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Commentary and concepts

Development of a simple algorithm to guide the effective management of traumatic cardiac arrest☆

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ABSTRACT

Background: Major trauma is the leading worldwide cause of death in young adults. The mortality from traumatic cardiac arrest remains high but survival with good neurological outcome from cardiopulmonary arrest following major trauma has been regularly reported. Rapid, effective intervention is required to address potential reversible causes of traumatic cardiac arrest if the victim is to survive. Current ILCOR guidelines do not contain a standard algorithm for management of traumatic cardiac arrest. We present a simple algorithm to manage the major trauma patient in actual or imminent cardiac arrest.
Methods: We reviewed the published English language literature on traumatic cardiac arrest and major trauma management. A treatment algorithm was developed based on this and the experience of treatment of more than a thousand traumatic cardiac arrests by a physician – paramedic pre-hospital trauma service.
Results: The algorithm addresses the need treat potential reversible causes of traumatic cardiac arrest. This includes immediate resuscitative thoracotomy in cases of penetrating chest trauma, airway management, optimising oxygenation, correction of hypovolaemia and chest decompression to exclude tension pneumothorax.
Conclusion: The requirement to rapidly address a number of potentially reversible pathologies in a short time period lends the management of traumatic cardiac arrest to a simple treatment algorithm. A standardised approach may prevent delay in diagnosis and treatment and improve current poor survival rates.

1. Introduction and background

The mortality rate from cardiac arrest associated with trauma is extremely high. All patients with unsurvivable injuries will, by definition, suffer cardiac arrest. For this group only injury prevention measures are likely to improve survival. The published literature before 2005 suggested that the resuscitation of patients who suffer traumatic cardiac arrest (TCA) on scene was at worst futile and at best associated with very poor rates of survival and even worse rates of neurologically intact survivors.[1–4] Survival rates of 0–2.3% were reported and the few survivors often had poor neurological outcome. Four studies published more recently[5–8] have suggested better survival rates. The exact reasons for this improvement in mortality are unclear but the (still poor) survival rates were now comparable with published survival rates for out-of-hospital cardiac arrest survival rates of all causes.[9,10] The 'futility' argument therefore became considerably weaker and the 2005 and 2010 ILCOR resuscitation guidelines[11] give clear guidance on management of TCA. The risks to rescuers and costs of futile resuscitation are still present and it is therefore important that resuscitation efforts are restricted to patients with a chance of survival.

Analysis of the characteristics of survivors in one large series[5] suggested that patients with TCA primarily due to hypovolaemia outside hospital seldom survive. This is most likely to be due to the high rate of bleeding (usually non-compressible) necessary to cause cardiac arrest to occur before arrival in hospital. Patients arriving shortly before or after cardiac arrest in an emergency department may have an increased chance of survival with the immediate availability of blood products and surgical intervention.

Early aggressive management of external (compressible) haemorrhage may prevent cardiac arrest or, where simultaneous volume expansion is immediately available, lead to return of spontaneous circulation in some cases. Recent military experience has concentrated on aggressive haemorrhage control with tourniquets, topical haemostatic agents and improved pressure dressings.[12,13] The proportion of hypovolaemic civilian trauma cases that have

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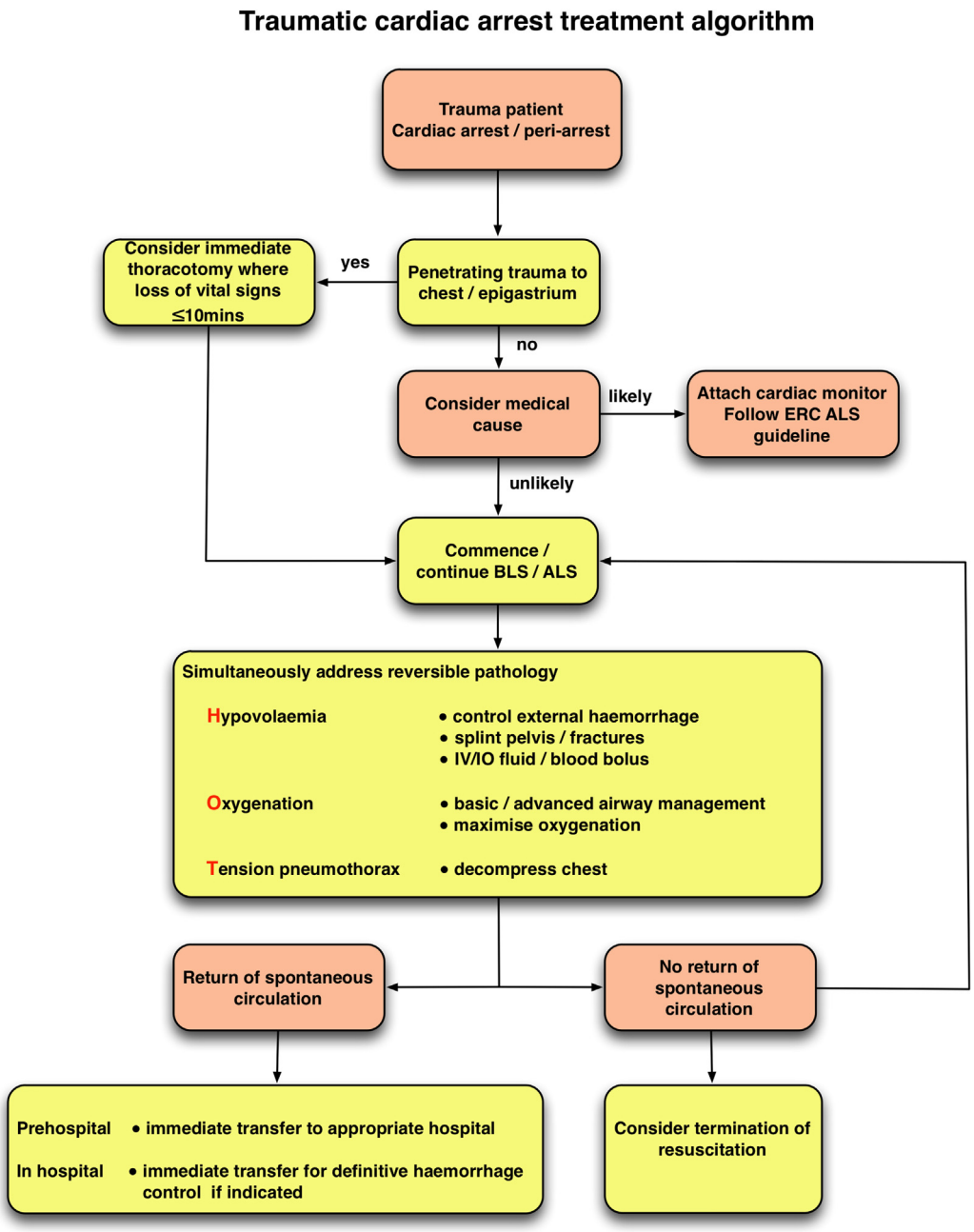

Fig. 1. Treatment algorithm for traumatic cardiac arrest.

external compressible haemorrhage is likely to be much lower than in the military environment due to the different mechanisms (blast and ballistic trauma vs. predominantly blunt trauma). Analysis of civilian TCA survivors has indicated that most survivors had pathology which could be relatively easily reversed once access to the patient was achieved.[5] These included reversal of hypoxaemia or hypoventilation, relief of tension pneumothorax and immediate implementation of standard advanced life support in the group of patients who have sustained a 'medical cardiac arrest' as part of or cause of their 'trauma episode'. In these cases outcome is likely to depend on the well-established prognostic indicators of early CPR and defibrillation[11] as well as the nature and severity of any injuries. The only well-established operative intervention, which can result in neurologically good outcome in TCA, is immediate thoracotomy for penetrating chest trauma. This is likely to be particularly successful where cardiac arrest is due to cardiac tamponade and a simple cardiac wound.[14] In most emergency medical service (EMS) systems thoracotomy is only conducted in the emergency department. EMS crews must move at-risk patients quickly to where thoracotomy is available. Where physician-based pre-hospital care is available, resuscitative thoracotomy can be performed successfully on scene.[15,16] Survival appears much more likely if the procedure is carried out at the time of cardiac arrest and delay is reported to result in almost certain mortality. All of the potentially reversible pathologies were addressed in the 2010 ILCOR guidelines[11] but because a limited number of interventions need to be performed in a very short time period to address reversible pathology the management of TCA is

suitable for a treatment algorithm. We have reviewed the published data on TCA and constructed a simple treatment algorithm to address key reversible pathologies. The algorithm does not differentiate between pre-hospital and in-hospital care. Where time critical reversible pathology exists it requires the same treatment regardless of where the patient is at the time of diagnosis. Some pre-hospital services may not be able to deliver all required interventions on scene but if this is the case the algorithm can be used to assist in the identification of priorities and consider how urgent transfer to hospital can address any remaining issues (Fig. 1).

2. Explanation of algorithm

The algorithm aims to rapidly identify and correct reversible causes of TCA. Transport of TCA patients from the pre-hospital to hospital setting with on-going cardiopulmonary resuscitation is usually futile and key interventions need to be performed as soon as possible, usually on-scene. Patients arriving at a hospital in traumatic peri- or cardiac arrest need reversible causes immediately excluded and managed prior to transfer for diagnostic imaging or surgical intervention. The treatment priorities in this algorithm have been applied by a physician-led pre-hospital trauma service to over a thousand TCA's attended over an eighteen year period. Published results demonstrate that adherence to these principles can result in good survival rates from TCA.[5,16]

2.1. Diagnosis of traumatic cardiac arrest

The diagnosis of TCA is based on rapid clinical assessment.[11] Agonal, abnormal or absent spontaneous respiration and absence of a central pulse over a 10 s period should immediately prompt entry into the algorithm if there is a possibility that the cardiac arrest could be traumatic in origin. Recognition of the peri- or cardiac arrest state should take less than 10 s and not be delayed to initiate monitoring. In cases where death can be categorically confirmed (decapitation, rigour mortis etc.) resuscitation should not be commenced. Where available, rapid assessment with focused ultrasound may be useful in the diagnosis and management of the peri-arrest patient but should not delay urgent intervention.[17]

2.2. Trauma resulting in a peri-arrest patient

Victims of major trauma may present in a peri-arrest state. Cardiovascular instability, including bradycardia, profound hypotension or rapidly falling blood pressure, loss of peripheral pulses, together with a deteriorating conscious level should immediately alert the emergency care provider of imminent cardiac arrest. Rapid, targeted interventions may prevent cardiac arrest. Peri-arrest patients should immediately be entered into the algorithm. In cases where the patient is still self-ventilating, early drug-assisted tracheal intubation may be required.

2.3. Basic/advanced life support

Patients in TCA should have basic and, if available, advanced life support commenced immediately. All emergency care providers should be familiar with recognition of cardiac arrest and initiation of basic life support. Depending on the cause of traumatic cardiac arrest chest compressions may provide some blood flow during cardiac arrest and should be continued whilst the history and mechanism of injury is established. In profound hypovolaemia, chest compressions are likely to be ineffective due to poor cardiac filling and external compression of an empty heart.[18] Haemorrhage control and volume replacement should occur immediately. Immediate diagnosis of hypovolaemia may be difficult and, if in doubt, chest compressions should be continued. The patients with the greatest chance of survival are normovolaemic and cardiac compressions may be at least partially effective while reversible pathology is addressed simultaneously. Standard BLS/ALS without urgent attention to reversible pathology is unacceptable and unlikely to result in return of spontaneous circulation (ROSC) (unless the cardiac arrest was of 'medical origin'). If cardiac compressions have been started they should be continued until interventions addressing reversible pathology are commenced.

2.4. Penetrating trauma

Patients with penetrating wounds to the chest, epigastrium or between the scapulae resulting in cardiac arrest usually have cardiac tamponade and obstructive shock or have an empty heart as a result of hypovolaemia.[19] For the patient to have any chance of survival, immediate surgical intervention is required. Surgical intervention, in the form of resuscitative thoracotomy, should be performed immediately in any patient with penetrating trauma to the chest or epigastrium in peri- or established cardiac arrest. Timing of this intervention is critical. The chances of survival after emergency thoracotomy fall rapidly after loss of vital signs.[11] In the emergency department it has been demonstrated that if blunt trauma patients have had more than 5 min of CPR or penetrating trauma patients have had more than 15 min resuscitative thoracotomy is likely to be futile.[20] In contrast in the penetrating trauma patient where loss of vital signs has occurred in the presence of a thoracotomy provider or in the 10 min period before, the procedure has been effective and should be carried out without any delay for less effective interventions.[16] Pre-hospital resuscitative thoracotomy should be performed if trained personnel are on-scene because patients who lose vital signs on scene rarely survive even if emergency thoracotomy is performed in the emergency department.[15,16] Pre-hospital thoracotomy has been associated with a significant survival rate in patients with cardiac tamponade[5,16] but needs to be performed in systems with clear governance processes in place.[21] Patients presenting to the emergency department in cardiac arrest or peri-arrest should be considered for immediate resuscitative thoracotomy on arrival.[22] Any delay in undertaking resuscitative thoracotomy when it is indicated will decrease the patient's chance of survival. Resuscitative thoracotomy undertaken in the pre-hospital or emergency department setting does not aim to address all the possible lesions that can result in cardiac arrest following penetrating chest trauma. An immediate cardiothoracic or trauma surgical response will only be available in a proportion of cases. Resuscitative thoracotomies performed by non-specialist surgeons or non-surgeons can only be expected to address a limited number of pathologies. Pre-hospital resuscitative thoracotomy aims to treat simple cardiac wounds, resulting in pericardial tamponade.[23] The majority of traumatic pericardial tamponades contain considerable volumes of clotted blood and there is no place for needle pericardiocentesis in treatment.[15] Therefore thoracotomy and formal pericardotomy are needed. Where release of cardiac tamponade does not result in ROSC patients may benefit from high quality, internal cardiac massage to achieve return of spontaneous circulation. Resuscitative thoracotomy in TCA from blunt trauma is much less likely to be successful and injuries present are more likely to be complex and less amenable to treatment by non-surgeons.[23,24] The availability of blood for immediate transfusion may improve outcome in these patients but further research is required in this area.

2.5. Traumatic versus medical cardiac arrest

Establishing the origin of cardiac arrest may not be straightforward. A primary medical arrest may occur prior to a patient suffering a traumatic insult. Such patients may initially appear to

have suffered a TCA but have suffered minimal, if any, injuries. Primary medical cardiac arrests resulting in falls from height or road traffic collisions are examples which may typically result in emergency care providers suspecting cardiac arrest of traumatic origin. Close attention should be paid to witness history and an accurate scene assessment made to establish the course of events and mechanism of injury. If there is a possibility that the patient has suffered a primary medical cardiac arrest, chest compressions should be continued, a defibrillator requested immediately and ILCOR resuscitation algorithms followed. Where medical cardiac arrest is not suspected cardiac monitoring should still be applied early in the resuscitation attempt. Standard defibrillation should be carried out if a rhythm compatible with defibrillation is discovered in the traumatic cardiac arrest patient.

2.6. 'HOT' – hypovolaemia, oxygenation and tension pneumothorax

Victims of TCA may have one or more injuries resulting in severe hypovolaemia, critical hypoxaemia or tension pneumothorax, either in isolation or concurrently. Active management of these conditions needs to be addressed simultaneously by the pre-hospital or hospital trauma team.

2.6.1. Hypovolaemia

Active external haemorrhage should be controlled with the application of immediate direct pressure to actively bleeding wounds. After bleeding from isolated bleeding wounds has been effectively controlled volume re-expansion should follow. Recent military experience has focused on aggressive management of compressible haemorrhage with the use of pressure dressings, topical haemostatic agents and tourniquets.[12] Control of obvious haemorrhage can only be beneficial although clear evidence of survival benefit is scarce. Routine translation of tourniquet use to civilian practice is even less likely to demonstrate benefit since, in contrast to military mechanisms of injury, blunt trauma rarely results in traumatic amputation and in civilian practice a tourniquet is likely to be applied much later after injury than point of wounding application by a wounded soldier or his immediately available colleagues. The availability and use of tourniquets in civilian trauma practice may be increasing on the basis of recent military experience and civilian major incidents[25,26] and tourniquet use is incorporated into the American College of Surgeons Advanced Trauma Life Support course.[27]

After initial haemorrhage control and other critical interventions have been achieved fractures of the pelvis and long bones should be splinted. Haemorrhage into pelvic and long bone fractures can be significant. Open fractures with haemorrhage need immediate attention and should be dealt with as 'active external haemorrhage'. Closed fractures should be splinted to prevent ongoing haemorrhage after initial urgent interventions. If there is a suspicion of a pelvic fracture a pelvic binder should be applied taking care to minimise patient movement during application and the pelvis reduced to anatomical position. Long bone fractures should be reduced to anatomical position and splints applied.

A patient in TCA as a result of hypovolaemia is unlikely to achieve return of spontaneous circulation unless haemorrhage control is performed in combination with intravascular volume replacement.

Where patients are peri-arrest or where bleeding has been addressed early volume replacement with blood products is required. Administration of blood is likely to be more beneficial than crystalloid or colloid infusion in this patient group.[28] Where indicated, blood and blood products should be transfused immediately on arrival at the emergency department or in the pre-hospital setting if available. Pre-hospital activation of major transfusion protocols should diminish the time required for the patient to receive blood products.[25] In hospital, blood products should be immediately available and massive transfusion protocols initiated.[29]

2.6.2. Oxygenation

Airway management and optimising oxygenation are important. Hypoxia secondary to complete or partial airway obstruction, traumatic asphyxia and ventilatory failure may be the cause of cardiac arrest and can be straightforward to treat. Major trauma victims are likely to have a high oxygen requirement. Initial attention should be paid to high quality, basic airway management with cervical spine control, using airway adjuncts if required. Attention to basic airway management is paramount to the unconscious trauma patient who is at risk of airway compromise. Definitive airway management, in the form of a cuffed tracheal tube, should be achieved as early as possible. Advanced airway management should be achieved within a safe operating system and several guidelines are available.[30–32] Ventilation through a tracheal tube will ensure high concentration oxygen delivery, protect against airway soiling and provide positive pressure ventilation. Intubation without drug assistance is likely only to be possible in patients with a very high mortality rate.[33,34] A small proportion of trauma patients who are not in cardiac arrest require drug assisted intubation to facilitate tracheal intubation and adequate ventilation.[35]

2.6.3. Tension pneumothorax

Tension pneumothorax should be actively excluded in TCA. Needle chest decompression is rapid and within the skill set of most ambulance personnel but is of limited value in TCA.[36,37] A proportion of patients will have soft tissue greater than the length of a standard 14-gauge cannula when placed in the second intercostal space, in the mid-clavicular line, which may lead to ineffective chest decompression.[38] Cannulae are also prone to kinking or blockage.[39]

Tracheal intubation, positive pressure ventilation and formal chest decompression will effectively treat tension pneumothorax in patients with TCA. Simple thoracostomy[40,41] is easy to perform and used routinely in several pre-hospital physician services. This consists of the first stage of standard chest tube insertion – a simple incision and rapid dissection into the pleural space in the positive pressure ventilated patient.[37,40–42] Chest tube insertion is carried out after the resuscitation phase. Tube thoracocentesis requires additional equipment, takes longer to perform and creates a closed system that has the potential to re-tension. Chest drain tubes may become blocked with lung or blood clots and have the potential to kink.[43,44]

2.7. Post-ROSC care

If return of spontaneous circulation is achieved in the pre-hospital setting, rapid transport to an appropriate hospital is required. A pre-alert should be passed to the receiving hospital. Following in-hospital resuscitation from TCA hypovolaemic patients should be immediately transferred to an operating theatre or interventional radiology facility to control major haemorrhage. More stable patients may be considered for further diagnostic imaging. In patients with ROSC consideration should be given to local guidelines in place for management of trauma patients. Examples may include target blood pressures for patients with ongoing haemorrhage or the institution of mild hypothermia in patients with neurological injury. If ROSC is not achieved on-scene, consideration should be given to terminating the resuscitation attempt.

3. Discussion

The use of algorithms in emergency medicine and pre-hospital care ensures standardised, rapid delivery of clinical interventions in a structured manner for critically unwell patients. Resuscitation algorithms for medical cardiac arrest are well established and incorporated into regular training for both pre-hospital and hospital personnel. It is important that providers of emergency care appreciate that resuscitation from cardiac arrest is not always futile. Outside specialist centres, EMS personnel and hospital staff involved in emergency care are unlikely to be involved in trauma resuscitation on a regular basis. Having a standard algorithm should assist clinicians in the provision of rapid, effective, consistent treatment to victims of major trauma resulting in near or actual TCA. It also focuses care on the likely key reversible pathology. The absence of a treatment algorithm may delay treatment or result in resuscitation not being attempted.[45] Provision of a resuscitation algorithm for TCA provides a treatment framework for pre-hospital and emergency department clinicians and has the potential to improve survival.

4. Conclusion

A standard simple approach to traumatic cardiac arrest is feasible and addresses all key reversible pathology that needs to be addressed to maximise the chance of survival. Use of a treatment algorithm can rapidly and simultaneously address reversible causes of traumatic cardiac arrest and has the potential to save lives.

Conflict of interest statement

No conflicts of interest to declare.

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