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Acute posttraumatic thoracic aortic changes in computed tomography imaging

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Summary

Acute traumatic aortic injury (ATAI) is a serious clinical condition in patients with multiorgan trauma. It results from motor vehicle accidents, pedestrian-automobile collisions and, less frequently, falls from height. Young men comprise the majority of patients with ATAI. In this publication we present examples of posttraumatic aortic changes identified in CT polytrauma (trauma CT) followed by CT angiography examinations performed between 2010 and 2012 in the CT and MRI Laboratory of Clinical Radiology and Diagnostic Imaging Department in Provincial Hospital No. 2 in Rzeszow. The aim of this study is to present morphological variants of posttraumatic aortic injuries and potential CT imaging pitfalls. Widened mediastinal silhouette in CT scoutview (topogram) may suggest the presence of posttraumatic lesions of thoracic aorta. In trauma CT scan, a hemorrhage may be suggested by blurring of the border between the aorta and periaortic adipose tissue, and/or increase of mediastinal adipose tissue density. Sudden change in aortic wall outlines, extravasation of blood/contrast medium outside the vessel, and/or delamination (tear) of tunica intima are likely changes visible in CT imaging after administration of contrast medium. When assessing CT examination one should keep in mind possible changes, which may mimic thoracic aortic injury, including thymic residual tissue, "ductus bump" or mediastinal hemorrhage of a different etiology. ATAI is associated with high mortality, which is directly dependent on the time from injury to implementation of treatment. A seemingly good condition of the patient should not influence the extent or rapidity of diagnostic imaging.

MeSH Keywords: Angiography • Aorta • Mediastinal Diseases • Multiple Trauma

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Background

Acute traumatic aortic injury (ATAI) constitutes a serious clinical problem among patients suffering from multiorgan trauma. The mechanism of injury is usually rapid deceleration (sudden horizontal braking), mainly among victims of car and motorcycle accidents, pedestrians hit by motor vehicles and, less often, due to falls from height. A great majority of such injuries involves young males. ATAI is associated with high mortality – 80–90% of patients die at the site of the accident, only 15–20% of patients survive transport to the hospital. If aortic injury remains undiagnosed, 30% of victims will die within the first 6 hours and another 40% within 24 hours. If not recognized and untreated as much as 90% of patients will die within 4 months, while 60–80% of patients will survive if radical therapy is undertaken [1–7].

The goal of this publication is to present morphological variants of posttraumatic changes of thoracic aorta and possible diagnostic pitfalls in CT imaging.

Location of Injury

Posttraumatic aortic changes are typically located at the places of its fixation. In 79-90% of cases they involve aortic isthmus (Figure 1), followed by aortic arch, root of aorta and, particularly rarely, the distal part of descending aorta in the aortic hiatus of the diaphragm. Aortic isthmus is a 2-cm-long section of proximal descending aorta

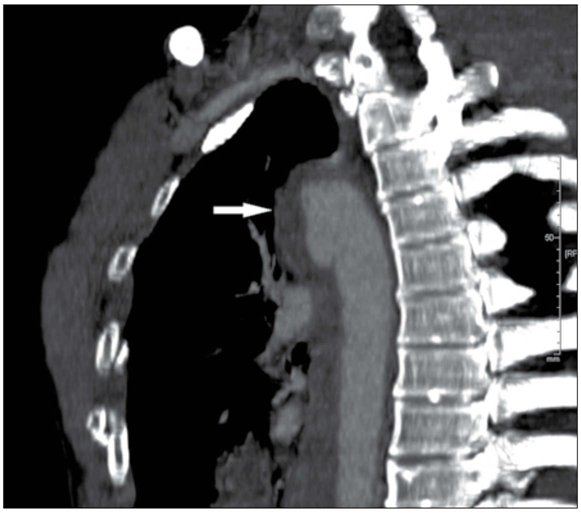

Figure 1. CT angiography of the aorta, MPR reconstruction. Irregular contour of aortic isthmus – posttraumatic aortic injury (arrow).

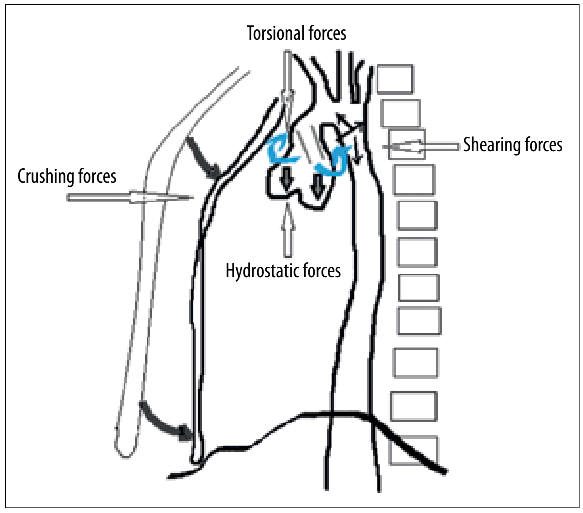

Figure 2. Schematic depiction of mechanisms of injury resulting in ATAI.

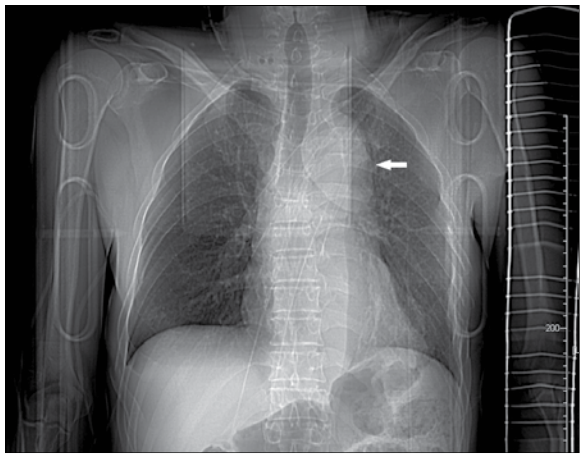

Figure 3. CT topogram. Widened mediastinum – indirect sign of ATAI (arrow).

beginning immediately below the origin of left subclavian artery and extending to the attachment of arterial ligament located on the lesser curvature of aortic arch [1,3,5,6,8,9]. The root of aorta is formed by: aortic valve, aortic annulus, aortic sinuses, sinotubular junction and ascending aorta [10]. Frequency of occurrence of posttraumatic changes of ascending aorta is estimated at about 5%, although literature reports that it reaches 25% in autopsies. This discrepancy most likely results from lethal complications related to this location, such as tearing of aortic valves, damage to coronary arteries or hemorrhage into pericardial sac with cardiac tamponade [1]. In 15% of cases injuries of ascending aorta and aortic branches accompany descending aortic trauma [11].

Mechanism and Pathophysiology of Injury

It is estimated that about 75–80% of ATAI cases result from high-velocity motor vehicle accidents. The latest literature underscores that side impact more often leads to aortic injuries than, as thought previously, head-on collisions [4]. Aside from deceleration forces, crushing forces are also of great importance [1]. Extent of aortic injuries is very broad – from an intramural hematoma, through intimal delamination, tunica media damage, to complete aortic transection [1]. Aortic injuries may also lead to pseudoaneurysm formation or acute posttraumatic dissection.

We can distinguish four major coexisting mechanisms leading to ATAI: shearing forces, rapid deceleration, hydrostatic forces and forces that crash the aorta between anterior thoracic wall and thoracic spine (so-called osseous pinch). Forces acting on the aortic isthmus include shearing and bending forces. During rapid deceleration the aortic arch, which is relatively more mobile than a well-secured descending aorta, is displaced anteriorly leading to injury of vascular wall at their junction. A similar mechanism produces aortic injuries involving the root and aortic hiatus. Bending forces lead to folding of the aorta on the left pulmonary artery and left main bronchus. "Osseous pinch," in which aorta becomes crushed between anterior osseous structures (sternum, clavicle, 1st rib) and the spine due to chest compression, is another important mechanism of aortic injury (Figure 2). Direct aortic compression leads to significant increase in blood pressure within the vessel, reaching as much as 2000 mmHg. Generated hydrostatic forces act mainly on the aortic isthmus, but may be also transferred retrogradely to its proximal part, resulting in damage to aortic root and subsequently pericardial bleeding with consequent cardiac tamponade [1,4].

Diagnostics

Contrast-enhanced multislice computed tomography, a so-called trauma CT, is the method of choice in patients with multiorgan trauma. Plain chest x-ray is of limited significance in the diagnostics of thoracic aortic transection due to its low sensitivity and specificity – about 55–59% [3]. Changes suggesting aortic injury may be noted on a CT topogram (as in chest x-ray). These changes include the following: widening of mediastinum >8 cm at the level of aortic arch, blurring of aortic borders, displacement of the esophagus/gastric probe and/or trachea/endotracheal tube to the right, downward shifting of left main bronchus,

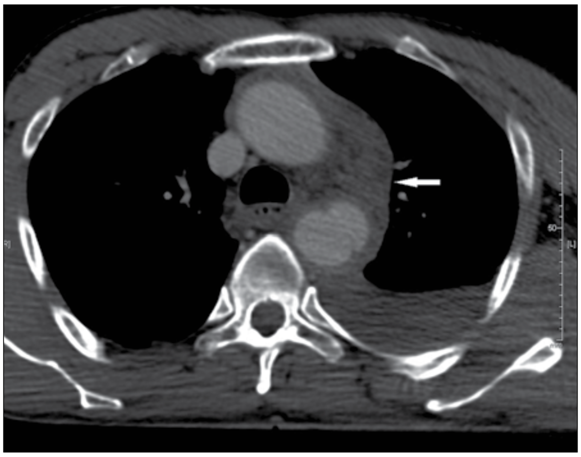

Figure 4. CT angiography of the aorta. Heterogenic mediastinal adipose tissue (arrow).

Figure 5. CT angiography of the aorta. Mediastinal hematoma (arrow).

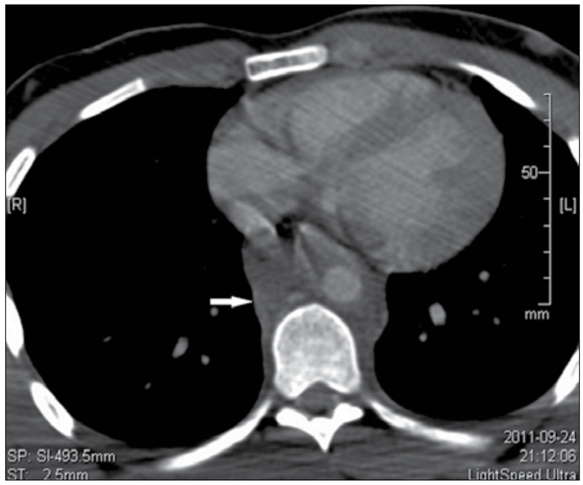

Figure 6. CT angiography of the aorta. Periaortic hematoma (arrow).

Figure 7. CT angiography of the aorta. Intimal flap (arrow).

pleural thickening in left lung apex indicating extrapleural bleeding, a so-called "apical pleural cap," and fracture of the 1st or 2nd rib [1,4,7] (Figure 3).

Sensitivity and specificity of computed tomography in identification of transections and other aortic injuries reaches 92–100% [3,12]. Symptoms of ATAI in CT examination may be divided into direct and indirect. Indirect symptoms include: mediastinal fat heterogeneity (Figure 4) and mediastinal bleeding (Figure 5), including a periaortic hematoma (Figure 6). Mediastinal hemorrhage is the single most important indirect symptom suggestive of ATAI, although its presence is more often due to venous damage than to posttraumatic aortic changes [13,14]. Presence of periaortic hematoma alone is associated with a high proportion of false-positive results. Therefore, ATAI should not be diagnosed based on its presence alone [5]. Location of bleeding in the mediastinum is very important – isolated bleeding into anterior or posterior (perivertebral) mediastinum is hardly ever a symptom of ATAI, usually encompassing periaortic region and/or superior and middle mediastinum [15]. Periaortic hematoma located at the level of diaphragmatic crura is another, less sensitive (70%) but highly specific (94%) indirect symptom, which may indicate posttraumatic aortic injury. Visualization of this type of lesion in posttraumatic abdominal CT examination necessitates performance of aortic CT imaging [9]. Direct symptoms may be demonstrated with contrast-enhanced examination and include the following: abnormal aortic contours, intimal delamination (intimal flap) (Figure 7), pseudoaneurysm formation (Figure 8), pseudocoarctation (gradual local narrowing of vascular lumen) (Figure 9), thrombi bulging into the arterial lumen, and contrast extravasation [2,6,7,13,15]. We rarely observe that last symptom in clinical practice, as it is the evidence of acute bleeding [4]. Damage to vascular intima alone, a so-called minimal aortic injury (MAI) involving an intimal flap <1 cm without coexistent large periaortic hematoma, is the mildest form of aortic injury. It occurs in about 10% of patients with ATAI [4,12].

Angio-CT with automatic contrast administration is the gold standard if changes are demonstrated in computed tomography. It enables visualization of the aorta in an arterial phase, allowing for its precise examination and planning of surgical treatment without the necessity of performing a classical angiography. An ECG-gated angio-CT examination allows for elimination of pulsation artifacts and is especially useful in imaging of posttraumatic aortic root lesions [3].

Diagnostic Pitfalls

While assessing computed tomography examination of a trauma patient one should remember about possible presence of other changes imitating posttraumatic lesions. Broadening and mediastinal fat density change may also

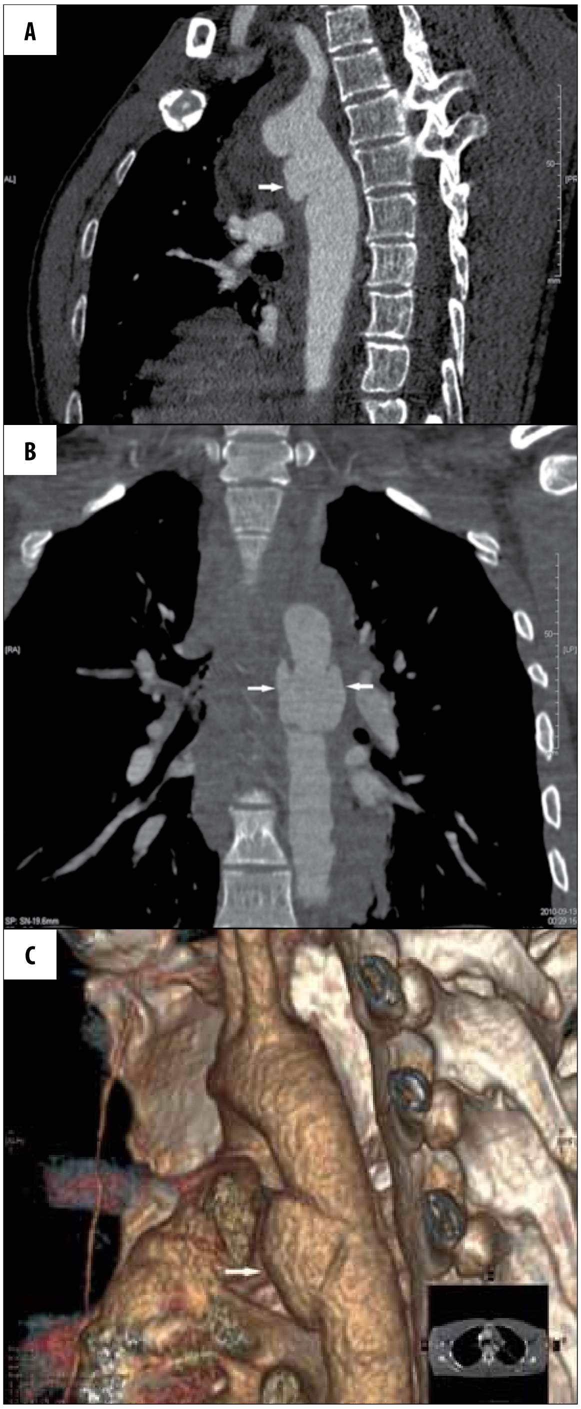

Figure 8. CT angiography of the aorta. (**A, B**) – MPR reconstruction. (**C**) – 3D reconstruction. Pseudoaneurysm (arrow).

result from tortuous course of vessels in the presence of residual thymus, pericardial diverticulum, lymphadenopathy or mediastinal lipomatosis. Mediastinal bleeding does not have to be a consequence of aortic trauma. It may result from fracture of the sternum or the spine, as well as venous and arterial damage [1,2,4,7,12,13,15]. Location of bleeding is important with regard to differentiation of the source of bleeding. Isolated perivertebral bleeding is rather a consequence of spinal trauma. Anatomical structures of the mediastinum and the aorta itself may imitate

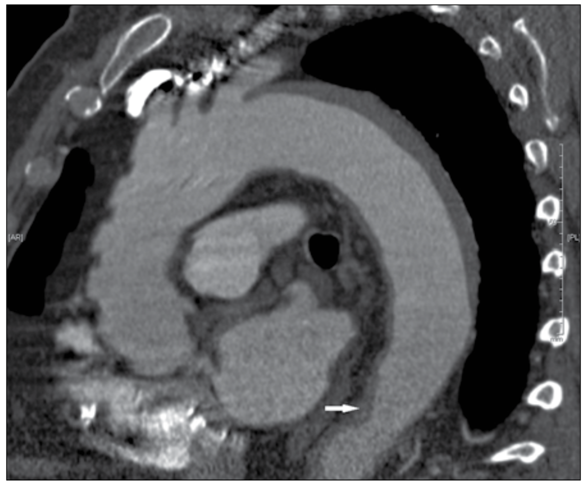

Figure 9. CT angiography of the aorta – MPR reconstruction. Aortic pseudocoarctation (arrow).

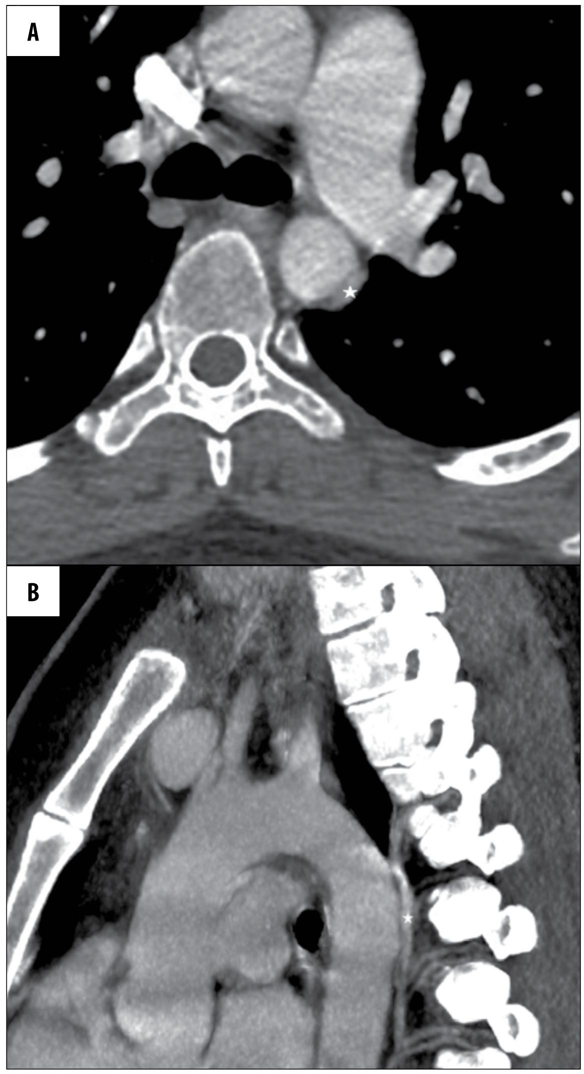

Figure 10. Trauma CT scan. (**A**) – axial plane. (**B**) – MPR reconstruction. A diagnostic pitfall – vein mimicking an intimal flap (arrow).

posttraumatic aortic lesions. The most important ones are veins: left intervertebral vein adhering to the aortic arch and accessory azygos vein located on the posterolateral side in the immediate proximity of descending aorta (Figure 10). Presence of contrasted blood in those vessels as well as in the aorta may be suggestive of an intimal flap. A so-called "ductus bump," a smooth bulging of the medial contour of its descending part at the level of arterial ligament, is an anatomical variant involving the aorta [4,15,16]. One should remember about the possibility of mild physiological dilatation of aortic lumen immediately behind the isthmus [4]. Lung lesions may also be a source of diagnostic problems. In particular, it is true for contrast-enhanced areas of atelectasis, especially the segments of left lower lobe adjacent to the aorta, and left-sided pleural effusion [2,4,13,15]. Differentiation between pseudoaneurysms should take into consideration pseudoaneurysms formed on the ground of atherosclerotic lesions [12].

Technical and mechanical conditions, such as: heart contractions, motion artifacts (including breathing), volume averaging, beam hardening (e.g. from ECG leads), or those related to high concentration of contrast in brachiocephalic veins or superior vena cava, may be a separate source of diagnostic difficulties [4,12,15,17].

Treatment

Posttraumatic thoracic aortic lesions in a great majority of cases require the fastest possible surgical intervention. A classical method of surgical management involves excision of the damaged part of the aorta via left lateral thoracotomy in the 4^{th} or 5^{th} intercostal space. A newer method, less invasive, shorter and less prone to complications, consists of endovascular prosthesis implantation from the femoral artery, most often the right one. Angio-CT examination, preferentially ECG-gated, should be performed in the course of planning such procedure [3,4]. Image analysis should include measurements of aortic diameter at nine levels, i.e. aortic bulb, sinotubular junction, middle part of ascending aorta, origin of brachiocephalic trunk, level between the origin of left internal carotid artery and left subclavian artery, 2 cm below the origin of left subclavian artery, middle part of thoracic descending aorta, level of aortic hiatus and the level of origin of cephalic trunk. Moreover, diameter of right subclavian artery (used for connecting patient to extracorporeal circulation) and right brachial artery, distance between the origin of left subclavian artery and cephalic trunk should be also evaluated. It is also necessary to assess the diameter, course and degree of calcification of iliac and femoral arteries, which are used during extracorporeal circulation or for endovascular access. Measurements should be performed perpendicularly to the long axis of the vessel and wall-to-wall (as opposed to wall-to-thrombus) [3].

Conclusions

Patients with multiorgan trauma should be first assessed for the presence of posttraumatic aortic lesions. Suspicion of aortic injury in trauma CT necessitates conducting an angio-CT examination, which is necessary for planning of surgical treatment. Time between trauma and implementation of treatment is the decisive prognostic factor. A seemingly good general clinical condition of a patient should not influence the speed and extent of diagnostics.

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