TRANSESOPHAGEAL ECHOCARDIOGRAPHY IN THE DIAGNOSIS OF TRAUMATIC RUPTURE OF THE AORTA

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Abstract *Background.* Rupture of the aorta is a major cause of death after motor vehicle accidents. Survival depends on early diagnosis, and emergency aortography is the standard imaging method. Although transesophageal echocardiography is noninvasive and can provide high-resolution images of the aorta, information about its value in patients with trauma is limited. We conducted this study to assess prospectively the value of transesophageal echocardiography in the emergency evaluation of patients at risk for aortic injury.

Methods. Transesophageal echocardiography of the aorta was attempted in 101 patients admitted to the emergency room with a diagnosis of possible traumatic rupture of the aorta. Echocardiography and aortography personnel were notified simultaneously of the arrival of the patient, and the two tests were performed sequentially by operators who were blinded to the results of the other test. The sensitivity and specificity of transesophageal echocardiography were calculated on the basis of the results of aortography of the arch, surgery, or autopsy.

Results. Transesophageal echocardiography was attempted in 101 patients. The study was successfully performed in 93 patients but could not be completed in 8 because of lack of cooperation on the part of the patient (7 patients) or maxillofacial trauma (1 patient). Despite a high injury-severity score (mean, 29.6), transesophageal echocardiography was performed without complications, and within a mean (±SD) of 29±12 minutes. Eleven of the 93 studies (12 percent) demonstrated rupture of the aorta near the isthmus. The findings were confirmed in 10 of the 11 patients by aortography (9 patients), surgery (9 patients), or autopsy (1 patient), yielding a sensitivity of 100 percent and specificity of 98 percent for the detection of injury to the aorta. There was one false positive echocardiogram.

Conclusions. Transesophageal echocardiography is a highly sensitive and specific method of detecting injury to the thoracic aorta. This technique can be used safely and quickly in critically injured patients with suspected traumatic rupture of the aorta and compares favorably with arch aortography. (N Engl J Med 1995;332:356-62.)

TRAUMATIC rupture of the thoracic aorta is a common and often fatal injury resulting from sudden deceleration in high-speed motor vehicle accidents.[1] Survival depends on early and accurate diagnosis and prompt surgical treatment.[2-4] Although standard chest radiography is useful as an initial screening test, the diagnosis of aortic rupture requires confirmation by aortography, computed tomography, or magnetic resonance imaging before surgical repair.[4-6]

Transesophageal echocardiography is an effective means of imaging the aortic arch and descending aorta.[7-10] Recently, its use has been reported in small series of patients who had sustained blunt chest trauma.[11-15] The purpose of our study was to evaluate prospectively the safety and efficacy of transesophageal echocardiography in patients in whom acute traumatic injury to the thoracic aorta was suspected.

METHODS

Patients

We studied patients admitted to the emergency room with acute chest trauma during a 24-month period. The criteria for enrollment (approved by the Human Institutional Review Board) were that the patients have blunt chest trauma and that aortic trauma be suspected on the basis of the nature and severity of the injury, findings on chest radiography associated with mediastinal hematoma, or both.[4,5] Transesophageal echocardiography was attempted in every case in which the necessary equipment and personnel were available. The results of aortography, surgery, and autopsy were used to substantiate the echocardiographic findings.

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Chest Radiography

Chest radiographs were obtained with standard emergency room film techniques with the patient in the anteroposterior supine position, with use of a 100-cm focal distance, a 75-kV peak, and 2 to 3 mA-sec. Films obtained on admission were reviewed by staff radiologists for findings traditionally associated with aortic trauma: mediastinal widening, a blurred aortic knob, apical capping of the lung, a depressed left bronchus, a displaced nasogastric or endotracheal tube, mediastinal emphysema, or fractured first or second ribs.[5]

Transesophageal Echocardiography

Transesophageal imaging of the thoracic aorta was performed by experienced operators, who were unaware of the results of aortography, using commercially available machines with monoplane probes (in 52 percent of the patients) or biplane probes (48 percent) and 5.0-MHz transducers (Hewlett–Packard 77020AC, Andover, Mass.). After informed consent was obtained, scanning was performed in the emergency department, surgical intensive care unit, or operating room. Introduction of the probe was accomplished after the application of lidocaine spray to the posterior pharynx and the administration of intravenous midazolam or morphine, when necessary, for sedation.[7] The aortic valve, sinuses of Valsalva, ascending aorta, arch, and descending thoracic and abdominal portions of the aorta were evaluated in transverse or longitudinal planes, or both. Depth, gain, acoustic power, and gray levels were adjusted for optimal real-time imaging of the aortic wall while a careful search was made for evidence of intimal disruption, medial tears, and perivascular hematoma. Imaging of the heart, great vessels, and valves was also performed to evaluate the possibility of myocardial contusion, pericardial effusion, valvular abnormalities, and left ventricular dysfunction.

Aortography

Thoracic aortography was performed by staff radiologists, who were blinded to the results of echocardiography, with the use of 6-French pigtail catheters inserted into the aortic arch by the retro-

grade femoral approach.[4] Anteroposterior and 45-degree right posterior oblique views were obtained after the administration of 40 to 70 ml of contrast medium, with additional views obtained as needed. The thoracic aorta was assessed for evidence of an intraluminal flap (filling defect), extravasation of dye (pseudoaneurysm), or an abnormal contour of the aortic wall (intramural hematoma).

Statistical Analysis

The results of transesophageal echocardiography and angiography were compared with Fisher's exact test and the chi-square test.[16] Angiography was considered the reference standard unless confirmation was available from surgical procedures or autopsy. The sensitivity of echocardiography was calculated as the number of true positive results divided by the number of true positive and false negative results; the specificity was calculated as the number of true negative results divided by the number of true negative and false positive results; and the positive predictive value was calculated as the number of true positive and true negative results divided by the total number of tests. Nonparametric data from subgroups with and without aortic rupture were compared with the Mann–Whitney rank-sum statistic, whereas unpaired t-tests were used for normally distributed data, with a two-tailed P value below 0.05 considered to indicate statistical significance. Chi-square contingency tables were used to compare nominal data for the subgroups.[16]

Results

Study Population

During the study period, 121 patients were admitted to the emergency room with blunt chest trauma and were suspected of having sustained aortic injury. Twenty patients underwent aortography alone, because of the lack of available equipment or operators to perform echocardiography, and were therefore excluded from the analysis. Operators were unable to perform transesophageal echocardiography in 8 of the 101 patients in whom it was attempted (7.9 percent) because of difficulty in achieving sedation (in 6 patients), refusal of the patient to give consent (1 patient), or mandibular fracture (1 patient). Analysis of clinical characteristics such as age, mechanism of injury, findings on chest radiography, and outcome for the 28 patients who did not undergo transesophageal echocardiography revealed no statistical differences from the remaining 93 patients, who constituted the study group.

These 93 patients, whom we studied prospectively, underwent transesophageal echocardiography and had the findings confirmed by angiography, surgery, or autopsy. There were 69 male patients and 24 female patients in this group, with a mean (±SD) age of 44.2±18 years (range, 13 to 87). The principal cause of trauma to the trunk was motor vehicle accidents (in 69 patients). Other patients were hit by cars while walking (8), fell from a height (6), were injured in motorcycle accidents (7), were crushed by cars (2), or had gunshot wounds (1).

At the time of admission, 35 patients required endotracheal intubation. The mean injury-severity score[17] was 29.6±15 (range, 5 to 75 for the population studied). The systolic blood pressure at presentation was 129.6±28 mm Hg (range, 70 to 198).

Table 1 shows clinical and radiographic findings for the 93 patients, divided according to whether or not they had aortic rupture. The subgroups were statistically similar (P not significant) in terms of all characteristics except the injury-severity score ($P<0.001$) and the mortality rate ($P<0.02$), both of which were significantly higher in the group with aortic rupture. (The injury-severity score assigns 25 points for aortic injury, accounting for the difference between the groups.)

Table 1. Clinical and Radiographic Characteristics of 93 Patients Evaluated for Aortic Trauma.

Characteristic	Rupture (N = 11)	No Rupture (N = 82)
Age — yr		
Mean ±SD	42.9±15.1	44.5±19.2
Range	17–66	13–87
Sex — M/F	7/4	62/20
Mechanism of injury — no. (%)		
Motor vehicle accident (unrestrained)	7 (63.6)	48 (58.5)
Motor vehicle accident (restrained)	2 (18.2)	12 (14.6)
Pedestrian hit by car	0	8 (9.8)
Motorcycle accident	1 (9.1)	6 (7.3)
Fall	1 (9.1)	5 (6.1)
Gunshot	0	1 (1.2)
Crushed by car	0	2 (2.4)
External chest trauma — no. (%)	2 (18.2)	16 (19.5)
Intubation — no. (%)	5 (45.5)	30 (36.6)
Systolic blood pressure — mm Hg		
Mean ±SD	118.8±33.4	130.6±26.5
Range	70–170	76–198
Heart rate — beats/min		
Mean ±SD	115.7±30.3	103.8±22.9
Range	62–167	60–178
Glasgow coma score		
Mean ±SD	12.1±3.8	12.3±3.8
Range	6–15	3–15
Injury-severity score*		
Mean ±SD	51.1±15.2	26.7±13.3
Range	25–75	5–75
Chest-film findings		
No. of signs/patient		
Mean	2.70	2.48
Range	0–6	1–6
Wide mediastinum — no. (%)	10 (90.9)	74 (90.2)
Normal — no. (%)	1 (9.1)	0
Death — no. (%)†	4 (36.4)	9 (11.0)

*$P<0.001$ for the comparison between the groups.

†$P<0.02$ for the comparison between the groups. None of the deaths were due to aortic injury.

Patients incurred multiple injuries as a result of their accidents, most commonly closed head injury (50 patients), fractured extremities (47 patients), and facial fractures (21 patients). The mean Glasgow coma score for the group was 12.3±3.7 (range, 3 to 15). Remarkably, only 18 (19.4 percent) had visible evidence of external thoracic trauma. Thirteen patients (14.0 percent) ultimately died during hospitalization as a result of associated injuries, but no deaths were related to aortic injury (Table 1). The four deaths in the group with aortic injury were due to multiorgan-system failure (two patients), acute myocardial infarction (one patient), and hemorrhage from pelvic fracture (one patient).

Transesophageal echocardiography was performed before aortography in 62 patients (66.7 percent); the mean time required to perform echocardiography was

29.4±12 minutes, as compared with 75.5±34 minutes for aortography ($P<0.001$).

Radiographic Findings

The major abnormalities on the chest film included a widened mediastinum (90.3 percent), fractures of the first or second ribs (50.5 percent), apical capping (30.1 percent), hemothorax or pneumothorax (27.9 percent), and an abnormal aortic knob (19.4 percent). One patient with aortic injury had a normal chest film (Table 1). The average number of findings indicative of mediastinal hematoma was 2.70 for those with aortic injury, and 2.48 for those without (P not significant).

Findings on Transesophageal Echocardiography

The clinical features, radiographic findings, and outcome of the 11 patients with echocardiographic evidence of aortic rupture are shown in Table 2. The typical appearance was a mobile 2-to-3-cm echogenic flap or intraluminal mass located just distal to the isthmus (Fig. 1, 2, and 3). In one patient the tear was found in the descending aorta, superior to the gastroesophageal junction. In six cases the injury had an echocardiographic appearance similar to that of aortic dissection, with a flap completely traversing the lumen (Fig. 1); however, the lesion was localized to a 3-cm section of the aorta. In two cases, a large, protruding echogenic mass, resembling a thrombus, was seen at the arch or isthmus (Fig. 2). In the remaining three cases, a thin, highly mobile, linear flap was found extending from the aortic wall (Fig. 3). In all cases, the lesion was identified within minutes in both the horizontal and vertical planes in the patients who underwent biplane imaging.

Findings on Aortography

Seven patients had aortographic findings characteristic of aortic rupture[18]; three other aortic injuries were confirmed by surgery or autopsy. Figure 4 shows a typical positive angiogram, with a disrupted, hazy aortic contour distal to the arch.

One patient (Patient 3) underwent emergency surgery, without aortography, because she had a positive

Table 2. Clinical Data on Patients with Aortic Rupture.

Patient No.	Age (yr)	Sex	Mechanism of Injury*	Associated Injuries	External Thoracic Injury	Radiographic Findings	Findings on Transesophageal Echocardiography†	Findings on Aortography†	Findings on Surgery or Autopsy‡
1	62	F	MVA	Closed head injury, fractured ankle	Yes	Wide mediastinum, tracheal deviation, apical cap, depressed left bronchus, fracture of ribs 1 and 2	+	+	Intimal flap
2	66	F	MVA	Fracture of multiple ribs	Yes	Wide mediastinum, tracheal deviation, depressed left bronchus, fracture of scapula and ribs 1, 3, and 5	+	+	Intimal flap
3	31	F	MVA	Closed head injury, lacerated liver, hemoperitoneum	No	Wide mediastinum, abnormal aorta, hemothorax, pulmonary contusion, fractured scapula	+	Not done	Intimal flap
4	17	M	MVA	Ruptured spleen, gastric perforation, cardiac contusion	No	Wide mediastinum, abnormal aortic knob, apical cap	+	+	Intimal flap
5	27	M	MVA	Closed head injury, fractured radius and ulna, lacerated spleen, renal contusion	Yes	Wide mediastinum, fracture of ribs 1 and 2, depressed left bronchus	+	+	Intimal flap
6	32	M	Fall	Ruptured bladder, retroperitoneal hematoma, fractured pelvis, fracture of vertebrae L2 and L5, fractured tibia and radius	No	Abnormal aortic knob	+	+	Intimal flap
7	41	M	MVA	Closed head injury, fractured pelvis, fracture of vertebrae L1 through L4	Yes	Wide mediastinum, apical cap, fractured scapula	+	−	2-cm intimal–medial tear in aortic isthmus
8	66	M	MVA	Closed head injury, lacerated spleen and liver, transection of iliac artery, retroperitoneal hematoma, fractured pelvis, lacerated ileum and cecum	No	Wide mediastinum	+	Not done	On autopsy: linear tear in aorta at diaphragm
9	29	M	MVA	Closed head injury, fractured pelvis, ruptured bladder	No	Wide mediastinum, depressed left bronchus, pneumothorax, hemothorax, ruptured diaphragm	+	−	Repeated transesophageal echocardiography negative at 1 wk
10	46	F	MVA	Cardiac contusion	No	Normal	+	+	Intimal flap
11	43	M	MVA	Closed head injury, fractured clavicle, dislocated shoulder, pneumothorax	No	Wide mediastinum, abnormal aorta, apical cap, hemothorax	+	+	Intimal flap

*MVA denotes motor vehicle accident.

†A plus sign denotes that the study was positive for aortic rupture, and a minus sign that it was negative.

‡The findings listed are from the surgical procedure, except as otherwise specified.

Figure 1. Transesophageal Echocardiogram of the Descending Aorta in the Horizontal Plane in a Patient with Aortic Rupture.
The injury occurred at the aortic isthmus and produced a mobile flap (resembling that seen in aortic dissection) that completely crossed the aortic lumen. The tear was confirmed by aortography and successfully repaired.

transesophageal study and had a large area of aortic rupture, which was successfully repaired. Another patient (Patient 8) with a positive echocardiogram did not undergo aortography because of severe head injury and poor prognosis; this patient died in the hospital. A postmortem examination subsequently confirmed the echocardiographic findings indicating aortic rupture.

The echocardiographic and angiographic data were discordant in two cases. Patient 7 was shown at surgery to have aortic injury; he therefore had a false negative aortogram. The other (Patient 9) had a negative angiogram with a positive echocardiogram but did not undergo surgery. A second transesophageal echocardiogram obtained one week later was negative.

Surgical Findings

The morphologic features of the lesions seen on transesophageal imaging were confirmed in 10 patients who underwent surgery or autopsy. Patients with sessile flaps were found to have intraluminal thrombus overlying the site of rupture, whereas patients with thin flaps had shallow, linear tears.

Sensitivity and Specificity

Comparison of the results of transesophageal echocardiography with those of aortography, surgery, and autopsy revealed that there were 10 true positive echocardiograms, 82 true negatives, and 1 false positive. The results of echocardiography were concordant with those of at least one of the other methods in 92 of 93 cases; thus, the sensitivity of transesophageal echocardiography was 100 percent, the specificity was 98 percent, and the positive predictive value was 99 percent ($P<0.001$). In the patient with the single false positive echocardiogram (Patient 9) a thin (3 to 5 mm) flap was apparent at the aortic isthmus, but the aortogram was interpreted as normal. A follow-up echocardiographic study seven days later was normal, and no aortic surgery was performed.

One other patient (Patient 7) had a positive trans-

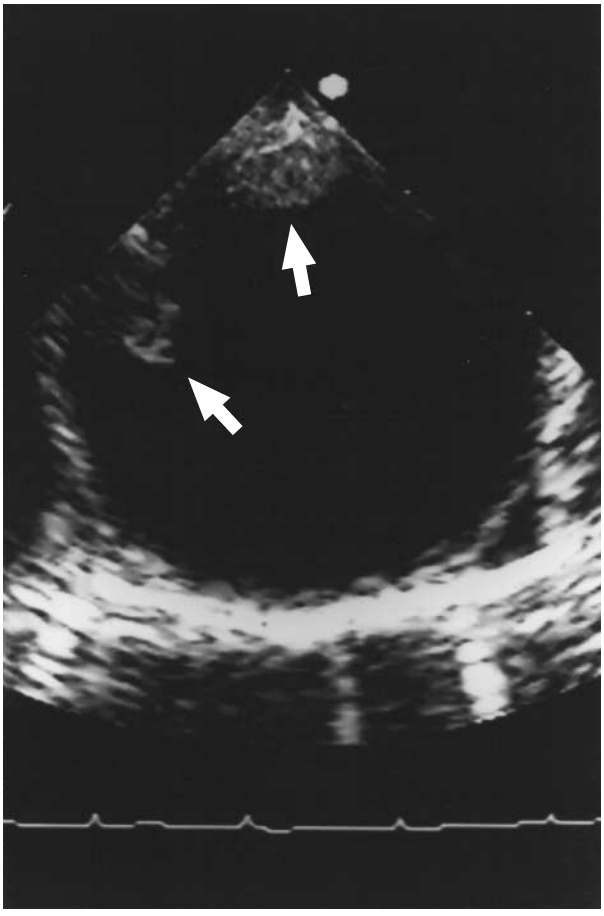

Figure 2. Horizontal-Plane Transesophageal Echocardiogram of a Patient with Aortic Rupture.
The injury was seen in the descending aorta just below the arch and appeared as two large, protruding masses (arrows). At surgery, large thrombi were found overlying the tear sites.

esophageal study but a negative aortogram. At thoracotomy, a 2-cm linear rupture through the intima and media of the posterior wall of the thoracic aorta was found. Intraoperative transesophageal echocardiography was used to localize the transection, which was successfully repaired.

Discussion

Blunt chest trauma commonly results from motor vehicle accidents in which the sternum of an unrestrained driver strikes the steering wheel at impact.[5] Rupture of the aorta has been estimated to account for up to 18 percent of deaths in motor vehicle accidents.[19] As a result of rapid deceleration of the thorax and compression of the diaphragm, the aorta is subjected to extreme torque and compression at points of attachment: the sinuses of Valsalva, the isthmus, and the diaphragm.[20] With compression of the mediastinum, the heart may be displaced into the right or left side of the chest, producing further stress at these points. The severe aortic-wall stress from intraluminal hypertension results in rupture through the intima, often continuing into the media and adventitial layers. Complete rupture usually results in death at the scene, whereas patients with a contained hematoma may survive to reach the hospital.

Figure 3. Horizontal-Plane Transesophageal Echocardiogram of a Patient with Confirmed Aortic Rupture.

A thin, highly mobile linear flap (arrow) was evident at the cross-sectional level of the aortic isthmus.

Figure 4. Aortogram (Anteroposterior View) of a Patient with a Positive Transesophageal Echocardiogram.

The aortic contour is disrupted in the descending aorta just below the arch. This appearance and site of injury are typical of patients with deceleration injuries of the aorta.

Traumatic injury to the aorta requires emergency treatment because up to 40 percent of patients die within 24 hours if surgery is not performed.[2] Since only two thirds of patients have external evidence of thoracic trauma, emergency room physicians and surgical trauma teams must maintain a high index of suspicion in order to make a prompt diagnosis.[3,21,22]

Chest films have been extensively evaluated as a method of screening for aortic rupture. Markers of mediastinal hematoma on the chest film include a widened mediastinum, blurred aortic knob, loss of concavity of the aortopulmonary window, left apical extrapleural cap, displacement of the nasogastric tube, tracheal deviation, and left hemothorax.[23-27] Fractures of the first and second ribs, clavicle, and sternum are also associated with aortic injury.[28] Taken singly or in combination, these findings lack sufficient sensitivity and specificity to identify patients with aortic rupture reliably.[22,27] At best, the plain film is a useful initial screening test to determine which patients with trauma require more definitive testing.

Currently, aortography of the arch remains the diagnostic standard for aortic rupture.[5,27] At major trauma centers, the decision to proceed to aortography is based on the mechanism and severity of injury and the findings on the chest radiograph. Since this strategy lacks

specificity, a busy trauma center may perform hundreds of aortograms per year.[5] Gundry et al. have recommended that all patients over 65 years of age who have thoracic trauma undergo aortography, because of the higher prevalence of aortic transection in this age group.[27] However, others have described fatal complications of thoracic aortography and have warned against its routine use in accident victims.[29,30] Few reports have focused on imaging strategies to identify a group of patients in whom aortography is unnecessary. Our data indicate that the use of transesophageal echocardiography can serve this important function in the emergency evaluation of patients with blunt chest trauma.

Case reports have described the appearance on the transesophageal echocardiogram of aortic intimal disruption as a mural flap within the aortic lumen, often associated with brightness and thickening of the surrounding wall, suggesting contained hematoma.[14,15,31] Sparks and coworkers[13] described their experience with 11 patients with chest trauma who were selected for transesophageal study because they had either equivocal or positive aortograms. The authors were aware of the results of aortography, yet three of six patients with rupture had negative transesophageal examinations. One additional patient with a positive echocardiogram underwent exploratory thoracotomy but had no evidence of aortic injury. Brooks et al.[11] described 21 patients with blunt chest trauma and a wide mediastinum who were examined both with transesophageal echocardiography and either with aortography or at autopsy. Three of these patients had evidence of aortic disruption on echocardiography, and the findings were confirmed by angiography. Shapiro et al.[12] prospectively evaluated 19 patients who presented with blunt chest trauma. Three of the 11 patients who had undergone aortography had evidence of aortic injury, but aortic tears were identified on transesophageal echocardiography in only 2. One study had false negative results. These reports suggested that transesophageal echocardiography might be useful for visualizing the ruptured aorta, but a larger, prospective, blinded trial was needed to establish its sensitivity and specificity. In our study transesophageal studies were performed before angiography in two thirds of the cases, and the results of imaging were confirmed by aortography, surgery, or autopsy.

Despite their severe injuries, transesophageal echocardiography was carried out in 93 of the 101 patients in whom it was attempted (92 percent). In 51 of 55 patients who were awake and not intubated, a standard protocol using topical and intravenous anesthesia provided adequate sedation. For patients who had previously been intubated, passage of the transesophageal probe was often accomplished without intravenous sedation. There was no important hemodynamic deterioration during the studies, and no cases of aspiration.

Although cardiac and radiology teams were notified simultaneously, transesophageal echocardiography was performed first in the majority of cases and required an average of only 30 minutes to complete. Echocardiography yielded additional data about left ventricular function, wall motion, and the presence and severity of valvular lesions — information that was generally not available with other emergency imaging techniques.

The most common location of aortic injury due to blunt chest trauma is the isthmus, just distal to the left subclavian artery.[18] Other locations include the ascending, descending, and abdominal segments of the aorta and the arch.[18,19] In our series the aorta had ruptured in one patient near the diaphragm (Patient 8). In all cases, transesophageal echocardiography yielded a detailed, high-resolution image of all segments of the aorta except a 3-to-5-cm portion of the upper ascending aorta.[32] Although this region can represent a "blind spot" because of the interposition of the trachea, injuries limited to this segment are extremely rare.

As in previous studies, it was not possible to distinguish patients with and without aortic injury on the basis of the clinical presentation and chest film. Although few studies have examined its sensitivity and specificity in patients with trauma, aortography has historically been considered the reference standard. False positive aortograms do occur and are attributed to an atheromatous aorta or ductal diverticula, whereas false negatives have been ascribed to poor opacification by contrast agents, an inadequate number of views, or thrombosis of the pouch.[3,4,18,33] As in other series, our transesophageal findings correlated well with the results of aortography.[11,12] On the basis of our experience, transesophageal scanning can be used as the primary imaging method or as an adjunctive noninvasive test for patients with equivocal angiographic findings.

Transesophageal echocardiography has several advantages over other imaging methods in the evaluation of critically ill patients with trauma. It can be performed in the emergency room, intensive care unit, or operating room while other measures for stabilization of the patient continue.[34] The need to move a critically ill patient in order to perform magnetic resonance imaging or computed tomography and the difficulty of monitoring patients during the imaging procedures are serious drawbacks to these techniques. Thus, the clinical use of these methods is often limited to screening for mediastinal hematoma in patients who are already undergoing head or abdominal imaging.[18]

Because the descending aorta is scanned in close proximity to the esophagus, the potential exists for near-field artifacts caused by excessive gain and reverberations.[9,10] However, careful attention to overall gain, depth, and dynamic-range controls can eliminate these artifacts. Biplane or multiplane imaging is recommended in such cases.

Since transesophageal echocardiography is a tomographic technique, its capacity to visualize the innominate, left carotid, and subclavian arteries is limited. Although traumatic injury to these branches is rare and usually apparent clinically, aortography is clearly necessary when injury to these vessels is suspected.

The safe passage of the transesophageal probe in pa-

tients with trauma, who may have injuries to the cervical spine or skull fractures, requires considerable skill on the part of the operator and careful attention to sedation, along with limitation of excessive neck and head movements. Transesophageal studies should not be attempted in patients who are combative or have unstable neck and spine injuries.

The presence of preexisting atheroma may pose a problem in patients being evaluated for aortic trauma. Although this "aortic debris" can be similar in appearance and location to intimal injury, the atheromatous lesions are characteristically diffuse and associated with extensive aortic-wall calcification and fibrosis.[35] In elderly patients with trauma, however, protuberant atheromatous lesions in the aortic arch may produce false positive results on transesophageal study. In these cases, aortography of the arch is advisable to provide complementary data on the integrity of the vessel wall.

Both our series and that of Brooks et al.[11] included cases with discordant findings on transesophageal echocardiography and angiography. We believe that intimal disruption was unequivocally present in the transesophageal images of our patient with the false positive result; aortography was negative for rupture in this case because the tear, though present, did not involve the full thickness of vessel media and adventitia. Indeed, the high resolution of transesophageal echocardiography may make it possible to use this method to identify aortic intimal injuries that are below the threshold of detection of angiography. In such cases, aortography can be used to determine whether thoracotomy is needed.[36]

Transesophageal imaging of the aorta is a highly sensitive and specific method of detecting aortic injuries in patients with blunt chest trauma. This technique can be performed quickly and safely in critically injured patients and compares favorably with aortography of the arch in the detection of these lesions. Moreover, transesophageal echocardiography can also be used as the primary imaging technique in such patients.

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CORRECTION

Notice of Redundant Publication: Transesophageal Echocardiography in the Diagnosis of Traumatic Rupture of the Aorta

To the Editor: Smith et al. (Feb. 9 issue)[1] report the use of transesophageal echocardiography to diagnose aortic trauma in a series of 121 patients at the University of Kentucky Medical Center over a 24-month period. The same authors have reported on two similar series in the past two years from the same institution.[2,3] The first article, by Kearney et al., describes a series of 69 patients followed for 18 months, and the second, by Buckmaster et al., a series of 160 patients followed for 33 months. The findings in these studies are similar and demonstrate the high sensitivity and specificity of transesophageal echocardiography for the detection of traumatic rupture of the aorta.

The authors do not indicate in the most recent paper[1] whether these series were consecutive or whether, in fact, these studies all involve the same patients. From the methods described, it would appear that the latter may be the case.

These are important studies, because they suggest that transesophageal echocardiography could replace aortography as the gold-standard investigation for aortic trauma. The conclusions of the papers will obviously be much stronger if the studies involved consecutive series with a total sample of 350 patients. We request that the authors describe more clearly the patients in these three series.

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2. Kearney PA, Smith DW, Johnson SB, Barker DE, Smith MD, Sapin PM. Use of transesophageal echocardiography in the evaluation of traumatic aortic injury. J Trauma 1993;34:696-703.
3. Buckmaster MJ, Kearney PA, Johnson SB, Smith MD, Sapin PM. Further experience with transesophageal echocardiography in the evaluation of thoracic aortic injury. J Trauma 1994;37:989-995.

To the Editor: Smith and colleagues assert that transesophageal echocardiography is sensitive and specific enough to be used as the primary imaging method in patients with suspected traumatic rupture of the thoracic aorta. We agree with them that the distal portion of the ascending aorta, as well as the branches of the aortic arch, cannot be adequately assessed by transesophageal echocardiography. However, we do not agree that traumatic injury to these branches is ``rare and usually apparent clinically.´´

We reviewed our experience in patients with blunt chest trauma who underwent aortography because mediastinal blood was apparent on chest radiography. We identified 81 patients who had angiographic evidence of traumatic injury to the thoracic aorta or its branches (75 from motor vehicle accidents, 4 from falls, 1 from being hit by an automobile, and 1 from a crush injury). Among these 81 patients, 66 had only aortic rupture. Fifteen patients (18.5 percent) had injuries of the aortic branch vessels. Three of these patients had not only ruptures of the thoracic aorta but also a total of four injuries to the aortic branches. The other 12 had a total of 19 injuries to the aortic branches but had intact aortas. The 23 ruptured branches were the following arteries: brachiocephalic (5), right subclavian (3), left common carotid (4), left subclavian (7), vertebral (2), and internal thoracic (2). The mediastinal blood seen on chest radiography had an identical appearance whether the injury was to the thoracic aorta, its branches, or both.

Transesophageal echocardiography has completely replaced aortography at our institution in cases of suspected nontraumatic acute aortic dissection.[1] However, until the major noncoronary branches of the thoracic aorta can be adequately and consistently evaluated by this method, aortography should remain the primary imaging method used to evaluate patients with mediastinal blood visible on chest radiography after blunt trauma. In this setting, transesophageal echocardiography could be of supplementary benefit in the occasional aortic isthmus in which a ``bump´´ to the ductus arteriosus cannot be distinguished from an aortic rupture.

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1. Bansal RC, Chandrasekaran K, Ayala K, Smith DC. Frequency and explanation of false negative diagnosis of aortic dissection by aortography and transesophageal echocardiography. J Am Coll Cardiol 1995;25:1393-1401.

To the Editor: Smith et al. attribute a positive predictive value of 99 percent to transesophageal echocardiography in the diagnosis of aortic rupture. The positive predictive value of a test is the percentage of true positive results among all positive results. On the basis of the results presented, Table 1 can be constructed. Using the following formula, one can calculate the positive predictive value of the test:

Positive predictive value = true positives/(true positives + false posi-

tives) = 10/(10 + 1) = 10/11 = 90.9 percent.

It is not my intention to underestimate the value of this method and the conclusions presented. My concern is that the concept of the positive predictive value is very basic, and the value should not be calculated incorrectly.

Table 1. Results of Transesophageal Echocardiography Used to Detect Aortic Rupture.

Table 1. Results of Transesophageal Echocardiography Used to Detect Aortic Rupture.

Test Result	Aortic Rupture	
	Absent	Present
Negative	82 (true negative)	0 (false negative)
Positive	1 (false positive)	10 (true positive)

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The authors reply:

To the Editor: We wish to acknowledge substantial redundancy of patients in our 1995 *Journal* study[1] of 93 patients with suspected aortic injury. Seventy-six of these patients, 8 of whom had positive results on transesophageal echocardiography, had been included in a study of 160 patients with the same condition published in the *Journal of Trauma* in 1994.[2] The 1994 study also included many patients described one year earlier in our initial report of the successful use of transesophageal echocardiography to diagnose thoracic aortic injury.[3] Although we cited the 1993 report in our article in the *Journal,* we neglected to cite the larger 1994 study[2] and failed to inform you that that study had been accepted for publication. We sincerely apologize for any confusion about the total number of patients studied and any duplication of data.

In response to Drs. Smith and Bansal, we have reviewed our four-year experience with injuries to arch vessels. Of 6158 patients admitted because of blunt trauma, 251 had suspected aortic injuries, 172 underwent angiography, and none had injuries to the arch vessels. We have evaluated three injuries to the subclavian artery, which involved a pulse deficit in one case, a brachial plexopathy in the second, and both conditions in the third. We have not seen any patients with blunt trauma who had injuries to the innominate or proximal carotid arteries.

The available studies support our conclusions. In an autopsy series of 275 patients[4] and a clinical study of 73 patients with blunt thoracic injury,[5] there was only 1 patient with an injury to an arch vessel, and that injury was contiguous with an aortic injury. A collective review[6] showed that with the exception of the brachiocephalic trunk, other clinical and radiographic signs usually accompany injuries to the arch vessels. Thus, our experience and those reported confirm that injuries to these vessels are ``rare and usually apparent clinically.´´

As pointed out by Dr. Azevedo, the positive predictive value of transesophageal echocardiography was incorrectly reported in our paper. The value is the number of true positive results divided by the number of all positive results[7] and is 10/11 or 90.9 percent. Notably, the one patient with a ``false positive´´ result of transesophageal echocardiography did not undergo surgery and may actually have had a false negative angiographic study. Since a patient with negative bedside transesophageal echocardiography could avoid aortography, the most relevant statistic is the negative predictive value: 82 true negative results divided by a total of 82 negative results, or 100 percent.

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