Use of CT for Diagnosis of Traumatic Rupture of the Thoracic Aorta

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CT imaging of traumatic aortic rupture has been both advocated and disparaged in the current literature as a reliable diagnostic modality. In a retrospective review of blunt chest trauma patients at our institution evaluated by both thoracic CT and arteriography, we found a 17% false negative rate and a 39% false positive rate. Although we feel CT is not sufficiently sensitive at present to evaluate traumatic rupture of the aorta directly, it is an invaluable adjunctive imaging modality for stable blunt chest trauma patients with equivocal chest radiographs or arteriograms. (Ann Vasc Surg 1993; 7:130-139.)

Aortic rupture from blunt chest trauma and sudden deceleration has a grave prognosis, causing instantaneous death in 80% to 90% of cases. Without surgical intervention, half of the survivors will die from their injury within 24 hours. The majority of clinically identifiable aortic injuries are at the isthmus, with only 5% in the ascending segment and less than 1% in the low descending aorta. Early diagnosis is essential to improve a patient's chances of survival. Aortography, as indicated by high clinical suspicion of injury and/or chest x-ray findings, has been the gold standard for evaluation of the aorta in such cases.

The potential of CT in the evaluation of traumatic rupture of the aorta has been studied with conflicting results. Heilberg et al. were among the earliest proponents of the use of CT in evaluating aortic trauma. Their initial results from a series of 10 patients suggested CT is capable of detecting aortic tears. Fenner et al. showed CT and arteriography to have comparable specificity (CT 96%, arteriography 92%) and false positive rates (CT 3.8%, arteriography 7.7%) when CT was used as a screening tool for aortic rupture. Madayag et al. used dynamic CT to screen for aortic injury in patients with blunt chest trauma who had normal initial chest x-ray findings. The authors concluded that emergent aortography should be performed only on patients with either abnormal chest x-ray or abnormal CT findings. Woodring and Dillon stated that if CT reveals no evidence of mediastinal hemorrhage, emergency thoracic arteriography is not necessary. In contrast to these reports, Goodman noted that "CT has not been shown to be of benefit in the diagnosis of aortic trauma" and "... is not applicable to the evaluation of aortic injuries." In a study of aortic disease by White et al., the diagnosis of aortic rupture was missed by CT in their two cases of acute chest trauma. They state in their discussion that although acute aortic rupture from blunt chest trauma is sometimes diagnosable by CT, sensitivity and specificity are inadequate. Miller et al. reiterated this viewpoint in their study, concluding that chest CT has no screening role in the evaluation of blunt trauma patients with possible vascular injury. We recently had a case that called into question the confidence that can be placed in a CT scan negative for direct aortic injury. We present a retrospective review of
our experience with CT and arteriography in such cases. In addition, we reviewed the recent literature in an effort to determine the efficacy of CT in the diagnosis of traumatic rupture of the aorta.

METHODS

A retrospective study of all radiographic records on file at the University of Chicago from 1984 to 1991 produced 18 consecutive cases of patients presenting to the emergency department with suspected aortic injury from blunt chest trauma that were evaluated by both thoracic CT and arteriography. Vascular injury was found in three of these patients, yielding an incidence of 17%. During this same time period, 37 patients had emergent arteriography without thoracic CT based on clinical impression. Of these patients, four had aortic injuries and one had a left subclavian arterial injury, yielding a 14% incidence. Although our patient group excludes patients who had arteriography without CT based on clinical impression, we believe this does not create a significant bias since it is the stable patients with lower clinical suspicion for aortic injury for whom CT has been advocated as the imaging modality to precede or preclude arteriography.

All patients had admission portable chest x-ray studies performed in the emergency department. CT scans were performed on a Siemens DR3 scanner from 1984 to 1989 and on a GE 9800 from 1989 to 1991. In one case an Imatron fast-scanner was used. All CT scans were performed with contrast enhancement using 50 ml of Conray-60 administered as a bolus infusion. The single study performed on the Imatron scanner was performed using 30 acquisitions over a 12-second period, also using a 50 ml bolus infusion of Conray-60. Aortograms were performed using biplane cut-film techniques, with more recent studies supplemented by digital arteriography as indicated. All chest x-ray, CT scan, and arteriogram results presented are the final interpretations of attending radiologists. Arteriographic results were reported at the time the examination was completed. Chest x-ray and CT scan results were usually reported the following day, with arteriography results known at the time of reporting.

RESULTS

There were 14 male patients and four female patients, whose ages ranged from 6 to 85 years. Half of the patients were men between the ages of 27 and 54 years. The mechanism of injury was a motor vehicle accident in 15 patients (83%), with three patients (7%) incurring their injuries after falling from a height.

The initial portable chest x-ray findings revealed widening of the superior mediastinum in 61%, multiple rib fractures in 28%, pulmonary contusion in 39%, and hemothorax or effusion in 17%. Less frequent findings (incidence of 11% or less) included sternal or vertebral fracture, pneumothorax, apical cap, blurring of the aortic knob without mediastinal widening, and no abnormality. A list of observed portable chest x-ray findings and their frequencies is given in Table I. Since mediastinal widening was the most frequent plain film finding to prompt further evaluation by arteriography, it is interesting to note that CT demonstrated mediastinal hemorrhage in only half the patients with mediastinal widening and no abnormality. A list of observed portable chest x-ray findings and their frequencies is given in Table I. Since mediastinal widening was the most frequent plain film finding to prompt further evaluation by arteriography, it is interesting to note that CT demonstrated mediastinal hemorrhage in only half the patients with mediastinal widening and no abnormality. A list of observed portable chest x-ray findings and their frequencies is given in Table I. Since mediastinal widening was the most frequent plain film finding to prompt further evaluation by arteriography, it is interesting to note that CT demonstrated mediastinal hemorrhage in only half the patients with mediastinal widening and no abnormality. A list of observed portable chest x-ray findings and their frequencies is given in Table I. Since mediastinal widening was the most frequent plain film finding to prompt further evaluation by arteriography, it is interesting to note that CT demonstrated mediastinal hemorrhage in only half the patients with mediastinal widening and no abnormality.

Fifteen patients had normal aortograms. One patient had a normal CT scan. Six patients had CT scans that showed mediastinal hematomas abutting or surrounding the aorta, although subsequent aortograms were normal. Eight patients had CT scans that showed no direct evidence of aortic injury but confirmed other injuries suspected on the portable chest x-ray film. Three of these eight patients' scans showed significant injuries not suspected on the chest x-ray film; specifically, there were multiple thoracic vertebral fractures with air in the spinal canal in one patient, a pneumothorax in the second patient, and subluxation of the L1-L2 level in the third. These CT findings are listed in Table II.

Three patients had vascular injuries diagnosed by arteriography. All three patients had widening of the superior mediastinum on their initial

<table>
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<tr>
<th>Table I. Frequency of findings on initial portable chest radiographs</th>
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<tr>
<td>Findings</td>
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<td>---------------------------</td>
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<tr>
<td>Mediastinal widening</td>
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<tr>
<td>Pulmonary contusion</td>
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<tr>
<td>Multiple rib fractures</td>
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<tr>
<td>Effusion/hemothorax</td>
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<tr>
<td>Normal</td>
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<tr>
<td>Pneumothorax</td>
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<tr>
<td>Vertebral fracture</td>
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<tr>
<td>Apical cap</td>
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<tr>
<td>Blurring of aortic knob</td>
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<td>Sternal fracture</td>
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Table II. Findings on thoracic CT scans

<table>
<thead>
<tr>
<th>Findings</th>
<th>No.</th>
<th>Incidence</th>
<th>Occult on chest x-ray films</th>
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<tr>
<td>Mediastinal hemorrhage</td>
<td>7</td>
<td>39%</td>
<td>2</td>
</tr>
<tr>
<td>Pulmonary contusion</td>
<td>4</td>
<td>22%</td>
<td>1</td>
</tr>
<tr>
<td>Effusion/hemothorax</td>
<td>4</td>
<td>22%</td>
<td>0</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>3</td>
<td>17%</td>
<td>1</td>
</tr>
<tr>
<td>Rib fractures</td>
<td>3</td>
<td>17%</td>
<td>0</td>
</tr>
<tr>
<td>Normal</td>
<td>1</td>
<td>6%</td>
<td>0</td>
</tr>
<tr>
<td>Vertebral fracture</td>
<td>1</td>
<td>6%</td>
<td>1</td>
</tr>
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portable chest x-ray film (Figs. 1 and 2). None of the vascular injuries sustained was suspected on the basis of the CT findings. The first patient's CT scan was degraded by artifact from motion and ECG leads. This image quality is not uncommon in the trauma setting, particularly when multiple injuries are present or suspected, necessitating intubation, cardiac monitoring, or a backboard. No gross evidence of mediastinal hemorrhage or aortic abnormality was considered to be present (Fig. 3). The arteriogram showed a tear of the aorta at the level of the isthmus (Fig. 4). The patient died of a myocardial infarction before the injury could be repaired. The second patient's CT scan showed a slightly increased anterior mediastinal density contiguous with adjacent contused lung and a hematoma surrounding fractures of T12 and L1 that extended toward the aorta (Fig. 5). Note the difference in quality of contrast enhancement at the level of the isthmus compared with the level of the diaphragms, despite optimal dynamic scanning. The decreased distal enhancement is an inherent disadvantage of dynamic scanning and is caused by spreading out of the contrast bolus over time. Thoracic aortic scanning is timed to optimize the bolus effect at the level of highest suspicion, that is, the aortic isthmus, at the expense of distal thoracic aortic enhancement. There was considered to be no CT evidence of vascular injury; however, the aortogram showed an intimal flap at the level of the right hemidiaphragm (Fig. 6). At surgery an intimal tear involving one third of the vessel circumference was found and repaired. The paraspinal hematoma seen on the CT scan was intraoperatively determined to be due to vertebral fractures. The patient recovered uneventfully. The third patient's CT scan (not shown) showed a right paratracheal hematoma and a small amount of soft tissue density posteromedial to the descending aorta that was not believed to be arterial in origin. The arteriogram (not shown) showed a tear of the

Fig. 1. Initial portable chest x-ray film of patient 1. There is mediastinal widening and right hemidiaphragm elevation. The apparent rightward tracheal deviation is caused by the rotated position of the patient.

Fig. 2. Initial portable chest x-ray film of patient 2. The superior mediastinum is slightly widened. Perihilar and left retrocardiac densities are consistent with areas of atelectasis and/or contusion. A nasogastric tube is in place.
Fig. 3. Thoracic CT scans of patient 1. Images are degraded by artifacts from ECG leads and from patient motion. Scans from the level of the suprasternal notch (A), at the level of the aortic isthmus (B), and just inferior to the isthmus (C and D) show no evidence of hemorrhage, contrast extravasation, or intimal abnormality. Soft tissue density at the lung bases is due to atelectasis.
Fig. 3, cont’d. For legend see p. 133.

Fig. 4. Thoracic arteriogram of patient 1. Anteroposterior (A) and oblique (B) views show an aortic tear at the level of the isthmus.
Fig. 5. Thoracic CT scans of patient 2. **A.** Scan just above the level of the aortic isthmus shows no evidence of mediastinal hemorrhage, contrast extravasation, or intimal irregularity. Increased density in the left anteromedial and mid-lung regions is caused by atelectasis and/or contusion, with more extensive involvement seen on lung windows (not shown). **B.** A scan just above the level of the diaphragms shows a hematoma surrounding the vertebral column and extending to the descending aorta. **C.** The sagittal reconstruction at this level with bone window settings more clearly demonstrates the L1 and L2 fractures.
rupture include lucency within the contrast-opacified aorta caused by an intimal flap irregularity of the opacified aortic lumen, periaortic or intramural aortic hematoma, pseudoaneurysm, or aortic dissection. Unfortunately these findings are not consistently visualized in aortic injuries; several false negative results are reported. This probably relates to the pathophysiology of these injuries. The majority of traumatic aortic ruptures are transverse, with dissection being a rare complication. Because of the axial scanning plane used in CT, transversely oriented injuries may not be demonstrated because of partial volume averaging within the scan plane. The axial scanning could explain some of these false negative reports and might be expected to produce such a result in aortic injury without complete transmural involvement or without dissection. In addition, the absence of mediastinal widening on plain films or mediastinal hemorrhage on CT scans does not exclude the possibility of aortic injury. Distal thoracic aortic injuries may also be missed in dynamic CT scanning due to loss of the contrast bolus effect over time, as seen in our second patient.

The value of thoracic CT lies in its improved visualization of mediastinal anatomy, often sub-optimally evaluated on the initial chest radiograph. When mediastinal widening is suspected on a chest radiograph, CT can determine whether this is due to magnification artifact, mediastinal hemorrhage, or other etiologies. Causes other than mediastinal hemorrhage include lung contusion or atelectasis adjacent to the mediastinum, mediastinal effusion or hemothorax, periaortic lymphadenopathy, mediastinal fat, hialtal hernia, and anatomic variants. In the absence of strong clinical suspicion of aortic injury, such findings may obviate the need for arteriography. Mediastinal hemorrhage may be focal periaort-ic, focal but separate from the aorta, or diffuse. A periaortic hematoma is considered direct evidence of aortic injury, in which case arteriography is indicated. Diffuse or focal mediastinal hemorrhage, often from small vessel bleeding caused by shearing forces, may indicate a more severe degree of injury than initially suspected and increase one’s suspicion of aortic injury. It has been suggested that mediastinal hematoma remote from the great vessels and attributable to sources other than the aorta, such as vertebral fractures, should decrease suspicion for aortic injury. Egan et al. stated that CT is useful in excluding aortic injury in a sta-

ble patient with mediastinal widening that may be caused by other thoracic injuries. In the study by Ishikawa et al., 48 cases were positive for mediastinal hematoma on CT, 15 of which were due to fracture of a thoracic bony structure. They concluded that arteriography can be deferred or performed electively if a hematoma is separable from the great vessels and localized to the site of a fracture. In contrast, Brooks et al. state they do not believe the position of a hematoma in the mediastinum is a feature by which major vascular injury can be identified. We agree that the location of a hematoma should be used cautiously if at all to exclude the possibility of vascular injury, since forces severe enough to fracture a vertebral body may also be transmitted through the mediastinum to the aorta. This is substantiated by our series in which six patients with mediastinal hemorrhage suspicious for vascular injury on CT had normal aortograms, whereas one patient with a paraspinal hematoma due to vertebral fractures had a significant aortic injury. Clinical discretion should prevail in the final decision of whether or not to obtain an arteriogram.

CT can also be used as an adjunctive imaging modality in cases of unclear arteriographic findings. The differential diagnosis for an abnormal aortogram in a patient with blunt chest trauma includes aortic rupture, physiologic streaming of contrast, ductus diverticulum, localized dissecting aneurysm, and atherosclerotic aneurysm. Streaming of contrast should be recognized at arteriography by its inconstant appearance from one film to the next. It should also resolve with a larger injection volume. Ductus diverticulum, a remnant of the ductus arteriosus, can mimic a traumatic pseudoaneurysm. Richardson et al. reported one such case in which CT helped confirm the absence of aortic injury at the site in question. In most cases, CT is able to differentiate between aortic tortuosity, atherosclerotic aneurysm, and dissecting hematoma, particularly when used in conjunction with the arteriogram. Aortic tortuosity is seen on CT as an aorta of normal caliber (allowing for volume averaging in tangential sections) with a shifting position in the mediastinum on consecutive slices. An atherosclerotic aneurysm appears as a localized dilatation of the aorta with varying degrees of mural thrombus and peripheral mural calcifications. Aortic dissection can be identified by two or more lumens filling with contrast, which would be seen arteriographically, or by inward displacement of intimal calcifications.
CONCLUSION

The high mortality of traumatic aortic rupture in patients surviving long enough to reach a hospital requires early detection to expedite surgical intervention. Aortography, as indicated by high clinical suspicion with or without suggestive chest x-ray findings, remains the gold standard for diagnosis of aortic injury. By comparison, the role of CT scanning in evaluation of aortic injury is the subject of much controversy. In our experience utilizing CT in the evaluation of traumatic aortic rupture, we have had a 17% false negative rate and a 39% false positive rate. Because of the relatively small number of blunt aortic trauma cases seen in our institution, the number of cases in our series is too small to attain statistical significance. Given the high fatality rate associated with traumatic aortic rupture, however, we believe that the false negative rate we found is unacceptable.

Although CT scanning may at times show direct evidence of aortic injury, we are not convinced that a normal CT scan excludes the possibility of significant vascular injury. This is primarily due to the possibility of missing transversely oriented injuries inherent in the axial scanning technique. On the other hand, CT does have a major role in evaluating trauma patients at our institution because of its excellent demonstration of mediastinal anatomy. In stable patients with equivocal chest radiographs but with low clinical suspicion of vascular injury, CT can differentiate mediastinal hematoma from other causes of mediastinal widening. CT often shows additional unsuspected findings such as sternal or vertebral fractures, which could implicate a greater severity of injury than initially believed and provide an indication for arteriography. Finally, in cases where arteriography is unclear, as in ductus diverticulum, acute dissection, or atherosclerotic aneurysm, CT may help elucidate confusing arteriographic findings.

In conclusion, we believe that CT is not sufficiently sensitive at the present time to directly assess traumatic aortic rupture. Although it is invaluable as an adjunctive imaging modality in stable blunt chest trauma patients with equivocal chest radiographs or arteriograms, arteriography remains the method of choice for diagnosing traumatic aortic rupture.

REFERENCES


