Diagnosis of Injuries of the Aorta and Brachiocephalic Arteries Caused by Blunt Chest Trauma: CT vs Aortography

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OBJECTIVE. The purpose of this study was to evaluate the role of chest CT in the triage of patients with potential injuries of the aorta and brachiocephalic arteries caused by blunt trauma and to test the value of chest CT scans in limiting the number of screening aortograms.

SUBJECTS AND METHODS. A prospective study was done with 107 patients who were examined because of possible laceration of the aorta or brachiocephalic vessels. Chest radiographs were obtained in 107 patients, aortograms in 105, and chest CT scans in 90. This evaluation concentrates on the 88 patients who had both CT and aortography. Findings on CT scans were categorized as normal, equivocal, suggestive of, subtly positive for, or grossly positive for mediastinal hematoma.

RESULTS. Findings on CT scans were considered normal in 18 patients. Sixteen had normal aortographic findings. Two of the 18 had clinical follow-up without aortography. Findings on CT scans were considered equivocal in 25 patients, suggestive of hematoma in 13, subtly positive for hematoma in 24, and grossly positive for hematoma in 10. Subsequent aortography showed injuries in four patients who had abnormal CT findings. Nineteen other patients had aortography because of grossly abnormal findings on chest radiographs, and one aortic injury was detected.

CONCLUSION. The value of chest CT as a preliminary procedure to avoid thoracic aortography in patients with blunt trauma was limited in our series. Chest CT scans with normal findings effectively exclude aortic/brachiocephalic injury; however, only about 25% of our patients had chest CT scans with unequivocally normal findings, and most patients required further evaluation with aortography.

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The role of CT in the examination of patients with suspected injury of the aorta or brachiocephalic vessels caused by blunt trauma remains controversial. Some [1–5] strongly favor the use of CT in screening these patients for mediastinal hematoma. Others challenge the accuracy of CT findings or the validity of CT usage [6, 7]. Our interest in the subject is piqued by a 24-year experience in the diagnosis of injuries of the aorta or brachiocephalic vessels in a level I trauma/teaching center where more than 300 thoracic aortograms are obtained annually for this purpose. Because of the risk involved and the time and expense of angiography, we seek accurate and relatively noninvasive screening techniques. Accordingly, we compared the relative accuracies of chest radiography, CT, and thoracic aortography in 107 patients with possible aortic/brachiocephalic vessel injury caused by blunt chest trauma who were examined at our institution. Our primary purpose was to evaluate the role of CT in the diagnostic triage of these patients.

Subjects and Methods

From February 1990 to February 1991, 107 patients were examined at Ben Taub General Hospital in Houston because of possible laceration of the aorta or brachiocephalic vessels.

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A vascular injury was assumed to be present until proved otherwise. All chest radiographs were initially interpreted by a radiology resident in the emergency department. Selection of patients for further examination was determined by abnormal findings on chest radiographs and by the severity of the mechanism of injury as judged by the senior surgical resident. Anteroposterior chest radiographs were obtained in 91 supine patients, and posteroanterior chest radiographs in 16 upright patients. The findings suggestive of mediastinal hemorrhage were mediastinal widening accompanied by displacement of recognizable mediastinal structures or obscuring of normal mediastinal tissue planes. These were subdivided into a variety of signs reported previously [8]. Patients considered to have unequivocal evidence of mediastinal hematoma on chest radiographs had immediate thoracic aortography. All other patients had CT, and most of these subsequently had thoracic aortography. From approximately 300 patients with a history of blunt chest trauma, 107 were selected for CT or angiography or both.

In our population of patients, the mechanisms of injury considered severe were as follows: high-speed motor vehicle accidents, 35 patients; high-speed frontal impact, 25 patients; ejection from a vehicle, 13 patients; fall from a height (30–50 ft [9–15 m]), 10 patients; automobile-pedestrian accidents, six patients; automobile-train accidents, three patients; motorcycle accidents, two patients; motor vehicle–bicycle accidents, two patients; and thrown from a horse, one patient. Of the 10 remaining patients, seven had abnormal findings on chest radiographs despite a history of low-impact motor vehicle accidents, and three had unclear clinical indications.

Multiple injuries were common: 44 patients had associated serious injuries to the torso, the head, or the extremities. Twelve had head injuries, and 12 had pelvic fractures, three of whom also had extremity fractures. Eleven had abdominal injuries that required surgical exploration before further chest imaging. Six other patients had extremity fractures, and 29 patients had multiple rib fractures usually associated with hemopneumothorax and lung contusion. One of these also had a cardiac contusion, and another had fractures of the sternum and thoracic spine. Two other patients had fractures of the sternum, and two others had cardiac contusion.

All examinations and procedures were directly supervised and reviewed by staff members during regular working hours or by the upper level in-house radiology residents on call for CT and interventional radiology, after hours. The after-hours procedures were subsequently reviewed by a staff radiologist. In order to avoid interpretation bias, a blinded retrospective review of all CT scans was done by one radiologist, without knowledge of prior interpretations or the results of angiography.

CT was done with a GE 9800 Quick scanner. Initially, a bolus of 50 ml of 60% ionic contrast material (Conray) was injected into the patient's brachial vein. The left brachial vein was the preferred route in order to provide opacification of the left innominate vein. The rate of injection was 2.5 ml/sec, for 20 sec. This was followed by an injection at 0.5 ml/sec throughout the remainder of the examination, for a total dose of 150 ml. Beginning 40 sec after the start of injection, contiguous 1-cm sections were scanned from above the thoracic inlet to the level of the diaphragm. Scan time was 5 sec per section with a 7-sec delay between sections.

Aortography was performed in the standard fashion with a 7-French pigtail catheter and a femoral artery approach. Sixty milliliters of nonionic contrast material (75.5% iohexol 350) was injected at a rate of 40 ml/sec, and cut-film images were obtained in the left anterior oblique and anteroposterior projections. Steep right anterior oblique (≥75°) or lateral digital images were also obtained routinely by using 40 ml of 75.5% iohexol 350 injected at a rate of 25 ml/sec.

Ninety of 107 patients were evaluated with chest CT, 88 of whom subsequently underwent thoracic aortography. Four suffered thoracic aortic injuries. Two patients with normal findings on chest radiographs and CT scans were not evaluated with thoracic aortography. In addition, CT was not done in 19 patients who were evaluated directly with thoracic aortography. This decision was arbitrary in some but was a function of abnormal findings on chest radiographs in most. One proved to have an aortic injury.

Results

Chest Radiographs

Table 1 depicts staff members' interpretations of the chest radiographs. The majority of the disagreements with the residents' interpretations were in deciding whether findings were normal or equivocal. Residents categorized findings as normal in 17 patients and as equivocal in 30, whereas staff members considered findings normal in eight patients and equivocal in 39. This, no doubt, represented a greater reluctance on the part of the staff to consider findings on a chest radiograph absolutely normal. Agreement between the resident and staff members in the remaining three categories was remarkable. Both groups categorized findings as suggestive of hematoma in 24 patients, subtly positive for hematoma in one, and grossly positive for hematoma in 18.

Interpretation of chest radiographs in the 19 patients who did not have CT did not vary significantly from resident to staff. The results were as follows: findings were equivocal in eight, suggestive of hematoma in four, subtly positive for hematoma in one, and grossly positive for hematoma in six. One patient in this group had a laceration (intimal tear); this was not proved.

TABLE 1: Comparison of Groups of Patients Evaluated with Chest Radiography and CT for Possible Mediastinal Hematoma

Findings on Chest Radiographs	Findings on CT Scans					
	Normal	Equivocal	Suggestive	Subtly Positive	Grossly Positive	Total
Normal	5	3	0	0	0	8
Equivocal	12	11	6	8	2	39
Suggestive	0	7	4[a]	12[b]	1	24
Subtly positive	0	0	0	0	1	1
Grossly positive	1	4	3	4[b]	6[b]	18
Total	18	25	13	24	10	90

[a]Intimal tear (unproved).
[b]Lacerated aorta.

CT Scans

CT was done immediately after examination in the emergency department in 86 of 90 patients. Four others had emergency laparotomies before their chest CT examination. The quality of the scans was graded as 1–4 (acceptable, good, very good, and excellent). Two CT studies were acceptable, 11 were good, 39 were very good, and 38 were excellent. The blinded retrospective review of all CT scans produced no disagreements in interpretation.

Findings on CT scans were considered indicative of hematoma in 34 patients; they were categorized as grossly positive for hematoma in 10 and subtly positive for hematoma in 24 (Table 1). In the group with grossly positive findings, large or diffuse collections of fluid were evident (Fig. 1A). In the group with subtly positive findings, distribution of the hemorrhage consisted of focal areas of fluid or fluid infiltrating mediastinal fat. Bleeding was commonly localized to the anterior mediastinum above and/or anterior to the arch in 14 of the 24 (Fig. 2A). Hematomas in the remaining 10 patients were quite varied in location. They were adjacent to the descending aorta in one, anterior to the arch and in the pulmonary window in two, in the anterior and in the middle portion of the mediastinum as well as the paratracheal region in two, in the pulmonary window and around the isthmus in two, anterior to the arch and along the descending aorta in one, in the pulmonary window and paratracheal area in one, and in zone I of the neck adjacent to the anterosuperior mediastinum in one.

As with the chest radiographs, primary disagreements in CT interpretation by residents vs staff members were in deciding whether findings were normal or equivocal; again staff members were more reluctant to call findings absolutely normal. Staff members categorized CT findings as equivocal in 25 patients and normal in 18, whereas the residents categorized the findings as equivocal in 19 and normal in 24. In those patients with findings suggestive of hematoma on chest radiographs, residents and staff members sometimes disagreed about which CT findings were suggestive of and which were subtly positive for mediastinal hematoma. The staff members' interpretations resulted in two fewer patients with findings considered subtly positive for hematoma. For patients with findings on chest radiographs that were subtly positive for or grossly positive for hematoma, residents and staff members agreed completely on interpretation of CT scans.

Aortograms

Thoracic aortograms were obtained in 105 of the 107 patients. They showed aortic lacerations in the region of the isthmus in four of the 105. A fifth had an intimal defect that may have been a laceration. This patient's condition was extremely unstable, which prevented surgery. Findings on CT in this patient were suggestive of hematoma (Table 2). Ultimately the patient died of multiple injuries, and no autopsy was done. Three of the four patients with proved lacerations had CT, and each had recognizable hematoma in the mediastinum (Table 2). In one with an obvious mediastinal hematoma, a large false aneurysm was clearly recognizable on CT scans and on the subsequent aortograms (Figs. 1B and 1C). In the two remaining patients, mediastinal hematomas were quite subtle (Figs. 2A and 3A). In one, aortographic findings were equally subtle; a small false aneurysm and an associated intimal tear were detected (Fig. 2C). In the other, the injury was large and the catheter bumped into a partially blocked aorta (posttraumatic coarctation) [8] at the time of aortography. A false aneurysm with considerable distortion was visualized when hand injection of contrast material and digital technique were used (Fig. 3B).

Discussion

Injuries of the aorta or brachiocephalic vessels caused by blunt trauma continue to be a diagnostic dilemma. Despite a deluge of new high-tech imaging techniques, catheter aortography continues to be the most reliable method of diagnosis. In our experience, the number of aortic injuries detected

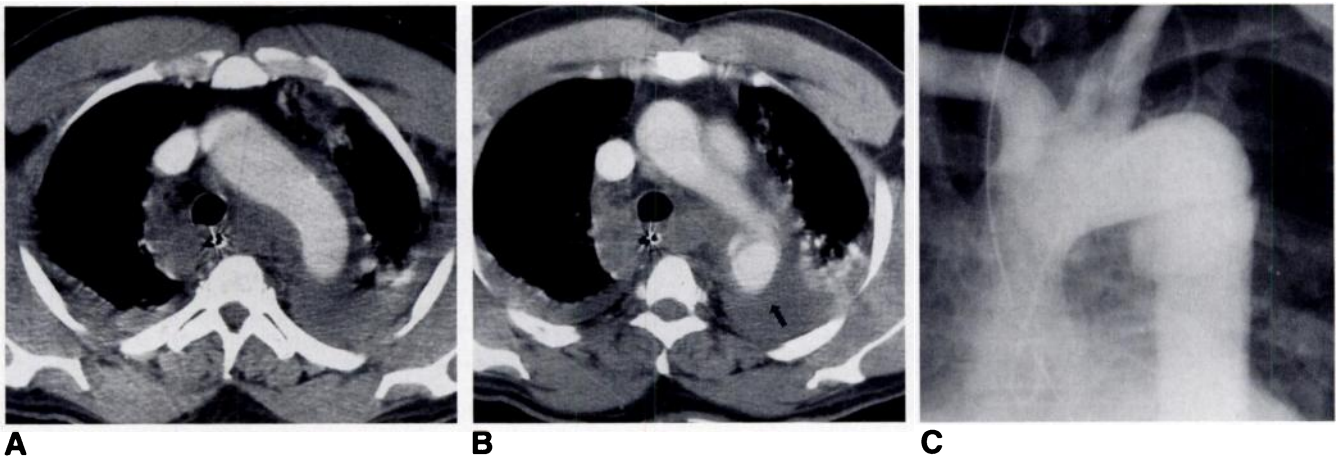

Fig. 1.—Mediastinal hematoma and false aneurysm of thoracic aorta in a 62-year-old man who was injured in a high-speed motor vehicle accident.
***A,* Contrast-enhanced CT scan of chest shows diffuse homogeneous increased density (hematoma) surrounding aortic arch, trachea, and esophagus.**
***B,* Contrast-enhanced CT scan 2 cm lower shows a large false aneurysm (*arrow*) at level of isthmus.**
***C,* Thoracic aortogram in left anterior oblique projection also shows false aneurysm and associated laceration.**

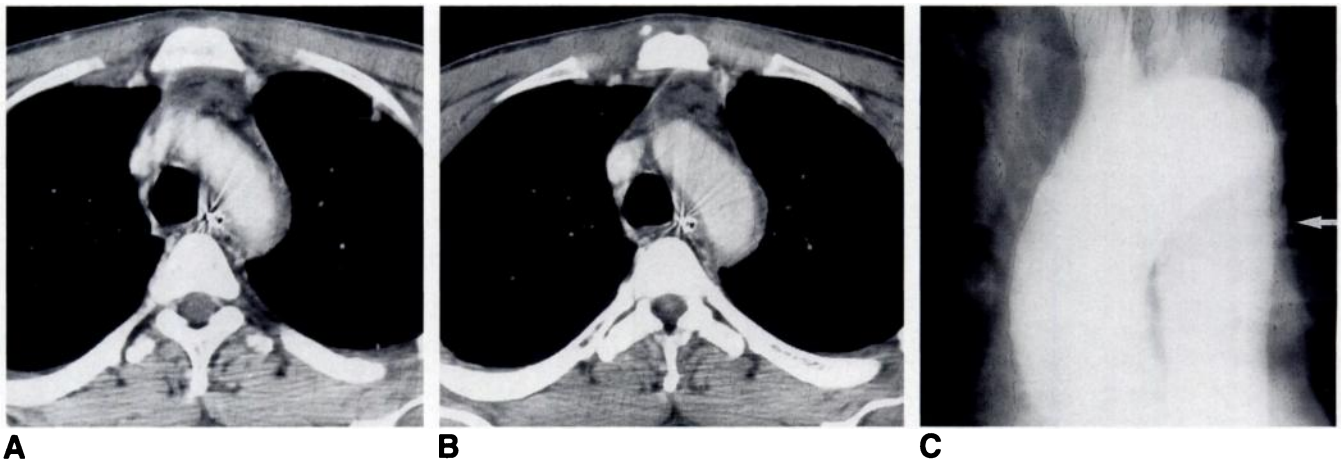

Fig. 2.—Subtle mediastinal hematoma in a 38-year-old man who was found unconscious after being thrown from a horse.
***A*, Contrast-enhanced CT scan of chest shows a small hematoma represented by a heterogeneous but rather focal density anterior to aortic arch.**
***B*, Contrast-enhanced CT scan of section 1 cm caudal to *A* shows a small heterogeneous focal density (hematoma) anterior to aortic arch (subtly positive for hematoma).**
***C*, Anteroposterior thoracic aortogram shows a subtle laceration and false aneurysm (*arrow*) that was not visible on standard left anterior oblique or lateral projections.**

TABLE 2: Comparison of Groups of Patients Evaluated with CT and Aortography for Possible Injury of Aorta or Brachiocephalic Arteries

Findings on CT Scans	Findings on Thoracic Aortograms			
	Normal	Subtly Positive	Grossly Positive	Total
Normal	16	0	0	16[a]
Equivocal	25	0	0	25
Suggestive	12	1[b]	0	13
Subtly positive	22	1[c]	1[c]	24
Grossly positive	9	0	1[c]	10
Total	84	2	2	88

[a]Two other patients with normal CT fndings were followed up clinically.
[b]Intimal tear (unproved).
[c]Surgically confirmed.

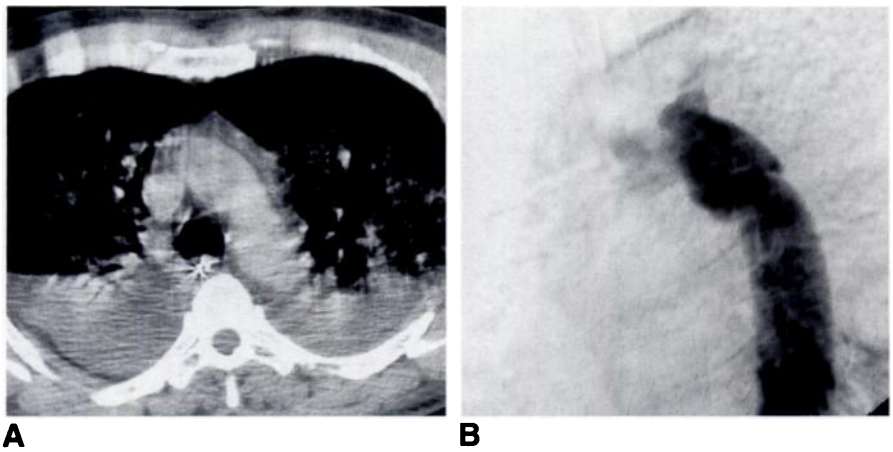

Fig. 3.—Modest-sized mediastinal hematoma shown by CT in a 48-year-old man who was injured in a motor vehicle accident.
***A*, Contrast-enhanced CT scan of chest shows a small hematoma displayed as a homogeneous density adjacent to anterior wall of aortic arch. Note bilateral pleural fluid collections.**
***B*, Left anterior oblique digital aortogram (hand injection) shows a laceration, a large false aneurysm, and constriction of aortic lumen (posttraumatic aortic coarctation).**

has often been as few as in this study (five of 105 studies in a year's time) or disturbingly high (six of 49 studies in a recent 4-month interval). Throughout the years [9], we have found that the diagnosis of laceration of the aorta or brachiocephalic vessels is sometimes difficult despite excellent aortography. As a result we have been skeptical of screening techniques that are less sensitive than aortography for excluding or detecting aortic injuries. Therefore, it was with mixed optimism and skepticism that we reviewed the results of this study.

Analysis of our CT results was based on the assumption that interpretations by staff members were slightly more accurate than interpretations by residents. CT seemed to be a reliable end point when the findings were normal. This occurred in 16 (18%) of 88 patients, all of whom had normal findings on aortograms. If the two patients who had normal findings on chest radiographs and CT scans but did not have aortography are included, this distribution increases to 18 (20%) of 90 patients. Furthermore, if the 18 patients with grossly positive findings on chest radiographs are also excluded (assuming that they should have bypassed CT), the number of patients who had CT decreases from 90 to 72. Thus the "potential" maximum number of patients in whom aortography could have been safely avoided would be 18 (25%) of 72. Alternatively, 54 (75%) of 72 still required aortography for a complete evaluation.

Our data base is strengthened by the fact that 105 of 107 patients had aortography, and 88 of 90 had both CT and aortography. From 1989 to 1992, the findings from at least six large studies on the relative value of CT for detecting mediastinal hematoma and potentially limiting aortography were published [1–6]. In 1989, Miller et al. [6] reported a 3-year experience in which 104 patients were evaluated with both CT and aortography. In 1991, Richardson et al. [1] described a 2-year experience of 117 patients who had CT for trauma, 26 (22%) of whom had follow-up aortograms. In the same year, Madayag et al. [2], using two protocols, reported on 144 patients who had had CT after trauma in the preceding 2 years. Sixty (41%) were evaluated with follow-up aortography. Morgan et al. [3], in 1992, described 160 patients evaluated with CT for chest trauma during the preceding 15 months. Ten (6%) had follow-up aortograms. In the same year, Raptopoulos et al. [4] described 326 patients who had chest CT after trauma during a 2-year span. One hundred thirty-one (40%) had follow-up aortograms. Finally, Agee et al. [5], in the same year, reported on a series of 105 patients who had CT in the preceding 5 years after blunt trauma, 11 (10%) of whom had follow-up aortograms. Our own series describes 90 trauma victims with chest CT evaluation, 88 (98%) of whom had follow-up aortograms. The only reported series with an angiographic follow-up similar to ours was that of Miller et al. [6] (100% vs our 98%). All the other studies relied heavily on clinical follow-up, especially in patients with low probability of injury.

The high percentage of angiographic follow-up in our patients allows us to confidently back up our CT interpretations. Contrary to the experience of Miller et al. [6], in which five vascular injuries were missed by CT, we had no false-negative findings on chest radiographs or chest CT scans. It is not known if the quality of CT scans in the two studies is comparable, but most of our CT scans (77 of 90) were considered to be very good or excellent.

Madayag et al. [2] noted a 28% prevalence of false-negative findings on chest radiographs [10], but they describe only one such incident in their own series in a patient whose CT scans and aortograms showed mediastinal hemorrhage and aortic injury. Their opinion appears to be based on the report by Gundry et al. [10] of 25 patients with lacerated aortas, four of whom apparently had no evidence of mediastinal hematoma on chest radiographs. No false-negative findings on CT scans were reported in Madayag's studies that used aortographic or clinical follow-up (two protocols).

Richardson et al. [1] had no false-negative findings on chest radiographs or CT scans according to clinical follow-up (no aortograms). Morgan et al. [3] had false-negative findings on one chest radiograph. Subsequent CT scans showed a mediastinal hematoma, but a follow-up aortogram showed no evidence of injury. They also reported no false-negative findings on CT scans when clinical follow-up only was used to determine the absence of injury.

Raptopoulos et al. [4] reported false-negative findings on chest radiographs in 15 patients. CT scans showed abnormalities in all 15, and angiograms showed a lacerated aorta in two. None of the findings on CT scans were false-negative. The voluminous data in this article are a bit difficult to interpret, but apparently most patients who had CT scans (272 of 326) were followed up clinically. Similarly, as shown by clinical follow-up, Agee et al. [5] had no false-negative findings on CT scans in 94 screened patients. The accuracy of the CT findings was high. Seven of nine patients who had CT evidence of mediastinal hematoma had lacerations of the aorta.

As indicated earlier, the majority of these researchers [1–5] think that CT is a reliable screening procedure to limit the number of aortograms in patients with blunt chest trauma. However, it is our observation that less than one fourth of our patients could be safely screened with chest radiographs and CT alone. With any interpretation other than a normal mediastinum, we considered angiography necessary because of the relatively broad zone between normal and subtly abnormal findings on CT scans. Unfortunately, the majority of the patients we evaluated fell into this zone, as 72% had findings inconclusive of or suggestive of mediastinal hematoma on CT scans (Table 2). Although no proved aortic lacerations were discovered angiographically in any patient with CT findings considered normal, equivocal for, or suggestive of hematoma (Table 2), the CT findings in the equivocal and suggestive groups were typically worrisome and not greatly different from those considered subtly positive for mediastinal hematoma. This perhaps can be appreciated by examining the four chest CT scans shown in Figures 2B and 4–6. Findings were categorized as equivocal on one (Fig. 4), suggestive of mediastinal hematoma on one (Fig. 5), and subtly positive for hematoma on two (Figs. 2B and 6). One of the patients with subtly positive findings (Fig. 2B) had a lacerated aorta diagnosed on the subsequent aortogram (Fig. 2C). This was confirmed at surgery. Ultimately, we considered differentiation between equivocal for, suggestive of, and subtly positive for hematoma arbitrary, because aortographic follow-up was necessary for all.

On the other hand, the reliability of unequivocally normal CT findings seems to be high (Table 2); 16 of the 18 patients in this category had normal findings on aortograms. The two who did not have aortography remain free of sequelae on clinical follow-up.

Our experience indicates that frequent use of CT of the chest in blunt trauma victims would not greatly diminish the number of screening aortograms in our institution. This opinion differs from those expressed in several recent reports [1–5]. Another consideration is that our selection of patients for CT and aortographic evaluation at the beginning is more stringent, but several cases in our series were selected primarily because of a severe mechanism of injury despite equivocal findings on chest radiographs. Could our accuracy be improved? Possibly

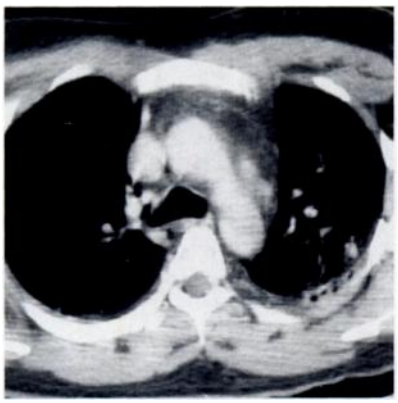

Fig. 4.—Findings equivocal for mediastinal hematoma. Contrast-enhanced CT scan of chest shows streaks of density in anterior mediastinal fat in a 34-year-old man involved in a high-speed motor vehicle accident. Aortographic findings were interpreted as normal.

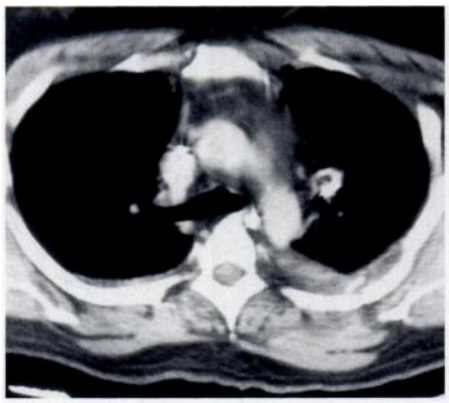

Fig. 5.—Findings suggestive of mediastinal hematoma. Contrast-enhanced CT scan of chest shows a broad irregular area of increased density in anterior mediastinal fat in a 30-year-old man injured in a head-on high-speed motor vehicle accident. Note bilateral pleural fluid collections. Aortographic findings were interpreted as normal.

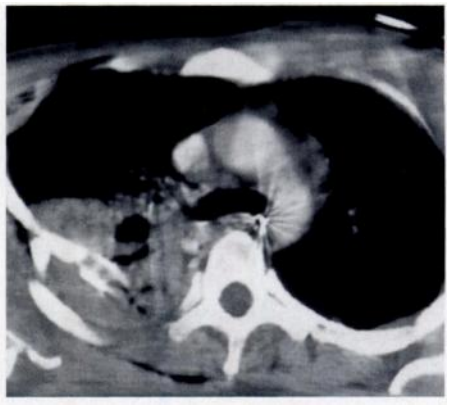

Fig. 6.—Findings subtly positive for mediastinal hematoma. Contrast-enhanced CT scan of chest reveals a small fluidlike density adjacent to anterior wall of aortic arch in a 50-year-old man with a closed head injury from a motorcycle accident. Note fractures in right scapula and right posterior part of rib cage plus fluid (blood) in posterior part of right hemithorax. Findings on thoracic aortogram were considered to be normal, and a subsequent abdominal aortogram showed a splenic injury.

so, by using 5-mm sections as suggested by Morgan et al. [3] or by using newer technology such as spiral CT if it were available to us. However, at this time, we think that the absolute exclusion of mediastinal hematoma by CT in order to avoid angiography is often difficult, which leads us to use angiography liberally. Finally, we are inclined to agree with the observation of Morgan et al. that the value of CT visualization of a normal mediastinum increases as the clinical and radiologic likelihood of acute injury decreases.

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The reader's attention is directed to the commentary on this article, which appears on the following pages.