Traumatic aortic injury (TAI) due to blunt trauma remains a highly lethal injury. It is reported to occur in 0.8% of motor vehicle collisions and to account for 16% of the fatalities from motor vehicle accidents.\textsuperscript{1,2} Mortality at the scene has been reported as 80% in autopsy series.\textsuperscript{3} Although it accounts for less than 1% of the trauma admissions to level I trauma centers, TAI represents the second most common cause of death due to blunt trauma after head injury.\textsuperscript{4} The region most susceptible to injury is the isthmus, where the relatively mobile thoracic aorta joins the fixed arch and the insertion of the ligamentum arteriosus.\textsuperscript{5,6} Aortic ruptures have been reported to occur at this site in 90 to 95% of cases. The therapeutic approach to these patients is increasingly controversial with regard to the timing of surgical or endovascular intervention versus close follow-up for minimal injuries. Recently, endovascular techniques have been used with success in the treatment of aortic injuries.\textsuperscript{4,7-16} Emergent surgical exploration has historically been advocated as the appropriate treatment for patients who present with a traumatic aortic injury.\textsuperscript{8} Endovascular repair is an especially attractive treatment modality in patients who have severe concomitant injuries, as it is a less invasive technique than conventional surgery.\textsuperscript{7}

Contrast-enhanced computerized tomography (CT), now using multidetector-row technology, has replaced traditional angiography as the screening diagnostic tool for TAI.\textsuperscript{7} This review delineates the current imaging evaluation of TAI, with focus on multidetector-row CT and with discussion of the key imaging findings that allow its diagnosis.

**TAI: Statistics**

The vast majority of aortic injuries occur from blunt trauma due to motor vehicle accidents and falls. From 2002 through 2004 there were 648 fatal accidents in Miami/Dade County. Approximately 19% of these fatalities were found to have aortic injury. In those same 3 years only 23.6% of accident victims with aortic injury survived to reach the hospital (Miami/Dade Coroner’s Report). Prompt diagnosis and treatment of patients with aortic injury is of the utmost importance since 30% will die within 6 hours and 40 to 50% die within 24 hours if left undiagnosed and untreated.\textsuperscript{3} Chronic pseudoaneurysms may form in 2 to 5% of patients with missed injuries.\textsuperscript{17,18}

The authors’ institution is a level 1 trauma center in south Florida with more than 3500 trauma admissions per year. Of these approximately 50% are due to motor vehicle accidents. In 2005 there were 17 cases of aortic injury due to blunt trauma resulting in an incidence of approximately 1.0%. This incidence is similar to other large series with incidences varying from 1.1 to 2.2%.\textsuperscript{19-21} Injury mechanisms to the thoracic aorta include shearing forces, torsion and hydrostatic forces, and the osseous pinch.\textsuperscript{21,22} The viscous response to the rate of chest compression is thought to give rise to the injuries.\textsuperscript{21} Approximately 90 to 95% of injuries to the thoracic aorta occur at the isthmus. Injuries to the ascending and more distal descending aorta comprise the remainder.\textsuperscript{21,23} Occasionally multiple injuries to the aorta may be seen\textsuperscript{24} (Fig. 1).

**TAI: Diagnosis**

Despite recent technological advances in CT, the initial assessment of the multitrauma patient is obtained with the use of plain radiographs and ultrasound. This is true for our institution and in 81% of institutions responding to a survey at a meeting of the Society of Emergency Radiologists.\textsuperscript{25} The chest radiograph can be quickly assessed for significant injuries such as pneumothorax, hemothorax, and fractures, and for evaluation of the mediastinum for signs of mediastinal hematoma. A totally normal upright chest X-ray (CXR) has a negative-predictive value approaching 98%\textsuperscript{26}; however, it is not always practical or feasible to obtain an upright film in the severely traumatized patient. In fact, 2 to 5% of patients with normal CXR have been documented to have TAI.\textsuperscript{37} Realistically, the screening CXR in trauma patients is not obtained under ideal conditions and accurate interpretation is hampered
by multiple factors. Indirect signs of possible TAI include shift of the trachea and nasogastric tube at the T-4 level, widened left and/or right paraspinal lines, presence of pleural accumulation (hemothorax), depression of the left main stem bronchus, apical pleural cap, ill-defined aortic knob, and widening of the mediastinum. Widening of the mediastinum is usually thought to be present if the mediastinum at the level of the aortic knob measures 8 cm or more or if the ratio of mediastinal width to chest width exceeds 25%. Reported sensitivities range between 81 and 100% with specificity of 60%. In a study conducted by Ho and coworkers, five experienced radiologists were asked to evaluate the mediastinum in 77 patients: 47 normals and 30 with TAI. Their study concluded that determinations of mediastinal widening were insensitive for predicting aortic injury with a significant interreader variability as to its presence. The radiologists’ overall impression of the mediastinum was found to be a more sensitive predictor of injury.

In the past few years there has been a dramatic change in the diagnosis and screening for TAI. The sensitivity, specificity, and negative-predictive value of TAI by conventional “step and shoot” scanners was not acceptable and the use of CT for screening was thought to be a waste of valuable time. Most of the early literature citing false-negative CTS were due to collimation greater than 5 mm or poor injection techniques. Most studies of the time were using 10-mm collimation and low injection rates. A great deal of motion artifact and poor spatial resolution were largely responsible. The arrival of single-slice helical

Figure 1 (A) A small pseudoaneurysm (white arrow) is noted projecting anteromedially from the proximal descending aorta. (B) A filling defect representing a small intimal clot (white arrow) is noted in the distal descending aorta.

Figure 2 A large pseudoaneurysm (white arrow) located near the isthmus is readily identified in this 3D volume-rendered image.
CT (HCT) revolutionized the methods by which polytrauma patients were screened due to its ability to decrease patient examination times to a fraction of the conventional scanners and new imaging protocols were used. With the arrival of multidetector-row CT (MDCT) the limiting factor was no longer the time required for image acquisition, but the time to get the patient on and off the scanner. With MDCT a study from the base of the skull through the symphysis pubis can be achieved in under a minute depending on the scanning parameters. Faster image reconstruction and thinner collimation with improved spatial resolution permits improved diagnosis of TAI.

At the Ryder Trauma Center all multitrauma patients are scanned on a multidetector scanner. The protocol used for multisystem evaluation includes the use of nonionic contrast delivered at a rate of 3 to 4 mL/s with a total volume delivered between 90 and 125 mL. Collimation of 3.2 mm with a pitch of 1.25 is used with reconstructed images at 1.6-mm intervals. This technique results in improved multiplanar reformations (MPR) and decreased image degradation due to stair-step artifacts. Although cardiac gating would further improve imaging of the ascending aorta, we do not use gating because of considerations of time, radiation dose, and integration with the whole-body scanning protocols we employ. Although we begin with interpretation of axial images, we routinely use the MPR to evaluate the spine and vascular structures including the aorta. Three-dimensional volume-rendered images and MPR are routinely used to better demonstrate lesions or abnormalities to our surgeons with a perspective with which they are more comfortable (Fig. 2).

Since the installation of our MDCT 4 years ago we have diagnosed 48 cases of TAI using MDCT, 17 of these in 2005. Of these 48 cases, all were diagnosed using direct signs of aortic injury. Direct signs of TAI include active extravasation of contrast (Fig. 3), pseudoaneurysm formation (Fig. 4), irregularity of the aortic wall, abrupt change in caliber of the aorta, dissection (Fig. 5), intimal flaps (Fig. 6), and filling defects (Fig. 1B). Indirect signs of possible aortic injury include periaortic hematoma and mediastinal hematoma. Direct signs have been shown to be more accurate than indirect signs for injuries to the aorta.34 Anterior mediastinal hematomas are usually the result of venous hemorrhage or due to fractures of the sternum. Mediastinal hematomas not immediately adjacent to the aorta are also likely to be secondary to venous bleeding.18-20 Periaortic hematomas were initially considered more suspicious for aortic injury even without a direct sign of aortic injury. The presence of periaortic hematoma on an HCT scan was regarded as a positive find for possible TAI and aortography was usually recommended as standard of care.30,35 At our institution we formerly performed aortography in the presence of periaortic hematoma without a direct sign of injury; however, in the

**Figure 3** (A) Complex pseudoaneurysm (long white arrow) with evidence of active extravasation (arrowhead) and mediastinal hematoma (shorter white arrow). (B) 3D volume-rendered image demonstrates the lesion (black arrow).
authors’ experience we have not found a positive case of TAI without a direct sign of injury. In the past few years, since the development of MDCT, Mirvis and coworkers now suggest that the presence of a periaortic hematoma without a direct sign of TAI does not necessarily require aortography. This, however, depends on the experience and confidence of the radiologist and the quality of the scanner and study.\textsuperscript{36} Although there are reports of positive aortograms with no direct sign of TAI, all of these cases were performed on helical scanners.\textsuperscript{30,35}

Aortography has long been held as the “gold standard” for the diagnosis of TAI with sensitivity and specificity approaching 100%. However, several studies using single-slice HCT as the diagnostic tool for TAI have shown sensitivities and specificities equal to that seen with angiography.\textsuperscript{18,19,23,35,37} Initially, at the authors’ institution all patients clinically suspected of having TAI or those patients with evidence of TAI on HCT required aortography. In two of our cases a lesion seen on HCT was not evident on routine digital subtraction aortography (LAO, AP, RAO views) and required special views determined by the location of the lesion on HCT. In another case, a trauma patient with a markedly widened mediastinum was referred for CT. The CT demonstrated the presence of a pericardial hematoma; the mediastinal widening was due to mediastinal lipomatosis. At surgery a laceration of the right ventricle was found. The correct diagnosis would have been missed if angiography had been performed in lieu of CT. Angiographic studies accurately demonstrate the lumen of the aorta and the injury but give little information about
the surrounding tissues. The ability of MDCT to accurately diagnose TAI as well as concurrent injuries in the rest of the body makes it more advantageous as a diagnostic tool in the trauma patient. Over time our trauma surgeons as well as our cardiothoracic surgeons became more comfortable with the diagnosis of TAI by HCT and later by MDCT. This was in large part due to the use of MPRs and 3D volume-rendered images (Fig. 7). MPRs with sagittal oblique projections along the long axis of the aorta are similar to the LAO projection used in aortography. Measurements of the length of the lesion, the distance from the injury to the great vessels, as well as the diameter of the aorta proximal and distal to the lesion can be readily acquired from the CT data sets. This information is important to the cardiothoracic surgeon contemplating thoracotomy as well as vascular surgeons considering endovascular repair. The 3D volume-rendered images can demonstrate the injury and its relationship to other structures in different lines of sight. The result has been wide acceptance of MDCT diagnosis of TAI and patients no longer require further evaluation with aortography before surgery.

The use of HCT and now MDCT has been useful in identifying minimal aortic injuries. These include small intimal injuries and small pseudoaneurysms. This is largely due to thinner collimation techniques possible with MDCT. The authors have had experience with several small intimal injuries. These are usually treated conservatively at our institution and are followed with a repeat study within a week. In our experience, small intimal injuries usually resolve within 2 weeks (Fig. 8). TAI is in fact a spectrum of lesions and they are not all treated in the same manner. Gavant proposed a grading system for TAI whereby small lesions such as intimal injuries and small (<1 cm) pseudoaneurysms be treated conservatively with

![Figure 5](image1.png) (A) Axial image demonstrates irregular and widened aortic contour (white arrow). A crescentic border (short black arrows) defines a traumatic aortic dissection. Note the different densities of contrast within the aortic lumen. Aortic dissection was confirmed by transesophageal echocardiography. (B) At a more inferior level the aorta returns to a more normal diameter. Minimal contour irregularity is still present (white arrow).

![Figure 6](image2.png) A small intimal flap (black arrow) seen on an axial 3D volume-rendered image.
Figure 7 Sagittal oblique (A) and coronal (B) MPR images demonstrate a large circumferential pseudoaneurysm, also shown on the MIP angiogram (C).
Figure 8  (A) A small intimal clot (black arrow) is noted near the isthmus.  (B) Aortogram demonstrates a filling defect (black arrow) corresponding to the clot seen on CT.  (C) Axial CT image at same level as in (A) obtained 2 weeks later demonstrates resolution of the intimal clot.
**Figure 9** (A) A small aortic pseudoaneurysm (white arrow), rib fractures (large white arrowhead), and subcutaneous emphysema (small white arrowheads) are seen. Bilateral chest tubes have been placed (black arrows). (B) Two weeks later the small pseudoaneurysm appears unchanged (white arrow). A large pleural accumulation is now present (arrowhead). (C) Image at 2 months again demonstrates the small pseudoaneurysm (white arrow) to be unchanged. Rib fractures (black arrows) have healed.

**Figure 10** (A) A large mediastinal hematoma (white arrow) causes mass effect on the left atrium. The patient had a large aortic injury (not shown). (B) Delayed image obtained at a slightly more superior level than in (A) demonstrates the hematoma to have increased in density (white arrow) signifying active extravasation.
In a recent case, a patient with a small pseudoaneurysm of the aorta is being treated conservatively and followed by MDCT on a regular basis. Over a 2-month period there has been no significant change in the appearance of the lesion (Fig. 9). Nevertheless, TAI is a dynamic lesion as evidenced by the mortality statistics. Not all patients die at the scene and those who manage to survive may die within hours if not treated. Patients with minimal injuries may not have evidence of significant mediastinal hematoma. Other patients have significant pseudoaneurysm formation with some evidence of surrounding hematoma. Still others have pseudoaneurysm formation with massive mediastinal hematoma and no evidence of active extravasation on the screening CT. It is important to remember that CT images are a reflection of what is occurring at the time the image was acquired.
whereas TAI is a dynamic process. The presence of a pseudoneurysm and mediastinal hematoma signifies that the aortic integrity has been compromised and the pseudoneurysm is being contained by the surrounding soft tissues. In one recent case report, a CT scan was diagnostic of TAI. A follow-up CT at a second center several hours later demonstrated progression of the injury. At our institution trauma patients frequently are evaluated by MDCT for injuries to the chest, abdomen, and pelvis. Delayed images of the abdomen and pelvis are routinely acquired as part of our protocol and these include images of the lower chest. In some cases, images of the lower chest demonstrate increased density of the mediastinal hematoma when compared with the initial images (Fig. 10) These findings are indicative of active extravasation and immediate intervention is necessary. In cases where the injury of the aorta appears to be contained, other injuries which may be more immediately life-threatening may be addressed first (Fig. 11). In this case, endovascular stents were successfully used to repair the aortic injury after laparotomy.

Recent literature points to delayed treatment of stable patients with TAI. Some investigators report improved results regarding morbidity and mortality when repair is delayed days to months in some cases.40

**Conclusion**

MDCT has emerged as the preferred method for screening in suspected cases of TAI. Thinner collimation and improved spatial resolution as well as its availability 24/7 have made it indispensable as a screening tool. It has been proven to be cost effective and accurate in the diagnosis of TAI. In the past few years MDCT has eliminated the need for aortography when direct signs of injury were present. Angiography is not necessarily required in cases with periaortic or mediastinal hematoma if the MDCT study is of good quality and the study is interpreted by experienced individuals. TAI is a dynamic process and the usefulness of delayed images of the chest when TAI has been diagnosed may prove to be of value in recognizing those patients that may need immediate intervention. This is especially true at present, when patients with TAI may not undergo treatment for days or even weeks after injury due to other injuries. Use of endovascular stents in the acute setting has become more popular and can be easily followed using MDCT.

**References**