temperature decreases [8]. The risk of cardiac arrest is high once core temperatures drop below 32° C, and increases substantially once the body's core temperature drops below 28° C [8]. Hypothermic patients have significantly diminished metabolic demands, causing a severely depressed heart rate, and an extremely high risk for asystolic cardiac arrest[3]. The four stages of accidental hypothermia (HT I through HT IV) are addressed in table 1 [8].

The cause of hypothermic cardiac arrest, particularly in an out-of-hospital setting, is widely discussed to evaluate prevention of cardiac arrest in severely hypothermic patients. Historically, "rescue collapse" was used to describe the cause of cardiac arrest due to hypothermia in the field. Rescue collapse is defined as "cardiac arrest that is related to the extrication and transport of a patient with deep hypothermia (stage HT III or IV)" [8]. Rescue collapse is due to both hypovolemia[4] and lethal cardiac arrhythmias that are caused by the rough handling of a patient [8]. This problem presents itself primarily in an out-of-hospital setting where both access to and transport of patients is often quite complex.

Table 1. Stages of hypothermia with their associated clinical symptoms and respective pre-hospital and in-hospital treatments.

STAGE	CLINICAL SYMPTOMS	CORE TEMPERATURE	TREATMENT
HT I	Conscious, shivering	32-35° C	Warm environment and clothing, warm sweet drinks, active movement
HT II	Impaired consciousness, not shivering	<28- 32° C	Cardiac monitoring, minimal movements to avoid arrhythmias, horizontal position and immobilization, full-body insulation, active external and minimally invasive internal rewarming
HT III	Unconscious, not shivering, vital signs present	<24-28° C	HT II management plus airway management as required; ECMO in cases with cardiac instability that is refractory to medical management
HT IV	No vital signs	<24° C	HT III management plus CPR and up to three doses of epinephrine per ACLS or PALS guidelines, and limited defibrillation; rewarming with ECMO or CPR with active external and alternative internal rewarming

1.2 ECMO

Extracorporeal membrane oxygenation (ECMO) is a specific manner of performing cardiovascular and pulmonary life-support through an external device [25]. Blood is drained from the vascular system, circulated through the ECMO circuit by pump, and reintroduced into the body [25]. As it passes through the ECMO unit, hemoglobin becomes fully saturated with oxygen and carbon dioxide is removed, thus acting as an external lung machine [25]. Blood may also be heated to an appropriate circulating temperature for a healthy patient, which can facilitate targeted temperature increase following hypothermic cardiac arrest. ECMO is indicated for three categories of failure: respiratory, cardiac, or a combination of the two [25]. There are two primary cannulation[5] techniques in patients requiring ECMO. The first is venovenous (VV) cannulation (figure 1) in which blood is removed from either the vena cava or the right atrium and returned to the right atrium following oxygenation and warming [25]. Cannulae are generally placed in the vena cava or directly into the right atrium; however, in the event of a dual cannulation, cannulae are placed in the common femoral vein and right internal jugular or femoral vein [25].

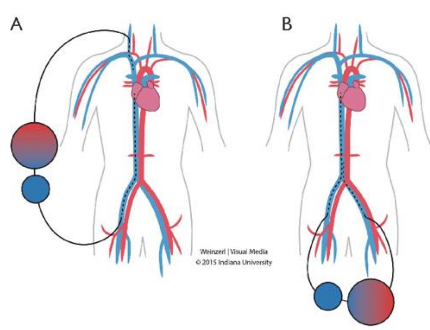

Figure 1. Diagram of cannulation sites for venovenous ECMO (VV ECMO).

VV ECMO is only indicated in patients that are hemodynamically stable[6] but experiencing respiratory compromise (in this patient, the ECMO is intended to provide respiratory support) [25]. If hemodynamically unstable, patients must be placed on venoarterial (VA) ECMO. VA ECMO is used in the extremely unstable patients that require both cardiac and respiratory support. The ECMO circuit "is connected in parallel to the heart and lungs, while in VV ECMO the circuit is connected in series to the heart and lungs" [25]. In VA ECMO (figure 2), blood bypasses both the heart and lungs and is pumped through the ECMO machine to take their place oxygenating and pumping the blood [25].

Cannulae are placed in the right atrium or vena cava to drain the blood and in the femoral, carotid, or axillary arteries to reintroduce oxygenated and heated blood. VA ECMO is indicated in stage HT III with cardiac instability or HT IV [8]. Table 2 [25] demonstrates the differences in indications and capabilities between VV and VA ECMO.

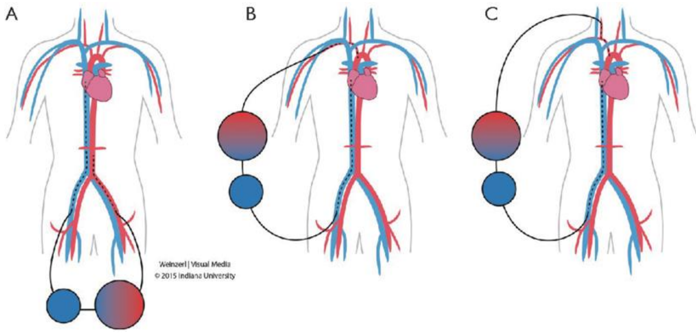

Figure 2. Diagram of cannulation sites for venoarterial ECMO (VA ECMO).

Table 2. Variations between VV and VA ECMO and their indications.

VA ECMO	VV ECMO
Provides cardiac support to assist systemic circulation	Does not provide cardiac support to assist systemic circulation
Requires arterial and venous cannulation	Requires only venous cannulation
Bypasses pulmonary circulation and decreases pulmonary artery pressures	Maintains pulmonary blood flow
Can be used in right ventricular failure	Can't be used in right ventricular failure
Lower perfusion rates are needed	Higher perfusion rates are needed
Higher PaO_2 is achieved	Lower PaO_2 is achieved
ECMO circuit is connected in parallel to the heart and lungs	ECMO circuit is connected in series to the heart and lungs

Unfortunately, complications associated with ECMO are common, which can cause significant increases in morbidity and mortality rates among patients placed on ECMO. It is unclear as to whether the complications originate with the underlying condition for which the patient requires ECMO or with the ECMO itself. The most common complication of ECMO is hemorrhage at the site of cannulation—most commonly in the groin or the neck—with up to 34% of patients undergoing VV ECMO and 17% of patients undergoing VA ECMO requiring surgery to correct this problem [25]. Due to use of heparin[7] as an anticoagulant in ECMO use, bleeding is often uncontrollable, and must be managed by stopping heparin and infusing platelets [25].

Ultimately despite these complications and limitations, VA ECMO is extremely effective at providing support to patients in cardiac arrest until they are able to support circulation independent of the ECMO machine, or until they receive a long-term ventricular assist device (VAD) [25]. Specific use in pediatric hypothermic cardiac arrest will be addressed in the following pages.

1.3 Hypothermic Cardiac Arrest

Hypothermic cardiac arrest presents a unique prospect for survival due to the preservative effects that cooling has on the body [41]. A hypothermic patient has decreased metabolic and cellular oxygen demands, which increases ischemic[8] tolerance of the brain and provides a greater likelihood of survival [49]. Primary hypothermic cardiac arrest in adult populations is traditionally a result of mountaineering accidents, exposures due to overdoses, or suicide attempts [36]. In contrast, hypothermic cardiac arrest in pediatrics is typically due to submersion accidents [36]. Drownings provide a unique situation as the decreased ability to hold one's breath leads to "early inhalation of water and accelerated cooling" [36]. Furthermore, one study suggests "extended hypothermia not only minimize[s] reperfusion injury, protect[s] the lungs from worsening pulmonary edema and accelerate[s] weaning from extracorporeal bypass, but also optimize[s] neuroprotection" [21]. Hypothermic cardiac arrest improves the likelihood of survival and good recovery, as drastically low temperatures creates a preservative effect on the body.

Prognostic factors in hypothermic cardiac arrest are variable. Many sources state that hyperkalemia[9] is a significant factor in likelihood of survival in hypothermic cardiac arrest; however, this cannot be confirmed as no specific research has been done on the matter [36]. Other sources state decreased serum pH increases mortality rates in hypothermic cardiac arrest, but this is also unconfirmed through lack of research [49]. While hypothermic cardiac arrest may be infrequent, the potential for dramatic neurological recovery following appropriate treatment motivates an opportunity to adapt treatment styles in both an in-hospital and out-of-hospital setting [36].

Unfortunately, the nature of hypothermic cardiac arrest (submersion, exposure, avalanche burial, etc.) significantly impacts the patient's prognosis, so generalized statements cannot be made about hypothermic cardiac arrest and the use of ECMO in these cases. Patients who experience hypothermic cardiac arrest secondary to submersion—suggesting aspiration[10] and hypoxia[11]—have poorer prognoses than patients who experience hypothermic cardiac arrest without drowning [11]. Unfortunately, *pediatric* hypothermic cardiac arrest primarily results from submersion accidents, decreasing the likelihood of successful resuscitation and recovery. Hypothermic cardiac arrest secondary to asphyxia shows increased levels of brain damage as it is "preceded by a period of hypoxic brain perfusion[12]" [11].

The European Resuscitation Council released guidelines with a modified approach to resuscitation of hypothermic cardiac arrest [8]. Hypothermic arrest results in accumulation of administered medications in the body as the cold state of the body does not allow for appropriate pharmacokinetics. Absorption of medications in hypothermia decreases by up to 44%, and distribution decreases by up to 40% [46]. As a result, the medications are both less effective and accumulate in the patient's bloodstream, meaning, upon return to normothermia[13], the patient experiences an influx of potent cardiac medications, which can precipitate lethal dysrhythmias. The European Resuscitation Council's guidelines suggest up to three defibrillations and the withholding of epinephrine[14] until the patient's core temperature has exceeded 30° C [8]. It further suggests that, upon reaching 30° C, epinephrine doses should be administered in intervals twice as long as in normothermic cardiac arrest patients [8] It may be reasonable to consider administration of a vasopressor[15] during cardiac arrest according to the standard ALS [advanced life support] algorithm concurrently with rewarming strategies. Nationwide, most prehospital protocols follow a combined format of the recommendations of both the European Resuscitation Council and the American Heart Association, administering up to three defibrillations and up to two doses of epinephrine.

1.4 ECMO in Hypothermic Cardiac Arrest

Extracorporeal membrane oxygenation (ECMO) is by far "the most effective way to warm an extremely hypothermic patient" [36]. ECMO creates improved prognosis for pediatric patients with a core temperature less than 30° C [6]. Pulseless patients with a core temperature less than 30° C who are treated with ECMO have a 15% survival rate with good neurological outcome, when compared to the 8% survival rate of those patients who are not treated with ECMO [6]. The remaining 85% of patients can become organ donors, while patients not treated with ECMO cannot [6]. The current European Resuscitation Council Guidelines state hypothermic patients in HT IV should be treated with extracorporeal circulation [34]. Primary Children's Medical Center in Salt Lake City has established trauma protocols for hypothermic pediatric patients with a core temperature below 30° C (figure 3) [7]. It is important to note that patients with a core temperature above 30° C no longer meet ECMO criteria, and may experience worse neurological outcomes.

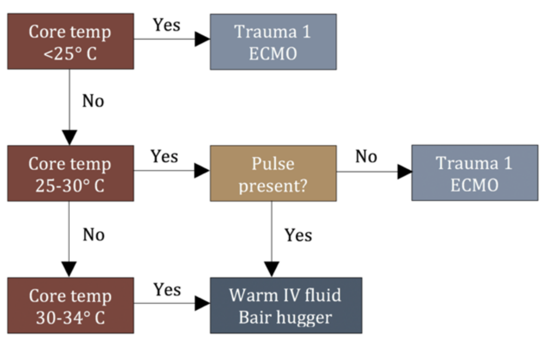

Figure 3. Primary Children's Medical Center ECMO initiation protocol for hypothermic patients.

To allow for the best opportunity for meaningful survival in a pediatric hypothermic cardiac arrest, a "preemptive protocol can facilitate prompt decisions and efficient delivery of care" [36]. Primary Children's Medical Center's trauma protocol for ECMO includes CPR, endotracheal or nasotracheal intubation[16] (or more invasive airway management if needed), a maximum of two doses of epinephrine, a maximum of three defibrillation attempts, and administration of a blood bank pack including six units of trauma blood, one unit of platelets, and one unit of fresh frozen plasma [7]. Primary Children's exclusion criteria (or contraindications) include major blunt or penetrating trauma [7]; however, a secondary protocol in use at Primary Children's states "contraindications for EC-CPR [extracorporeal CPR] support at our institution include known irreversible severe neurologic injury, uncontrolled hemorrhage, irreversible multiple organ system failure and pre-EC-CPR unwitnessed arrest outside the medical system (other than hypothermic arrest)" [41]. Ultimately, it is at the discretion of the attending emergency physician to decide if the patient's condition is too unstable to perform ECMO. Inclusion criteria for ECMO at Primary Children's consists of any patient with a core temperature below 30° C, including those with exposure to cold water less than 50° C and extended exposure to ice, snow, or wind [6].

2. Discussion

2.1 Prehospital Protocols

Current protocols nationwide contain little information on maintaining cool temperatures in pediatric patients suffering from hypothermic cardiac arrest with a core temperature less than 30° C. Salt Lake County's 2017 protocol simply states "no active external rewarming (no heat, forced hot air, warm packs, etc.)" for patients in HT IV, or what they consider "severe hypothermia" [43]. Few protocols nationally address ECMO criteria in hypothermic cardiac arrest. Rather, protocols encourage passive rewarming of all hypothermic patients by removing cold or wet clothing, applying dry insulation, warming the environment, and maintaining internal circulation by resuscitation of patients in cardiac arrest so external rewarming is effective. Two goals must be addressed at this point: first, protocols must be revised to incorporate new research supporting ECMO initiation in hypothermic cardiac arrest; and second, prehospital emergency care providers on every level must be trained to do what may initially seem counterintuitive and leave a cold patient cold—specifically patients in cardiac arrest with core temperatures less than 30° C.

2.2 A New Protocol

Ultimately, given the new information on hypothermic cardiac arrest, the first and most important change that must be made is in our nationwide prehospital protocols. The following is a proposed protocol, written by the author of this study, for pediatric hypothermic cardiac arrest, with guidance from Dr. Hilary Hewes at Primary Children's, and Dr. Peter Taillac at the University of Utah Hospital. As discussed previously, this protocol is structured on a combination of the American Heart Association and European Resuscitation Council's guidelines. A timeframe for transport of these patients was determined based on the Primary Children's ECMO protocol, with help from Dr. Hewes. Since the patients, according to the Primary Children's ECMO protocol, must be placed on ECMO within ninety minutes of being found down, the timeframe is somewhat limited [7]. Dr. Hewes stated it typically takes ten to thirty minutes to place the patient on ECMO after arrival in the emergency department, further limiting the location of the patient, as they now must be no more than sixty minutes from time found down to arrival at Primary Children's in order to meet the criteria for ECMO. Considering that a reasonable scene time and response time can take as long as thirty minutes, further protocol development was based on a maximum thirty-minute transport. This thirty-minute window includes both ground transport and air transport, with air transport significantly widening the spatial parameters of this protocol. Geographic information system (GIS) mapping software was used to create a map designating areas within which a patient can be found down while no more than sixty minutes from Primary Children's (assuming a thirty-minute scene time and a thirty-minute transport time) [33]. GIS is a geographical data system that can store, manipulate, and analyze said data for various reasons [33]. In this case, QGIS® software used the data for the area surrounding Primary Children's and determined the maximum distance from the hospital while still remaining within a thirty-minute ground transport [33]. In order to have a thirty-minute or less transport time by air, patients must be within sixty miles of Primary Children's. This can be variable in rural settings where EMS response may be delayed; therefore, air medical response should be heavily weighted when considering if a patient may meet inclusion criteria for this protocol and if ground response may delay care or fully exclude the patient from the protocol.

The following protocol includes three components: first, the modified Utah State Protocol, which was released on March 4, 2020 with specific directions to withhold rewarming practices and rapidly transport to an appropriate ECMO facility (figure 4) [43]; second, an easy to follow algorithm to be placed on fire engines and ambulances for ease of determining whether or not a patient falls under ECMO criteria (figure 5); third, a map created with GIS mapping software and Google Earth [33] for providers to determine whether they can transport their patient by ground or air to Primary Children's within the thirty-minute window provided (figures 6, and 7).

TEMPERATURE AND ENVIRONMENTAL EMERGENCIES

ALL PROVIDERS / EMT

- ❑ Scene and patient management
  - Remove patient from hot or cold environment, when possible
  - Focused history and physical exam
  - Body temperature and blood glucose assessment.
  - Assess level of consciousness; apply the ***Altered Mental Status Guideline*** if applicable.
  - Assess for underlying causes; medications, toxins, CNS lesions or other medical conditions.
- ❑ Cardiac monitor, ETCO2, and pulse oximetry monitoring when available
- ❑ **Treatment Plan**
  - **Heat Related**
    - Temperature elevation **WITHOUT** altered mental status (**Heat Exhaustion**)
      - Slow cooling with ice packs, wet towels, and/or fans to areas in the vicinity of carotid, femoral, brachial arteries.
      - If patient is alert and not nauseated, oral rehydration with water or balanced electrolyte solution.
      - Severe muscle cramps may be relieved by gentle stretching of the muscles.
    - Temperature elevation **WITH** altered mental status (**Heat Stroke**)
      - Aggressive cooling to unclothed patient utilizing fine mist water spray and fans in conjunction with ice packs to groin and axilla while maintaining modesty (NOT Recommended for children and infants)
      - Aggressive cooling should be stopped if shivering begins.
      - Monitor closely for dysrhythmia, recognize and treat with the appropriate ***Cardiac Patient Care Guideline***
    - Room temperature IV fluids should be administered for both heat exhaustion and heat stroke (AEMT and PM only)
    - Benzodiazepines may be used for shivering (AEMT and PM only)
  - **Cold Related**
    - Protect patient from further heat loss (application of blankets, removal of wet clothing, warm environment, etc.).
    - Suspicion of cardiac arrest in cold environment, assess for 30-45 seconds to confirm pulselessness.
    - Measure body temperature and treat accordingly
      - **Severe: <86°F (30°C)**
        - ➢ Use active external rewarming (heated oxygen, warm packs to neck, armpits, groin, etc.)
        - ➢ Administer warm IV fluids (AEMT/PM only)
        - ➢ Cardiac arrest: Chest compressions and ventilations. Limit defibrillation attempts to 3 and no external pacing. Likelihood of successful defibrillation improves as patient is warmed.
        - ➢ Pediatric cardiac arrest due to hypothermia (temperature <30 C/86 F): consider direct transport to Primary Children's Medical Center and **do NOT rewarm** this patient.
        - ➢ Adult cardiac arrest due to hypothermia (temperature <30 C/86 F): consider direct transport to University of Utah Medical Center and **do NOT rewarm** this patient.
        - ➢ Handle the patient gently during transport because rough movement may precipitate dysrhythmias.
      - **Moderate: 86-93°F (30-34°C)**
        - ➢ Use warm packs to neck, armpits, and groin
        - ➢ Warm IV fluids (AEMT/PM only)
      - **Mild: >93°F (34°C)**
        - ➢ Warm with blankets, warm environment, etc.
        - ➢ Frostbite precautions – Do not rub or use dry external heat. Re-warm with 40°C water if possible.
        - ➢ Warm IV fluids (AEMT/PM only)

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Figure 4. The modified Utah State Protocol for Temperature and Environmental Emergencies, released on March 4, 2020. Note the highlighted segment featuring modifications in pediatric care.

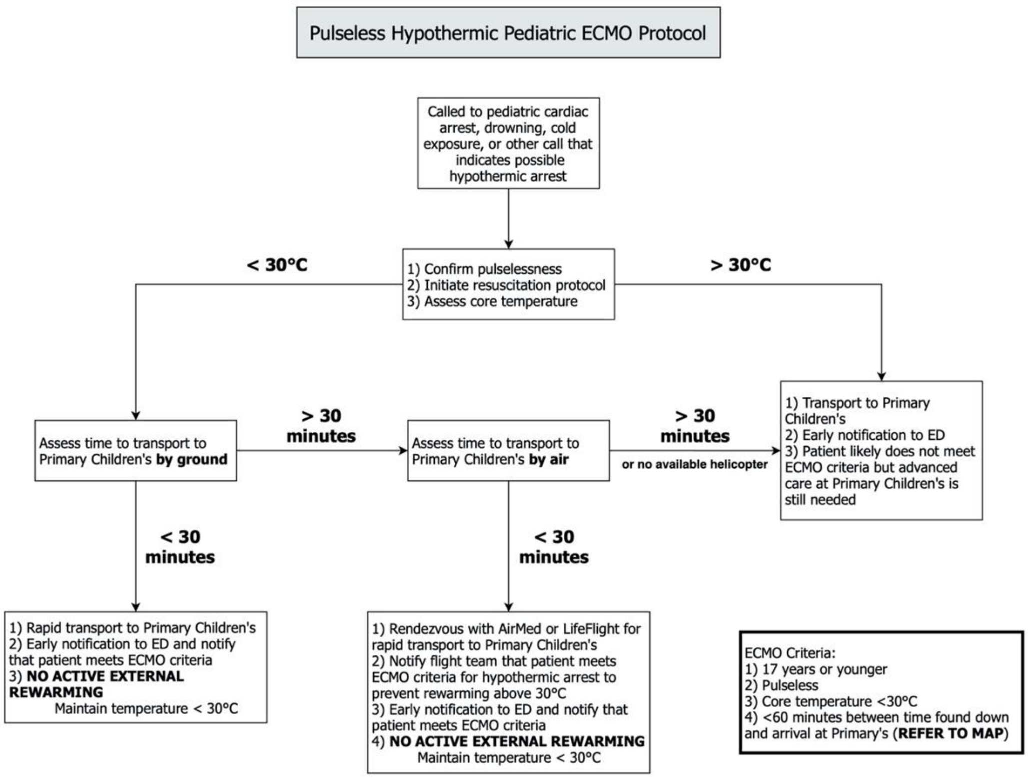

Figure 5. Proposed ECMO algorithmic protocol for local agencies within the geographic regions included in the GIS map.

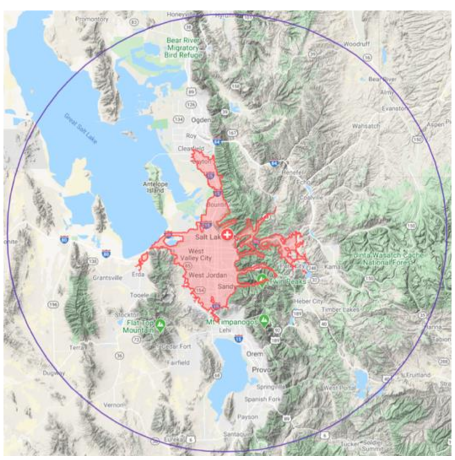

Figure 6. A regional map demonstrating the locations where patients are included in ECMO criteria. Patients within the purple circle are within a thirty-minute helicopter flight of Primary Children's, while patients within the red shaded area are within a thirty-minute ground transport of Primary Children's. Primary Children's Medical Center is noted by the white cross.

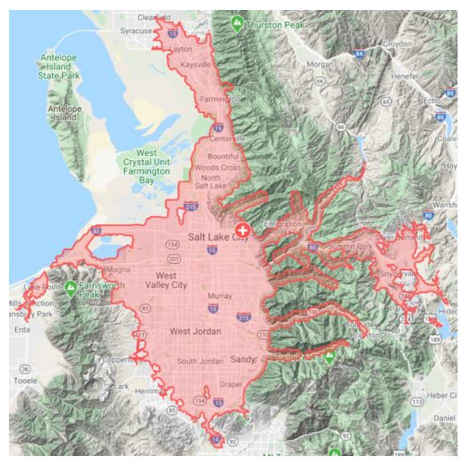

Figure 7. A zoomed in version of figure 6. Patients within the red shaded area are within a thirty-minute ground transport of Primary Children's. Primary Children's Medical Center is noted by the white cross.

2.3 Limitations of New Protocol Initiation

Despite an eagerness to change nationwide protocols, several limitations exist that must be addressed prior to attempting adaptations to the protocols. First, and perhaps most importantly is the accurate measurement of temperatures. Most prehospital agencies carry either tympanic[17] thermometers, or oral thermometers. In order to measure the exact 30° C core temperature necessary to rapidly transport this patient to an ECMO facility, core thermometers, or "properly calibrated, low-reading thermometers" [8] are required but rarely available in the prehospital setting. A patient's temperature will vary depending on the site used to measure said temperature, the patient's perfusion, and the environmental temperature [8]. Ideal core temperature would be measured in the esophagus, but most prehospital agencies do not allow for such measurements as they are not outfitted with proper equipment to measure the esophageal temperature [8]. Given that most agencies carry either tympanic or oral thermometers, they should consider that these often have a deficit of 0.1-0.7° C [12, 20, 24, 40] so a core temperature of 30° C may present as a tympanic or oral temperature of 29.3 to 29.9° C. Given these considerations, providers should still be able to follow this protocol without any changes to their treatment.

A secondary issue comes in the form of education. To establish this protocol, there must be widespread education of the complications of hypothermic cardiac arrest and the way in which prehospital providers can set their patient up for the greatest success and greatest likelihood of effective resuscitation with good outcomes. These providers should also be advised as to which facilities in their area are ECMO facilities, specifically pediatric emergency departments with ECMO capability.

3. Keys to Success

The keys to success for effective resuscitation of a pediatric patient, as outlined in this review, include the following—bear in mind, these refer *specifically* to protocols in Utah:

- Early recognition of severe hypothermia in a prehospital setting
- Early communication with and rapid transport to a pediatric facility with ECMO capabilities (Primary Children's Medical Center in the Intermountain West)
- Consult medical direction at Primary Children's Medical Center to allow for early notification to Intermountain Healthcare's pediatric LifeFlight team, or University of Utah Healthcare's pediatric AirMed team, and gathering of the ECMO and trauma teams to prepare for patient arrival
- Establish ECMO in pulseless pediatric patients with a core temperature of less than 30° C upon arrival at Primary Children's

4. Methods

In order to ensure proper care of pediatric patients experiencing cardiac arrest secondary to hypothermia, patients must be rapidly transported to a pediatric ECMO capable facility. The only pediatric facility with ECMO along the Wasatch Front is Primary Children's Medical Center. The protocol at Primary Children's for ECMO initiation in pulseless hypothermic patients requires that the patient be placed on ECMO within ninety minutes of initial rescue, and that the patient maintain a core temperature of 30° C or less for the entire duration of rescue and transport. After lengthy discussion with Dr. Hillary Hewes at Primary Children's, it was agreed that a maximum of sixty minutes could elapse between finding the patient to arrival at Primary Children's, which allows for staff at the hospital to have a thirty-minute window to place the patient on ECMO. Considering the variability in the amount of time it takes once a family member or bystander locates the patient and calls 9-1-1 to the time EMS arrives on scene and determines the patient is experiencing cardiac arrest secondary to hypothermia, an approximate window of thirty minutes can be assigned for scene time. This ultimately gives an approximate transport time of thirty minutes by ground or air, assuming a thirty-minute response and scene time, and a thirty-minute time in the emergency department prior to placement on ECMO. Unfortunately, this severely limits the counties and regions that fall under this proposed protocol and means that a new state-wide protocol is unrealistic. Regardless, using the map created with GIS software and the help of AirMed, a protocol appendix was created and proposed to Dr. Peter Taillac, the medical director for the state of Utah.

5. Implementation

Following implementation of the proposed protocol appendix, and the modifications to the state protocol that were released on March 4, 2020, the new protocol was proposed to numerous fire and EMS agencies that could realistically implement it. Two departments then received training on the protocol—Mountain West Ambulance Service, and Park

City Fire District. These firefighters, paramedics, and EMTs were then assessed using Albert Bandura's Social Cognitive Theory. Social Cognitive Theory (SCT) envisions human behavior as an interaction between an individual's behavior, personal factors, and environmental influences [4]. The cognitive factors include knowledge, attitudes, and expectations. The environmental factors include social norms, access within a community, and influence on others. Finally, the behavioral factors include skill, practice, and most importantly in this case, self-efficacy. Self-efficacy and team-efficacy are considered one's perception in one's ability to perform a certain task or handle a particular situation either individually or as a team respectively [27]. EMS is a team-based work environment, particularly when it comes to patient care; thus, the assessment of team-efficacy is the most important determination when implementing this new protocol, as patient outcomes must be assessed over several years due to the narrow patient population that this protocol is addressing. Assessing a provider's self- and team-efficacy with regard to the new protocol allows for evaluation of implementation ability in the short-term, while waiting to see the results of these changes over the long-term.

EMTs and paramedics were assessed using a ten-question pre-test evaluating their self- and team-efficacy. Four questions were demographic questions, three were knowledge-based, and three were related to each provider's team-efficacy. The EMTs and paramedics were then given a one-hour training on proper management of a pediatric patient in cardiac arrest secondary to hypothermia. Finally, they were given a post-test to determine both their improved knowledge of the newly understood material, and the increase in their team-efficacy to include this new protocol in their agency.

6. Results

This research is ongoing. As noted above, due to the rarity of these cases, it will require many years to evaluate whether this new protocol is effective at increasing the number of patients who receive ECMO following hypothermic cardiac arrest. Primary Children's, the only children's hospital in the area, typically sees fewer than 10 of these patients a year. That said, the results thus far are such that they have brought about the revision of an existing protocol, and the exploration of education principles used to teach the revised protocol to EMS providers.

Although the target patient population is a low-frequency population, even a small change to protocols can provide a high impact in the outcome of the patients. Survival rates of patients who are able to be placed on ECMO nearly double when compared to patients who don't receive ECMO, thus making this a high-priority change to EMS protocols. The former Utah State EMS Protocols from 2017 included rewarming techniques to all hypothermic patients, regardless of their temperature, their cardiac status, or their age. The gravity of these situations is apparent, and the revision of the existing protocol became necessary. Following extensive research on other emergency medicine systems and their implementation of ECMO criteria, a modified EMS protocol, with a case-specific algorithm was created. This included an in-depth map to alert EMS professionals as to when they are close enough to Primary Children's for their patient to meet ECMO criteria. Due to the relevance and significance of this proposed protocol, the Utah State Bureau of EMS Protocol Workgroup implemented changes to the state-wide protocol in March 2020, encouraging rapid transport to Primary Children's, and the withholding of rewarming when appropriate.

Following this development, and in order to effectively implement the change in protocol, training for EMS agencies within the boundaries of the protocol map was prioritized. Park City Fire District and Mountain West Ambulance Service welcomed a training, which educated their providers on the modification and implementation of the new protocol. Using the principle of team-efficacy, providers were assessed to determine their ability to put the protocol into practice.

Due to the nature of this protocol and investigation surrounding it, this research will be ongoing for years, if not decades, to verify its validity. Following further training of each remaining agency within the boundaries of this protocol, the focus of the research will be shifted to the individual patient cases and looking for improvement in outcomes and in the provider's ability to recognize these patients when they meet all appropriate criteria.

7. Conclusion

In order to effectively treat pediatric patients in hypothermic cardiac arrest, prehospital agencies across the nation must have revised protocols to rapidly transport, and refrain from rewarming patients who might qualify for ECMO. These providers must immediately recognize the life-threatening condition and understand that ECMO is the primary treatment as it supports improved outcomes in these patients. Patients must be rapidly transported to ECMO facilities to increase the chance of a good neurological outcome following successful resuscitation. The nation requires in-depth training and incorporation of effective protocols to improve team efforts in the resuscitation of pediatric hypothermic cardiac arrest patients.

8. Acknowledgments

I extend my profound gratitude to Chris Stratford for his mentorship and support over two years of research and development of this thesis. Since the beginning of my research in late 2017, Chris' creativity and guidance provided me with the motivation I needed to tackle each additional task that presented itself. Additionally, this labor of love would not have been possible without the enthusiasm of Dr. Peter Taillac at the University of Utah and Dr. Hilary Hewes at Primary Children's Medical Center who nurtured this idea and supported my development of such a complex protocol.

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10.Endnotes

1 Cyanosis: Blue skin, indicating hypoxia, or low levels of oxygen in the body

2 Fixed and dilated pupils: An indication of brain death

3 Asystolic cardiac arrest: Occurs when the heart has no electrical conduction whatsoever, in contrast with ventricular fibrillation (VF), ventricular tachycardia (VT), and pulseless electrical activity (PEA) where the heart continues to have electrical activity and often physical activity as well.

4 Hypovolemia: Low blood volume

5 Cannulation: To insert a cannula into (in this case, inserting it into a blood vessel for ECMO)

6 Hemodynamically stable: Patients with vital signs that support perfusion

7 Heparin: A compound used to prevent blood clotting

8 Ischemia: Inadequate blood supply to an organ

9 Hyperkalemia: High serum potassium levels

10 Aspiration: The action of drawing a breath (in this case inhaling fluid)

11 Hypoxia: Low oxygen levels

12 Perfusion: The passage of fluid through the circulatory system

13 Normothermia: Normal body temperature

14 Epinephrine: A sympathomimetic hormone that is used as treatment for cardiac arrest to stimulate the heart

15 Vasopressor: A medication that can cause constriction of blood vessels

16 Intubation: Placement of a breathing tube into the trachea either through the mouth or through the nose

17 Tympanic: Measuring temperature in the ear