Western Trauma Association Critical Decisions in Trauma: Resuscitative thoracotomy

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BACKGROUND: In the past three decades, there has been a significant clinical shift in the performance of resuscitative thoracotomy (RT), from a nearly obligatory procedure before declaring any trauma patient deceased to a more selective application of RT. We have sought to formulate an evidence-based guideline for the current indications for RT after injury in the patient.

METHODS: The Western Trauma Association Critical Decisions Committee queried the literature for studies defining the appropriate role of RT in the trauma patient. When good data were not available, the Committee relied on expert opinion.

RESULTS: There are no published PRCT and it is not likely that there will be; recommendations are based on published prospective observational and retrospective studies, as well as expert opinion of Western Trauma Association members. Patients undergoing cardiopulmonary resuscitation (CPR) on arrival to the hospital should be stratified based on injury and transport time. Indications for RT include the following: blunt trauma patients with less than 10 minutes of prehospital CPR, penetrating torso trauma patients with less than 15 minutes of CPR, patients with penetrating trauma to the neck or extremity with less than 5 minutes of prehospital CPR, and patients in profound refractory shock. After RT, the patient's intrinsic cardiac activity is evaluated; patients in asystole without cardiac tamponade are declared dead. Patients with a cardiac wound, tamponade, and associated asystole are aggressively treated. Patients with an intrinsic rhythm following RT should be treated according to underlying primary pathology. Following several minutes of such treatment as well as generalized resuscitation, salvageability is reassessed; we define this as the patient's ability to generate a systolic blood pressure of greater than 70 mm Hg with an aortic cross-clamp if necessary.

CONCLUSION: The success of RT approximates 35% for the patient arriving in shock with a penetrating cardiac wound and 15% for all patients with penetrating wounds. Conversely, patient outcome is relatively poor when RT is performed for blunt trauma, 2% survival for patients in shock and less than 1% survival for patients with no vital signs. Patients undergoing CPR on arrival to the hospital should be stratified based on injury and transport time to determine the utility of RT. This algorithm represents a rational approach that could be followed at trauma centers with the appropriate resources; it may not be applicable at all hospitals caring for the injured. There will be patient, personnel, institutional, and situational factors that may warrant deviation from the recommended guideline. The annotated algorithm is intended to serve as a quick bedside reference for clinicians. (*J Trauma Acute Care Surg.* 2012;73: 1359–1364. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Thoracotomy; resuscitative thoracotomy; emergency department thoracotomy; cardiopulmonary resuscitation; algorithm.

This is a recommended management algorithm from the Western Trauma Association (WTA) addressing the performance of resuscitative thoracotomy (RT). There are no published PRCT and it is not likely that there will be; the recommendations herein are not based on Level I evidence but on the best available published prospective observational and retrospective studies, as well as expert opinion of WTA members. The algorithm (Fig. 1) and accompanying comments represent a rational approach that could be followed at trauma centers with the appropriate resources; it may not be applicable at all hospitals caring for the injured. We recognize that there will be patient, personnel, institutional, and situational factors that may warrant deviation from the recommended guideline. The annotated algorithm is intended to serve as a quick bedside reference for clinicians.

In the past three decades there has been a significant clinical shift in the performance of RT, from a nearly obligatory procedure before declaring any trauma patient is deceased to a more selective application of RT. The value of RT in the resuscitation of the patient in profound shock but not yet dead is unquestionable. Its indiscriminate use, however, renders it a low-yield and high-cost procedure.[1–4] Overall analysis of the available literature indicates that the success of RT approximates 35% for the patient arriving in shock with a penetrating cardiac wound and 15% for all patients with penetrating wounds.[5] Conversely, patient outcome is relatively poor when RT is performed for blunt trauma, 2% survival for patients in shock and less than 1% survival for patients with no vital signs. Patients undergoing cardiopulmonary resuscitation (CPR)

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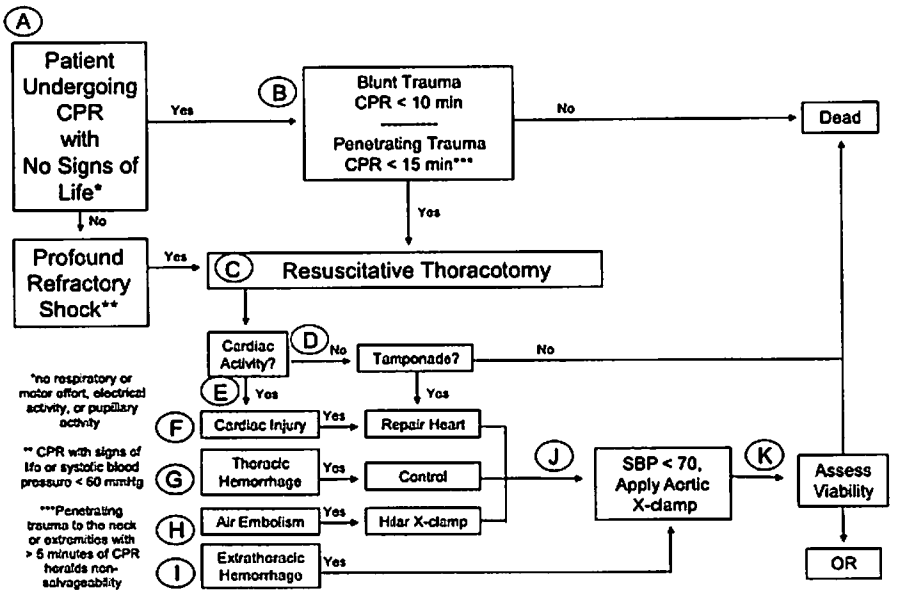


Figure 1.

on arrival to the hospital should be stratified based on injury and transport time to determine the utility of RT.[6-11]

Historical Perspective

Emergent thoracotomy came into use in the United States in the late 1800s and early 1900s for the treatment of injuries to the heart as well as for cardiac arrest. In 1874, Schiff promoted the concept of thoracotomy for open cardiac massage.[12] At the turn of the century, thoracotomy as a resuscitative measure had expanded indications for the treatment of penetrating chest injuries.[13,14] Although the most common reason for thoracotomy in the early 1900s was cardiovascular collapse from medical causes, the demonstrated efficacy of closed-chest compression in 1960[15] and the introduction of external defibrillation in 1965[16] virtually eliminated the practice of open-chest resuscitation for medical causes. The use of emergent thoracotomy following trauma initially declined in the 1940s as less invasive therapeutics, such as pericardiocentesis for cardiac tamponade, were preferred.[17] However, in the late 1960s, the pendulum swung again toward emergent thoracotomy, promulgated by the Ben Taub group for resuscitation of the moribund patient with penetrating cardiovascular injuries.[18] In the 1970s, the Denver General Hospital[3] and the San Francisco General Hospital[19] challenged the appropriate role and clinical indications for RT. In the ensuing swing of the pendulum during the subsequent four decades, several groups have attempted to elucidate the clinical guidelines for RT.[2,3,6-11,20-32]

Annotated Text for the RT Algorithm

A. At the scene, severely injured patients without electrical cardiac activity are declared dead. Patients in extremis but with electrical cardiac activity are intubated, supported with cardiac compressions, and transported rapidly to the hospital. Resuscitative efforts should not be abandoned prematurely in the potentially salvageable patient because field assessment of salvageability can be unreliable.

B. On arrival to the hospital, the time from initiation of CPR is determined directly from prehospital personnel. Only 1% to 2% of blunt trauma patients undergoing RT survive, regardless of clinical status on presentation. Blunt trauma patients with greater than 10 minutes of prehospital CPR and no signs of life (detectable blood pressure, respiratory or motor effort, cardiac electrical activity, or pupillary activity) are pronounced dead.[5,10] Penetrating torso trauma patients with greater than 15 minutes of prehospital CPR and no signs of life are pronounced.[5,7,10] Following these injuries, 14% of patients requiring RT are salvaged if they are hypotensive with detectable vital signs, whereas 8% of those who have no vital signs but have signs of life at presentation and 1% of those without signs of life are salvaged.[5,6] RT with aortic cross-clamping is a potential adjunct in the acute resuscitation of patients with neck or extremity vascular injuries, with an overall survival rate of 11%.[11] Those patients with penetrating trauma to the neck or extremity causing massive blood loss and arrest, with greater than 5 minutes of prehospital CPR and no signs of life, are pronounced. Patients within the time guidelines listed or those with signs of life trigger ongoing resuscitation and RT.

C. RT in this context refers to a thoracotomy performed at the first patient contact, before anesthetic induction. This is commonly referred to as an emergency department

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thoracotomy but should be differentiated from an operative RT. On patient arrival and determination for the need of RT, the patient's left arm should be placed above the head to provide unimpeded access to the left chest. The thoracotomy incision starts on top of the sternum and is carried transversely across the chest in the inframammary fold, with gentle curvature toward the patient's axilla. A clamshell thoracotomy should be the initial incision in a hypotensive patient with a penetrating wound to the right chest. This provides immediate, direct access to a right-sided pulmonary or vascular injury while still allowing access to the heart from the left side for open cardiac massage. If a bilateral thoracotomy is performed, the rib retractor should be placed at the sternum to enhance separation of the chest wall. If the sternum is divided transversely, the internal mammary vessels must be ligated when perfusion is restored. If the pericardium is not tense with blood, it should be picked up at the apex with toothed forceps and sharply opened with scissors. The pericardium should be opened from the apex toward the aortic root, anterior to the phrenic nerve. If tense pericardial tamponade exists, a knife or the sharp point of a scissors is often required to initiate the pericardotomy incision, with care taken not to injure the heart. Although occlusion of the thoracic aorta is typically performed after pericardotomy, this may be the first maneuver on entry into the chest for patients sustaining extrathoracic injury and associated major blood loss.

D. After performing the thoracotomy and pericardotomy, the patient's intrinsic cardiac activity is evaluated; patients in asystole without cardiac tamponade are declared dead. Patients with a cardiac wound, tamponade, and associated asystole are aggressively treated. First, the cardiac wound is repaired using a 3-0 nonabsorbable running suture (see F in Fig. 1). Following sufficient if not complete hemostatic repair, bimanual internal massage of the heart is initiated; this should be performed with a hinged clapping motion of the hands, with the wrists apposed, sequentially closing from palms to fingers. The ventricular compression proceeds from the cardiac apex to the base of the heart. Intracardiac injection of epinephrine may be administered into the left ventricle, using a specialized syringe, which resembles a spinal needle. Typically, the heart is lifted up slightly to expose the posterior left ventricle, and care is taken to avoid the circumflex coronary during injection. The heart is vigorously massaged to enhance coronary perfusion. After allowing time for vasopressors to circulate, the heart is defibrillated (30 J) using internal paddles. Following several minutes of such treatment, as well as generalized resuscitation, salvageability is reassessed; we define this as the patient's ability to generate a systolic blood pressure of greater than 70 mm Hg with an aortic cross-clamp if necessary.

E. Patients with an intrinsic rhythm following RT should be treated according to underlying primary pathology as follows: cardiac injury, thoracic hemorrhage, air emboli, or extrathoracic hemorrhage.

F. Those patients diagnosed with cardiac injury after pericardotomy should undergo cardiac repair, in the trauma bay or the operating room.[33,34] Cardiac bleeding sites should be controlled immediately with digital pressure on the surface of the ventricle and partially occluding vascular clamps on the atrium or great vessels. Efforts at definitive, hemostatic, cardiorrhaphy may be delayed until initial resuscitative measures have been completed. In the nonbeating heart, cardiac repair is performed before defibrillation and cardiac massage. Cardiac wounds in the thick walled left ventricle are best repaired with 3-0 nonabsorbable running or horizontal mattress sutures. Buttressing the suture repair with polytetrafluoroethylene (Teflon) pledgets is preferred for the thinner right ventricle. When suturing a ventricular laceration, care must be taken not to incorporate a coronary vessel into the repair. In these instances, vertical mattress sutures should be used to exclude the coronary and prevent cardiac ischemia. In the more muscular left ventricle, particularly with a linear stab wound, control of bleeding can often be temporized with a skin-stapling device. Low-pressure venous and atrial lacerations can be repaired with simple running or purse-string sutures. Use of a Foley catheter for temporary occlusion of cardiac injuries has been suggested, but this may inadvertently extend the injury owing to traction forces. RT has the highest survival rate following isolated cardiac injury;[6,18,35] 35% of adult patients presenting in shock and 20% without vital signs were salvaged after isolated penetrating injury to the heart if RT was performed.[5]

G. Life-threatening intrathoracic hemorrhage occurs in less than 5% of patients following penetrating injury presenting to the emergency department and in an even lower percentage of patients sustaining blunt trauma.[36] The most common injuries include penetrating wounds to the pulmonary hilum and great vessels; less commonly seen are torn descending thoracic aortic injuries with mediastinal rupture or blunt injuries to the pulmonary hila, azygous vein, and so on. Control of intrathoracic hemorrhage may entail hilar cross-clamping, direct digital occlusion of the injury, or even packing of the apices for subclavian vessel injuries.

H. Treatment for bronchovenous air embolism demands immediate pulmonary hilar cross-clamping to prevent further propagation of pulmonary venous air.[37,38] Placing the patient in the Trendelenburg's position traps air in the apex of the left ventricle; then with an open pericardium, needle aspiration is performed to remove intracardiac air. In addition, aspiration of the aortic root may be required to alleviate any accumulated air. Vigorous cardiac massage may promote dissolution of air already present in the coronary arteries,[39] and direct needle aspiration of the right coronary artery with a tuberculin syringe may be lifesaving. The production of air emboli is enhanced by the underlying physiology—there is relatively low intrinsic pulmonary venous pressure caused by associated hypovolemia and relatively high bronchoalveolar pressure from assisted

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positive-pressure ventilation. This combination increases the gradient for air transfer across bronchovenous channels.[40] Although more often observed in penetrating trauma, a similar process may occur in patients with blunt lacerations of the lung parenchyma.

I. The rationale for temporary thoracic aortic occlusion for the patient with massive hemorrhage is multifactorial. First, for patients with hemorrhagic shock, aortic cross-clamping redistributes the patient's limited blood volume to the myocardium and brain.[21,41–44] Second, patients sustaining intra-abdominal injury benefit from aortic cross-clamping owing to a reduction in subdiaphragmatic blood loss.[20] Third, occlusion of the descending thoracic aorta increases coronary filling and, thus, seems to increase the return of spontaneous circulation following CPR.[43,44] Reports of successful resuscitation using RT for patients in hemorrhagic shock and even sustaining cardiac arrest following extremity and cervical injuries exist.[11] In these situations, aortic cross-clamping may effectively redistribute the patient's blood volume until replacement and control of the hemorrhagic source is possible. Optimally, complete removal of the aortic cross-clamp or replacement of the clamp below the renal vessel should be performed within 30 minutes because of the limited tolerance of the gut to warm ischemia. Furthermore, there is a finite risk of paraplegia associated with the procedure.[47–49]

J. If hypotension persists following thoracotomy and pericardotomy, the descending thoracic aorta should be occluded to maximize coronary perfusion and to decrease the required effective circulating volume to facilitate resuscitation. Typically, the thoracic aorta is cross-clamped inferior to the left pulmonary hilum; alternatively, it can be clamped above the lung in the more proximal descending aorta. Although some advocate taking down the inferior pulmonary ligament to better mobilize the lung, this is unnecessary and risks injury to the inferior pulmonary vein. Dissection of the thoracic aorta is optimally performed under direct vision by incising the mediastinal pleura and bluntly separating the aorta from the esophagus anteriolaterally and from the prevertebral fascia posteriorly; if excessive hemorrhage or protruding lung limits direct visualization, which is the more realistic clinical scenario, blunt dissection with one's thumb and fingertips can be performed to isolate the descending aorta. If the aorta cannot be easily isolated from the surrounding tissue, digitally occlude the aorta against the spine to effect aortic occlusion.

K. Reassessment of the patient following intervention and aggressive resuscitation efforts is performed. Resuscitation of the patient should include crystalloid, packed red blood cells, calcium, and bicarbonate. Vasopressors such as epinephrine and vasopressin may be given through peripheral or central access, and intracardiac epinephrine may be injected in the left ventricle. If the patient develops ventricular fibrillation, internal defibrillation at 30 J is performed with internal paddles placed directly on the myocardium. Occasionally, internal cardiac pacing is warranted. If the patient maintains a perfusing rhythm, salvageability is assessed; in our experience, this is defined as the patient's ability to generate a systolic blood pressure of greater than 70 mm Hg after a period of aggressive intervention.

Emerging data indicate that clinical results in the pediatric population mirror that of the adult experience. One might expect that children would have a more favorable outcome compared with adults; however, this has not been borne out in multiple studies.[50–54] Thus, as in adults, outcome following RT in the pediatric population is largely determined by injury mechanism and physiologic status on presentation to the emergency department.

DISCLAIMER

The WTA develops algorithms to provide guidance and recommendations for particular practice areas but does not establish the standard of care. The WTA develops algorithms based on the evidence available in the literature and the expert opinion of the task force in the recent timeframe of the publication. The WTA considers use of the algorithm to be voluntary. The ultimate determination regarding its application is to be made by the treating physician and health care professionals with full consideration of the individual patient's clinical status as well as available institutional resources and is not intended to take the place of health care providers' judgment in diagnosing and treating particular patients.

AUTHORSHIP

C.C.B., W.L.B., and E.E.M. designed the study, collected, analyzed and interpreted the data, and drafted the manuscript, while F.A.M., R.C., R.C.M., J.W.D., and J.S. critically reviewed it.

DISCLOSURE

The authors declare no conflicts of interest.

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EDITORIAL CRITIQUE

One of the remarkable offerings of the Western Trauma Association (WTA) is the critical annotated algorithm for the management of difficult clinical problems in trauma. In this issue, the authors discuss the role of resuscitative thoracotomy (RT) in the emergency department (ED) for the trauma patient undergoing cardiopulmonary resuscitation (CPR). Carefully defining the scope of RT, they suggest the following indications: blunt trauma patients with less than 10 minutes of prehospital CPR, penetrating torso trauma patients with less than 15 minutes of CPR, penetrating trauma to the neck or extremity with less than 5 minutes of prehospital CPR, and patients in profound refractory shock.

Most of these recommendations are widely acknowledged. For blunt trauma, however, many centers withhold RT lose VS in the ED In fact, these "restrictive" guidelines are enunciated by the National Association of EMS Physicians Standards and Clinical Practice Committee as well as the American College of Surgeons' Committee on Trauma

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