Blunt Traumatic Aortic Injury

A Review of Initial Diagnostic Modalities and a Proposed Diagnostic Algorithm

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Abstract

Background: Blunt traumatic aortic injury (TAI) is clinically difficult to diagnose, as signs and symptoms are unreliable and variable. The identification of TAI may be obscured by other injuries that are more apparent. Furthermore, radiologic evaluation of the mediastinum for this injury is not well defined. Most patients with TAI die immediately. Survivors have a contained rupture which requires crucial early diagnosis and treatment.

Material and Methods: A Medline search was conducted using the terms "traumatic aortic injury", "aortic injury", "aortic trauma", and "thoracic trauma" from 1966 until December 2002. Investigations used in the diagnostic evaluation of blunt TAI were reviewed and an initial investigative approach to this condition formulated.

Results: The choice of investigation for TAI depends on clinical suspicion, hemodynamic stability, availability, and rapidity of access to tests. These include chest radiography, helical computed tomography angiography (CT-A), transesophageal echocardiography (TEE), aortography, and intraarterial digital subtraction angiography (IA-DSA). CT-A is considered an excellent test in hemodynamically stable blunt thoracic trauma patients. TEE is preferred in unstable patients.

Conclusion: Investigations must confirm or exclude TAI with great precision. CT-A is a reliable screening and now primary diagnostic test in the hemodynamically stable patient. A negative CT-A excludes aortic injury, with a positive or equivocal CT-A leading to treatment or further diagnostic evaluation. TEE is appropriate for the hemodynamically unstable patient but is operator-dependent and not widely available. Aortography is still considered the reference test for blunt TAI and is used when the results from other modalities are inconclusive.

Key Words

Aortic injury · Blunt thoracic trauma · Mediastinum · CT angiography · Transesophageal echocardiography

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Introduction

High immediate mortality from aortic injury due to exsanguination remains a major problem in trauma management [1]. This risk persists for survivors in whom aortic injury remains undetected and therefore untreated. 90% of traumatic aortic injuries (TAI) result from penetrating causes such as gunshot or stab wounds, with only 10% being due to blunt thoracic trauma [2]. Blunt TAI is rapidly lethal in 90% of cases due to exsanguination [3–6], with survivors having a contained aortic leak [2, 7, 8]. TAI is the second most frequent cause of death in blunt trauma, causing 8,000 deaths in the USA each year [5]. There are two groups of survivors. Both present with a contained aortic hematoma but are at risk of subsequent rupture [8]. The first group are hemodynamically unstable on arrival to hospital and have a 2% survival rate. The second group are stable, and 75% survive with early diagnosis and treatment [9, 10]. Prompt recognition and treatment in survivors improves outcome [5] by lessening the risk of catastrophic rupture [11], which increases with time [4]. Left

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unrepaired, delayed rupture and fistulization to adjacent mediastinal structures can occur [2]. The outlook for those treated nonsurgically is poor, with < 2% surviving long-term owing to the formation of a chronic pseudoaneurysm [4, 8].

Aortic injury results from shearing stresses (torque and compression) on the thoracic aorta from rapid deceleration. Relatively mobile sections of the aorta move in relation to fixed parts such as the ligamentum arteriosum, aortic isthmus and diaphragmatic hiatus [4]. The aorta is compressed between bony structures [2], and acute aortic wall stress from intraluminal hypertension leads to rupture of the aorta [12]. Survival depends on an intact adventitial layer and the formation of a contained hematoma [4, 7, 12]. Most adult and pediatric [13] blunt TAI are transverse lesions found within close proximity of the ligamentum arteriosum [4, 6, 7] just distal to the origin of the left subclavian artery [6]. Ascending aortic injury comprises 5% of cases but is uniformly lethal. 1–3% percent of injuries occur in the descending aorta [6].

Blunt TAI is rare in children and occurs with other severe injuries [13]. As in adults, good outcome depends on early detection and treatment [14]. A high index of suspicion is required to make the diagnosis based on a history of rapid deceleration and high-risk injury patterns [4, 11]. These include high-speed collisions, ejection, pedestrian impact, and high falls [5, 15]. Mechanism of injury is a useful predictor of injury [11]. An abnormal mediastinum on chest film in a patient with significant blunt thoracic trauma requires further evaluation for aortic injury. Worryingly, a normal mediastinum may be found in up to 8.3% of proven aortic injuries [10, 16], with some clinicians advocating further investigation in high-risk injury mechanisms despite a normal chest film [11, 16].

TAI is difficult to detect [11], as only half [2, 8] to two-thirds [7, 12] of patients have external signs of thoracic trauma. Severe injuries requiring urgent intervention may be more apparent [4, 15]. Clinical findings such as systemic hypotension, upper limb hypertension, asymmetry of limb pulses and flow murmurs are not reliable for diagnosis [2, 11].

Investigational method depends on clinical suspicion, hemodynamic stability, availability, and rapidity of access to tests [4]. They include plain chest films, chest helical computed tomography angiography (CT-A), transesophageal echocardiography (TEE), aortography, magnetic resonance angiography (MRA), endovascular ultrasonography (USS), and intraarterial digital subtraction angiography (IA-DSA) [6].

Evaluation of the mediastinum for blunt TAI is not well defined. Investigation must confirm or exclude TAI with certainty due to the potentially lethal consequences of a missed diagnosis and the risk of unnecessary surgical intervention [16].

Material and Methods

Search Strategy

A Medline search was conducted using the terms "traumatic aortic injury", "aortic injury", "aortic trauma", and "thoracic trauma" from 1966 until December 2002. All article abstracts, including those from non-English citations and those available only as Internet publications, were examined.

Articles looking at the diagnostic evaluation of blunt TAI were reviewed and an initial investigative approach to this condition was formulated. Emphasis was given to large, rigorously conducted prospective studies with uniform entry selection criteria that included high risk injury mechanisms and/or mediastinal abnormalities on chest film. These studies used well-defined diagnostic criteria, imaging studies were interpreted by radiologists and results correlated with reference diagnoses at surgery, autopsy or aortography.

Our search was unable to identify any study in which patients were randomized at entry either to the imaging modality being tested or the widely accepted reference standard of aortography. Studies examined used risk stratification based on injury mechanism and mediastinal abnormalities on chest film. Subjects with very high risk of blunt TAI proceeded directly to aortography even if no mediastinal abnormality was seen on chest film. Those sustaining blunt thoracic trauma with lesser risk of aortic injury underwent the investigation being tested. Test investigations that were equivocal or inadequate were clarified with aortography. Using a nonrandomized clinical risk-stratification tool to determine what test is used initially may lead to misleading results. This strategy accepts the superiority of aortography without testing the assumption. As such, these comparative studies may overestimate the usefulness of aortography compared with other modalities. Findings at surgery or at postmortem comprise better reference diagnoses and allow critical evaluation of aortography itself.

Good studies blinded interpreting radiologists to reference results from aortography, surgery or autopsy.

Some studies conducted clinical follow-up or repeated imaging studies even if the initial result was negative. This is expected to reduce misclassification due to false-negatives. However, in no study did patients with negative test results undergo aortography unless there was high-risk mechanism, strong clinical suspicion despite negative screening test or the results of initial tests were equivocal. This would be expected to artifactually increase the diagnostic yield for aortography.

This review focuses on imaging modalities that are more established and have additional diagnostic utility for nonvascular injury. They include CT-A, TEE, aortography, and chest radiography. Endovascular USS, MRA and IA-DSA have not been rigorously evaluated, and studies are restricted to descriptions of abnormalities seen with these methods. Review articles were consulted for background epidemiologic and pathophysiologic information.

Results

Aortography

Although few studies have directly addressed the reliability of aortography in the detection of aortic injury, it remains the diagnostic standard [1, 8, 12] more than 40 years after TAI was first described by Parmley et al. [17]. Aortography has a reported sensitivity of almost 100% and specificity of 98% when compared with findings at surgery or at autopsy [4–6]. A retrospective review of 314 patients (ranging in age from 7 to 84 years, mean 37.7 years) with blunt thoracic trauma and widened mediastinum on chest X-ray found aortography to be 99.3% accurate, with two false-positive and, importantly, no false-negative results [18]. In another study, 209 patients with blunt thoracic injury underwent both angiography (either aortography or CT-A) and TEE, with angiography found to have 83% sensitivity and 100% specificity [19].

Aortography establishes the diagnosis, defines the anatomy of the lesion, identifies additional sites of aortic injury and is better than other investigations for detecting supraaortic vessel injury [12]. It is useful if angiography is required for extrathoracic aortic injury such as abdominal aortic injury [3, 12].

However, aortography is invasive as the aorta is catheterized during the study, not widely available, time-consuming to perform and difficult to interpret. Intraarterial administration of radiologic contrast (with its attendant risks) is required, and it necessitates transfer of an unstable or potentially unstable patient out of the resuscitation area [4, 10]. Aortography has an associated mortality of 0.03% [8].

Despite its disadvantages, a negative aortography rate as high as 90% is accepted because of the high morbidity and mortality of missed aortic injury [20]. A small number of false-positive aortograms [5, 21–24] can result from atheromatous or ulcerated aortic wall and ductal diverticula. False-negatives result from inadequate contrast distribution and therefore opacification of the aortic arch, thrombosis within an aortic pseudoaneurysm and performing an inadequate number of views [12, 23, 24].

Aortography is more likely to miss minor aortic injuries such as intramural hematoma or a dynamic intimal flap compared with CT-A or TEE [2, 6] and endovascular USS [20]. Nevertheless, the clinical significance of missed limited aortic injuries is unclear [19], with some able to be managed without surgery [25, 26].

Plain Chest Radiography

The supine anteroposterior (AP) chest film is an easily performed effective test for nonvascular traumatic chest injury that is relatively easy to interpret [5, 27]. In trauma, however, it magnifies and distorts the mediastinum thereby complicating the assessment of the aorta. Mediastinal anatomy is better assessed with an erect, inspiratory, posteroanterior (PA) projected chest film. This is difficult to perform in the trauma setting and is often clinically contraindicated [8]. Interpretation is confounded by variation in mediastinal width due to body habitus, respiratory phase, film projection, and rotation [9]. Although chest film is an acceptable initial screening test for TAI, it is clear that when used alone, it cannot detect or exclude aortic injury with adequate precision [4, 27].

A normal chest film is very sensitive for mediastinal hematoma [11] and has a > 90% negative predictive value. A retrospective review of the chest films of 205 blunt thoracic trauma patients who also had aortography found normal mediastinum on chest film able to exclude aortic injury. With mediastinal abnormality unable to predict aortic injury (as there are many nonaortic causes for mediastinal hematoma), a large number of negative aortographic examinations are performed if abnormal chest radiography alone is used as a screening tool [28]. Although a normal mediastinum in an adequate chest film makes aortic injury unlikely [4, 6, 12], it may be seen in up to 8.4% of proven aortic injury [2, 8, 10], particularly intimal injury [4, 5, 11].

Chest film findings have a > 80% sensitivity but < 50% specificity for detecting aortic injury [4, 6, 12], with a low positive predictive value of 5–20% [6]. Abnormalities such as widened mediastinum > 8 cm [5, 6, 8, 29], increased mediastinal to chest width ratio of > 0.25 [5, 6, 20] and loss of aortic arch contour [29, 30] correlate well with TAI. However, no study has shown these findings to reliably establish or exclude TAI [5, 6]. For instance, mediastinal widening has 90% sensitivity but only 10% specificity for TAI [8]. Other findings include opacified aortopulmonary window, abnormal or blurred aortic arch, left apical cap, downward displacement of left main bronchus, tracheal deviation to the right, nasogastric tube deviation to left, and paratracheal stripe widening [5, 6, 8, 27, 29–33]. These abnormalities serve only to alert the clinician to the possibility of aortic injury.

Chest films have limited utility in diagnosing TAI [27, 33, 34]. The quality of trauma chest films vary widely. Supine AP films distort mediastinal width and structures [11]. Multiple nonaortic injuries lead to mediastinal hemorrhage and similar chest film abnormalities, with only 20% of these patients ultimately having TAI [27]. Chest films are therefore better at excluding rather than predicting TAI. Chest film abnormalities warrant further investigation for TAI [4, 27]. Some clinicians advocate further investigations if there is a significant injury mechanism even with a normal mediastinum on chest film [8, 11, 16]. Chest films may have a role in the serial evaluation of the mediastinum when other investigations are not available [4, 27].

Computed Tomography Angiography

The reliability of CT-A in diagnosing TAI in the hemodynamically stable patient is well established [5, 9, 11, 35–38], as it compares favorably with aortography [1, 9, 11, 37, 38]. CT-A showing a normal mediastinum or mediastinal hematoma not related to the aorta or its branches makes TAI unlikely [11, 38]. If unequivocal signs of aortic injury are present, treatment is instituted, particularly if the patient becomes unstable with no other source of bleeding being evident. In the third situation, equivocal CT-A or suboptimal and uninterpretable images can be definitively clarified with aortography. Optimally performed and interpreted CT-A has become the preferred initial investigation for TAI. This is in addition to its well-accepted role as an intermediate screening tool to determine which patients sustaining blunt thoracic trauma will require aortography [38]. In this setting, patients with a normal mediastinum or nonaortic hematoma on CT-A could have the diagnosis safely excluded without aortography, as CT-A has a high negative predictive value. A positive CT-A using rigorous criteria such as direct signs of aortic injury will diagnose the condition or at least suggest it, improving diagnostic yield of [5, 11, 38] and reducing unnecessary aortography [6, 38]. CT-A has close to 100% sensitivity and high negative predictive value but reduced specificity with less positive predictive value. CT-A incurs rare false-negative but more false-positive cases, thereby not missing aortic injury at the expense of overdiagnosing the condition [38].

CT-A Versus Aortography

Two large well-conducted prospective trials comparing CT-A with aortography have been performed [9, 11, 38]. Helical CT-A was performed to specified protocols allowing optimal aortic phase contrast opacification. CT-A was interpreted by radiologists using predefined criteria. Direct signs of injury include luminal irregularity and abnormal aortic contour or caliber. Mediastinal hematoma not related to the aorta or its branches comprised indirect signs of aortic injury. Other categories were equivocal and negative for aortic injury.

Dyer et al. [38] evaluated 1,009 subjects with blunt thoracic trauma, and 802 patients (80%) had CT-A (Figure 1a). Of 638 subjects with a negative CT-A, 218 (35%) who also had high-risk injury mechanisms underwent aortography. The rest of this group was monitored clinically or with serial chest films, with no aortic injury being found. 207 (20%) patients with extremely high-risk injury mechanisms underwent immediate aortography and ten had aortic injury. No injury was detected at aortography in ten subjects with equivocal CT-A. 382 subsequently had aortography for abnormal CT-A or high-risk injuries with negative CT-A (Figure 1b). There were ten true-positive (all with direct signs of aortic injury), 372 true-negative and, crucially, no false-negative cases.

560 additional subjects were later recruited and the whole dataset reanalyzed for a total of 1,561 subjects [11]. CT-A had a sensitivity > 95% with negative predictive value close to 100% with rigorous diagnostic criteria. The only false-negative case had periaortic hematoma without direct signs of aortic injury but a positive aortogram. Specificity and positive predictive value improved when only direct CT signs of injury constituted a positive study. However, the positive predic-

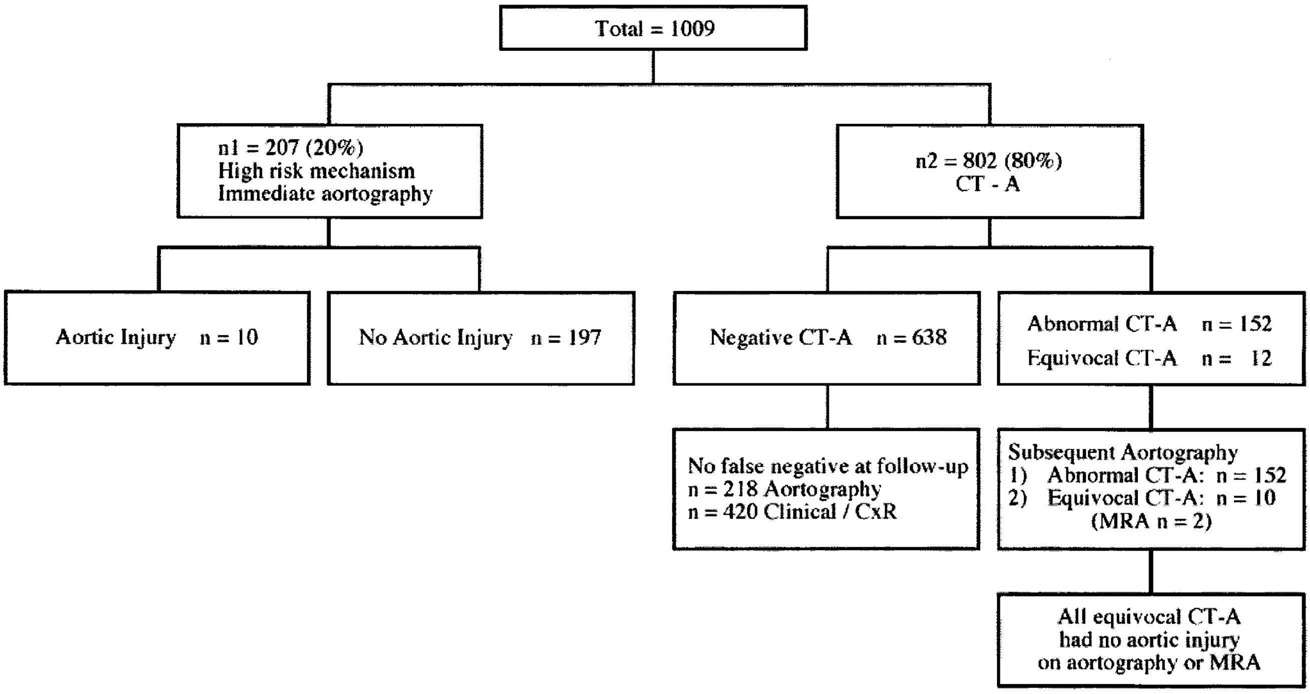

Figure 1a. Results of Dyer et al. [38].

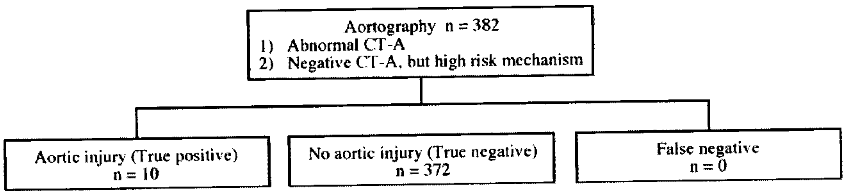

Figure 1b. Further results of Dyer et al. [38].

tive value of CT-A used in high-risk subjects remained at 40%.

CT-A was performed in 1,104 blunt thoracic trauma subjects with an abnormal mediastinum on chest film [9] (Figure 2), and 115 had mediastinal hematoma. 24 patients (22% of those with mediastinal hematoma) had direct signs of aortic injury. They then had aortography or proceeded directly to surgery. CT-A was found to be 100% sensitive, 99.7% specific with a 100% negative predictive value and positive predictive value of 89%. Subjects with normal mediastinum on CT-A had clinical follow-up only. As such, there may have been an overestimation of the usefulness of CT-A with only positive or equivocal cases selected for further aortography.

A prospective study [1] of 494 subjects found CT-A to be more sensitive (100% vs. 92%) but less specific (83% vs. 99%) than aortography, with a negative predictive value of 100% but positive predictive value of 50% only. CT-A is more sensitive (close to 100%) but less specific (40–83%, depending on diagnostic criteria used) for detecting blunt TAI [1, 9, 11, 37–39]. These studies support the use of CT-A as a primary diagnostic tool for blunt TAI. Periaortic hematoma or other direct signs of aortic injury are highly predictive for aortic injury [1]. A normal mediastinum requires no further evaluation, as CT-A has 100% negative predictive value and is not associated with any aortic injury [25]. An inconclusive or equivocal CT-A is clarified with aortography [5].

Aortic injury ranges from intimal and partial thickness tears to aortic disruption [7]. Gavant [35] formulated CT-A grades for aortic injury: grade 0 = normal mediastinum and aorta, grade 1 = abnormal mediastinum and normal aorta, grade 2 = minimal aortic injury with periaortic hematoma, grade 3 = confined aortic injury, and grade 4 = aortic rupture (Figure 3). Grading allows better delineation of injury and determines further investigation or intervention: grades 2 and 3 may proceed to confirmatory aortography if stable, grade 4 requires urgent treatment. Grades 0 and 1 do not have an aortic injury and require clinical follow-up only [6].

Nonhelical CT-A is less reliable than helical CT-A performed with rapid image acquisition in one breathhold and appropriately timed contrast distribution to the aorta [11]. CT-A is widely accepted as an excellent investigation for aortic injury [34, 40, 41]. It is noninvasive, and large volumes of data can be rapidly obtained in one breathhold with minimal respiratory misregistration [7, 41]. Improved image resolution [1] allows image reconstruction adequate for surgical planning [11, 38, 40]. CT-A is better at detecting intimal injuries than aortography [11]. Portable CT technology may allow serial CT examination in the treatment area enabling conservatively managed lesions to be monitored [35]. Compared with aortography, CT-A is more accessible, more rapid to perform and cost-effective.

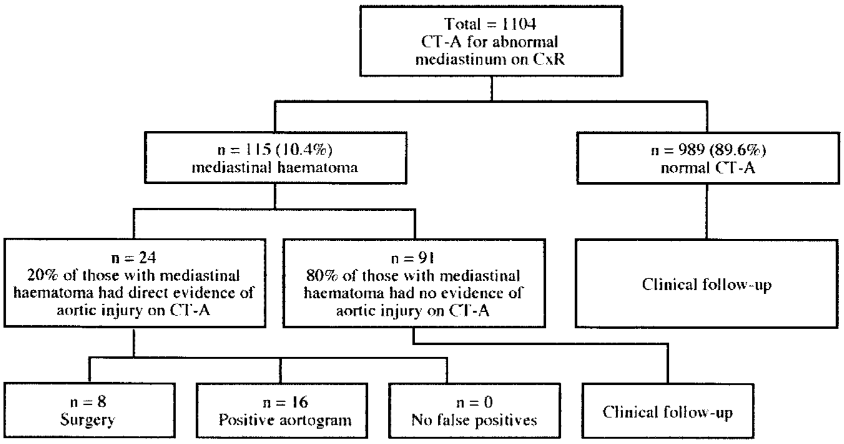

Figure 2. Results of Mirvis et al. [9].

Older nonhelical CT-A resulted in poorer and delayed images [1, 4]. Although it can differentiate between mediastinal hematoma from aortic injury and nonaortic causes, this technique is not anatomically accurate enough to determine treatment [1, 42]. Intravenous contrast administration has its attendant risks [4, 8].

CT-A Versus TEE

CT-A and TEE compare favorably with aortography in the evaluation for TAI. However, only one study [42] has directly compared CT-A with TEE prospectively. 110 subjects with blunt chest trauma had both TEE and CT-A. All aortic injuries were surgically confirmed. Although TEE and CT-A are comparable in detecting TAI requiring surgery, TEE was better at identifying luminal lesions as well as traumatic cardiac and valvular pathology [8]. Even though CT-A may miss subtle intimal injuries, these patients may safely be clinically monitored.

Limitations and Benefits of CT-A

CT-A is able to demonstrate nonaortic mediastinal, pulmonary and thoracic vertebral injuries not detected by aortography or TEE. However, up to four-fifths of mediastinal hematoma found on CT-A is due to nonaortic causes, including nonaortic vessel injury, tracheobronchial injury and sternal, vertebral and posterior rib fractures [4]. Despite only a 20% positive yield, CT-A can reduce the proportion of patients selected for aortography by 30–90% [4, 6, 25, 42].

CT-A is recommended in the hemodynamically stable blunt thoracic trauma patient with high-risk

Figure 3. ((■■■ Figure and caption still missing)).

injury mechanism despite a normal chest film. Patients with equivocal findings on, or suboptimally performed and therefore difficult to interpret, chest film as well as those with chest film abnormalities suspicious of aortic injury can be further evaluated using CT-A. CT imaging for nonthoracic injury can be carried out at the same time [8]. In centers without helical CT, a normal mediastinum on nonhelical CT-A is reassuring.

Transesophageal Echocardiography

Transthoracic echocardiography produces suboptimal images in two-thirds of patients with thoracic trauma, resulting in a low diagnostic yield [15]. TEE is better at assessing for blunt TAI and can be performed in an unstable patient without impeding resuscitation, it can better detect intimal tears compared with CT-A or aortography [43] and may be used to monitor surgical repair or the follow-up of equivocal cases [6].

When performed and interpreted by experienced clinicians, TEE has excellent accuracy for detecting TAI [12, 19, 23, 24, 44]. Smith et al. [12] prospectively assessed 93 of 101 subjects with blunt thoracic injury as well as mediastinal abnormalities on chest film with TEE. TEE was unable to be performed in eight patients due to poor patient cooperation or facial trauma. TEE followed by aortography was performed and interpreted by staff blinded to the results of other test. Aortography and results at surgery and autopsy were used as reference standards. Eleven of 93 subjects who had TEE had a proven injury. The other 82 had comparable injury severity and patterns but no aortic injury. There were eleven true-positive and 82 true-negative echocardiograms. One false-positive TEE had a negative aortogram and normal follow-up TEE. One positive TEE had a false-negative aortogram with an injury demonstrated at surgery. The sensitivity of TEE for TAI was 100%, specificity 98%, and positive predictive value 99%. Two other prospective studies [19, 24] comparing TEE and aortography with surgery and autopsy findings showed that TEE was 100% sensitive and specific. Goarin et al. [19] found TEE to be 98% sensitive and 100% specific compared with aortography and/or contrast-enhanced CT in 209 blunt thoracic trauma patients, 42 (20%) of whom had proven aortic injury.

TEE is relatively less time-consuming and can be performed in the treatment area on an unstable patient without interfering with resuscitative, therapeutic or diagnostic procedures. It can be taken to the patient, avoiding a hiatus in treatment or transfer of an unstable patient from the treatment area [3, 4, 15, 44, 45]. TEE enables assessment of injury to the heart and its valves and can identify mural thrombus and intimal injury not seen on aortography and CT-A. It does not require a contrast agent. Unlike aortography, the injured portion of the aorta is not catheterized, averting further injury [3, 44].

Several studies [42, 45] refute the reliability of TEE for diagnosing TAI. There were two false-positive and three false-negative results from 34 studies prospectively performed and interpreted by nonblinded trauma surgeons [45]. Saletta et al. [42] found three false-negative tests that resulted in delayed diagnosis until surgery or aortography. TEE is highly operator-dependent [3, 4, 6, 44], and is ideally performed by an operator at a major cardiothoracic trauma center [44] with continuing quality assurance and accreditation processes [15].

TEE is better able to assess the descending aorta [46] than the proximal arch and distal ascending aorta, which are suboptimally visualized due to interposition of the trachea [3, 4, 8, 12, 15]. Pneumomediastinum impairs visualization of the aorta [15], and aortic atheroma can be mistaken for intimal injury or flaps [4]. Sedation and intubation may be required [4, 8]. TEE is contraindicated with facial, cervical spine and esophageal injury [4].

Aortic rupture on TEE requires surgical intervention, especially in an unstable patient. An equivocal result such as periaortic hematoma with an unclear source should proceed to aortography [3, 15]. If clinical suspicion of an aortic injury remains high despite a negative TEE, serial echocardiographic examination or aortography is required [12, 19, 23, 24, 44].

Magnetic Resonance Angiography

Although chest MRA can demonstrate acute aortic injury and mediastinal hematoma, it does not have a role in the emergency evaluation of the trauma patient, because it limits access to the critically ill patient for monitoring and treatment. Furthermore, motion artifacts may mimic dissection, and MRA is technically limited by many factors such as pacemakers and metallic foreign bodies [4, 8]. MRA can only be performed in the stable patient [4] and is useful to assess chronic traumatic aortic pseudoaneurysm [8, 26]. The aorta and periaortic tissues can be visualized without contrast [4]. The entire chest can be assessed for nonvascular injuries. Imaging of other traumatized body regions is possible, but is unacceptably time-consuming in the critically injured patient. On the other hand, MRA is noninvasive, provides accurate and comprehensive images, and can be repeated [26].

In a study by Fattori et al. [26], 20 of 24 subjects with suspected blunt TAI undergoing MRA and/or aortography had contained aortic injury. They had serial MRA, and stability or expansion of the lesions at follow-up determined type and timing of treatment. 19 required delayed or planned surgical repair, and one injury healed spontaneously. MRA is useful for monitoring posttraumatic contained aortic pseudoaneurysm for which repair may be delayed, especially if the patient is initially unstable from other injuries.

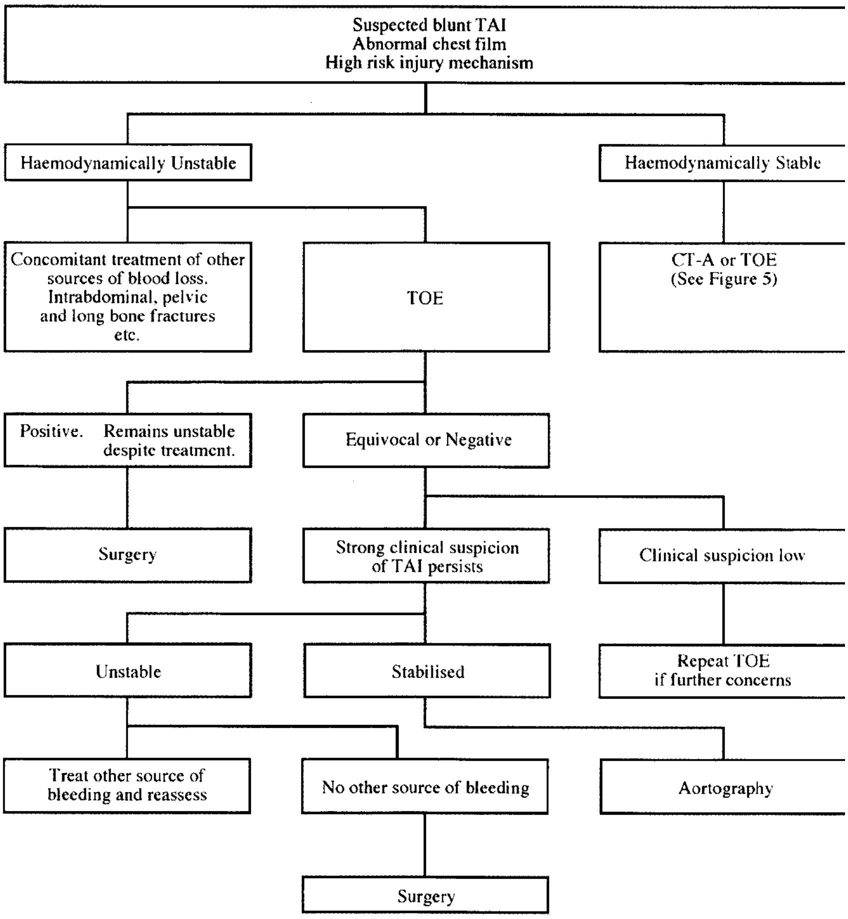

Figure 4. Investigation of suspected blunt traumatic aortic injury.

Endovascular Ultrasound

Endovascular USS may be used to clarify subtle aortographic changes that may represent mural injury without associated pseudoaneurysm or intimal flaps [47]. Compared with aortography, USS may be better at detecting subtle aortic injury [20]. USS allows improved anatomic delineation of subtle injuries such as intimal dissection and the internal extent of aortic laceration associated with a pseudoaneurysm. Real-time sonographic evaluation enables the differentiation of dynamic intimal flaps from fixed artifact such as atherosclerotic changes [20].

Aortic injury and their sonographic characteristics have been reported by Uflacker et al. [20] and Williams et al. [47]. A sonographic probe mounted on a catheter is introduced over a guidewire after femoral arterial cannulation. Apart from the local and systemic complications of femoral arterial and aortic cannulation, this technique is limited by the degradation of image quality by the acoustic shadow produced by the guidewire, which may obscure 10–40% of the field of circumferential view of the aortic lumen. The limited field depth of currently available transducer probes may be inadequate to evaluate the whole thickness of the aortic wall and periaortic tissues as well as the proximal aorta. Evaluation of aortic branch vessels would require separate catheterization of each branch of interest. The probe may worsen preexisting injury or injure an intact vessel. A relatively large arterial puncture entry site is required, and the probes are expensive [20, 47].

Endovascular USS remains an operator- and interpreter-dependent adjunct that complements aortography in the delineation of subtle aortic injury. The two combined become highly specific. By itself, endovascular USS has no useful role in the emergency evaluation of aortic injury [20, 47].

Intraarterial Digital Subtraction Angiography

Few studies have specifically examined the role of IA-DSA in blunt TAI. This method proved 100% accurate in detecting later confirmed aortic rupture in ten of 61 blunt thoracic trauma patients with an abnormal mediastinum on chest film [48]. Aortic injury was detected by

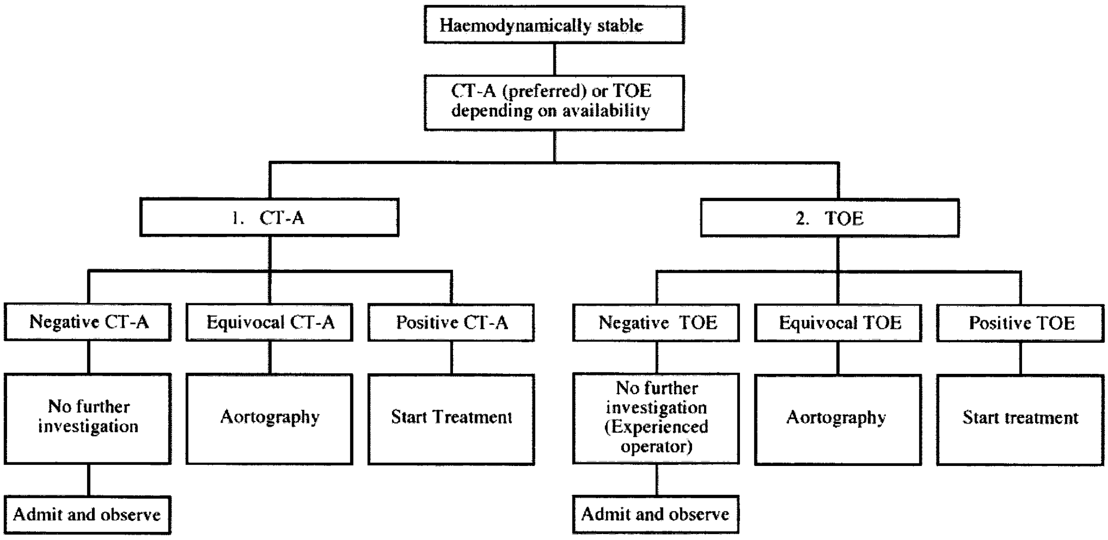

Figure 5. Investigation of suspected blunt traumatic aortic injury in a stable patient.

IA-DSA in all 15 blunt thoracic trauma patients with proven aortic rupture in another study [49]. Compared with conventional aortography, IA-DSA in faster to perform, uses smaller arterial catheters and requires less contrast [48].

Discussion

Hemodynamic stability of the patient with blunt thoracic trauma and suspected TAI determines the choice of diagnostic modality. The unstable patient requires correction of immediate life-threatening injuries during resuscitation and control of nonthoracic sources of bleeding. TEE is performed with concurrent resuscitation in a critical care venue by an experienced operator looking for aortic (and cardiac) injury (Figure 4). A positive TEE with ongoing instability from an aortic injury requires surgical treatment. An equivocal or negative TEE accompanied by strong clinical suspicion of aortic injury and persistent instability in the absence of continuing nonthoracic bleeding requires consideration of surgical intervention. If stability is achieved, consideration should be given to aortography. An equivocal or negative TEE accompanied by low clinical suspicion and the achievement of hemodynamic stability requires observation and reconsideration of the diagnosis as clinically indicated.

The investigation of choice in the hemodynamically stable patient is CT-A read by an experienced radiologist (Figure 5). TEE performed and interpreted by an experienced operator is used in the stable patient if CT-A is not available. A positive result will require treatment. Equivocal results are clarified with aortography in the first instance and follow-up CT-A or TEE if aortography is not available. A negative result requires no further investigation for aortic injury, and the patient may be admitted for observation. Missed aortic injury needs consideration if the patient's hemodynamic state deteriorates and no other source of bleeding is identified.

Conclusion

CT-A is a reliable screening tool and now primary initial diagnostic investigation for aortic injury in the hemodynamically stable patient with blunt thoracic trauma. A normal CT-A excludes aortic injury, while a positive or equivocal CT-A warrants treatment or clarification with aortography respectively. TEE, being operator-dependent and not widely available, has a role in hemodynamically unstable patients treated at experienced cardiothoracic trauma centers. Aortography remains the diagnostic standard for blunt TAI and is used when CT-A or TEE is inconclusive. MRA, endovascular USS and IA-DSA have not been used in the initial evaluation of blunt TAI.

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((Copyeditorial remark:

■1: Two «doubles» in the manuscript's Reference section were deleted [nos. 12 + 14 and 43 + 47 were identical]))