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Torso damage control for ongoing hemorrhage: Tips and tricks

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ABSTRACT

Thoracic injuries are common and occur in combination with other injuries in various compartments representing a significant pattern of injury in any trauma center. Injured patients presenting with exsanguinating hemorrhage from the thoracic cavity are an acute subset of patients that can be extremely challenging to any trauma surgeon as the immediate need to diagnose and intervene is critical. Diagnosis is based on traumatic history pattern and hemodynamics, assisted with plain films, ultra-sound and properly placed chest tubes. The chest should always be considered as a source of unexplained hemodynamic instability with hemorrhage identification by tube thoracostomy, pericardial window or surgical thoracotomy if the patient is already in the OR or if imaging is not available. Various surgical incisions are possible for thoracic traumatic bleeding with various exposure advantages and disadvantages with care and thought prior to incision. Regardless, delay to intervention or trepidation is lethal particularly in these challenging trauma patients.

Thoracic injuries are common and occur in combination with other injuries in various compartments representing a significant pattern of injury in any trauma center. Injured patients presenting with exsanguinating hemorrhage from the thoracic cavity are an acute subset of patients that can be extremely challenging to any trauma surgeon as the immediate need to diagnose and intervene is critical [1]. General surgeons are quite comfortable and confident entering the abdomen for bleeding. The chest, however, may not be as familiar depending on the surgeon, hospital setting, or practice patterns. Time for consultation with CV or specialist surgeons may not be available or appropriate, and although damage control of the abdomen is routine, damage control of the chest may only be a rare entity in all but the worst of trauma cases.

The goal with this review is to allow for a framework for various strategies and considerations when dealing with exsanguinating thoracic trauma as well as several methods to damage control of the chest should it be required. Technical details of managing cardiac and pulmonary bleeding will be discussed separately. Furthermore, this review is framed to be helpful from the perspective of a general surgeon taking trauma call who will perform and guide the operative approach and damage control closure if indicated. The cognitive decision-making process in managing the acute patient is emphasized as most important as opposed to considering thoracic trauma as merely a technical endeavor.

IDENTIFYING THORACIC HEMORRHAGE: YOU THINK IT WOULD BE EASY

Identifying thoracic hemorrhage in the chest is the first step prior to any operative approach discussion and is a dynamic interplay of the patient's physiology, clinical examination, plain x-rays, and ultrasound as well as simple thoracic interventions such as needle or tube thoracostomy. Termed *occult*, injuries of the heart [2], great vessels, or large named vessels occur with regularity in some centers. Related to short prehospital times, supine positioning on transport, or other factors, a certain amount of time is required for physiologic changes to be evident. The patient's hemodynamic status, respiratory physiology, and chest x-ray guide the initial management with the assistance of ultrasound. Most important, however, the practitioner must remain vigilant that a problem is occurring and should only be later reassured as information is collected.

Needle and tube thoracostomies are common interventions when thoracic trauma is apparent and indication for drainage or evacuation of air or both is present [3]. The utility of a properly placed chest tube in thoracic trauma patients cannot be understated. Tube thoracostomy must be considered a potentially therapeutic procedure as well as a diagnostic intervention. The patient's physiologic response, or lack of, as well as the amount and character of drainage, is imperative in the initial triage of thoracic injury. Post chest tube CXR, if possible, will further add context to the patient's current condition and potential for deterioration. Operative triggers based on drainage volume over time provide initial guidance; however, the decision to intervene surgically is complex and may be outside (above or below) simple parameters. The

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trauma surgeon must focus not only on the chest tube output but on all of the information that is occurring around this relatively straightforward intervention.

Tips. A properly placed chest tube is more often therapeutic, and no further intervention is needed.
- Chest tube outputs of 1500 mL or 200/h suggest bleeding from a named vessel or structure; however, it is always the patient's physiology that guides the operative plan.
- Consider chest tubes as a diagnostic intervention in context with the post placement CXR.
- A gum elastic bougie can be used to "Seldinger technique" a chest tube in individuals who are obese or where the chest tube is to be guided to a specific region of the hemithorax.
- Consider gentle Yankauer suction of the hemithorax prior to placing the chest tube if a stable retained hemothorax is present.

I THINK WE HAVE A BLEEDING PROBLEM. HOW AM I GOING TO DEAL WITH THIS?

When dealing with exsanguinating thoracic trauma, the first question that the trauma surgeon needs to ask is as follows: what is/are the most likely source of bleeding and what are the potential surgical incisions to expose and control or manage that bleeding? Unlike the abdomen, the choice of thoracic cavity incision in trauma needs to be deliberate because a suboptimal decision will not allow visualization of the problem structure or, at minimum, pose a significant exposure penalty.

The decision-making process in real time, for true hemorrhage from the torso, is complex because information is not always apparent or interpreted correctly. The surgeon may also be reluctant to acknowledge the chest as the source of potential bleeding due to unfamiliarity. Patients with thoracic hemorrhage may have a normal-appearing hemodynamic status only to deteriorate in minutes or after an intervention such as intubation [4]. Should bleeding be suspected, the perception of time required for definitive control may or may not be accurate, and allowances to change course should not reflect indecision but adaptation to the current patient situation. At minimum, the trauma surgeon should prepare a cognitive algorithm for thoracic incision choice and strategies based on multiple levels of patient acuity and anticipate any system challenges.

Finally, the thoracic incision choice in trauma could be best articulated as "choosing the *best* incision to expose the *most likely* bleeding structure within the *time* allowance of the patient's physiology." With this in mind, various scenarios will be covered that should highlight the previous statement and allow for guidance or consideration.

PATIENT PROGRESSING TO ARREST: BLUNT OR PENETRATING INJURIES: THIS IS EASY

Indications for thoracotomy in the ER are well published and are generally accepted with some allowances [5,6]. Depending on the institution, this may or may not be a common procedure, and the various health professionals involved may have designated roles or instructions to follow. The necessary equipment to perform the procedure should be routinely checked. Because the trauma surgeon is most likely to be directly performing or guiding the procedure, the task at hand is not only the thoracotomy procedure but to maintain "situational awareness," remaining cognizant of the patient's resuscitation and safety of surrounding personnel.

To achieve the objectives of a resuscitative thoracotomy, a proper incision over the fourth intercostal space or just below the inframammary crease. The incision should be started near midline over the manubrium, along the crease, and essentially to the axilla. There is a tendency to extend straight down or inferior/posterior as opposed to curving into the axilla, leading to a low thoracotomy. Although the anatomy is consistent, there can be significant variety in patient body habitus, leading to challenging exposure of desired anatomy for even the most seasoned surgeon. Once inside the chest, expanding lung during breaths confirms intubation (which may have been chaotic), and the surgeon is scanning for an obvious source of bleeding and activity status of the heart within the pericardial sac. If the heart is poorly visualized due to incision or body habitus or if a cardiac intervention is required, extending the thoracotomy by dividing the manubrium with scissors, bone cutters, or Lebsche knife allows for a significant improvement in exposure and working room of the heart. Note that if the abdominal cavity is full of blood or if the thoracotomy is performed in a lower intercostal space, the diaphragm can be quite elevated in the chest, leading to some confusion and difficulty identifying structures. The presence of blood or a bulging pericardium will lead to immediate opening of the sac to relieve the tamponade or examination and repair prior to clamping the aorta. Lack of findings or trauma to the pericardium will lead to clamping the aorta as the injuries are sorted to preserve blood flow to vital structures. At minimum, the order of interventions once in the chest, followed by what to do if physiology is restored, should be deliberate by the trauma surgeon.

STABLE PATIENT: BLUNT OR PENETRATING CHEST INJURIES. THIS IS EASY

The utility of a CT chest with contrast in trauma patients allows for a large amount of information and accurate diagnosis of injuries. Provided the patient is hemodynamically normal and not deteriorating, imaging of the aorta as well as subclavian and thoracic outlet at the neck is extremely useful in penetrating injuries in this topographical area. Arterial injuries can be contained and, if able, best managed by endovascular means [7]. The allure of "information" must not deter a clear operative indication particularly if hemodynamics suggest possible ongoing hemorrhage.

Tip. Make sure the contrast injection is on the opposite vein from the arterial imaging of the subclavian artery desired.

THE UNSTABLE DETERIORATING PATIENT WITH THORACIC TRAUMA. I HAVE A PLAN SO THAT YOU WON'T DIE FROM HEMORRHAGE

Thus far, no distinction between penetrating and blunt injuries has been made, as the initial management parallel each other well. Severe blunt injuries may be significantly more challenging because the global injury burden to the entire body is often high and not in isolation to the chest. Any severe blunt trauma to the chest can lead to exsanguination from any and all large vessels, lung, and thoracic wall as well as bleeding from herniated liver or abdominal viscera from the abdomen. Herniated cardiac injuries are well reported as well as blunt perforation of the various heart chambers. Rib fractures and the associated impact or compression into the chest cavity are known to lacerate the lung and even perforate the heart. The trauma surgeons may find themselves in the OR for abdominal or other operative indications with hemodynamic instability that is not easily explained. The trauma surgeons need to consider the chest as the cause of this instability. Finger thoracostomy with additional chest tubes, minithoracotomy, and pericardial window (through the central tendon of the diaphragm during laparotomy) are perfectly acceptable to rule out the chest as a source of hemorrhage.

Anterior Thoracotomy. From a practical trauma perspective, the left anterior thoracotomy allows visualization of the left lung, posterior thoracic wall and spine, descending aorta, and the pericardium. If a concomitant laparotomy is required, positioning is assisted with several bumped behind the left chest and shoulder to slightly rotate the patient medially to improve exposure and allow better prep and draping

posteriorly. With a couple degrees of additional rotation, the exposure within the thorax can be greatly improved. Care must be taken to elevate the arm to a neutral position and not stretch the brachial plexus at the shoulder. At minimum, positioning and prepping the chest posteriorly will allow prompt access at a time it may be needed the most or placement of chest tube intraop.

A right thoracotomy as an initial step of managing an unstable trauma patient can certainly be indicated; however, some pause is generally taken, as there are limited visualization and surgical access to critical structures such as the heart or upper mediastinum without additional maneuvering. Generally, if there is pulmonary bleeding or bleeding from the thoracic wall of the right hemithorax, starting with a right thoracotomy is reasonable. With initial temporization, the incision can be extended to expose the bleeding structure. Occasionally, brisk liver bleeding into the chest can occur from a missile trajectory through the thoracoabdominal region. Analogous to an ED thoracotomy, extending the incision to T to a laparotomy or sternotomy or dividing the manubrium can allow improved visualization.

Thoracic junctional traumas in the area of the clavicle are some of the most challenging injuries for surgeons to deal with. Penetrating injuries within these areas with hemodynamic changes or opacified hemithorax on CXR indicate a high probability that immediate surgery is required. Delaying surgical intervention with additional chest tubes, intubation, or repeat imaging must be avoided by the trauma surgeon leading the team. Should the decision for surgery be pursued, a generous and "high," usually the fourth intercostal space, thoracotomy (right or left depending on the injury) will allow for initial packing and direct pressure to the subclavian vessels superior within the hemithorax or direct clamp placement if visualized. An anterior thoracotomy is less than ideal for a definitive repair of vascular structures; however, it is a lifesaving strategy to temporize as standard clavicular incisions or sternotomy is performed.

Clamshell. Extending thoracotomy to a clamshell is technically straightforward, mirroring the incision performed to the contralateral hemithorax. The decision to extend may vary from patient to patient. Extension allows for excellent visualization and management of cardiac wounds and pulmonary hilum injuries as well as visualization and initial surgical control of the great vessels and upper mediastinum. Technical tips: When extending the contralateral thoracotomy, extending superiorly by a rib space or two will greatly assist in visualization of upper mediastinal or subclavian injuries should they be suspected. The great vessels and upper mediastinum are invested in thymus and connective tissues which need to be gently or bluntly swept off the manubrium and surrounding thoracic cage to allow for identification of the bleeding vessel. Well described in trauma technical chapters, the left innominate vein may need to be identified, exposed, and divided to expose the proximal take-off of the great vessels from the arch of the aorta. Prompt division of the innominate vein cannot be stressed enough because there may be a tendency to persist with retraction or other interventions in an attempt to control arterial bleeding. The left innominate vein can be elusive in its initial appearance based on the patient's volume status and the tissues investing the area. Once identified, two clamps or a vascular stapler will open the field posteriorly for visualization of the arch or the aorta. Note that there is diminishing visualization in the superior mediastinum as you approach the fulcrum of the thoracic inlet with a clamshell. Sternotomy to open the thoracic cage may need to be considered.

Sternotomy. All surgeons taking trauma call must be familiar with and prepared for performing a sternotomy regardless of practice patterns. Cardiac tamponade from a precordial stab wounds is an extremely salvageable subset of penetrating injuries provided a surgical intervention is promptly performed. Tips: Mark the upper notch and lower xiphoid process, and maintain a mental image to stay midline as possible. Divide subcutaneous tissues with cautery to expose and score the manubrium along the midline. The upper manubrium must be freed of any ligamentous tissues, as the sternal saw will not divide this well and may get hung up. Bluntly removing the attachments to the upper sternum works well with gentle cautery. Note that in true cardiac tamponade, the venous structures of the neck are dilated and engorged and can lead to impressive venous bleeding from the anterior jugular or other veins. Do not persist in attempting to control venous bleeding and simply proceed with the sternotomy. Relieving the tamponade will lead to normalization of pressures and resolution of venous bleeding or easier identification of any additional nuisance bleeding vessels. Any remaining inferior ligamentous attachments can be divided with scissors. Lap pads can be placed on either side of the sternum for the marrow to tamponade prior to placement of the retractor. The pericardium can then be opened sharply in the setting of tamponade and incised inferiorly and superiorly to allow visualization of the heart. With the urgency of the interventions needed in trauma, the pericardium is not sewn to the surrounding areas like in elective surgery. The pleural cavity can be entered bilaterally from a sternotomy and hemothorax drained. Visualization of structures other than the medial lungs and hilum is not possible.

DAMAGE CONTROL OF THE CHEST

Temporary closure of the chest for trauma is a required skill for trauma surgeons and a reflection of prudent decision prior to physiological exhaustion of the trauma patient [8]. The most common indication for damage control of the chest is coagulopathy of trauma where the primary goal transitions to restoration of physiology as opposed to definitive surgical endeavors. Second look of cardiac, lung, or mediastinal repairs may be indicated. Damage control of the chest is analogous to damage control laparotomy; however, unlike the abdomen, free movement of the lung and heart is required, and temporary pack placement into bony or thoracic wall defects may not work as well given the expansion space and collapsible lung. Liberal use of hemostatic agents is of great assistance.

Several options for temporary closure of a thoracotomy are available with the goal of physical tamponade of bleeding surfaces, movement of the heart and lungs, drainage of accumulating blood, and protective covering of the thoracic cavity. No specific commercial product is available for this purpose, and any temporary closure is improvised to achieve the goals of damage control. A few technical notes: The internal mammary artery (IMA) **must** be confirmed to be controlled, as it is transected in the resuscitative procedure and may not have bled initially to draw the need for surgical control. The bleeding IMA can be subtle with a large volume over time often without a significant spurting to draw the surgeon's attention. Depending on the patient's body habitus, the muscle edges or the raw intercostal muscle surfaces at the posterior aspect of the thoracotomy can be packed with a suitable number of packs and hemostatic agents. A chest tube should be placed if not present already. Removal of the Finochietto allows the chest cavity to recoil closed over the packs to a certain extent. Further packs can then be placed in the wound, and the skin can closed temporarily with a running suture. Leaving the skin open is a reasonable option if reintervention or reopening the chest is anticipated such as during intermittent arrest requiring cardiac massage or if significant coagulopathic bleeding is occurring. Securing and achieving suction with a VAC are not possible, and so Ioban can be used. If the bleeding is not significant, a temporary closure by placement of a saline bag opened and stapled (Bogota bag) allows for a direct window to the patient's cardiac status. This is easily opened and closed in the ICU setting if required.

Closure of the damage controlled chest should be as soon as possible, which leads to fewer complications or concerns for infection, generally within 12–24 hours if possible. Saline cleansing and debridement or removal of any nonviable tissue is all that is required. Any hemostatic

agents should be washed or removed. Sternal closure with wire is standard, although newer devices are now available that resorb. Subcutaneous tissues to cover bone and deep tissues should be approximated minimizing any dead space. The skin can be left open or loosely approximated because superficial surgical site infection may occur. Postoperatively, these wounds **must** be closely examined for any infection and opened if indicated.

Temporary closure of the sternum and sternotomy is safe and may not lead to significant increase in complications such as osteomyelitis if closed promptly within 24 hours. After all attempts at cautery of the skin edges and marrow have been made, 2–3 lap pads can be placed with the goal to be in contact with any raw surfaces. Ioban can be used to secure the packs and close the wound. Chest or mediastinal tubes are not required and may be left for the definitive closure. Should accumulation of blood occur, the dressing can be removed or incised open at the bedside.

SUMMARY

In conclusion, traumatic thoracic hemorrhage must be promptly identified and intervened upon when indicated for the patient to have the best chance of survival. Diagnosis is based on traumatic history pattern and hemodynamics, assisted with plain films and properly placed chest tubes. The chest should always be considered as a source of unexplained hemodynamic instability with hemorrhage identification by tube thoracostomy, pericardial window, or surgical thoracotomy if the patient is already in the OR or if imaging is not available. Delay to intervention or trepidation is lethal in hemorrhaging patients.

Surgical incision options for the chest in trauma generally consist of left and right anterior thoracotomy, and sternotomy with possible extension to include others to properly expose the bleeding structure. The first and critical decision to be made is a thought process of what structure(s) is likely bleeding and how best to expose that structure. Optimal intercostal rib space entry will significantly facilitate surgical exposure. Nonstandard exposures, trap door, or invasive dissections may be indicated depending on the wound pattern with the sole goal to control bleeding.

Temporary closure or damage control of the thoracic cavity may be indicated particularly when coagulopathy of trauma is occurring or when time for a definitive closure of the chest is not possible. Raw surfaces and incision lines should have packs or hemostatic agents directly in contact to promote hemostasis while allowing lung and cardiac expansion. Temporary skin closure directly with suture, Ioban wrap, or Bogota (saline bag) stapled are options, with the latter being easier to remove for ICU interventions. The chest should be closed in 12–24 hours if at all possible or as soon as the patient's physiology allows for return to the OR. No alteration in closure technique is generally indicated other than consideration to leave skin open or loosely closed and close surveillance post op for surgical site infections.

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