IMAGING DIAGNOSIS OF THORACIC AORTA AND GREAT VESSEL INJURY

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INTRODUCTION

The rapid diagnosis of traumatic injury to the aorta and its major branches following major blunt trauma is both extremely urgent and potentially challenging. The combination of the relative rarity of the injury (< 0.5%)of major trauma admissions, and high lethality when not treated (40% mortality by 24 hr. post injury) creates this demanding clinical situation. The advent of newer imaging modalities including multi-detector row helical CT (MDCT), intravascular and transesophageal sonography, and occasionally magnetic resonance imaging have been key factors in establishing the diagnosis with higher accuracy and in less time than had been true prior to application of these techniques. Still, in most centers, the chest radiograph continues to serve as the initial diagnostic study for detecting evidence of injury within the mediastinum. This remains a very sensitive study for detection of mediastinal hemorrhage and potential aortic injury, but is significantly impaired by its low specificity. MDCT has rapidly become the secondary study obtained for patients with radiographic abnormalities of the mediastinal contour replacing the previous "gold standard" thoracic angiography in many institutions. As described below, the high sensitivity of MDCT has increased the recognized spectrum of aortic and great vessels injuries and increased the potential for selective non-surgical management of some injuries.

HOW TO USE THE CHEST RADIOGRAPH

Most acute blunt trauma victims who are hemodynamically stable will undergo a chest radiograph among several routine admission studies. The chest radiograph can detect a number of immediately life-threatening traumatic pathologies including gross hemothorax, tension pneumothorax, tension pneumopericardium, and ruptured diaphragm with massive herniation. Careful inspection of the mediastinum is required to detect contour abnormalities that suggest hemorrhage. Over the past decades many radiologic findings have been described to indicate a high likelihood of mediastinal hematoma. A mediastinal diameter at the level of the arch of greater than 8cm (widened mediastinum), or a mediastinal: chest width ratio of >0.25% at the same level have been popular, though unreliable, indicators for further investigation for potential aortic injury.

It is the disturbance of the normal shadows of the mediastinal contour, such as an obscured aortic arch or descending aorta, or an abnormal coutour of the arch, loss of the aortico-pulmonary window, widening of the left paraspinal stripe or its extension to the left extra-pleural apex, and right paratracheal soft tissue density that most accurately indicate potential mediastinal hematoma. Unfortunately, this approach requires a well-established knowledge of radiographic anatomy, experience in interpreting a large number of chest radiographs in trauma patients, and specific experience with radiographs of patients with mediastinal hemorrhage. Large series have verified the limited utility of simple quantitative measures of the mediastinal diameter to guide management.

The presence of a mediastinal contour abnormality is still a very non-specific finding for major thoracic arterial injury. A number of reasons account for this limitation among them; limited quality of portable radiographs, sub optimal or lack of patient cooperation, magnification and distortion of mediastinal silhouettes related to the supine view, non-traumatic causes of mediastinal contour abnormality such as lymphadenopathy, mediastinal lipomatosis, vascular ectasia, and aberrant vascular branching among others. In many cases the mediastinal contour is altered by both traumatic and non-traumatic entities. In trauma patients, common sources of obscuration of the mediastinal margins include atelectasis, medial pleural effusions, and lung contusions and hematomas. Another serious limitation of chest radiography in the diagnosis of traumatic aortic injury (TAI) is the fact that most patients (approx. 80%) with mediastinal hemorrhage will not actually have a major thoracic arterial injury. Thus, even if all patients with true mediastinal hemorrhage could be selected by radiography, the true positive rate would only reach 20% for vascular injury.

The use of erect or true erect (leaning forward 15 degrees) can improve on the specificity of the chest radiograph and can often show a normal mediastinal contour when the supine view appears abnormal. A chest radiograph with a normal mediastinal contour for age has at least a 98% negative predictive value for TAI. Again, the accurate interpretation of the chest radiograph and the decision to accept it has showing a normal mediastinum or to go on to further imaging is vitally important and requires both experience and confidence.

THORACIC CT'S EMERGENCE IN DIAGNOSING MAJOR VASCULAR INJURY

Beginning in 1983, numerous studies have appeared in the literature describing the use of computed tomography to diagnose TAI. Of course, the earliest papers included relatively small series and used the relatively slow, low-resolution conventional CT systems of the early to mid-1980s. Naturally, these early attempts at "CT-angiography" using 8 – 10mm slice thickness were limited, but still clearly showed that aortic injuries could be diagnosed with CT. The issue of overall accuracy was still open to question. Over the next 15 years debate among surgeons and cross-sectional imagers raged over the true accuracy of CT and whether high accuracy could be achieved routinely or only in specialized trauma centers. The time-honored "gold standard" of thoracic angiography remained firmly in place in many institutions. A number of issues crystallized as this debate continued. It was obvious that angiography was invasive, costly, and difficult to initiate quickly. In most polytrauma cases, CT scans were already indicated for assessment of other body regions. Finally, it became clear with careful review that thoracic angiography for aortic injury was often both challenging for interpretation and occasionally incorrect diagnostically. With the advent of multi-detector CT and the potential to create angiographic-like images of the aorta and its major branches the pendulum for most trauma centers swung towards MDCT as the test of choice in stable blunt trauma patients without a clearly normal mediastinal contour by chest radiography.

CT TECHNIQUE AND FINDINGS IN AORTIC AND MAJOR BRANCH VESSEL INJURY

The diagnostic accuracy of CT for thoracic aortic and major branch vessel injury steadily improves as one moves from single-slice helical to 4-row, and subsequently 16-row MDCT. At each step image quality is improved both by use of thinner axial slices and decreased motion artifact. The quality of multiplanar reformations (MPRs) in any orthogonal axis or in the curved axis of the aorta and its first-order branches improves similarly with use of thin (1-2mm) and overlapping axial slices. In my practice, we perform the thoracic CT with a 16-slice scanner using the 16 X 1.5 mm detector array, 0.75 sec. scan time, and pitch varying from 1 to 1.2. Axial mages are usually viewed with fusion of three 1.5mm images, which are subsequently saved to PACS. If needed the axial 1.5 mm images our available for three days on-line. All reformations are acquired using the original 1.5mm axial images. All thoracic studies are performed with intravenous contrast enhancement using automated bolus triggering. The chest images are routinely viewed in soft tissue, lung, and bone windows. For general blunt trauma cases reformatted studies are not obtained unless the study is positive and further elucidation of the injury is needed.

Almost all TAIs are associated with hemorrhage around the aorta or its proximal branches. The quantity of mediastinal hemorrhage can range from minimal and focal to abundant and diffuse. Periaortic hemorrhage may also spread through the diaphragmatic hiatus to the abdominal aorta and may indicate thoracic aortic injury from an abdominal CT. This is one sign seen on an abdominal CT that should initiate a mandatory evaluation of the thoracic aorta.

A number of direct signs of aortic and proximal branch vessel injury can be observed on contrast-enhanced MDCT. In the most typical case a pseudoaneurysm or contained partial aortic wall tear is seen at the level of the left mainstem bronchus and left pulmonary artery projecting anteriorly from the aorta. This region is believed to be prone to injury through shearing effects and stretching, compression, and torsion. Also, the relative disorganization of the elastic lamina at the level of the remnant ductus arteriosus may create a local weakness in the wall at this level. The pseudoaneurysm is usually delineated by intimal flaps on either side and may be larger in size than the true aortic lumen. The pseudoaneurysm is usually relatively small in longitudinal extent and diameter (1-3 cm), with an acute angle with the aortic wall, and smooth exterior surface.

The second most common site of injury is the ascending aorta just above the valve ring. This site is seldom seen clinically due to its high early mortality. Other sites of potential injury include the aortic arch, arch – branch vessel origins, and descending aorta. In the author's experience, injuries to the arch itself are more common in elderly individuals with ecstatic aortas than is seen in a younger population.

When the aortic pseudoaneurysm is large it may indent the lumen of the aorta and produce a coarctation leading to decreased perfusion below the level of injury. This finding is manifest as a sudden decrease in the diameter of the aorta along a segment without major branches. The descending and abdominal aorta will appear smaller in caliber than would be expected. Clinically there will be a decrease in blood pressure and pulse strength in the lower extremity. A small-appearing abdominal aorta is another CT sign that should prompt assessment of the thorax in a blunt trauma patient. Pseudocoarctation occurs in about 10% of cases of TAI. Other signs of direct aortic injury on CT include an irregularly shaped lumen, one or more linear filling defects due to intima flaps, intraluminal blood clot, sudden narrowing of the luminal caliber as noted above, and rarely extravasation of intravenous contrast into the periaortic hematoma. In most cases these injuries are quite apparent on high-quality multidetector row systems. If there are no direct findings on the axial images, but there is periaortic or great vessel blood, then thin-slice multiplanar reformations (MPR) along the aortic and great vessel axes should be obtained, as these can enhance appreciation of injuries that may be subtle on axial views alone. When there are direct findings of aortic and branch vessel injury further assessment by MPR along the major vascular axes is also valuable to demonstrate the injury in relation to other vessels. On occasion, I have found endoluminal (angioscopic) views helpful in verifying subtle injuries. The term traumatic aortic dissection is not appropriate for most aortic injuries. These injuries may contain a short segment where blood under pressure dissects into an otherwise normal aortic media, but this is not a principal feature of the injury. In rare cases I have seen long medial or sub-adventitial dissections within a normal aorta resulting from blunt trauma that extent from the thoracic aortic tear into the abdominal aorta, but these are exceptional injuries.

To be of true value, the MDCT study of the aorta should not only demonstrate the presence of an injury, but also characterize its severity, size, and extent. A small intimal irregularity may be managed effectively by blood pressure control and observation where as large pseudoaneurysm will typically be managed surgically, or in some centres by end vascular stinting. It is vital to show the relationship of the injury to adjacent branches, the branching pattern that will be encountered at surgery, and the existence of more than one site of injury. While a typical proximal descending aorta repair will be performed through a posterior left thoracotomy, an arch or proximal branch vessel injury requires a median sternotomy for adequate exposure, but would be sub-optimal for the typical injury site. MPR, surface contour, and volumetric images are usually best to display the relationship of an aortic or branch injury to the surrounding vascular and non-vascular structures. The precise distance from the edges of the injury to adjacent arterial branches is helpful in planning endovascular stent placement when appropriate.

SHOULD AORTOGRAPHY BE PERFORMED?

The use of aortography has diminished with the ascent of MDCT for trauma imaging. Still aortagraphy can have a role, but should be used selectively. If a good quality MDCT shows normal vasculature without hemorrhage around the major thoracic arteries, no further studies are required. In cases where there is perivascular blood, but normal vessels on MDCT the decision of how to proceed is based on experience in the institution. Individuals with wide experience in chest CT interpretation for trauma may confidently consider the study normal for the vessels and not proceed to further investigation. Those with lesser experience may opt to perform other studies such as aortography or intravascular / transesophageal sonography. The decision of which study to obtain should be made based on experience of the examiner availability. It should rarely be necessary to perform an “exploratory thoracotomy” given current diagnostic capabilities. In patients with unequivocally positive studies for one or more injuries it should not be necessary to perform aortography, and in fact introduces a potentially long delay in initiating surgical care. Blood pressure control should be an immediate step in management once a possible aortic injury is seen, but this is not a foolproof method to avoid a sudden complete tear, free hemorrage, and rapid exanguination. Any question of active bleeding from the aorta into the mediastinal hematoma should demand immediate thoracic surgery as this situation can become rapidly fatal. It seems prudent that the urgency for definitive diagnosis of a major intrathoracic aortic branch vessel injury should be the same as for the thoracic aorta, although the natural history of these injuries is less well known.

WHAT ARE THE PITFALLS IN THE MDCT DIAGNOSIS OF AORTIC?

As in all diagnostic studies increased use and familiarity with the method uncovers new difficulties. Technical problems in performing the enhanced thoracic CT will limit the utility of the study, but even a complete lack of intravenous contrast should allow the diagnosis or exclusion of mediastinal hemorrhage and thus lead to the correct next step. A number of situations can confound interpretation of even well performed MDCT studies. Among these are very subtle injuries, a background of severe atherosclerotic disease with ulceration, variants in vascular branching and diverticular branch vessel origins, as well as the ductus diverticulum. Similarly, a diverticular origin of the bronchial artery can mimic an injured aorta. A traumatic pseudoaneurysm and inflammatory aortic ulceration could appear similar although the former is typically in the proximal and the latter in the mid-descending aorta. The presence of concurrent mediastinal blood would of course favor a traumatic etiology of a questionableaortic wall abnormality. Thoracic angiography can also present difficulties for interpretation of some of these entities and may entirely miss an injury that is not shown in profile. Again, MDCT is complimentary with angiography and sonography and these studies can be helpful if the MDCT is equivocal.

HOW WILL IMAGING IMPACT THE FUTURE OF TREATMENT OF MAJOR THORACIC ARTERIAL INJURY?

Just as diagnostic capabilities for detection of major thoracic arterial injuries have grown significantly in the last decade so has the range of treatment options. Traditionally, most centers will urgently undertake surgical repair of these arterial injuries under partial or complete bypass to avoid sudden complete vessel wall rupture. More recently, non-operative management using blood pressure control and serial observation has been shown as a viable alternative. Also, endovascular stent placement, to protect the injured area while maintaining major branch perfusion, has been more commonly utilized either as a temporizing or definitive treatment. While several clinical factors bear on the decision as to what approach to use such as age, associated injuries, high-risk pre-morbid conditions, as well as local facilities and expertise and the nature and extent of the injury will also influence this decision. In the future the precise grading of major arterial injuries by MDCT as has been proposed previously should be performed in an effort to scale management of a given injury to an appropriate level of intervention to achieve successful long-term treatment.

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