Desperate times call for desperate measures

Resuscitative thoracotomy in a prehospital setting

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CASE INTRODUCTION

It is 5 pm on New Year's Eve and you are on service as an emergency physician in training for the London Helicopter Emergency Medical Service (HEMS). The London Ambulance Service Control informs you of a stabbing incident in the town of Watford, England. Your helicopter arrives on the scene 10 minutes after the call and 13 minutes after the incident, along with land ambulance and police. After the scene is declared safe, you are directed to the patient, JJ, a 24-year-old male who has suffered a stabbing outside of a local bar. His friend, who made the call to EMS, tells you JJ lost consciousness about 3 minutes after the insult. The patient has no signs of life, with no palpable carotid pulse or measurable blood pressure. He is apneic and his pupils are fixed and dilated. You notice a 2-cm wound in the midclavicular line, just superior to the left nipple, consistent with a penetrating stab wound. Cardiac monitors are attached and show an initial rhythm of asystole. Closed cardiac massage is undertaken immediately with rescue breaths given using bag-valve-mask. Simultaneously, the patient is cannulated in both antecubital fossae and is administered 1 mg adrenaline with 1000 mL 0.9% saline. Emergent decompressive needle thoracotomy is performed on the left chest by placing a 14-gauge, 3.5-inch angiographic catheter into the chest cavity at the midclavicular line in the second interspace. There is no release of air but periodic bubbles and blood appear to come from the left lung. After 2 minutes of unsuccessful CPR, there is still no palpable pulse and you notice the patient's neck veins are distended, with normal air entry and no dullness to percussion in the left hemithorax. Your helicopter is about 10 minutes away from the nearest major trauma centre.

RESUSCITATIVE THORACOTOMY

The thoracotomy, perhaps one of the most invasive interventions in modern medicine, involves making a surgical incision along the chest wall to gain access to the organs of the thorax for purposes of treatment, examination, and/or removal. Occasionally, the procedure is utilized in the context of a patient in extremis or cardiac arrest due to thoracic trauma, with the primary objective of restoring cardiac output, organ perfusion, and minimizing exsanguinating hemorrhage.¹⁻⁴ The collection of such techniques is termed a resuscitative thoracotomy (RT), which was first successfully performed by Ludwig Rehn in 1896 on a young gentleman dying of cardiac tamponade from a right ventricular stab wound.^{1,2} Rehn's RT forms the bedrock of the modern-day RT.

It is worth noting that there are inconsistencies in the terminology surrounding RTs. For the purposes of this article, all thoracotomies are RTs and these can be further classified by the setting in which they take place: emergency department thoracotomy

(EDT) or prehospital thoracotomy (PHT).

EMERGENCY DEPARTMENT THORACOTOMY

Since its inception at the turn of the 20th century, the indications for RT have become increasingly selective. Once the most commonly performed procedure in cardiovascular collapse by medical causes, the overwhelming effectiveness of closed-chest compressions demonstrated in 1960 and external defibrillation in 1956 rendered the practice of RT for medical cardiac arrest virtually extinct.^{2,5,6} However, advancements in cardiothoracic surgical technique and equipment have yielded promising outcomes for RT in patients with life-threatening thoracic traumas.⁷ Yet, consensus over exactly who should be performing it and when is still lacking. It is clear that resuscitative thoracotomy is the only potentially life-saving therapy for patients suffering penetrating thoracic trauma who progress to pulselessness before, or in spite of, the availability of medical resuscitation.^{1,8,9} Furthermore, while RT would ideally be performed by a cardiothoracic surgeon in the operating room, approximately 10-15% of thoracic trauma victims require immediate thoracotomy. Therefore, EDT often takes place to address the patient in a more optimal therapeutic time window.¹

Common predictors of survival in EDT including mechanism of injury, anatomical location of the injury, number of wounds, presenting signs of life, performance of CPR, and transport time have been extensively studied.^{1,3,8-11} The Eastern Association for the Surgery of Trauma (EAST) elucidated survival and neurological outcomes of EDT based on multiple survival predictors from 72 clinical studies.¹⁰ Consistent with previous literature, stab wounds had the highest hospital survival rate (15.8%), followed by gunshot wounds (7.2%) and blunt injury (2.3%). Unsurprisingly, they also found significantly greater rates of survival in those presenting to the ED with sinus rhythm (33.3%) or signs of life (19%) than those presenting with asystole (2.6%) or no signs of life (2.9%). Accordingly, US guidelines by the American College of Surgeons (ACS) Committee on Trauma only recommend EDT in patients enduring penetrating cardiac injuries with witnessed signs of life.¹¹

Revisiting our patient JJ, we notice that he is pulseless, with a penetrating thoracic injury and no measurable signs of life. The EAST guidelines would suggest JJ has an approximately 8.3% chance of survival with EDT. The caveat is that these guidelines do not include time from cardiac arrest to EDT as a mediating factor when estimating rates of survival. The prognosis of patients who arrest on scene is alarmingly dismal, with numerous reports of 100% mortality.¹²⁻¹⁶ This is further highlighted by the 13.6% survival observed in patients not requiring pre-hospital CPR versus 5.2% in those who did require it.¹⁰ This has contributed to the controversy

regarding the situations in which RT is indicated. Several guidelines consider RT futile in patients who require CPR for >15 minutes in penetrating thoracic trauma or >10 minutes in blunt thoracic trauma.^{3,17,18} Still others conclude that RT should be abandoned altogether in patients without signs of life or with blunt thoracic trauma.^{15,19}

PREHOSPITAL THORACOTOMY

Data collected in patients undergoing RTs over the last 50 years has demonstrated the time-sensitive nature of the procedure, as well as the urgency of transporting patients to the ED. Gervin et al. demonstrated a steep drop in survival of patients with penetrating cardiac wounds if the time of arrest to the ED was beyond 15 minutes.²⁰ One report delineated a prehospital time of 30 minutes as the cut-off for considering EDT.²¹ Furthermore, less than 20% of patients with penetrating wounds of the heart reach the hospital alive and it is not uncommon for EMS to encounter time intervals much greater than 15 minutes between cardiac arrest and EDT.²² It seems likely that in such circumstances there may be an appreciable survival benefit to be had if RT is performed prior to hospital arrival.

The first case report of a successful PHT in 1994 involved a 30-year-old man with a penetrating stab wound and loss of all vital signs.²³ The surgeon at the scene was riding as an observer with a Houston Fire Department EMS supervisor. The use of physicians in prehospital care is not traditionally practiced in North America however it is routine practice in many European prehospital systems. The London Helicopter Emergency Medical Service (HEMS) trauma teams have lead the way in the provision of PHT. Since the first reported post-RT survivor in 1993, numerous case reports of neurologically intact survivors have followed.²⁴⁻²⁹ Recently, they retrospectively evaluated 71 PHTs from 1993-2008 of which there were 13 survivors.²⁸ Furthermore, 11 of the 13 survivors were either in asystole or pulseless electrical activity (PEA) and 10 had good neurological outcomes. Consistent with survival prediction data from EDTs, no survivors have been reported by HEMS in patients sustaining gunshot wounds. A case series of 34 PHTs performed on blunt trauma patients in Japan also reported no survivors, in line with similar investigations performed elsewhere.³⁰⁻³² Thus, only patients with penetrating thoracic injuries, cardiac arrest and at least 5 minutes' transport time to an ED meet the current London HEMS criteria for PHT.

The Figure outlines a decision algorithm for initiating PHT based on current available evidence.

You make a provisional diagnosis of cardiac tamponade. Given the 10-minute transport time to a cardiothoracic unit, you elect to initiate a RT. You perform the initial clamshell thoracotomy with a left anterolateral thoracotomy in the 5th intercostal followed by extension to a right anterior thoracotomy in the same interspace. The sternum is split with trauma sheers and you incise the pericardium, which releases a large amount of clotted blood. You use a Foley catheter to occlude a 1-cm laceration seen in the right ventricle and cross-clamp the thoracic aorta. The patient is loaded onto the helicopter at which point

you initiate internal cardiac massage. Another 1 mg of adrenaline is administered along with emergency-release packed red blood cells.

Figure 1. Decision tree for prehospital resuscitative thoracotomy. RT is indicated in penetrating thoracic injury with or without previously witnessed cardiac activity or with unresponsive hypotension (SBP <70 mmHg) despite vigorous resuscitation. Adapted from Chalkias AF, 2009.³⁴

SHOULD WE INVEST IN TEACHING AND EXPANDING THE PROVISION OF PHT?

The use of PHT by non-cardiothoracic surgeons has been met with resistance from hospital-based providers and, in particular, surgeons. US guidelines on termination of resuscitation in prehospital traumatic cardiopulmonary arrest are written to fit the US setting of care where physicians capable of providing RT are not present in the prehospital setting. As such, these guidelines state that “in the case of penetrating trauma, patients without vital signs will not survive even with the most aggressive of therapies.”¹⁹ However, this notion has been challenged in non-North American settings where physician-led prehospital systems are available and ev-

idence has been generated that demonstrates neurologically intact survivors of PHT even when patients have lost vital signs and are in asystole.^{2,3,28,29,33}

The American College of Surgeons published guidelines on EDTs in 2001 in which they voiced concerns about the qualifications of non-surgeons performing the procedure in the ED.¹¹ However, in a study by Athanasiou et al., the number of survivors of EDTs performed by non-surgeons was not statistically different to survival in EDTs performed by surgeons.²⁹ In one cadaveric pilot study, non-surgical trainees performed a clamshell thoracotomy in a similar time and with similar complication rates to experienced surgeons after completing a 1-day course.⁴ The physicians staffed on the London HEMS physician-paramedic teams are typically either ER doctors or anaesthetists. The PHT is designed to be uncomplicated, as it is often performed by non-surgeons to ensure the procedure may be carried out rapidly when required.

In regions where prehospital EMS contain physician-paramedic teams and the prevalence of thoracic trauma is sufficiently high, it is potentially reasonable to provide education and funding for this lifesaving technique. One such example is the Pre-Hospital Emergency Resuscitative Thoracotomy (PERT) course run by the Royal College of Surgeons of England.² This course combines academic knowledge of the anatomy, ethics, and public health issues of PHT with hands-on training of the procedure and decision making.

The skepticism around PHTs is expected to diminish once it is fully understood that most eligible patients would never encounter a surgeon before death. Even with this shift in thinking, however, any jurisdiction considering the implementation of PHT must consider alterations to the composition of their EMS teams, their traumatic cardiac arrest standard operating procedures, and the availability of resources to provide the requisite education to trainees.

Approximately 3 minutes after injecting the adrenaline JJ reverts to sinus rhythm with a heart rate of 125 beats/min, a palpable carotid pulse and respiratory efforts. He is rushed into the operating room at St. Mary's Hospital for definitive cardiothoracic management and wound closure. He is then transferred to the ICU and discharged 17 days later, neurologically intact. On follow-up examination 12 months later JJ is stable, healthy, and resuming normal activity.

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