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Telemedicine REsuscitation and Arrest Trial (TREAT): A feasibility study of real-time provider-to-provider telemedicine for the care of critically ill patients

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Abstract

Background: Protocol-based resuscitation strategies in the Emergency Department (ED) improve survival for out-of-hospital cardiac arrest (OHCA) and severe sepsis but implementation has been inconsistent.

Objective: To determine the feasibility of a real-time provider-to-provider telemedical intervention for the treatment of OHCA and severe sepsis.

Materials and methods: A three-center pilot study utilizing a "hub-spoke model" with an academic medical center acting both as the hub for teleconsultation as well as a spoke hospital enrolling patients. Eligible patients were adults presenting with either return of spontaneous circulation (ROSC) following OHCA or with severe sepsis. Telemedical encounters were monitored for quality of interface and patient level data (demographics, physiologic, laboratory, treatment) were abstracted.

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Results: Over a 12-week period, there were 80 text alerts. Of 38 OHCA alerts, 13 achieved ROSC (34.2%), 85% underwent teleconsultation (11/13). Of 42 "lactate ≥4 mmol/L" alerts, 33.3% (14/42) were determined to have severe sepsis and underwent teleconsultation. Mean time from OHCA teleconsultation request to live connection: 3.7 min (95% CI 1.6–5.8); mean call duration: 71.7 min (95% CI 34.6–108.8). Mean time from sepsis teleconsultation request to connection: 8.4 min (95% CI 4.5–12.3); mean call duration: 61.5 min (95% CI 37.2–85.8).

Discussion: Telemedicine provides a robust and reliable means of quickly bringing expertise virtually to the bedside at the most proximal point in a patient's hospital care.

Conclusions: Real time ED-based telemedical consultation for patients with ROSC after OHCA or severe sepsis has the potential to improve the dissemination and implementation of evidence-based care.

Keywords: Health sciences, Medicine

1. Introduction

The optimal treatment of critical illness and injury was a driving force behind the development of the field of emergency medicine and continues to define its maturation as a medical subspecialty. Cardiac arrest represents a leading cause of death in the United States; with out-of-hospital cardiac arrest (OHCA) affecting some 300,000 citizens each year and producing roughly 40,000 victims requiring post-arrest care [1, 2, 3]. After achieving return of spontaneous circulation (ROSC), rapidly deployed, medically sophisticated interventions can impact outcomes, providing substantial survival and neurologic outcomes benefit [2] [3]. Severe sepsis is the 11th leading cause of death, affecting over 750,000 patients per year and accounting for roughly $17 billion of healthcare spending annually [4] [5]. Rapid identification of severe sepsis using serum lactate [6] and initiation of protocolized care, the most well-known form of which is Early Goal-Directed Therapy (EGDT), can prevent sudden cardiovascular collapse and progression to multi-organ dysfunction syndrome [7] [8].

Protocol-based resuscitation algorithms have been demonstrated to improve survival for OHCA and severe sepsis [2] [3] [8, 9, 10, 11, 12]. Despite this, implementation of best practices including protocolized severe sepsis care and initial post-cardiac management bundles, has been inconsistent. Only 25% of providers, and only a third of hospitals, report implementing therapeutic hypothermia (TH) as part of post-cardiac arrest care [9] [13] [14]. Similarly, implementation of EGDT has been poor with only 7% of academic emergency departments (EDs) reporting EGDT as standard treatment in 2005 [15]. A 2010 survey of Pennsylvania EDs reported only 2/3 performing EGDT "more often than not", and even specialized tertiary care facilities with international expertise in

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sepsis care have reported EGDT utilization rates of 58% for EGDT-eligible patients [13] A 5-fold regional variation in survival (3–16.3%) has been observed for OHCA in US cities [1], a component of which can be attributed to the quality of post-arrest care, and similar variability has been described for sepsis outcomes [16].

Real time near continual assessment of resuscitation endpoints is the new paradigm for both OHCA and severe sepsis, and this resuscitation strategy was integrated into both the American Heart Association's and Surviving Sepsis Campaign's initial resuscitation management bundles [5] [17]. Given the burden of these diseases, the time-sensitive nature of care, and recognized knowledge gaps, alternatives are needed in order to provide appropriate, evidence-based care for patients. Potential barriers include: knowledge gaps, provider staffing, and lack of access to subspecialty consultants [18, 19, 20, 21]. One method of overcoming barriers to implementation is the early involvement of a resuscitation expert. Telemedicine has proven to be a versatile, effective, and efficient platform for real-time support and consultative services for patients suffering from acute ischemic strokes in rural EDs [22] [23], however ED-based applications outside of this setting have not been tested. In the Telemedicine REsuscitation and Arrest Trial (TREAT), we sought to determine the feasibility of a real time provider-to-provider telemedical intervention for the treatment of critically ill post-arrest and severe sepsis patients within the ED.

2. Materials and methods

2.1. Study design and setting

TREAT is a pilot study performed in three affiliated hospitals within a health system including a large referral academic medical center and two academic affiliates. A "hub-spoke model" was created with the academic medical center acting both as the hub for telemedical consultation for all three hospitals as well as a spoke hospital enrolling patients. The "hub" institution has an annual volume of 66,440 patients with an average of 22% admission rate. The two affiliated centers ("spokes") treat between 34,000 and 38,000 patients per year and, when needed, transfer patients to the hub institution. The study took place over a twelve week time period (03/2013-06/2013). The study was approved by the Institutional Review Board at the University of Pennsylvania and deemed exempt from informed consent, as on-call providers would otherwise be involved with the patient care at baseline. All on-call providers are credentialed in all three EDs and each ED utilized the same, remotely accessible, electronic medical record (EMR).

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2.2. Patient identification and selection

Eligible patients were adults (>18 years of age) presenting to one of the three EDs with either ROSC following OHCA or with severe sepsis or septic shock [4]. Automated text messages linked to the ED EMR alerted on-call telemedical consultants of all patients with serum lactate levels ≥4 mmol/L or "cardiac arrest" as the presenting complaint in real-time (Fig. 1). Bedside clinicians in the ED determined when telemedical consultation would be initiated based on inclusion criteria for severe sepsis/septic shock or induction of therapeutic hypothermia as defined by current literature and local practices (Fig. 4 and Fig. 2). The protocol developed for this feasibility trial was built in conjunction with the local ED teams and the emphasis was to have teleconsultation triggered by the bedside clinician at their discretion. Although serum lactate and EMR compliant of "cardiac arrest" were automated alerts, allowing telemedical consultants to know if a potential case was present, ultimately, the decision to call the telemedical consultants was at the discretion of the clinical management team.

2.3. Telemedicine equipment

A mobile, wirelessly connected, HIPAA compliant, commercially available telemedical cart (developed by a private telemedical vendor) was placed in the

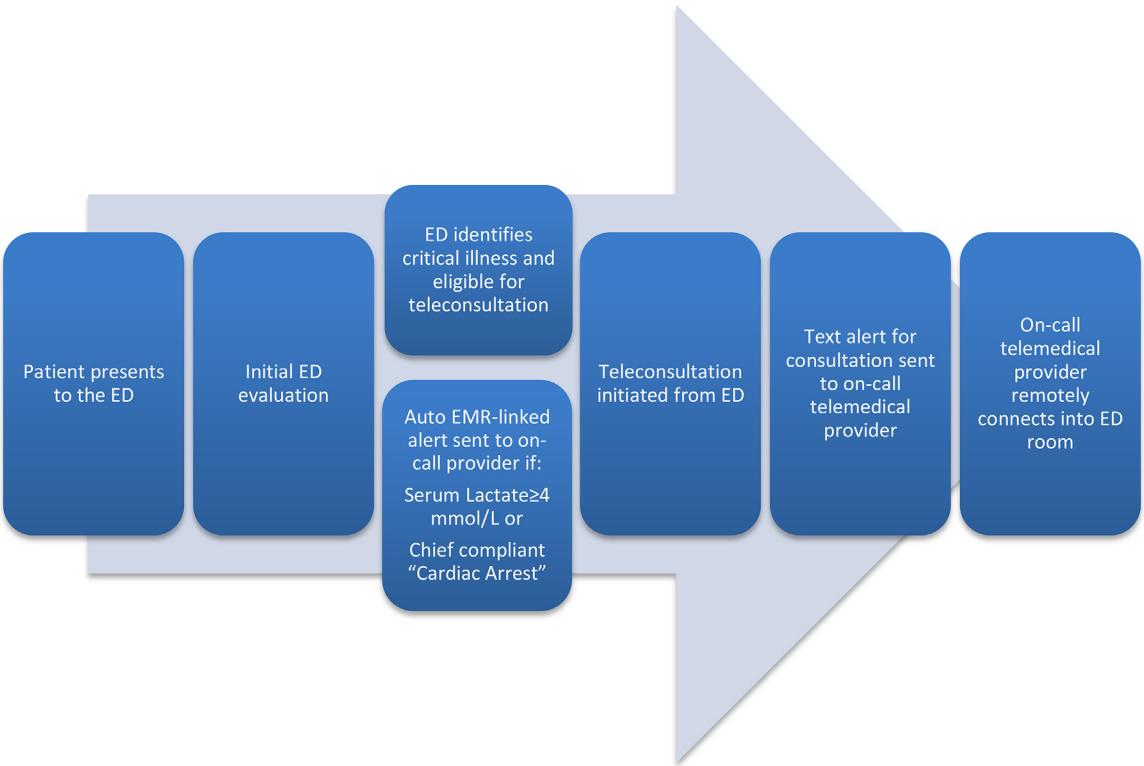

Fig. 1. Telemedical Consultation Flow Diagram. Flow diagram followed to initiate teleconsultation.

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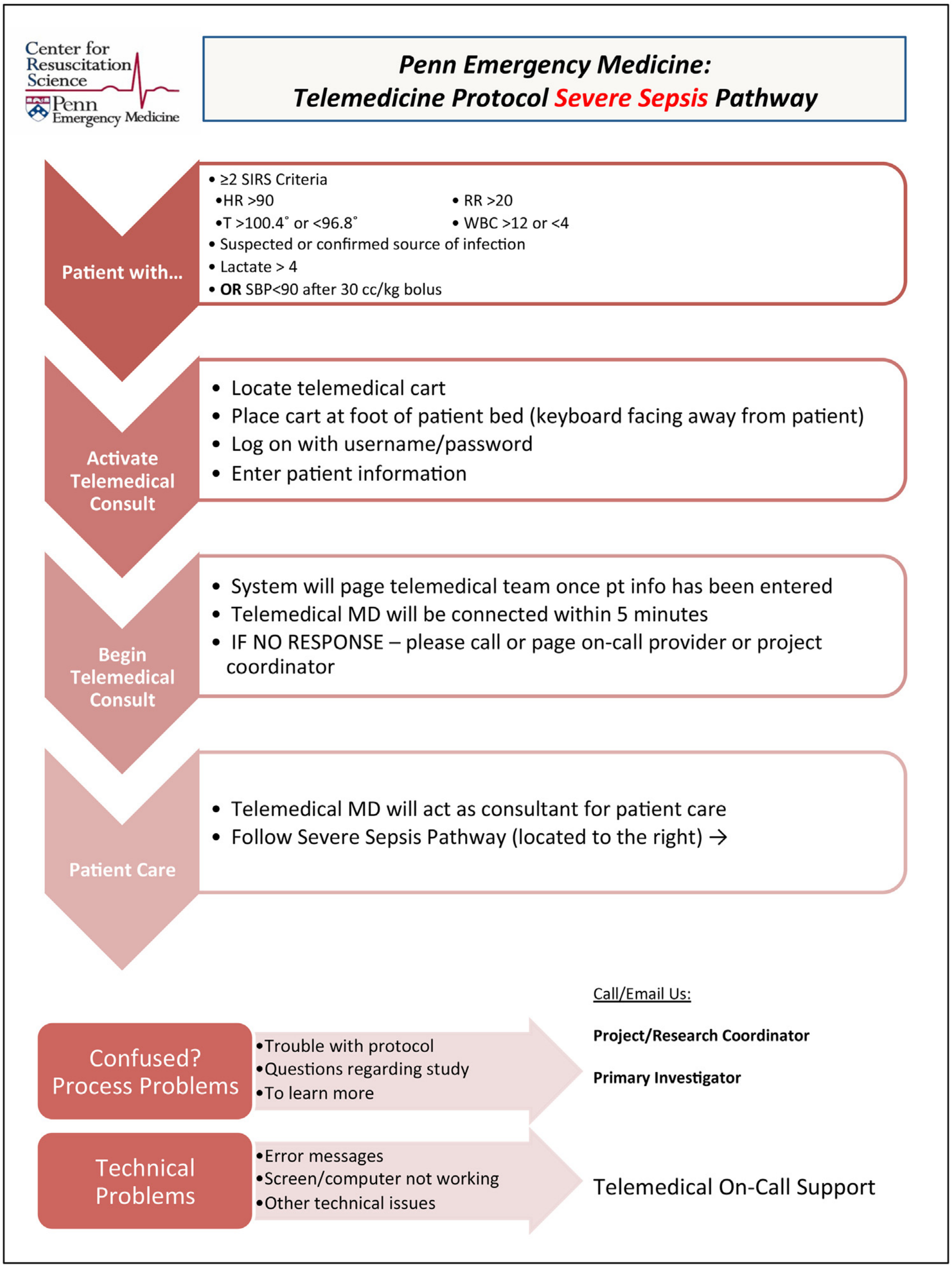

Fig. 2. Early Goal-Directed Therapy Flow Sheet.

ED of all three hospitals (Fig. 3). Each cart was equipped with a computer with telemedical software, two large (front and back facing) flat panel high definition monitors, pan/tilt/zoom video camera, speaker, and microphone. On-call telemed consultants were supplied with a wirelessly connected laptop, headphones, and mobile hotspot to ensure Internet connectivity 24 h a day, 7 days a week. The on-call team consisted of four attending emergency physicians, two clinical nurse specialists, and a research coordinator.

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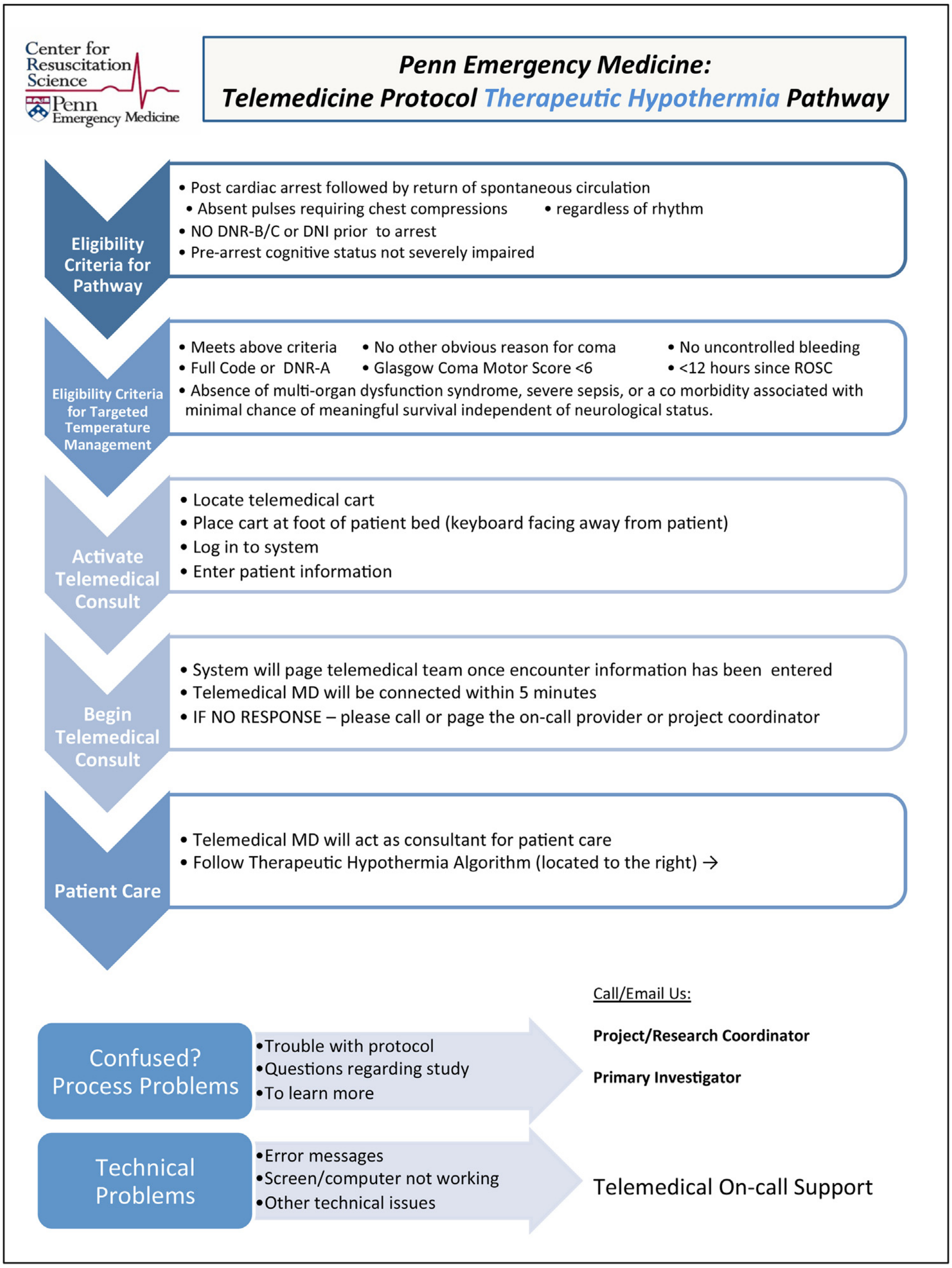

Fig. 3. Therapeutic Hypothermia Flow Sheet.

2.4. Telemedical consultation

All on-call physicians, nurses, and ED nurses and paramedics received training on the use of the telemedical cart by the project manager at the outset of the study. On-call providers also received training on how to access the cart remotely using the telemedical software. When deemed appropriate by the ED clinical team as describe above, a telemedical consultation was initiated by placing the

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Fig. 4. Telemedical Cart. Still image of telemedical cart.

telemedical cart in the patient ED room and logging into the system. The creation of this consult automatically sent a text message alert to the on-call telemed team, allowing them to enter the patient encounter from their remote location (Fig. 1). As soon as the on-call provider was available, a real-time audiovisual connection was established giving patients, family members, nursing staff, and physicians (residents and attendings depending on the site) the ability to communicate with the remotely located resuscitation physician. Both the local ED provider and the remote physician had the ability to control the video camera located in the patient ED room – allowing for the remote provider to visually assess the patient, examine in-room monitors and procedures, and speak face to face with anyone in the patient room.

2.5. Data collection and analysis

Separate standardized data collection sheets were created for EGDT- and TH-eligible patients (Appendix A in Supplementary material). Each telemedical patient

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encounter was monitored for connection times, number of connection attempts, disconnections, and quality of audiovisual connection. Patient level data (demographics, physiologic, laboratory, and treatment data) was abstracted from the ED EMR. Variables included age, gender, vital signs, EGDT parameters (mean arterial pressure [MAP], central venous pressure [CVP], central venous oxygen saturation [$SCVO_2$], urine output), serum lactate levels, prehospital cardiac arrest data (location, bystander CPR, initial cardiac rhythm, automated external defibrillator [AED] application, defibrillation, epinephrine administration), time-stamps of telemedical connection, time of clinical interventions, clinical decision-making, and assessment of audiovisual connection. Data were entered into an Excel spreadsheet (Version 14.6; Microsoft Corporation, Redmond, Washington) and descriptive statistics were performed. Results were reported as numbers and percentages for demographic data such as age and sex of study subjects and as mean ± standard deviation (mean ± S.D) for descriptive data.

2.6. Assessment of technological and practical feasibility

The aim of the TREAT study was to assess the technological feasibility of performing real-time telemedical consultation for the treatment of critically ill patients within the ED. A key component to the delivery of telemedical care is reliable technology and connectivity. The specific objective endpoints were: time to established telemedical connection with on-call team, number of connection attempts and number of unintentional disconnections. At the end of each consultation patients, ED staff, and the remote clinical were asked to rate the audio and visual connection. Adequacy of patient selection for EGDT or post-cardiac TH was determined via chart review and expert adjudication. Adequacy of patient management was determined using time-sensitive guidelines set forth by the Surviving Sepsis Campaign and the American Heart Association.

3. Results

Over a 12-week period, there were 80 automated text alerts (38 “cardiac arrest,” 42 “lactate ≥4 mmol/L”). Of the 38 cardiac arrest automated text alerts, 13 achieved ROSC (34.2%), 11 underwent telemedical consultation (84.6% with ROSC); 69.2% were TH-eligible. During the study period, 14 (33.3%) patients with a serum lactate >4 mmol/L were determined to have severe sepsis or septic shock and underwent a telemedical consultation.

Characteristics and descriptive statistics of patients undergoing telemedical consultation for post-cardiac arrest care and severe sepsis/septic shock are shown in Table 1 and Table 2. Mean age for post cardiac arrest patients was 52.2 years. The majority of cases were found to have a prehospital cardiac rhythm of asystole (54.5%), be witnessed events (72.7%), and had EMS administered epinephrine

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Table 1. Post Cardiac Arrest Consultations.

	Male	%/SD	Female	%/SD	Total	%/SD
Demographics						
Cases (n)	8	63.6	3	36.4	11	100.0
Age (mean)	53.1	17.7	49.6	14.2	52.2	16.1
Event Location (%)						
Private Residence	6	75.0	1	33.3	7	63.6
Nursing Home	1	12.5	1	33.3	2	18.2
Other	1	12.5	1	33.3	2	18.2
Post ROSC Vital Signs: Mean (SD)						
Heart rate	113	60	115	49	114	40
Systolic Blood Pressure	106	17	130	71	113	40
Diastolic Blood Pressure	63	21	73	34	66	24
Mean Arterial Pressure	76	18	92	46	81	28
Oxygen Saturation	90	12	80	17	86	14
Prehospital Care (%)						
Initial Cardiac Rhythm: Asystole	6	75.0	1	33.3	7	54.5
Witnessed Event	5	62.5	3	100.0	8	72.7
Bystander CPR	1	12.5	1	33.3	2	18.2
Bystander AED use	0	0.0	0	0.0	0	0.0
EMS Defibrillation	1	12.5	1	33.0	2	18.2
# of Defibrillations: Mean (SD)	0.1	0.4	0.5	1.0	0.3	0.7
EMS Epinephrine	4	0.0	3	100.0	7	63.6
# of Epinephrine: Mean (SD)	1.6	1.5	1.5	1.3	1.5	1.4
Therapeutic Hypothermia Management (%)						
Initiated (%)	6	71.4	3	100.0	9	81.8

ROSC: return of spontaneous circulation, AED: automated external defibrillator.

(63.6%). Mean age for severe sepsis/septic shock patients undergoing telemedical consultation was 69.1 years. Average initial lactate was found to be 5.4 mmol/L (95% CI 3.1–7.7), an average of 2100 mL (95% CI 1404.4–2795.6) of IVF was given during the ED stay, and mean repeat lactate was 3.7 mmol/L (95% CI 2.1–5.3). Mean times from triage to critical interventions were: initial lactate 67.8 min (13.9–121.7), IVF 66.3 min (40.5–92.1), and antibiotics 121.6 min

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Table 2. Severe Sepsis Consultations.

	Male	%/SD	Female	%/SD	Total	%/SD
Demographics						
Cases (n)	7	50	7	50	14	100
Age: mean (SD)	67.3	24.9	70.6	24.9	69.1	20.8
Vital Signs: Mean (SD)						
Max Temperature (F)	101.6	2.6	99.9	2.6	100.6	2.8
Max HR	120	19	113	19	116	21
Max RR	29	3	22	3	23	6
Low MAP	76	21	78	21	77	18
Patient Management						
Initial Lactate (mmol/L)	4.1	5.6	6.5	5.7	5.4	4.4
IVF (mL)	1,925	1,687	2,251	1,687	2,100	1,328
Repeat Lactate (mmol/L)	3.3	4.1	4.1	4.1	3.7	3.1
Time to Lactate (min)	98.8	32	36.9	32.5	67.8	102.9
Time to IVF (min)	43.6	50.1	85.7	50.1	66.3	49.3
Time to Antibiotics (min)	115.7	46.6	127.6	46.6	121.6	81.7
Time to Central Access (min)*	104.6	71.4	222.5	71.4	172.1	88.1
Time to Vasopressor (min)*	121	–	310	–	168.3	133
Early Goal Directed Therapy						
Initiated (%)	7	100	7	100	14	100

HR: Heart Rate, RR: Respiratory Rate, MAP: Mean Arterial Pressure, IVF: IV fluid.
* Limited values reported in electronic medical record.

(78.8–164.4, Table 3). All TH-eligible cases utilized telemedicine and induction of TH was started during the consult.

Table 3 reveals telemedicine connection times and connection rating. Average time from OHCA teleconsultation request to live telemedical connection was short (3.7 min, 95% CI 1.6–5.8). Mean call duration was 71.7 min (95% CI 34.6–108.8). Mean number of connection attempts was 1.1 (secondary to failed login attempts from consultant), with no complete disconnections. Sepsis teleconsultations had a mean time to connection of 8.4 min (95% CI 4.5–12.3), call duration of 61.5 min (95% CI 37.2–85.8), and mean number of connection attempts 1.1 and disconnection 0.2 per call.

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Table 3. Telemedical Consultations.

	OHCA	Severe Sepsis
Telemedical Consultations (n)	11	14
Connection Time (min)	3.7	8.4
Consult Duration (min)	71.7	61.5
Connection Attempts	1.1	1.1
Disconnections	0	0.2
	Mean Rating (SD)	
Consultant ability to SEE	5.0 (0)	4.6 (1.1)
Consultant ability to HEAR	4.7 (0.5)	4.6 (1.1)
Staff/Patient ability to SEE	4.9 (0.3)	4.5 (1.1)
Staff/Patient ability to HEAR	4.8 (0.4)	4.5 (1.1)

Likert Rating: 5 = Strongly Agree, 1 = Strongly Disagree. All values reported as means unless otherwise noted.

Consultants, ED staff, and patients ranked ability to see and hear the consultant or ED team on a Likert scale (1 = strongly disagree, 5 = strongly agree). Table 3 displays results, overall consultants consistently ranked ability to see and hear for both disease states highly (4.6–5.0 on Likert scale), with staff and patients ranking their ability to see and hear the consultant similarly (4.5–4.9).

4. Discussion

We piloted a provider-to-provider hub-spoke telemedical network with 24 h on-call resuscitation specialists available for teleconsultation regarding the assessment and initiation of proven resuscitation bundles for critically ill patients within the ED. We demonstrate the feasibility of using real time ED-based "telemedical consultation" or "telementoring" for the care of critically ill patients presenting to the ED with either ROSC after OHCA or severe sepsis/septic shock. Telemedicine provides a robust and reliable means of quickly bringing expertise virtually to the bedside at the most proximal point in a patient's care in the ED and has the potential to improve the dissemination and implementation of evidence based best clinical practice in this population.

Telemedicine may offer a novel solution to improving the dissemination of medical expertise and knowledge and thus impact patient care – allowing clinical experience and knowledge only available in a limited number of centers to reach community, remote, or rural hospitals. Telemedicine has evolved from the relatively simple "store and forward" concept used to transmit images to remotely

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located specialists, to more sophisticated real-time high resolution video conferencing that allows an individual to be at the bedside in a matter of minutes. There has been a call for further, expanded applications of telemedicine in the ED, the American College of Emergency Physicians (ACEP) states, “the ED may be an ideal place for telemedicine . . . ” and claimed significant applications for telemedicine in the ED for “decision-making aids, remote sensing (or sharing images between healthcare centers), and collaborative real-time patient management [24].” EDs have slowly expanded the applications of telemedicine, now working as a means to improve access to sub-specialty services such as dermatology and psychiatry – services traditionally known for high demand, low supply cultures, but little has been done to test the ability to utilize telemedicine for real time teleconsultation in order to improve outcomes for the critically ill patient.

Several studies have demonstrated the importance of not only earlier recognition of disease processes but also early and aggressive resuscitation [2] [3] [5] [8, 9, 10, 11, 12]. EDs continue to care for an increasing number of patients who may potentially benefit from aggressive therapies such as TH and protocolized sepsis resuscitation [25, 26, 27, 28, 29]. Despite advancements in early diagnostics (i.e. triage serum lactate screening), mortality remains high [30]. Telemedicine offers the tools needed to quickly involve a critical care specialist early on in the disease progression. The data from this study show that a remotely connected specialist was able to connect and interact with the patients and ED staff within 5–10 min despite their varied locations in the world at the time of teleconsultation request.

We found that telemedicine offered the capability for both the remote physician and the ED staff to interact clearly and without disturbance. Initiation of protocolized care occurred in all eligible patients utilizing telemedicine. Telemedicine may offer the means for improved clinical decision-making and the uptake of evidence-based care [31, 32, 33, 34, 35]. Based on the interactions we observed during the study period, we believe telemedicine allows for an additional expert to become an instant part of the patient care team. Our team was able to remotely diagnose, adjust, and trouble shoot patient care devices such as the TH cooling wraps, mechanical ventilators, IV medications, and to observe and supervise procedures. Telemedicine also allowed for the patient and family members to have one-on-one access to a resuscitation expert in the middle of a busy and crowded ED during any time of day or night. This pilot briefly revealed provider and patient comfort with the communication modality and anecdotally patients and their families expressed relief in knowing they (or their loved one) was being closely monitored. In-house providers brainstormed about future uses including the potential of using the platform for a “telementoring” means of delivering bedside teaching and continuing medical education (CME), which to our knowledge, does not exist.

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The TREAT study has several limitations. The study was conducted within one health system and only within three hospitals of varying capacities and therefore may not be generalizable to other hospital systems. All on-call providers were credentialed at each hospital and were familiar with both the staff and EMR, thus this study avoided the complications of provider credentialing, malpractice, and payment schedules. Though the on-call providers were credentialed at each hospital and members of the academic faculty, in-house ED staff often expressed concern over who was ultimately managing the patient's care. To address this concern, this pilot was aimed at feasibility and thus deferred final management guidelines to the in-house physician. The hub institution also has a Center for Resuscitation Science dedicated to improving ED-based resuscitation care and aggressive TH and EGDT programs. Further, the study was conducted over a brief, 12-week-long period and only enrolled 25 patients. However, the study's primary aim was not to analyze patient outcomes or specific details of clinical care but to examine the feasibility of using an innovative telemedicine platform to connect remote providers, ED providers, patients, and family members. Finally, though we found during the course of the study that we were able to adjust and trouble shoot patient care devices such as cooling wraps, arterial lines, and mechanical ventilators, these troubleshooting abilities were not anticipated a priori and outcomes were not hypothesized prior to study initiation.

5. Conclusions

The TREAT study reveals the practical feasibility of using teleconsultation for post-arrest and septic shock patients. In this trial, telemedicine was a reliable means of virtually connecting a provider with the bedside team within minutes. TREAT sheds light on the future of connected health care delivery for critical illness, dissemination and implementation of evidence-based care, and the way we approach the care for unplanned critical illness within the ED. In TREAT-2, our future plan is to evaluate the impact of using telemedical consultation on the adherence to best practices and patient outcomes for post-arrest and septic shock patients in the ED. Further analysis should also focus on the impact of telemedicine on hospital level factors such as costs, staffing and patient flow.

Declarations

Author contribution statement

Anish Agarwal, David F. Gaieski, Sarah Perman, Benjamin Abella, Brendan Carr: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Marion Leary, Gail Delfin: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

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Conflict of interest statement

The authors declare no conflict of interest.

Additional information

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