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Damage control surgery for thoracic injuries

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Summary Damage control of thoracic injuries begins frequently with an emergency department thoracotomy via an anterolateral incision. Bleeding and air leaks are quickly temporised. As opposed to abdominal damage control where most injuries can be temporised, most thoracic injuries require initial definitive repair. Thus, the goal of thoracic damage control is to perform the least definitive repair using the fastest and easiest techniques to shorten the operative time as much as possible. There are some injuries that can be temporised and require re-operation once physiologic normality has been achieved.

Introduction

The main principles of damage control were developed with regard to controlling ongoing bleeding and contamination of the abdominal cavity in the presence of hypothermia, coagulopathy and metabolic acidosis during the initial operation.[21,22] Subsequently, the patient would undergo resuscitation in the intensive care unit and return to the operating room under more desirable physiologic criteria for completion of their operation. These principles apply as well for patients sustaining thoracic trauma displaying signs of physiologic exhaustion. As opposed to abdominal damage control, there are intra-thoracic injuries that require definitive repair at the initial operation, as well as those that can be temporised. Therefore, the approach to thoracic damage control should be to perform procedures that are technically faster and simpler for definitive repair and to perform manoeuvres to temporise those injuries that do not require immediate repair in the patient in extremis.[15,32] This approach, the abbreviated thoracotomy, has been described in the literature and decreased predicted mortality of 59% to actual mortality of 36%.[26] A guide to the different aspects of damage control of the thoracic cavity ensues.

Emergency department thoracotomy (EDT)

All damage control for victims of trauma begins in the emergency department. The patient most likely to require damage control for intra-thoracic injury is the unstable patient with penetrating chest trauma. Patients requiring emergency department thoracotomy for blunt thoracic trauma have a dismal survival rate and are therefore not advocated unless specific criteria are met.[2,8,30] A definitive airway should be secured whether by endotracheal tube or by surgical techniques. Thoracostomy tubes placed along the anterior axillary line at the level of the fifth intercostal space or needle decompression of the thorax in the second intercostal space along the midclavicular line can be used to alleviate a tension pneumothorax. Large bore access for resuscitation fluids should be established percutaneously or via cutdown. Emergency release blood should be made readily available in the resuscitation bay and a blood sample should be sent to blood bank for type

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and cross. An assessment of potential trajectory of the wound, if possible, should be attempted either by physical examination or radiographic evaluation.

For patients with witnessed or antecedent (within 10 min) loss of vital signs after penetrating thoracic injury, thoracic damage control should begin with EDT. The primary objectives of EDT are to release pericardial tamponade, control intrathoracic bleeding, control massive air embolism or bronchopleural fistula, permit open cardiac massage and to allow for cross-clamping of the descending thoracic aorta.[2] The standard incision of a left anterolateral thoracotomy extends from the sternum to the stretcher laterally made below the nipple at the fifth intercostal space. The chest wall muscles are divided with a knife quickly down to the level of the intercostal muscles. The intercostal muscles are divided above the rib in an area large enough for to two fingers to be inserted into the thoracic cavity so as to avoid lacerating the lung or heart. A pair of Mayo scissors is then used to slide along the pleura and intercostal muscles to the extent of the incision thereby opening the entire thoracic cavity. If extension is required for better visualisation of a wound or if the wounds are transthoracic, the sternum can be divided with a Lebske knife or a pair of trauma shears. A chest wall retractor is placed with the bar towards the table in the event that the incision needs to be extended across the sternum. The left hand is placed lateral and posterior to the lung with the palm against the lung parenchyma. The endotracheal tube is momentarily disconnected from the ambu bag or ventilator to allow better visualisation as the hand lifts and compresses the lung tissue anteromedially. This provides visualisation and access to the descending thoracic aorta. The mediastinal pleura is divided quickly, but carefully around the aorta and a vascular clamp is placed across it after digital mobilisation. Pericardial tamponade is released by opening the pericardium. Typically the pericardium is taut from blood that has collected underneath making it difficult to grab with a pair of forceps. Either a pair of Metzenbaum scissors or a #10 blade scalpel turned at an oblique angle so as not to injure the underlying epicardium, is used to make a defect in the pericardium. This defect is then extended in a vertical fashion so that it extends from the root of the aorta to the apex of the heart. Care is taken to not injure the phrenic nerves, which run in a vertical fashion along the lateral aspect of the pericardium. The heart is delivered from its pericardial cavity and the cardiac defect can be temporised with digital control. A polypropylene suture on a large needle can be used to rapidly over sew the deficit. Other options include a #14 or #16F Foley catheter with a 5 cc balloon inflated and placed gently under tension through the wound. Alternatively, a skin stapler can be used to rapidly reapproximate the wound.

Exsanguination from the lung or a massive air leak can be temporarily alleviated by vascular clamp placement around the hilum or by dividing the inferior pulmonary ligament and twisting the lung 180° on its axis.[29,36] Bleeding from the thoracic outlet can be controlled by transcutaneous placement of a #16 or #18F Foley catheter with a 30 cc balloon through the wound tract and traction against the chest wall at the first rib near the cuppula to tamponade the injured vessel.[5,10] If the vessel can be identified intrathoracically, a vascular clamp may be placed across it proximal to the injury. Alternatively, digital compression may be the best option to temporise the bleeding until a better incision can be made in the operating room to gain access to the injured vessel. This is not optimal as it may hinder visualisation and takes the hand of the surgeon out of use. Once bleeding, tamponade and massive air leak have been temporised in the resuscitation bay, the patient is taken to the operating room for definitive repairs as the patient physiology will allow.

Operating room (OR)

In the operating room the patient is placed in supine position with both upper extremities extended laterally and slightly cephalad. For patients who have had emergency department thoracotomy, a longitudinal roll is placed just to the left of the spine over the length of the thorax posteriorly to rotate the patient slightly in the left AO position to about 15°. The patient is prepped and draped from the neck to the knees so that the groin is available in the event that the saphenous vein is needed for vascular conduit. We use the Arctic Sun® warming device placed on the patient's back and buttocks and assists with prevention of heat loss and rewarming. Blood should be readily available in the OR. An arterial line is placed to allow invasive haemodynamic monitoring. Dual lumen endotracheal tube placement is usually not a practical option in these patients, therefore if unilateral deflation is necessary for treatment or better visualisation, anaesthesia staff can use either a bronchial blocker or perform a mainstem intubation. A bronchoscope may be necessary for a diverted left mainstem bronchial intubation.

Cardiac injury

Cardiac injuries temporised during the initial EDT can be reinforced if necessary using a 3.0 or 4.0

propylene pledgeted suture. Pledgets can be fashioned from Teflon or pericardium.[12] They allow for compression of the cardiac musculature by the suture while preventing the suture from tearing through the myocardium. Suturing widely below the vessel repairs lacerations in close proximity to coronary vessels. This will tent the vessel upward upon tying the suture. Distal coronary artery lacerations or transections can be ligated with impunity.[12,33] Though proximal injuries can require cardiopulmonary bypass, this injury has been reportedly repaired with ''off-pump'' bypass grafting.[7] Saphenous vein is the conduit of choice. Posterior cardiac injuries should be suspected in all patients with penetrating cardiac wounds. Sponges can be placed posteriorly to help elevate the heart to provide a better posterior view without compressing the venous return. Another alternative is placing a curved Satinsky clamp on the fat pad at the apex of the heart to allow for gentle traction to lift the heart providing a posterior view.[11]

Lung injury

Less than 20% of patients undergoing thoracotomy for trauma will require a lung resection.[9,20,24,25] The treatments of lung injuries include pneumonorraphy, wedge resection, pulmonary tractotomy, lobectomy and pneumonectomy. Pneumonorraphy, or oversewing of the entrance and exit wounds, can lead to ongoing bleeding within the lung parenchyma and spilling bronchial blood aspiration into the uninjured lung. Adequate haemostasis must be present before using this technique. Peripheral injuries that involve only a small portion of lung tissue can be easily managed by wedge resection using a GIA stapler. Larger wounds with significant bleeding can be controlled, initially, by temporarily clamping the pulmonary hilum. This also obviates the possibility of air embolism in patients on positive pressure ventilation with significant air leak. If the wound is through and through and does not proceed to the hilar vessels, the quickest way to gain control of bleeding is by performing a pulmonary tractotomy. This is achieved by placing a linear stapler across the tract and dividing the tissues. The wound tract is then inspected, bleeding vessels are ligated and air leaks are controlled. This technique has allowed for preservation of lung tissue by avoiding lobectomy or pneumonectomy and increasing survival.[4,31,32,35]

If the injury extends to the hilum, often a lobectomy or pneumonectomy is required. If time and patient physiology allow, vessel and bronchus isolation and control should be achieved to allow for minimal tissue loss. However, in damage control a large TA stapler can be placed across the vessels and bronchus taking the specimen en bloc. This allows for either rapid lobectomy or pneumonectomy.[8,28] This should be avoided if at all possible in the damage control approach. Survival from trauma pneumonectomy is variable from 0 to 50%[3,19,20,25,27,31] and the principles of damage control would dictate performing less of an operation rather than more of one.

Intrathoracic vascular injury

The approach to treating penetrating vascular injuries of the thorax begins with planning of exposure to gain optimal proximal and distal control. The patient with a damage control procedure likely already has an anterolateral thoracotomy, which may allow for good proximal control, but frequently does not provide for adequate distal control or exposure for repair. Median sternotomy or supraclavicular extension or both may be required to provide this exposure, however the ''trap door'' incision has significant associated morbidity.[34] In situations when distal control is difficult to obtain, a Fogarty catheter placed under direct vision through the wound into the lumen distally can provide that control. Alternatively a balloon angioplasty catheter can be used to provide endo luminal vascular tamponade.[23]

Primary repair, after exposure and control are obtained, can frequently be performed. When primary repair cannot be achieved a graft should be placed. For vessels greater than 5 mm, polytetrafluoroethylene or knitted Dacron are the conduits of choice. [16,32,34] If the patient is in extremis and there is not enough time to suture a graft in place, an option is to place a temporary shunt. An Argyle carotid shunt can be placed into the vessel as a temporary measure with plans of later repair when the patient has been physiologically captured.[13,14,18] Dr. Wall et al. describes the use of a chest tube to shunt the aorta.[32] With respect to difficult subclavian artery injuries, if there is no time to place a shunt and the patient is dying, the subclavian artery can be ligated. The incidence of ischaemia to the ipsilateral limb is low.

Injuries to the jugular or innominate vein can be repaired with lateral venorraphy or ligated with impunity. Injuries to the vena cava can also be shunted if repair or reconstruction is not possible.

Tracheobronchial injury

The distal half of the trachea is located intrathoracically. Injury to the tracheobronchial tree is rare. Blunt trauma is the most frequent cause of trauma to this region of the trachea, however as discussed earlier, emergent thoracotomy for blunt trauma is almost always futile due to other associated injuries. Approximately 18% of distal tracheal or bronchial injuries are due to penetrating trauma.[1,17] As with any trauma patient an airway should be secured prior to other interventions. In emergent situations, where tracheal injury is suspected, this can be accomplished by the placement of the endotracheal tube surgically through the wound tract. In the setting of a damage control procedure with a secured airway and a bronchial injury, early clamping of the hilum of the lung can stop an air leak. Injuries to the trachea can be repaired primarily without tension. Monofilament suture is used in a running fashion either through or around the tracheal rings making sure that there is mucosa to mucosa approximation. The knots should be placed on the outside of the airway to reduce the likelihood of suture granuloma or stricture. A vascular pedicle, such as intercostal muscle, should be used to buttress the repair to decrease the likelihood of leak or fistula formation. In times of extremis bronchial injuries should be treated with lobectomy or pneumonectomy.

Oesophageal injury

The majority of oesophageal injuries are a result of gun shot wounds. Blunt oesophageal injury is exceedingly rare. The treatment should be primary repair if less than 50% of the circumference is injured. The repair should be reinforced with pleura, intercostal muscle, pericardium, or omentum. If the injury is greater than 50% circumference, exclusion with a cervical esophagostomy and a gastrostomy tube, which can be placed once physiologic order has been restored is one option. A second is placement of a salem sump in the oesophagus just proximal to the injury and as with all forms of treatment of oesophageal injury, whether by primarily repaired or not, wide drainage with a thoracostomy tube. The latter is the preferred choice in the patient with an oesophageal injury who has exhausted physiologic reserve. At the definitive operation the surgeon will decide whether primary repair or diversion should be performed based on timing as well as tissue appearance and the surrounding inflammatory response, though a conservative approach is the safest.

Intraoperative coagulopathy

The management of ongoing bleeding or ''oozing'' in the cold, coagulopathic patient with intra-abdominal trauma is frequently managed by packing off the abdomen and providing some form of biological dressing to the abdomen. Once this is achieved the patient is taken for arteriogram to embolize bleeding vessels or to the intensive care unit for warming, correcting coagulopathy and resuscitating the patient. This is rarely an option in thoracic injuries. Cardiopulmonary physiology with the irritability of the cold heart and the ventilatory requirements preclude tight packing of the thoracic cavity. With the exception of the apex of the mediastinum and the deep sulcus of the thoracic cavity, packing cannot be achieved without causing the potential for either cardiac or pulmonary collapse. Therefore, alternative methods of controlling surgical bleeding must be employed.

Temporary thoracic closure

Closure of a damage control thoracotomy can present perplexing problems. Frequently once intrathoracic bleeding has been alleviated the major source of blood loss comes from the vascular thoracic wall. The cold, coagulopathic patient may have surgical or non-surgical bleeding coming from this source. In times of extremis, towel clips can be placed across the incision to temporarily close the thoracic cavity so as to decrease heat loss. However, towel clips do not provide for hemostasis of the chest wall and make arteriography challenging if required. A second option, if physiology allows, is an en masse closure taking the thoracic cage, muscles and skin in a running interlocking suture, which provides better hemostasis of the thoracic wall. Closure of the chest wall by either of these methods may not be tolerated by the irritable, distended heart. This will present upon closure as hypotension from poor cardiac output or inability to ventilate the patient. In such situations another option is to use a ''Bogota bag'' to provide a temporary covering without exerting undue intrathoracic pressure.[29,31]

Postoperative care in the intensive care unit

The postoperative care can be as challenging as the initial operation if not more. The main points of part two of damage control can be applied here with rewarming, correcting coagulopathy and resuscitation.[6,22] If arteriography is necessary for bleeding, this should be accomplished prior to transfer to the intensive care unit. Patients with lung injuries that have been managed by pneumonorraphy, wedge resection, or tractotomy should have aggressive pulmonary toilet with therapeutic bronchoscopies as necessary. Attempts should be made to keep these patients a little on the ''dry'' side in attempts to prevent further lung injury while still providing adequate resuscitation.[32]

Ongoing bleeding in the intensive care unit is a very challenging problem in this patient population. It is very difficult to elucidate whether the bleeding is surgical in nature or due to the patient being cold and coagulopathic. The patient who has ongoing surgical bleeding may not correct the coagulopathy or normalise temperature. However, returning an unstable patient to the operating room for non-surgical bleeding can be fatal. This decision is one made by the surgeon based on judgement.

In patients who have had temporising procedures, such as shunting of vasculature, ligation of vasculature with planned bypass, or those requiring more formal oesophageal repair, they should return to the operating room once physiologic criteria have been restored. Haemostasis and closure of the thoracic wall in the standard fashion can be accomplished at this time. At least two large thoracostomy tubes should be placed. We like to place an angled tube over the diaphragm and a second straight tube at the apex of the thoracic cavity. Other tubes should be placed in accordance with the injuries being treated.

Complications

Two common complications that are unique to this patient population are cardiac tamponade and air leak. Cardiac tamponade presents as hypotension, jugular venous distension and muffled heart sounds. If a pulmonary artery catheter is present, equalisation of pulmonary and systemic pressures may be seen. Echocardiography can be of value in making the diagnosis. Treatment consists of opening the wound to release the tamponade. Air leaks should be attempted to be managed conservatively with thoracostomy tube drainage. Persistent leaks may require re-operation with repair or resection of the involved lung parenchyma. The use of high frequency oscillating ventilators may reduce the transbronchial pressures thereby allowing for these leaks to resolve, but it only theoretical at this point without any defined studies.

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