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CLINICAL MANAGEMENT UPDATE

Guidelines for the Diagnosis and Management of Blunt Aortic Injury: An EAST Practice Management Guidelines Work Group

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STATEMENT OF THE PROBLEM

Blunt injury to the aorta (BAI) is responsible for approximately 8,000 deaths each year in the United States. This injury most commonly results from motor vehicle collisions but may also result from pedestrian mishaps, falls from height, and crushing thoracic injuries. The majority of patients who sustain BAI die at the scene. The patients who reach the hospital alive have a reasonably good expectation of survival, providing their BAI is diagnosed and treated in a timely manner. These patients often have multiple injuries, a condition that complicates their diagnosis and treatment. In addition, operative management may result in complications such as paraplegia and acute renal failure. No single center has a large amount of experience with this injury; therefore, it is important to consider all of the available data when coming to conclusions regarding the best method of diagnosis and treatment of BAI.

PROCESS

Identification of References

A MEDLINE search was performed for the years 1966 to 1997. All English language citations with the subject words *thoracic aorta* and *wounds, nonpenetrating* were retrieved. Letters to the editor, isolated case reports, animal studies, meta-analyses, and review articles were deleted from further review. However, the bibliography sections of review articles and meta-analyses were used to identify additional references not retrieved with the MEDLINE search. This process resulted in 137 articles that were reviewed by a group consisting of trauma surgeons, thoracic surgeons, and a trauma radiologist. This group collaborated to produce the above recommendations and the following evidentiary table (Table 1).

Quality of the References

The quality assessment instrument applied to the references was that developed by the Brain Trauma Foundation and subsequently adopted by the EAST Practice Management Guidelines Committee. Articles were classified as class I, II, or III according to the following definitions: Class I: A prospective randomized clinical trial. There were no Class I articles reviewed. Class II: A prospective noncomparative clinical study or a retrospective analysis based on reliable data. Class III: A retrospective case series or database review.

RECOMMENDATIONS

The level of the following recommendations corresponds roughly to the class of references that support it.

Level I

There is insufficient evidence to support a standard of care on this topic.

Level II

The possibility of a BAI should be considered in all patients who are involved in a motor vehicle collision, regardless of the direction of impact.

The chest x-ray is a good screening tool for determining the need for further investigation. The most significant chest x-ray findings include (but are not limited to) widened mediastinum, obscured aortic knob, deviation of the left mainstem bronchus or nasogastric tube, and opacification of the aortopulmonary window.

Angiography is a very sensitive, specific, and accurate test for the presence of BAI. It is the standard by which most other diagnostic tests are compared.

Computed tomography of the chest is a useful diagnostic tool for both screening and diagnosis of BAI. Spiral or helical computed tomographic scanners have an extremely high negative predictive value and may be used alone to rule out BAI.

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When these scanners are used, angiography may be reserved for patients with indeterminate scans.

Prompt repair of the BAI is preferred. If the patient has more immediately life-threatening injuries that require intervention such as emergent laparotomy or craniotomy, or if the patient is a poor operative candidate because of age or comorbidities, the aortic repair may be delayed. Medical control of blood pressure is advised until surgical repair can be accomplished.

Level III

The presence of physical findings such as pseudocoarctation or intrascapular murmur should be investigated further.

Transesophageal echocardiography is also a sensitive and specific test. There are several limitations to this test. It does require training and expertise that may not be as readily available as angiography.

Repair of the aortic injury is best accomplished with some method of distal perfusion, either bypass or shunt. Neurologic complications seem to correlate with ischemia time; therefore, this time should be kept to a minimum.

SCIENTIFIC FOUNDATION

BAI is the second most common cause of death in blunt trauma patients.[2] The majority of patients die at the scene, with only 13 to 15% arriving at the hospital with signs of life.[2,141] The remainder of patients will die within the first few days of hospitalization if the BAI is not promptly diagnosed and treated.[2]

The most common mechanism of BAI seems to be from a motor vehicle collision with frontal and lateral impacts occurring with approximately equal frequency.[5,15] Other common mechanisms include pedestrian/vehicular incidents and falls. Most patients who sustain BAI die at the scene or during transport. Of the patients who arrive alive to the hospital, there are many varied signs and symptoms they may present with. The most commonly noted signs in these patients are pseudocoarctation and intrascapular murmur.[17,24,28,36] Absence of any of these signs does not entirely rule out BAI, as it has been reported with a normal physical examination.[22,23]

The chest radiograph (CXR) has been studied extensively as a screening test. There is some evidence that an erect posteroanterior view is better than a supine anteroposterior view.[25] A widened mediastinum has been the most frequently cited CXR finding that triggers additional work-up for BAI.[1,2,14,20,22,24,26] The widened mediastinum may be defined as a measured width greater than 8 cm,[11,21,24,35] a mediastinal/chest width ratio of >0.38,[11] or simply the physician's impression that the mediastinum is widened.[3,20] Mediastinal abnormalities on the CXR that are considered strongly suggestive of BAI include an obscure or indistinct aortic knob,[1,3,13,14,25,27,30,34,35] depression of the left mainstem bronchus,[6] deviation of the nasogastric tube,[6,19] and opacification of the aortopulmonary window,[1,4,25,30,35] Other commonly seen CXR findings include widened paratracheal and paraspinous stripes[4,12,25,30] and apical capping.[1] Findings such as pneumothorax and hemothorax are very nonspecific,[20] and there seems to be a negative association with fractures of the thoracic skeleton.[19,20,36] It is possible for BAI to occur in the presence of a normal CXR; therefore, patients injured by significant deceleration or acceleration mechanisms should undergo a screening test anyway.[7,10]

Angiography has been used as the gold standard diagnostic test for BAI.[41–43] It is the test to which all others are compared. There is a small incidence of false-positive angiograms resulting from anatomic abnormalities such as ductus diverticulum[42] that the physician should be aware of. Various techniques have been studied in an attempt to reduce the required dye load. These include intravenous and intra-arterial digital subtraction angiography,[39,40,43,138] and there is some evidence that intra-arterial digital subtraction angiography is as accurate as conventional angiography.

Computed tomography of the chest (CTC) seems to be a very useful diagnostic tool.[44,48] Its use ranges from the screening of all patients with blunt chest trauma[37,61,62] to studying only those patients with a normal or low suspicion CXR.[47,50–52] If the CTC is performed with a conventional scanner, most authors recommend following an abnormal CTC with angiography.[47,50,54] A potential problem with the CTC is that it may delay the time to angiography and, thus, to a definitive diagnosis.[57] This problem is resolved with newer generation scanners such as helical or spiral CT scanners. They are more sensitive[45,139] and seem to have 100% negative predictive value.[50,143,144] When helical or spiral CTC is used, angiography may be reserved for those patients with equivocal or indeterminate scans, because there is more anatomic detail present on the angiogram.[143,144]

Transesophageal echocardiography (TEE) has gotten much attention in the past 6 years. It is also a very sensitive screening test[10,63,65,67,70,71] but many authors also follow an abnormal TEE with angiography.[64,68,72] Unfortunately, TEE requires specific training and expertise[140] and may not be as readily available as CTC or angiography. Its usefulness may lie in the ability to follow small intimal injuries that are not seen on angiography[63] or for diagnosis in the patient too unstable to move to the angiography suite.[66] TEE does not visualize the ascending aorta or the aortic branches well and may miss injuries to these vessels.[73,74]

Once the diagnosis of BAI is made, most authors agree that prompt surgical repair is the best approach.[2,28,80,83] Immediate repair may not be possible for all patients, however, i.e., for patients unstable from intra-abdominal injuries who require laparotomy or patients with severe closed head injuries who require craniotomies.[76,84,86] Another subset of patients are those who are elderly or have comorbidities that prohibit emergency thoracic surgery.[77,81] These patients may be safely managed medically until these other factors have been resolved.[143] Pharmacologic control of blood pressure with beta-blockers or nitroprusside is extremely important when delayed or nonoperative management is contemplated.[78,79,82,88,91,143] The use of specialized monitoring devices such as a pulmonary artery catheter may be useful, especially in the patient who has sustained a significant blunt cardiac injury as well.[85]

Several different techniques of repairing the BAI have

been reported. These techniques include both direct suture repair[115,122] and placement of a prosthetic graft.[128] The most feared complications of BAI repair are paraplegia and renal failure, both of which result from ischemia during the repair. Ischemic complications correlate with the time the aorta is clamped.[2,102,106,114] In addition, there are more metabolic derangements resulting from reperfusion when the clamp and sew method is used.[124] Various methods of distal perfusion ranging from heparin-bonded (Gott) shunts[78,79,90,96,109,127] to partial or full cardiac bypass with and without systemic heparinization[55,98,99,103,105,114,116,118,128,130,133] have been shown to be helpful in minimizing distal ischemia. Although there is a theoretical risk of increased bleeding from head or abdominal injuries with systemic heparinization, Pate[116] found no increase in hemorrhage in his series. These methods should be used in all patients or at least in those patients in whom a prolonged clamp time is anticipated.[2,97,107] Other protective measures such as hypothermia may also be helpful.[94,98] A dedicated thoracic surgeon may be best qualified to repair BAI,[92] although Kim et al.[108] believes that full-time trauma surgeons have equally good results. Close communication between the surgical and anesthesia teams is essential.[104,124]

SUMMARY

In summary, BAI is a lethal result of severe blunt trauma. It should be considered in all patients who sustained injury by a deceleration or acceleration mechanism, especially in the face of physical or radiographic findings suggestive of mediastinal injury. Angiography remains the "gold standard" for diagnosis, although CT scanning is taking more of a role, especially for screening. Diagnosis should be followed by prompt surgical repair using some method of distal perfusion to minimize renal and spinal cord ischemia. If prompt repair is not feasible because of other injuries or comorbidities, medical control of blood pressure is warranted in the interim.

FUTURE INVESTIGATION

Less invasive diagnostic testing should be investigated as it becomes available in a prospective manner. In addition, the optimal method of distal perfusion during surgical repair should also be investigated in a prospective manner. As the number of patients who actually survive to surgery is relatively small, this may best be accomplished through a multicenter trial.

TABLE 1. **Blunt aortic injury: evidentiary table**[a]

Reference No.	Author reference	Title	Class	Conclusions
Which patients to screen?				
1	Dalldorf et al. *Am Surg* 1990	Traumatic rupture of the aorta: indications for aortography	2	Retrosp. 102 pt with angio for BCT. CXR, angio and chart reviewed by 3 blinded reviewers. Req angio for pt with: WM, abn arch, APW opacification, or apical capping.
2	Fabian et al. *J Trauma* 1997	Prospective study of blunt aortic injury: multicenter trial of the American Association for the Surgery of Trauma	2	Prosp. 274 pt with BAI 85% had WM on CXR. 8.7% with paraplegia correlated with cross-clamp times—bypass may allow longer cross-clamp time without increasing risk of paraplegia. Rec: prompt dx and thoracotomy.
3	Gundry et al. *J Trauma* 1983	Assessment of mediastinal widening associated with traumatic rupture of the aorta	2	149 pt including 16 with BAI. Films retrosp. reviewed by blinded surgeon and radiologist. WM in 89% of BAI. Aortic knob obscure in 82% (all with WM). 91% had obliterated paraspinous stripe (all with WM), 76% with APW obliteration (all with WM), 36% with HTX, 25% bronchus depression, etc. Rec: most reliable is WM (physician's sense) and obscure aortic knob.
4	Heystraten et al. *Acta Radiol* 1988	Chest radiography in acute traumatic rupture of the thoracic aorta	2	Retrosp. 123 pt with BCT to determine CXR findings indicative of BAI. 61 had BAI, 62 had negative angio. Not blinded to angio results. Findings identified as significant were: widened paratracheal stripe, opacified APW, displaced NGT and widened right paraspinal stripe. Best combination of 2 signs was widened paratracheal stripe and opacified APW.
5	Katyal et al. *J Trauma* 1997	Lateral impact motor vehicle collisions: significant cause of blunt traumatic rupture of the thoracic aorta	2	Retrosp. 97 pt with BAI at surgery or autopsy. 49.5% resulted from lateral impact and 50.5% from nonlateral impact. Rec: consider BAI in all victims of severe MVC.
6	Marnocha and Maglinte *AJR Am J Roentgenol* 1985	Plain-film criteria for excluding aortic rupture in blunt chest trauma	2	Retrosp. 86 pt with BCT and angio. 13 had BAI. 6 radiologic signs were significant: NGT deviation, LMSB depression, tracheal deviation, apical cap, loss of aortic contour, and loss of aortic knob. Only NGT deviation and depression of LMSB were significant on multivariate analysis, although 27 did not have an NGT and in 3 the bronchus could not be assessed. Conc: before CXR, a NGT should be inserted. If the patient has neither deviation of trachea or NGT and a nl aortic knob and contour aortic rupture is unlikely and follow-up evaluation is unnecessary.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
7	Marsh and Sturm *Ann Thorac Surg* 1976	Traumatic aortic rupture: roentgenographic indications for angiography	2	Retrosp. 47 pt with angio for BCT. 5 pt had +angio, 40 were nl and 2 were false positive. All 5 pt with BAI had: WM, tracheal shift, indistinct aortic outline, pleural cap, and loss of APW. 4 had depressed LMSB. Elimination of pt with nl CXR would reduce negative angios by 50%. They caution that BAI can occur with nl CXR so nature of injury and physical findings should be taken into consideration.
8	Plewa et al. *Am J Emerg Med* 1997	Cervical prevertebral soft-tissue measurements and chest radiographic findings in acute traumatic aortic injury	2	Retrosp. review of CXR and C-spine films of 13 pt with BAI and 19 pt without BAI. +BAI pt had WM, no difference in width of neck soft tissues. Conc: cervical soft tissue swelling not a useful marker for BAI.
9	Shackford et al. *J Trauma* 1978	The significance of chest wall injury in the diagnosis of traumatic aneurysms of the thoracic aorta	2	Prosp. 35 pt with BCT had angios. Rec. angio for BCT with WM or UE pulse deficit/murmur. Hx of BCT alone doesn't require angio.
10	Vignon et al. *J Trauma* 1996	Routine transesophageal echocardiography for the diagnosis of aortic disruption in trauma patients without enlarged mediastinum	2	Prosp. 40 pt with BCT—6 with WM, 34 without WM. 2 pt had BAI: 1 in each group. Rec: TEE in all pt with severe BCT regardless of CXR findings.
11	Woodring and King *J Trauma* 1989	Determination of normal transverse mediastinal width and mediastinal-width to chest-width (M/C) ratio in control subjects: implications for subjects with aortic or brachiocephalic arterial injury	2	4 groups: 100 control pt without trauma, 32 pt with acute injury to aorta or brachiocephalic arteries, 30 pt matched to injured pt with BCT but nl angio, 28 controls. CXR reviewed by 2 authors (1 blinded). Nl transverse mediastinal width ranged 3.7–8.5 cm with a mean of 5.94, and 95% were <7.5 cm. Nl M/C ratio was 0.19–0.48 with mean of 0.30, and 95% were <0.38. Films were supine AP. Correlation of increasing M/C ratio with age. In 32 pt with major vessel injury, 59% had transverse mediastinal width >7.5 and 31% had M/C ratio >3.8. Conc: transverse width and M/C ratio have an unaccepted low sensitivity in differentiating pt with BCT who have nl and abn findings.
12	Woodring et al. *Radiology* 1982	The right paratracheal stripe in blunt chest trauma	2	Retrosp. 102 pt with BCT. 48 pt with abnormal R paratracheal stripe (>5 mm at 2 cm above azygos arch). 11 pt with widened stripe and 1 pt with nonvisualized stripe had BAI. Rec: pt with normal R paratracheal stripe do not need angio.
13	Ayella et al. *J Trauma* 1977	Ruptured thoracic aorta due to blunt trauma	3	Review of approach used at MIEMS to diagnose and treat BAI. Emphasizes value of "true erect" AP chest film if no spine injury. No mention made of other contraindications to "true erect" film, i.e., femur or pelvis fracture. "WM" not as important a finding as "obscure mediastinal structures" to screen patients at risk for further evaluation. 75% survival.
14	Barcia and Livioni *Radiology* 1983	Indications for angiography in blunt thoracic trauma	3	Retrosp. 113 pt with BCT and angio. 17 were + for BAI. Abn aortic knob and WM in all BAI. All other radiographic signs nonspecific. Most sensitive criteria are WM and abnormal aortic knob.
15	Ben-Menachem *J Trauma* 1993	Rupture of the thoracic aorta by broadside impacts in road traffic and other collisions: further angiographic observations and preliminary autopsy findings	3	Demonstrated that occupants in collisions (frontal or lateral impact) may have BAI. Less impact protection from airbags and belts in lateral impact collisions.
16	Clark et al. *J Trauma* 1990	Blunt aortic trauma: signs of high risk	3	Advocate early thoracotomy without aortography if "high risk" signs are present, i.e., L HTX> 500 mL + WM, or pseudocoarctation, abn mediastinum with neck hematoma.
17	DeMeules et al. *J Thor Cardiovasc Surg* 1971	Rupture of aorta and great vessels due to blunt thoracic trauma	3	Retrosp. 15 pt with BAI. 73% mortality from associated injuries or delay in dx. Rec: angio in pt with WM, thoracic fx, pulse deficit, or unexplained hypotension.
18	Feczko et al. *J Trauma* 1992	An autopsy case review of 142 nonpenetrating (blunt) injuries of the aorta	3	92% of deaths occurred within 4 h of injury; 62% died within 30 min of injury. Vehicular collision impact forces were split about evenly between "frontal" and "lateral" crashes, i.e., no collision pattern is exempt from considering BAI.
19	Gerlock et al. *AJR Am J Roentgenol* 1980	Traumatic aortic aneurysm: validity of esophageal tube displacement sign	3	Retrosp. 46 pt with BCT: 28 had a NGT. All pt with NGT displacement had BAI. Also significant were tracheal shift and lack of rib fractures.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
20	Gundry et al. *J Trauma* 1982	Indications for aortography in blunt thoracic trauma: a reassessment	3	Retrosp. 173 pt with BCT and angio. 19 were + for BAI. WM was best radiographic predictor of BAI (84% accurate). HTX, 1st rib fx, PTX or apical cap were not predictive. Murmur was best clinical predictor (all had WM). Rec: most useful criteria for angio is WM (includes physician sense of WM).
21	Kram et al. *J Vasc Surg* 1987	Clinical and radiographic indications for aortography in blunt chest trauma	3	Retrosp. 76 pt with BCT and angio. 10 had BAI. WM present in all BAI. Angio had 10.5% complication rate. Rec: WM > 8 cm most sensitive indicator of BAI.
22	Kram et al. *Ann Thorac Surg* 1989	Diagnosis of traumatic thoracic aortic rupture: a 10-year retrospective analysis	3	Ret. 82 pt with BCT—12 had BAI WM most sensitive finding on CXR for BAI >1/2 pt with BAI have no physical finding.
23	Lee et al. *J Trauma* 1997	Noncorrelation between thoracic skeletal injuries and acute traumatic aortic tear	3	Retrosp. 548 pt with BCT evaluated by angio or CTC—62 had BAI. No single thoracic skeletal injury is predictive of BAI.
24	Mattox et al. *JACEP* 1978	Suspecting thoracic aortic transection	3	Retrosp. 100 pt with angio for BCT. 28 had BAI (6 died before angio). 22 pt with BAI and angio had: 22 WM > 8 cm, 21 tracheal deviation. Physical findings associated with BAI were paraplegia, systolic murmur, stridor, and dyspnea.
25	Mirvis et al. *Radiology* 1987	Value of chest radiography in excluding traumatic aortic rupture	3	Retrosp. 205 pt with angio for BCT. Most discriminating signs were loss of APW, abnormal aortic knob, tracheal shift, and widened paraspinal line. Erect view slightly better than supine. Admission CXR remains best screening test for BAI.
26	Pastershank and Chow *J Can Assoc Radiol* 1974	Blunt trauma to the aorta and its major branches	3	Retrosp. 23 pt: 4 with BAI Rec: angio in all BCT with WM.
27	Petty et al. *Postgrad Med* 1991	Chronic posttraumatic aortic pseudoaneurysm: recognition before rupture	3	Retrosp. 11 pt with chronic pseudoaneurysm after remote trauma. Conc: most sensitive CXR finding is abn knob.
28	Richardson et al. *South Med J* 1979	Traumatic rupture of the thoracic aorta	3	Retrosp. 167 angio in pt with BCT. 29 showed BAI 67% survival. Rec: angio in pt with BCT and radiographic abnormalities or signs (pulse deficit, murmur) with repair immediately after dx.
29	Richardson et al. *Ann Surg* 1990	The widened mediastinum: diagnostic and therapeutic priorities	3	Review of 408 CXR with WM. 35 pt had BAI 34 were operated on. Operative mortality was 44%. Conc: diagnosis of BAI remains a significant challenge.
30	Shaikh et al. *Am Surg* 1986	Aortic rupture in blunt trauma	3	Retrosp. 8 pt with BAI. Most common CXR findings were WM, indistinct aorta, and APW opacification. 6 pt had right paratracheal stripe.
31	Smith and Champ *Am J Surg* 1986	Traumatic rupture of the aorta: still a lethal injury	3	Retrosp. 61 pt with BAI (including autopsy records). Rec: angio in any pt with significant deceleration injury.
32	Spouge et al. *Pediatr Radiol* 1991	Traumatic aortic rupture in the pediatric population: role of plain film, CT and angiography in the diagnosis	3	Retrosp. 54 pt aged 22 day–16 y with BCT. 50 pt without BAI are compared with 4 with BAI. 25/50 pt without BAI had abn CXR, 13 had nl CXR when repeated. None of 50 nl pt had angio.
33	Sturm et al. *Ann Emerg Med* 1984	Significance of symptoms and signs in patients with traumatic aortic rupture	3	Retrosp. 50 pt with BAI vs. cohort of 50 BCT with negative angio. Signs/sx of BAI just as likely to occur in patients without BAI CXR best "screening" test. Study design problem: assumes signs/sx not mentioned in record were not present.
34	Sturm et al. *Surgery* 1979	Ruptured thoracic aorta: evolving radiological concepts	3	Retrosp. 18 pt with BAI: 15 survived to angio, 3 confirmed by autopsy. All 18 had indistinct aortic contour, 16 with apical cap, 15 displaced SVC, 11 WM > 8 cm, 11 opacified APW. Conc: WM not most common CXR abnormality, but loss of aortic contour is.
35	Sturm et al. *Ann Emerg Med* 1983	Chest roentgenographic findings in 26 patients with traumatic rupture of the thoracic aorta	3	Retrosp. 26 pt with BAI. 23 had distorted aortic contour, 22 had opacified APW, 21 had WM > 8 cm, 13 had apical cap. Conc: distortion of aortic contour, loss of APW and WM were most common CXR findings of BAI.
36	Trachiotis et al. *Ann Thorac Surg* 1996	Traumatic thoracic aortic rupture in the pediatric patient	3	Retrosp. 6 pt Aged 8–16 y with BAI with additional 5 cases from literature. Noted absence of rib fx in these pt. Also increased incidence of pre-op paraplegia (4/11). 2/6 pt (40%) had sx of pseudocoarctation. Rec: use of CTC and TEE in the early diagnosis of BAI.
37	Vloeberghs et al. *Acta Chir Belg* 1988	Posttraumatic rupture of the thoracic aorta	3	4 pt with "nl" CXR subsequently proven to have BAI Rec: CTC on all "major trauma victims."

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
38	Woodring *J Thorac Cardiovasc Surg* 1989	The potential effects of radiographic criteria to exclude aortography in patients with blunt chest trauma	3	Retrosp. analysis of 32 pt with known BAI or aortic branch injury. 94% have abnormal CXR. Any type of abn mediastinum on CXR should have an angio.
Angiography as a diagnostic test				
39	Mirvis et al. *AJR Am J Roentgenol* 1986	Thoracic aortic rupture: advantages of intra-arterial digital subtraction angiography	2	Prosp. 61 pt with DSA for BCT. 10 + for BAI only 10 of the negative studies were compared with conventional angio. Rec: IA-DSA to reduce time and dye load.
40	Eddy et al. *Am J Surg* 1990	Rapid diagnosis of thoracic aortic transection using intravenous digital subtraction angiography	2	50 pt with BCT and abn CXR had IV-DSA. 67% were good quality. IV-DSA useful as positive screening test but not reliable if negative or poor quality.
41	Sturm et al. *Am J Emerg Med* 1990	Thoracic aortography following blunt chest trauma	2	Retrosp. 314 pt with BCT and angio. 47 had BAI. Angio was 99.3% accurate. No false negative angios. Rec: use angio to dx BAI after BCT.
42	Morse et al. *Am J Roent* 1988	Traumatic aortic rupture: false-positive aortographic diagnosis due to atypical ductus diverticulum	3	Retrosp. 314 angio for BCT. Found 26% incidence of ductus diverticulum. Warn that it may produce false-positive angio results.
43	Pozzato et al. *Cardiovasc Intervent Radiol* 1991	Acute posttraumatic rupture of the thoracic aorta: the role of angiography in a 7-year review	3	Retrosp. 15 pt. WM and obscuration of aorta were indications for angio. CTC did not help in diagnosing BAI. DSA and conventional angio were used. DSA required less time to perform.
138	Johnson et al. *J Vasc Interv Radiol* 1997	Comparison of digital subtraction and cut film arteriography in the evaluation of suspected thoracic aortic injury	3	Prosp. 100 pt with BCT. All had angio performed by "cut film" and IA-DSA techniques. Studies reviewed by blinded radiologists. Both techniques were equally sensitive, specific, and accurate.
Computed tomography as a diagnostic test				
44	Fisher et al. *AJR Am J Roentgenol* 1994	Diagnosis of injuries of the aorta and brachiocephalic arteries caused by blunt chest trauma: CT vs aortography	2	Prosp. evaluation of CT for BAI using GE9800 Quick scanner (not spiral or helical). 107 pt: 88 with CT and angio (4 had BAI, 19 with only angio (1 BAI). No false negatives with CT.
45	Gavant et al. *Radiology* 1995	Blunt traumatic aortic rupture: detection with helical CT of the chest	2	Prosp. 1518 pt with BCT and helical CTC. 127 had abn CTC followed by angio. 21 BAI on angio. Rec: helical CTC for screening of pt with BCT.
46	Gavant et al. *AJR Am J Roentgenol* 1996	CT aortography of thoracic aortic rupture	2	Axial CTC images can find all BAI CT angiography using advanced software techniques and helical scan hardware can demonstrate all BAI > 15 mm long. CT angio could replace conventional angio in most cases.
47	Madayag et al. *Radiology* 1991	Thoracic aortic trauma: role of dynamic CT	2	114 pt with BCT: 21 had angio for abnormal CXR with 2 + for BAI. 93 had nl CXR and CTC: 10 had angio for abn CTC with 1 + BAI. Rec: If CXR is nl, do CTC as screening test. If CTC is abn, do angio.
48	Durham et al. *Ann Surg* 1994	Computed tomography as a screening exam in patients with suspected blunt aortic injury	2	Prosp. evaluation of standardized protocol using CXR, CTC and angio to diagnose BAI. Stable pt With abn CXR and CTC followed by angio. At least 2 radiologists detected on CTC all cases later proven to have BAI but all radiologists did not agree on CTC interpretations.
49	Miller et al. *Surgery* 1989	Role of CT in diagnosis of major arterial injury after blunt thoracic trauma	2	Prosp. 153 pt with BCT and abn CXR (WM or APW): 49 excluded for instability. 104 pt had both CTC and angio. 5 pt had BAI, but only 3 were dx by CTC. Conc: CTC inadequate for screening.
50	Mirvis et al. *Radiology* 1996	Traumatic aortic injury: diagnosis with contrast-enhanced thoracic CT-five-year experience at a major trauma center	2	A "negative" CTC has a 100% negative predictive value for presence of BAI. CXR with normal mediastinal contour needs no further evaluation. Unequivocally abn CXR should go to angio or surgery. Equivocal or technically unsatisfactory CXR should have a CTC. Only pt with para-aortic, middle mediastinal, or superior mediastinal hematoma on CTC need angio confirmation.
51	Richardson et al. *AJR Am J Roentgenol* 1991	Value of CT in determining the need for angiography when findings of mediastinal hemorrhage on chest radiographs are equivocal	2	Prosp. protocol of 90 pt with BCT who had equivocal CXR. They underwent dynamic CTC. 6% of CTC were inadequate, 16 showed mediastinal hemorrhage with 4 +angio for BAI. Rec: CTC for screening in pt with BCT and equivocal CXR.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
143	Fabian et al. *Ann Surg* 1998	Prospective study of blunt aortic injury: helical CT is diagnostic and antihypertensive therapy reduces rupture	2	Prosp. helical CTC for BCT. 494 pt with evidence of mediastinal hematoma or aortic injury. 71 were +BAI. Initially all abn CTC were confirmed with angio, later only indeterminate/equivocal CTC confirmed with angio. Helical CTC was 100% sensitive, with 100% negative predictive value. 58 pt received beta-blocker or nitroprusside for BP control before repair: 19 ultimately managed nonoperatively, none died from BAI. Rec: helical CTC for dx of BAI with aggressive BP control before repair.
144	Mirvis et al. *J Trauma* 1998	Use of spiral computed tomography for the assessment of blunt trauma patients with potential aortic injury	2	Prosp. 1104 pt with helical CTC for BCT and abn mediastinum on CXR: 25 pt had +BAI, 16 were confirmed with angio. Sensitivity of spiral CTC is 100%, with 100% negative predictive value and 99.7% accuracy. Rec: spiral CTC for dx of BAI and angio only for equivocal CTC.
52	Agee et al. *J Trauma* 1992	Computed tomographic evaluation to exclude traumatic aortic disruption	3	Retrosp. 133 pt with BCT and abn CXR. Evaluated with CTC or angio. 28 pt taken directly to angio without CTC because of strong suspicion of BAI. 105 pt had CTC—if negative no further w/u. Rec: CTC as screening test in pt with abn CXR unless "strong suspicion" exists when angio should be done first.
53	Biquet et al. *Eur Radiol* 1996	Computed tomography of thoracic aortic trauma	3	Retrosp. 28 pt with BCT evaluated by CTC. 12 had BAI, CTC was false negative in 1 pt with subclavian artery injury. Need for angio was obviated in 67% of pt with BCT.
54	Brooks et al. *Clin Radiol* 1989	Computed tomography in the diagnosis of traumatic rupture of the thoracic aorta	3	No case known of "negative" CTC scan and proven torn aorta. Mediastinal hematoma on CTC is indication for aortography.
55	Franchello et al. *Int Surg* 1997	Rupture of thoracic aorta resulting from blunt trauma	3	Retrosp. 29 pt operated on for BAI. CTC was false negative in 27% and required angio even if positive. 33% of non-bypass pt had paraplegia vs. 0% of bypass pt. Conc: CTC is "waste of time" and not useful. Also rec bypass technique.
56	Heiberg et al. *AJR Am J Roentgenol* 1983	CT in aortic trauma	3	Retrosp. 10 pt with CTC and angio for BCT. 3 were + for BAI. CTC was 100% sensitive.
57	Hills et al. *Aust N Z J Surg* 1994	Traumatic thoracic aortic rupture: investigation determines outcome	3	Retrosp. 38 pt with BAI: 18 were potential survivors. Pt who died had delay to angio, many from having CTC first. Rec: early angio without CTC.
58	Kawada et al. *J Cardiovasc Surg* 1990	Surgical experience with traumatic rupture of the thoracic aorta	3	Retrosp. 9 cases, 4 using Biomedics pump with good results. Also rec: CTC for dx.
59	Mirvis et al. *AJR Am J Roentgenol* 1987	Role of CT in excluding major arterial injury after blunt thoracic trauma	3	CTC for pt with WM on CXR can reduce need for angio, by 50%.
60	Morgan et al. *Radiology* 1992	Evaluation of traumatic aortic injury: does dynamic contrast-enhanced CT play a role?	3	CTC added <1 min to time for abdominal CT. Only 1 case of proven BAI in 160 pt with CTC.
61	Raptopolous et al. *Radiology* 1992	Traumatic aortic tear: screening with chest CT	3	No pt with normal CTC had BAI proven by angio or surgery. 2 pt with "normal" CXR had "positive" CTC and "positive" angio. CTC should be part of screening approach used to diagnose BAI.
36	Trachiotis et al. *Ann Thorac Surg* 1996	Traumatic thoracic aortic rupture in the pediatric patient.	3	Retrosp. 6 pt aged 8–16 y with BAI with additional 5 cases from literature. Noted absence of rib fx in these pt. Also increased incidence of pre-op paraplegia (4/11). 2/6 pt (40%) had sx of pseudocoarctation. Rec: use of CTC and TEE in the early dx of BAI.
37	Vloeberghs et al. *Acta Chir Belg* 1988	Posttraumatic rupture of the thoracic aorta	3	4 pt with "nl" CXR subsequently proven to have BAI Rec: CTC on all "major trauma victims."
62	Wilson et al. *Am Surg* 1994	Role of computed tomography scan in evaluating the widened mediastinum	3	No pt with CTC interpreted as "negative" later demonstrated to have BAI. Supports use of "screening" CTC to lower frequency of angio.
139	Wicky et al. *Eur Radiol* 1998	Spiral CT aortography: an efficient technique for the diagnosis of traumatic aortic injury	3	Spiral CTC performed in 487 pt. Confirmed by angio in 5 of the 14 pt with BAI. Rec: spiral CTC should replace angio for screening and dx.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
Transesophageal echocardiography as a diagnostic test				
63	Brooks et al. *J Trauma* 1992	The use of transesophageal echocardiography in the evaluation of chest trauma	2	Prosp. 21 pt with suspicion for BAI evaluated with TEE and angio. (Some TEE done post angio). TEE useful to follow small intimal injuries or for screening.
64	Buckmaster et al. *J Trauma* 1994	Further experience with transesophageal echocardiography in the evaluation of thoracic aortic injury	2	Prosp. 160 pt with suspicion of BAI evaluated by TEE, angio or both. TEE was 100% sensitive and 99% specific and could also detect cardiac abnormalities. Rec: TEE as dx test of choice and reserve angio for equivocal TEE results.
65	Catoire et al. *J Trauma* 1995	Systematic transesophageal echocardiography for detection of mediastinal lesions in patients with multiple injuries	2	Prosp. 70 pt with BCT had TEE within 48 h, 13 had suspected BAI—all TEE negative. TEE felt to be sufficient dx tool.
66	Cohn et al. *J Trauma* 1995	Exclusion of aortic tear in the unstable trauma patient: the utility of transesophageal echocardiography	2	Prosp. 53 pt with BCT had angio if stable (43) or TEE if unstable (10). TEE may be useful in unstable pt with BCT.
67	Kearney et al. *J Trauma* 1993	Use of transesophageal echocardiography in the evaluation of traumatic aortic injury	2	Prosp. 69 pt with BCT and suspicion of BAI had TEE and angio. TEE had sensitivity/specificity of 100% vs. angio with 67%/98%. TEE more accurate.
68	Minard et al. *J Trauma* 1996	A prospective analysis of transesophageal echocardiography in the diagnosis of traumatic disruption of the aorta	2	Prosp. 34 pt with BCT evaluated by TEE and angio. (21 TEE before angio, 13 angio before TEE). TEE only 57% sensitive and 91% specific. Rec: TEE used as adjunct to angio but not as replacement.
69	Saletta et al. *J Trauma* 1995	Transesophageal echocardiography for the initial evaluation of the widened mediastinum in trauma patients	2	Retrosp. 114 pt with TEE for BCT. 89 pt had negative TEE and no BAI. 17 pt were indeterminate and had nl angio. 8 pt had BAI—only 5 dx by TEE. All FN-TEE died. TEE only 82% accurate. Rec: do not rely solely on TEE.
70	Shapiro et al. *J Trauma* 1991	Cardiovascular evaluation in blunt thoracic trauma using transesophageal echocardiography (TEE)	2	Prosp. 19 pt with BCT and WM on CXR. 11 had angio. 3 pt had BAI on angio but only 2 seen on TEE. Conc: TEE safe in pt with BCT and gives information about cardiac function but has limitations in dx of BAI.
71	Smith et al. *N Engl J Med* 1995	Transesophageal echocardiography in the diagnosis of traumatic rupture of the aorta	2	Prosp. 101 pt with BCT had TEE, which was successful in 93 pt without complications. 11 pt (12%) had +BAI confirmed by autopsy, angio, or surgery. 1 false positive TEE. Conc: TEE compares favorably with angio.
72	Vignon et al. *Circulation* 1995	Role of transesophageal echocardiography in the diagnosis and management of traumatic aortic disruption	2	Prosp. study of TEE in pt with BCT and WM. TEE compared with angio, operative findings, or autopsy. 14/32 exams were positive, with 11 subadventitial injuries and 3 intimal injuries. 18 exams were negative. Of the 11 positive exams, one was false negative TEE confirmed at autopsy, remaining 10 were true positives confirmed at OR or autopsy. Rec: TEE for screening and use of angio if TEE is equivocal.
10	Vignon et al. *J Trauma* 1996	Routine transesophageal echocardiography for the diagnosis of aortic disruption in trauma patients without enlarged mediastinum	2	Prosp. 40 pt with BCT—6 with WM, 34 without WM. Rec: TEE in all pt with severe BCT regardless of CXR findings.
140	Goarin et al. *Chest* 1997	Use of transesophageal echocardiography for diagnosis of traumatic aortic injury	2	28 pt with BAI compared with 30 trauma pt without BAI. All had TEE. Positive findings on TEE include intraluminal stripes, intimal lesions, and hemomediastinum. Rec: TEE for BAI be done only by trained operators.
73	Ahrar et al. *J Trauma* 1997	Angiography in blunt thoracic aortic injury	3	Retrosp. 89 pt with blunt vascular injury—75 pt with BAI (3 with branch injuries also), 14 pt with injury to aortic branches alone. Feel that TEE would have missed branch injuries and that TEE alone is inadequate w/u of BCT.
74	Mollod and Felner *Am Heart J* 1996	Transesophageal echocardiography in the evaluation of cardiothoracic trauma	3	6 TEEs performed by cardiologist. 3 were positive: 1 had equivocal angio. Also report 2 intimal injuries that were conservatively managed and demonstrated resolution over 3 wk. Conc: TEE is a potentially good screening tool but may be inaccurate in injuries to ascending aorta.
75	Sparks et al. *Arch Surg* 1991	Transesophageal echocardiography: preliminary results in patients with traumatic aortic rupture	3	Retrosp. 11 pt with TEE/angio. Six had BAI but only 3 had +TEE. Conc: TEE poor screening test with complications.
36	Trachiotis et al. *Ann Thorac Surg* 1996	Traumatic thoracic aortic rupture in the pediatric patient	3	Retrosp. 6 pt aged 8–16 y with BAI with additional 5 cases from literature. Noted absence of rib fx in these pt. Also increased incidence of pre-op paraplegia (4/11). 2/6 pt (40%) had sx of pseudocoarctation. Rec: use of CTC and TEE in the early diagnosis of BAI.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
When (and if) to repair?				
76	Borman et al. *Am J Surg* 1982	Treatment priorities in combined blunt abdominal and aortic trauma	2	Retrosp. 33 pt with BAI: 16 required laparotomy—11 laparotomies 1st, 5 thoracotomies 1st. Rec: laparotomy 1st in combined injuries. If pt has VSS, get angio before laparotomy. Delayed thoracotomy safe in combined injuries.
77	Camp and Shackford *J Trauma* 1997	Outcome after blunt traumatic thoracic aortic laceration: identification of a high-risk cohort	2	Retrosp. 395 pt with BAI. No difference in mortality in stable pt operated on in 4 h or >24 h. Better survival when SBP controlled to 90–140. Direct repair without cross-clamp had 80% mortality vs. all other techniques (clamp/sew, bypass or shunt; 13–34% mortality). Increased mortality with age and cardiac disease—these pt may benefit from longer preoperative preparation or nonoperative management.
2	Fabian et al. *J Trauma* 1997	Prospective study of blunt aortic injury: multicenter trial of the American Association for the Surgery of Trauma	2	Prosp. 274 pt with BAI. 85% had WM on CXR. 8.7% with paraplegia correlated with cross-clamp times—bypass may allow longer cross-clamp time without increasing risk of paraplegia. Rec: prompt dx and thoracotomy.
78	Kirsh et al. *Ann Surg* 1976	The treatment of acute traumatic rupture of the aorta: a 10-year experience	2	Retrosp. 43 pt with BAI repaired with shunt or bypass. 50% survival with bypass, 86% survival with shunt. Rec: control SBP < 120 pre-op and use of external nonheparinized shunt.
143	Fabian et al. *Ann Surg* 1998	Prospective study of blunt aortic injury: helical CT is diagnostic and antihypertensive therapy reduces rupture	2	Prosp. helical CTC for BCT. 494 pt with evidence of mediastinal hematoma or aortic injury. 71 were +BAI. Initially all abn CTC were confirmed with angio, later only indeterminate/equivocal CTC confirmed with angio. Helical CTC was 100% sensitive, with 100% negative predictive value. 58 pt received beta-blocker or nitroprusside for BP control before repair: 19 ultimately managed nonoperatively, none died from BAI. Rec: helical CTC for dx of BAI with aggressive BP control before repair.
79	Akins et al. *Ann Thorac Surg* 1981	Acute traumatic disruption of the thoracic aorta: a ten-year experience	3	Retrosp. 44 pt with BAI. 23 pt repaired with L heart bypass with 39% mortality. No mortality with other methods in 14 pt. Lower mortality in pt with delayed operation for other injuries or comorbidities. Conc: heparinized shunt preferred method. Delayed (or no) repair safe in select patients when blood pressure controlled.
80	Bodily et al. *J Trauma* 1977	The salvageability of patients with post-traumatic rupture of the descending thoracic aorta in a primary trauma center	3	Retrosp. 39 pt with BAI. 46% survival—better in those with VSS for >6 h before repair. All missed injuries died.
81	Camp et al. *J Trauma* 1994	Blunt traumatic thoracic aortic lacerations in the elderly: an analysis of outcome	3	Retrosp. 75 pt with BAI: 58 pt < 55 yr and 17 pt > 55 yr. 6 pt in each group had nonoperative management with 33% survival. Operative survival was 94% in young group and 9% in older group. Odds ratio analysis suggested a protective effect of nonoperative therapy in pt > 55 y. Conc: older pt with higher comorbidities and ISS may benefit from a nonoperative approach to BAI.
82	Fisher et al. *J Trauma* 1990	Conservative management of aortic lacerations due to blunt trauma	3	3 pt treated conservatively for BAI. All had small "nonthreatening" injuries and 2 had severe associated injuries. All remained stable or resolved on repeat angio with beta-blockade.
83	Fleming and Green *Ann Thorac Surg* 1974	Traumatic aneurysms of the thoracic aorta	3	Retrosp. 43 pt with BAI repaired: 10 acute, 33 > 90 day. Rec: repair of all BAI at time of dx.
84	Hudson et al. *Ann Vasc Surg* 1991	The management of traumatic aortic tear in the multiply-injured patient	3	Retrosp. 11 pt. Conc: BAI should be addressed after treatment of other injuries that cause blood loss.
85	Kram et al. *Ann Surg* 1988	Increased incidence of cardiac contusion in patients with traumatic thoracic aortic rupture	3	Retrosp. 13 pt operated for BAI. 62% had associated cardiac contusion. All isolated BAI survived, 38% combined injury died. Conc: increased frequency of cardiac contusion with BAI has increased mortality. Pt with cardiac contusion should have pulmonary artery catheter during BAI repair.
86	Maggisano et al. *Ann Vasc Surg* 1995	Traumatic rupture of the thoracic aorta: should one always operate immediately?	3	Retrosp. 59 pt: 12 pt in extremis, 3 stable pt with urgent repair, 44 pt with concomitant injuries or sepsis with delayed repair. Delayed pt received beta-blockade and vasodilators to maintain a MAP of 80. 31 then underwent operation with 90% survival and 3% paraplegia. All with clamp and sew technique. Conc: planned delay is appropriate and only 2/44 pt with planned delay ruptured before repair.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
87	McCollum et al. *J Trauma* 1979	Chronic traumatic aneurysms of the thoracic aorta: an analysis of 50 patients	3	Retrosp. 50 pt with thoracic aortic aneurysm and hx of BCT >3 mo ago. Rec: consider dx of chronic aneurysm in pt with hx of BCT. All should be repaired.
88	Pezzella et al. *Am Surg* 1978	Early diagnosis and individualized treatment of blunt thoracic aortic trauma	3	Retrosp. 44 pt. with BCT and WM had 13 +angios. 7 repaired immediately with 1 mortality, 6 delayed (days-years) or no (2) repair; all survived. States delayed repair is safe if BP is controlled.
89	Plume and DeWeese *Arch Surg* 1979	Traumatic rupture of the thoracic aorta	3	Retrosp. 15 pt with BAI: 11 underwent repair and 3 ruptured before repair. They discuss the advantage of atriofemoral bypass and mention antihypertensive therapy, but no data are presented to support these.
28	Richardson et al. *South Med J* 1979	Traumatic rupture of the thoracic aorta	3	Retrosp. 167 angio in pt with BCT. 29 showed BAI 67% survival. Rec: angio in pt with BCT and radiographic abnormalities or signs (pulse deficit, murmur) with repair immediately after dx.
90	Sharma et al. *Am J Surg* 1997	Surgical management of traumatic aortic disruption	3	27 pt who had surgery for BAI. 15 (59%) had another operative procedure before angio. Most (24) had Gott shunt. Rec: use of Gott shunt.
91	Warren et al. *Ann Emerg Med* 1992	Acute traumatic disruption of the thoracic aorta: emergency department management	3	Retrosp. 37 pt with BAI. State that early control of blood pressure using beta-blockade and nitroprusside lowers the mortality from BAI.
Best technique of repair?				
77	Camp and Shackford *J Trauma* 1997	Outcome after blunt traumatic thoracic aortic laceration: identification of a high-risk cohort	2	Retrosp. 395 pt with BAI. No difference in mortality in stable pt operated on in 4 h or >24 h. Better survival when SBP controlled to 90–140. Direct repair without cross-clamp had 80% mortality vs. all other techniques (clamp/sew, bypass, or shunt; 13–34% mortality). Increased mortality with age and cardiac disease—these pt may benefit from longer preoperative preparation or nonoperative management.
2	Fabian et al. *J Trauma* 1997	Prospective study of blunt aortic injury: multicenter trial of the American Association for the Surgery of Trauma	2	Prosp. 274 pt with BAI 85% had WM on CXR. 8.7% with paraplegia correlated with cross-clamp times—bypass may allow longer cross-clamp time without increasing risk of paraplegia. Rec: prompt dx and thoracotomy.
78	Kirsh et al. *Ann Surg* 1976	The treatment of acute traumatic rupture of the aorta: a 10-year experience	2	Retrosp. 43 pt with BAI repaired with shunt or bypass. 50% survival with bypass, 86% survival with shunt. Rec: control SBP < 120 pre-op and use of external nonheparinized shunt.
79	Akins et al. *Ann Thorac Surg* 1981	Acute traumatic disruption of the thoracic aorta: a ten-year experience	3	Retrosp. 44 pt with BAI. 23 pt repaired with L heart bypass with 39% mortality. No mortality with other methods in 14 pt. Lower mortality in pt with delayed operation for other injuries or comorbidities. Conc: heparinized shunt preferred method. Delayed (or no) repair safe in select patients when blood pressure controlled.
92	Albrink et al. *South Med J* 1994	Importance of designated thoracic trauma surgeons in the management of traumatic aortc transection	3	27 pt with BAI: 15 operated on by 2 dedicated thoracic thoracic surgeons, 12 by 10 general/thoracic surgeons. Most had clamp/sew. Lower clamp times, less blood loss and less renal failure in dedicated thoracic surgeon group. Conc: dedication and experience of surgeon is important when treating BAI.
93	Allmendinger et al. *Am J Surg* 1977	Deceleration injury: laceration of the thoracic aorta	3	Retrosp observation of 27 pt with BAI: 20 survived to angio, 7 died within 1 h of admission. 20 pt were operated: 17 with partial bypass or external shunt, 3 without. 3 pt developed paraplegia: 2 were shunted, 1 was not shunted.
94	Antunes *Ann Thorac Surg* 1987	Acute traumatic rupture of the aorta: repair by simple cross-clamp	3	16 pt using "special way" of cross-clamping technique. Rec: additional measures to protect spinal cord.
95	Appelbaum et al. *J Thorac Cardiovasc Surg* 1976	Surgical treatment for closed thoracic aortic injuries	3	Retrosp. 28 pt. Emphasized diagnosis on clinical grounds. Rec: clamp and sew technique.
96	Avery et al. *South Med J* 1979	Traumatic rupture of the thoracic aorta	3	Retrosp. 10 pt. Rec: use of temporary shunt.
97	Cernaianu et al. *Chest* 1992	Determinants of outcome in lesions of the thoracic aorta in patients with multiorgan system trauma	3	33 pt with BAI. Had increased incidence of paraplegia and renal failure with clamp/sew. Rec: clamp/sew unless cross-clamp time will be prolonged, i.e., multiple aortic tears.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
98	Chalant et al. *J Cardiovasc Surg* 1971	Surgical treatment of post-traumatic aneurysms of the thoracic aorta	3	Retrosp. 7 pt with BAI: 5 repaired with dacron, 2 sutured primarily. Rec: L heart bypass and hypothermia.
99	Contino et al. *Arch Surg* 1994	Use of carmeda-coated femoral-femoral bypass during repair of traumatic aortic pseudoaneurysms	3	Retrosp. 42 pt with operative repair of BAI. Three techniques: femoral-femoral bypass; left-heart bypass and clamp/sew. 1 case of paraplegia in clamp/sew. Rec: some form of bypass and prefer femoral-femoral bypass.
100	Cowley et al. *J Thorac Cardiovasc Surg* 1990	Rupture of thoracic aorta caused by blunt trauma: a fifteen-year experience	3	114 pt with BAI: 89 were operated on with 20% mortality. Paraplegia in 14% of survivors. Conc: no advantage or disadvantage in the use of a shunt for repair.
101	DelRossi et al. *Surgery* 1990	Traumatic disruptions of the thoracic aorta: treatment and outcome	3	Retrosp. 27 pt: 18 with clamp/sew, 5 with heparin-coated shunts, 1 with cardiopulmonary bypass. Conc: clamp/sew is better.
102	Eddy et al. *Arch Surg* 1990	Treatment of traumatic rupture of the thoracic aorta	3	Retrosp. 104 pt. with BAI. Increased cross-clamp time correlates with spinal cord ischemia.
103	Forbes and Ashbaugh *Arch Surg* 1994	Mechanical circulatory support during repair of thoracic aortic injuries improves morbidity and prevents spinal cord injury	3	Retrosp. 21 pt with mechanical circulatory support had 0% paraplegia vs. 9 pt with cross-clamp only and 44% paraplegia. Conc: perfusion of distal aorta may prevent spinal cord ischemia.
55	Franchello et al. *Int Surg* 1997	Rupture of thoracic aorta resulting from blunt trauma	3	Retrosp. 29 pt operated on for BAI. CTC was false negative in 27% and required angio even if positive. 33% of non-bypass pt had paraplegia vs. 0% of bypass pt. Conc: CTC is "waste of time" and not useful. Also rec. bypass technique.
104	Frick et al. *J Trauma* 1997	Outcome of blunt aortic injury in a level I trauma center: an 8-year review	3	Retrosp. 64 pt with BAI. Poor outcome correlated with age and ISS. No difference in operative technique. Rec: coordinated response of all team members.
105	Higgins et al. *Arch Surg* 1992	Mechanical circulatory support decreases neurologic complications in the treatment of traumatic injuries	3	19 pt with BAI: 10 repaired with mechanical circulatory support, 9 without. 33% of nonmechanical group had neurologic complications vs. 0% in mechanical support group. Rec: use of mechanical circulatory support decreases neurologic complications.
106	Hilgenberg et al. *Ann Thorac Surg* 1992	Blunt injuries of the thoracic aorta	3	Retrosp. 51 pt with BAI: 3 died before repair, 48 had +angio. 44 had repair. 13% of 23 Gott shunts and 5% of clamp/sew repairs had paraplegia. No statistical difference between shunt vs. no shunt. Clamping time was important.
107	Hunt et al. *J Trauma* 1996	Thoracic aorta injuries: management and outcome of 144 patients	3	Registry multicenter review of 144 pt with BAI. 5% had nl CXR, 1 had false negative angio. 113 had planned urgent operative procedures. Cross-clamp times of <35 min had 0% paraplegia vs. 16% paraplegia if cross-clamp time >35 min. Of pt with long cross-clamp time: 2/37 pt with cardiopulmonary bypass had paraplegia vs. 6/14 who had clamp/sew. Conc: paraplegia is minimized with short cross-clamp time or use of bypass if long cross-clamp time is anticipated.
58	Kawada et al. *J Cardiovasc Surg* 1990	Surgical experience with traumatic rupture of the thoracic aorta	3	Retrosp. 9 cases, 4 using Biomedics pump with good results. Also rec: CTC for diagnosis.
108	Kim et al. *J Trauma* 1994	Trauma surgeons can render definitive surgical care for major thoracic injuries	3	Retrosp. 18 pt with BAI. 17 had repair with partial bypass by trauma/general surgeons. All lived with no paraplegia. Conc: trauma surgeons can render comparable care for thoracic injuries to thoracic surgeons.
109	Kirsh et al. *Ann Thorac Surg* 1970	Repair of acute traumatic rupture of the aorta without extracorporeal circulation	3	Retrosp. 12 pt with BAI, repaired using simple nonheparinized bypass shunt. 1 paraplegia, 1 intraop death. Rec. use of shunt.
110	Kodali et al. *Circulation* 1991	Traumatic rupture of the thoracic aorta: a 20 year review 1969–1989	3	116 pt with BAI: 50 survived to OR: 31 had bypass, 14 had clamp/sew, 4 had shunt. 28% paraplegia in clamp/sew pt, 3% paraplegia in bypass/shunt pt. Rec: bypass or shunt for repair of BAI.
111	Mattox et al. *Ann Thorac Surg* 1985	Clamp/repair: a safe technique for treatment of blunt injury to the descending thoracic aorta	3	Retrosp. 45 pt with BAI. State clamp repair is better.
112	McCroskey et al. *Am J Surg* 1991	A unified approach to the torn thoracic aorta	3	Retrosp. 12 pt with BAI: 6 were clamp/sew and 6 were partial left heart bypass. No difference in outcome but rec: partial bypass.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
113	Merrill et al. *Ann Surg* 1988	Surgical treatment of acute traumatic tear of the thoracic aorta	3	Retrosp. 36 pt. operated on for BAI. 5 operative deaths—none related to technique used. Spinal cord injury occurs despite distal aortic perfusion.
114	Nicolosi et al. *Ann Thorac Surg* 1996	Mortality and neurologic morbidity after repair of traumatic aortic disruption	3	45 pt undergoing repair of BAI. Mortality predicted by preoperative hypotension and advanced age. 33% paraplegia in clamp/sew group vs. 0% in bypass group. Paraplegia also correlated with longer clamp times. Rec: L heart bypass for repair of BAI.
115	Orringer and Kirsh *Ann Thorac Surg* 1983	Primary repair of acute traumatic aortic disruption	3	5 of 49 BAI successfully repaired primarily.
116	Pate *Ann Thorac Surg* 1985	Traumatic rupture of the aorta: emergency operation	3	59 pt with BAI: 47 had bypass with 1 paraplegia (2%); 7 had clamp/sew with 3 paraplegia (42%). Rec: bypass with systemic heparinization.
89	Plume and DeWeese *Arch Surg* 1979	Traumatic rupture of the thoracic aorta	3	Retrosp. 15 pt with BAI: 11 underwent repair and 3 ruptured before repair. They discuss the advantage of atriofemoral bypass and mention antihypertensive therapy, but no data are presented to support these.
117	Pickard et al. *J Trauma* 1977	Transection of the descending thoracic aorta secondary to blunt trauma	3	Retrosp. 22 pt with BAI. All 14 angios were +. 17 pt to OR: 12 had dacron, 3 sutured. 9 bypass, 1 shunt. 1 paraplegia, 1 graft infection. Conc: that bypass/shunt not necessary.
118	Read et al. *Arch Surg* 1993	Partial left heart bypass for thoracic aorta repair: survival without paraplegia	3	Retrosp. 16 cases of BAI repaired with atriofemoral bypass. All in descending aorta. 88% survival. Mean cross-clamp time was 37 ± 17 min with no paraplegia. Support atriofemoral bypass as method of choice in repairing most BAI.
119	Reul et al. *J Thorac Cardiovasc Surg* 1974	The surgical management of acute injury to the thoracic aorta	3	Retrosp. 28 pt: 10 with BAI—8 had Dacron graft, 2 primary repair. Rec: use of bypass for repair.
120	Saylam et al. *J Cardiovasc Surg* 1980	Early surgical repair in traumatic rupture of the thoracic aorta	3	Retrosp. 10 pt with BAI. All had bypass successfully.
121	Schmidt and Jacobson *Arch Surg* 1984	Thoracic aortic injury: a ten-year experience	3	Retrosp. 41 pt with BAI. Rec: clamp and sew technique based on their historical experience.
122	Schmidt et al. *J Trauma* 1992	Primary repair of traumatic aortic rupture: a preferred approach	3	80 pt with BAI: 73 survived to OR. Most repaired with clamp/sew with 3% paraplegia. State primary repair (vs. graft) is best due to lower clamp time and fewer septic complications.
90	Sharma et al. *Am J Surg* 1997	Surgical management of traumatic aortic disruption	3	27 pt who had surgery for BAI. 15 (59%) had another operative procedure before angio. Most (24) had Gott shunt. Rec: use of Gott shunt.
123	Stiles et al. *Am J Surg* 1985	Management of injuries of the thoracic and abdominal aorta	3	Retrosp. 19 cases of BAI, including 16 at the isthmus, 1 ascending aorta, and 1 aortic arch injury. They used clamp and sew in all report only one case of paraplegia. The data analysis and reporting were limited.
124	VanNorman et al. *J Trauma* 1991	Hemodynamic and metabolic effects of aortic unclamping following emergency surgery for traumatic thoracic aortic tear in shunted and unshunted patients	3	Description of 9 pt with BAI: 2 shunted, 7 had clamp/sew. All pt had decrease in MAP, pH, and increase in potassium after unclamping with greater derangements in unshunted pt. Rec: close communication between surgeon and anesthesiologist during unclamping.
125	Vasko et al. *Surgery* 1977	Nonpenetrating trauma to the thoracic aorta	3	Retrosp. 19 pt with BAI. They argue for the merits of clamp and sew for repair.
126	Vaughn et al. *J Miss State Med Assoc* 1983	Blunt thoracic aortic injuries	3	6 cases of BAI repaired without active distal perfusion using only heparinized shunt or clamp/sew technique. Advocate this as acceptable approach if no pump team available.
127	Verdant et al. *Can J Surg* 1983	Major mediastinal vascular injuries	3	Retrosp. 37 pt with BAI. Aortography championed. Gott shunt recommended.
128	Von Oppell et al. *S Afr J Surg* 1996	Acute traumatic rupture of the thoracic aorta: A comparison of techniques	3	28 pt with BAI. All repaired safely with interposition graft and heparin-less bypass.
129	Wallenhaupt et al. *Am Surg* 1989	Current treatment of traumatic aortic disruptions	3	Retrosp. 18 BAI with 11% mortality. 9 were repaired with shunts (1 atriofemoral bypass, 8??), 9 without shunts. 42% paraplegia rate was associated with longer cross-clamp times (48 min with paraplegia, 26 without). Conc: shunting is indicated to minimize paraplegia rates.

TABLE 1. *Continued*

Reference No.	Author reference	Title	Class	Conclusions
130	Walls et al. *J Thorac Cardiovasc Surg* 1993	Experience with four surgical techniques to repair traumatic aortic pseudoaneurysm	3	Retrosp. 27 pt who had repair of BAI: 6 with partial bypass and heparinization, 7 with Gott shunt, 6 with clamp/sew, and 8 with bypass without heparinization. Rec: repair using centrifugal pump without systemic heparin.
131	Weimann et al. *Eur J Vasc Surg* 1992	Graft replacement of post-traumatic thoracic aortic aneurysm: results without bypass or shunting.	3	Retrosp. 13 pt with chronic BAI were operated on. Average time to operation was 3 y. Clamp/sew technique was used in all pt with average cross-clamp time of 38 min. No renal or neurologic complications noted.
132	Young et al. *West J Med* 1989	Surgical management of traumatic disruption of the descending aorta	3	20 pt. Different techniques used. Rec: multidisciplinary approach.
133	Zeiger et al. *J Cardiovasc Surg* 1990	Reappraisal of surgical treatment of traumatic transection of the thoracic aorta	3	Retrosp. 40 pt. 14 repaired with shunt or bypass with no paraplegia. 26 repaired with clamp/sew with 9 cases of paraplegia (35%). Rec: L heart bypass without heparin.
Miscellaneous references				
134	Hartford et al. *Am J Surg* 1986	Transection of the thoracic aorta: assessment of a trauma system	3	86 pt with BAI diagnosed by autopsy and clinical records. Unable to compare data with "pre-system" outcomes or patient distribution.
135	Pezella *Tex Heart Inst J* 1996	Blunt traumatic injury of the thoracic aorta following commercial airline crashes	2	While BAI is found frequently in lethal airline crashes, at least 50% of pt died from other causes with "contained" aortic hematoma. Emphasis on improving EMS response to commercial airline crashes.
136	Hill et al. *J R Coll Surg Edinb* 1996	Blunt traumatic rupture of the thoracic aorta: an epidemiological perspective	2	Incidence of BAI was 20–30/100,000/y in Sydney, Australia.
137	Stallone *Am J Surg* 1978	Management of ruptured thoracic aortic aneurysms.	3	Retrosp. 9 cases comparing arteriosclerotic injuries vs. trauma. Better prognosis with traumatic injuries.
141	Cameron et al. *Aust N Z J Surg* 1998	Aortic transection	3	2069 pt in Victoria, Australia with major trauma—19 with BAI, 8 survived to leave hospital. 13% of pt with MVC induced BAI will reach hospital with signs of life. Rec: improvements in prehospital communication, triage and interhospital transfers.
142	Tripp et al. *Cardiovasc Surg* 1997	Transected thoracic aorta: age-specific differences in incidence and possible reasons	3	Retrosp. analysis of North Carolina discharge database. Overall incidence of BAI was 0.07%, with significantly higher incidence in 21- to 30-year-old pt of 0.12%.

abn, abnormal; angio, angiography; Conc., conclusion; dx, diagnosis; fx, fracture; hx, history; L, left; nl, normal; pt, patient; Rec., recommendation; Retrosp., retrospective; sx, symptoms; w/u, workup; AP, anteroposterior; APW, aortopulmonary window; BAI, blunt aortic injury; BCT, blunt chest trauma; BP, blood pressure; CTC, computed tomography of the chest; CXR, chest radiograph; DSA, digital subtraction angiography; EMS, emergency medical system; HTX, hemothorax; IA-DSA, intra-arterial DSA; ISS, Injury Severity Score; IV-DSA, intravenous DSA; LMSB, left main-stem bronchus; MAP, mean arterial pressure; MIEMS, Maryland Institute for Emergency Medicine; MVC, motor vehicle crash; NGT, nasogastric tube; OR, operating room; PTX, pneumothorax; SBP, systolic blood pressure; SVC, superior vena cava; TEE, transesophageal echocardiography; UE, upper extremity; VSS, vital signs stable; WM, widened mediastinum.

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