Minimal traumatic aortic injuries: meaning and natural history

Victor X. Mosquera, Milagros Marini, Daniel Gulías, Ignacio Cao, Javier Muñiz, José Manuel Herrera-Noreña, José Manuel López-Pérez and José Joaquin Cuenca

Abstract

Objective. Minimal aortic injuries (MAIs) are being recognized more frequently due to the increasing use of high-resolution diagnostic techniques. The objective of this case series review was to report the clinical and radiological characteristics and outcomes of a series of patients with MAI.

Methods. From January 2000 to December 2011, 54 major blunt trauma patients were admitted to our institution with traumatic aortic injuries. Nine of them presented with MAI, whereas the remaining 45 patients suffered a significant aortic injury (SAI).

Results. MAIs accounted for 17% of the overall traumatic aortic injuries in our series. Major trauma patients with MAI and SAI were similar regarding the presence of severe associated non-aortic injuries and the expected mortality calculated by injury severity score, revised trauma score and trauma injury severity score. There were no statistically significant differences in in-hospital mortality between MAI (22.2%) and SAI (30.2%). No death in the MAI group was aortic related, whereas five deaths in the SAI group were caused by an aortic complication. The survival of MAI patients was 77.8% at 1 and 5 years. There was no late mortality among MAI patients. The survival of SAI patients was 69.7% at 1 year and 63.6% at 5 and 10 years. None of the seven surviving patients with MAI presented a progression of the aortic injury. In six patients, the intimal tear completely healed in imaging controls, whereas one patient developed a small saccular pseudoaneurysm.

Conclusions. Blunt traumas presenting MAI are as severe as traumas that associate SAI and present similar in-hospital mortality. In contrast to SAI traumas, in-hospital mortality due to MAI is not usually related to the aortic injury, so these injuries are more amenable to a conservative management. It is mandatory to perform a close imaging surveillance to detect early any potential adverse evolution of an MAI. Nevertheless, a balance must be struck between a close serial imaging surveillance and the potentially detrimental effects of obtaining high-resolution additional images.

Key words: Aorta, Trauma, Emergency medicine, Endovascular

Introduction

Nowadays, minimal aortic injuries (MAIs) are being recognized more frequently due to the increasing use of high-resolution diagnostic techniques, especially with the increasingly widespread use of multidetector computed tomography (MDCT).

Although prompt diagnosis and early operative repair have been the standard of care for the management of acute traumatic aortic injuries (ATAIs) since the classic study by Parmley *et al*. [1], clinical management with aggressive blood pressure control for patients who reach the hospital alive [2–4], the shift towards a more frequent use of endovascular techniques to repair these types of injuries [5] and the institution of surgical treatment in a delayed fashion after the stabilization of associated critical injuries [6] have changed the way ATAIs are managed.

MAIs may be the most amenable aortic injuries for non-operative management [7, 8]. Nevertheless, the long-term outcomes of MAIs are poorly documented. Most of the published studies focus only on significant aortic injuries (SAIs) and MAIs have only been reported in isolated case reports [9] or barely mentioned in other reports [2, 10, 11], with a lack of information about this subset of ATAIs.

The objectives of this case series review were to describe the clinical profile and early and long-term outcomes of a series of nine consecutive MAIs, and to compare such data with our last 10 years of experience managing ATAIs in major trauma patients.

Patients and methods

From January 2000 to December 2011, 54 consecutive major blunt trauma patients with ATAIs were admitted to our institution. Two patients were excluded from the analysis because of deficient documentation or because they were in extremis status on arrival.

Data were recorded on a standardized form that included information on patient demographics, the mechanism of injury, initial clinical presentation (blood pressure, respiratory rate, need of oral intubation at the site of the trauma or during transportation, Glasgow Coma Scale [GCS]), injury severity score (ISS) [12], abbreviated injury score (AIS) for each body area (head, chest, abdomen and extremities), revised trauma score (RTS) [13], trauma injury severity score (TRISS) [14], associated injuries and findings on diagnostic imaging tests.

For the purpose of the study, a major trauma patient was defined as a victim of trauma with an ISS > 15 [12] according to the published literature [12, 15].

An ISS score of >50 points predicts a mortality rate of >50%, whereas a score of >70 points predicts a mortality rate of nearly 100% [12]. The TRISS score directly predicts the expected death rate for blunt trauma [14].

The aortic injuries were classified as: (i) small intimal tear <10 mm; (ii) intramural hematoma without intimal tear; (iii) aortic transection and intimal tear >10 mm; and (iv) aneurysm/pseudoaneurysm. The site of the aortic injury (aortic root-ascending aorta, aortic arch, aortic isthmus, mid or distal descending thoracic aorta and abdominal aorta) and the type of definitive management (conservative, open repair or endovascular repair) were also recorded.

For the purpose of the study, the initial types of aortic injury were later divided into two categories [7]: MAI, which included the intimal tears <10 mm with minimal to no periaortic hematoma, and SAI, including intramural hematoma without intimal tear, aortic transection/intimal tear >10 mm, and aneurysm/pseudoaneurysm.

The mechanisms of blunt trauma were classified as: motor vehicle crash (MVC), motorcycle crash (MCC), fall, auto vs. pedestrian (AVP), crush under weight and others.

Hypotension was defined as a systolic blood pressure <90 mmHg or the need of fluid and/or inotropic support to maintain a blood pressure ≥90 mmHg. An abnormal respiratory rate was defined as bradypnoea <10 bpm or tachypnoea >30 bpm. GCS < 9 points was defined as the cut-off value for a neurologically bad prognosis on admission.

Penetrating trauma was an exclusion criterion in the study.

The Institutional Review Board approved this study based on retrospective data retrieval, waiving individual consent.

Imaging tests

The initial diagnosis of ATAIs was established in all patients within 24 h from admission mainly using CT scans. Transoesophageal echocardiography (TEE) was used as an auxiliary diagnostic test when required. Aortography was performed in some patients to further delineate the injury pattern at the discretion of the trauma team attending.

From January 2000 through to January 2006, CT examinations were performed using a dual-slice helical scan Philips CT-*Twin Flash* (Philips Medical System, Best, The Netherlands). From September 2006, CT studies were performed using an MDCT scan *Lightspeed™* VCT General Electric Company (NYSE: GE).

Before the incorporation of the MDCT scan, the protocol for routine chest CT in major trauma patients used 5-mm helical slices from the thoracic inlet to the symphysis pubis and the administration of 120 ml of intravenous iodinated contrast medium at a rate of injection of 3–4 ml/s. Our current CT protocol for major trauma with suspected vascular or aortic injury consists of a three-phase MDCT, including an unenhanced phase, a contrast-enhanced arterial phase and a delayed or portal venous phase, with 3D reconstructions. The MDCT is performed using 100 ml of intravenous iodinated contrast medium at 4 ml/s in order to maximize arterial enhancement. Axial images are acquired at 0.625 mm collimation during the arterial phase from the thoracic inlet to the symphysis pubis and during the portal venous phase. The images are routinely reviewed in the axial and coronal plane at font images and at a section thickness of 5 mm. In vascular MDCT, it is mandatory to generate oblique reconstructions that resemble the images obtained in conventional angiography, as well as sagittal, coronal and multiplanar reconstructions [16].

In our study, TEE was used as the preferred screening tool when a conservative approach was selected. Serial TEE studies (HP SONOS 5500, Philips Medical System, Best, The Netherlands) using a multiplane probe and a 7.0-MHz transducer were performed by experienced senior echocardiographists to

monitor the progression or resolution of the aortic injury. Follow-up TEE studies were performed on different days in each patient as determined by his clinical condition.

Management of acute traumatic aortic injuries

ATAI management was conservative treatment, thoracic endovascular aortic repair (TEVAR) or open surgical repair according to the clinical and radiological criteria of the trauma team which approached the patient. The criteria of patient management were modified with the incorporation of technological advances in both diagnostic and therapeutic fields, especially with the widespread use of TEVAR [8].

Medical therapy included limitation of intravenous fluid infusion once the systolic arterial pressure exceeded 100 mmHg and using beta-blockers to reduce the heart rate, cardiac contractility and blood pressure to the lowest amounts that still maintained adequate end-organ perfusion [2, 3, 17]. When heart rate and blood pressure were stable on oral therapy, the patients were transferred out of the intensive care unit (ICU). After discharge, the patients were followed in the outpatient clinic. Conservative management included a strict imaging surveillance protocol as we have previously published [8].

Statistical analysis

Data are expressed as mean and standard deviation or median and range, when appropriate. Proportions were compared with contingency tables by means of χ^2 with Yates' continuity correction or Fisher's exact tests. Student's *t*-test and the Mann–Whitney test were used to compare the means. $P < 0.05$ was considered significant.

Actuarial estimates of survival were accomplished with Kaplan–Meier methods. Differences in probability of survival between the groups were analysed with the log-rank (Mantel–Cox) test.

The SPSS statistical program for Windows version 17.0 (SPSS, Chicago, IL, USA) was used to perform data analysis.

Results

Among the 52 major trauma patients with ATAIs, nine patients met criteria for MAI while the remaining 43 cases presented with SAI. The epidemiological and clinical characteristics of the nine major trauma patients with associated MAI are described in Table 1.

Table 1. Epidemiological and clinical characteristics of MAI

No.	Sex	Age (years)	Mechanism of injury	Site of MAI	Diagnostic tests	ISS	TRISS	In-hospital death	Follow-up
1	M	19	MCC	Isthmus	CT, TEE, aortography	38	7.7	No	Resolution
2	M	43	MVC	Ascending aorta	CT, TEE	50	90.1	No	Resolution
3	M	58	MVC	Isthmus	CT, TEE, aortography	41	90.1	Yes, MOF	–
4	M	34	Crush	Isthmus	CT, TEE	50	59.7	No	Resolution
5	M	36	MCC	Descending aorta	MDCT, TEE	51	89.1	No	Small saccular pseudoaneurysm (1 cm diameter)
6	M	45	Crush	Arch	MDCT, TEE, aortography	30	12.3	No	Resolution
7	F	60	MCC	Abdominal aorta	MDCT, aortography	66	94.2	No	Resolution
8	F	77	AVP	Descending aorta	MDCT, TEE	45	85.7	Yes, brain injury	–
9	M	40	Crush	Abdominal aorta	MDCT, aortography	27	4.6	No	Resolution

M: male; F: female; MCC: motorcycle crash; MVC: motor-vehicle crash; AVP: auto vs. pedestrian; MOF: multisystem organic failure; ISS: injury severity score; TRISS: trauma injury severity score.

Patients with MAI were diagnosed by dual-slice helical CT in four cases (44.4%) and by MDCT in the remaining five patients (55.6%). The TEE was used as an auxiliary diagnostic test and as a monitoring tool in seven cases (77.7%) of MAI. Only patients with an injury of the abdominal aorta did not undergo a TEE study. An aortography was realized in five cases (55.6%) of MAIs, although in three of them it was done due to the need to perform embolization of bleeding abdomino-pelvic vessels. Figure 1 and Supplementary Video 1 show the results of imaging techniques in major trauma patients confirming the presence of MAI.
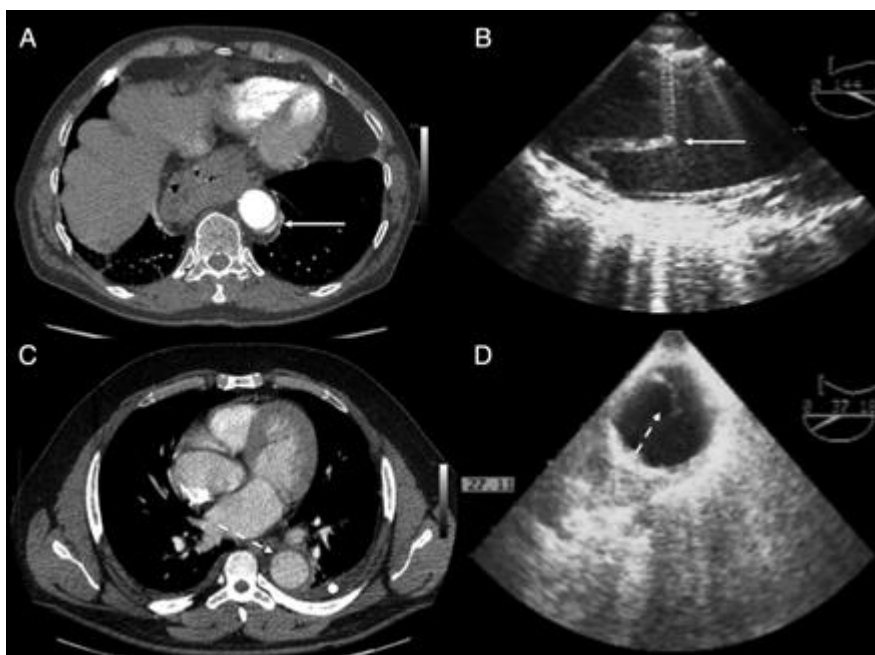
Figure 1. (**A**) On admission thoracic MDCT image from MAI Patient 5. The white arrow marks a small intimal tear. (**B**) Longitudinal descending aorta plane of Patient 5. Note the small intimal flap in the image (white arrow). (**C**) On admission thoracic MDCT image from MAI Patient 8. The dashed white arrow shows an intimal defect, whereas the asterisk marks the presence of mild pleural effusion. (**D**) Axial descending aorta plane of Patient 8. Note that the small intimal defect with minimal intraluminal thrombus (white dashed arrow).

Among patients with SAI, a dual-slice helical CT was used in 28 cases (65.1%) and an MDCT in 15 cases (34.9%). An echocardiogram was performed in 20 patients (46.5%). An aortography was required in 16 cases (37.2%).

The mechanism of trauma in SAI was MVC in 23 cases (53.5%), MCC in eight cases (18.5%), fall in six cases (14%), crush under weight in three cases (7%) and AVP in three cases (7%). In contrast, the cause of trauma in MAI was an MVC in three cases (33.3%), crush under weight in three cases (33.3%), MCC in two cases (22.2%), and AVP in one case (11.1%) ($P = 0.23$).

In the patients with SAIs, aortic injuries occurred at the aortic isthmus in 21 cases (48.9%), the mid and distal descending aorta in nine cases (20.9%), the aortic arch in six cases (14%), the abdominal aorta in five cases (11.6%) and the ascending aorta in two cases (4.6%). However, MAIs were located at the isthmus level in three cases (33.3%) followed in frequency by mid and distal thoracic descending aorta in two cases (22.2%), abdominal aorta in two cases (22.2%), aortic arch in one case (11.1%) and ascending aorta in one case (11.1%) ($P = 0.81$).

Overall expected mortality at admission was ≥50% according to an ISS score >50 points in 19 patients (44.2%), whereas the overall mean expected death rate calculated by the TRISS score was $49.4 \pm 38.7\%$. Although patients with MAI presented a higher proportion of ISS >50, this difference did not reach statistical significance (44.4% vs. 32.5%, $P = 0.76$). Likewise, there were no statistically significant differences between MAI and SAI in the presence of severe (AIS > 3) associated non-aortic injuries, severity of trauma determined by ISS (44.2 ± 11.9 vs. 43.2 ± 16.8, $P = 0.67$) and RTS (5.2 ± 1.6 vs. 5.6 ± 1.9, $P = 0.44$) and expected mortality calculated by TRISS ($59.3 \pm 39.6\%$ vs. $47.3 \pm 38.6\%$, $P = 0.64$).

Overall in-hospital mortality was 28.8% (15 patients). There were no statistically significant differences in in-hospital mortality between MAI (two cases, 22.2%) and SAI (13 cases, 30.2%) ($P = 0.94$). The causes of death among patients from both groups are shown in Table 2. None of the two deaths in the MAI group were related to the aortic injury.

Table 2. In-hospital mortality and causes of death among patients from both trauma groups

	MAI (n = 9)	SAI (n = 43)
In-hospital mortality	3 (33.3%)	13 (30.2%)
Causes of death		
Multisystem organ failure	1	3
Hypovolemic shock	–	5
Central nervous injury	1	2
Septic shock	–	1
Acute respiratory distress syndrome	–	2

Of the 43 patients with SAI, nine patients underwent open surgical repair of ATAI, while eight patients with SAI underwent TEVAR. All patients presenting with MAI ($n = 9$) underwent a conservative management, whereas 26 patients with SAI were non-operatively managed.

There were no differences in ICU and in-hospital stay between the groups. The mean ICU stay length in MAI was 17.2 ± 16 days and 18.5 ± 14.2 days in SAI ($P = 0.81$). The mean in-hospital stay length in MAI was 26.2 ± 35.1 days and 54.1 ± 87.7 days in SAI ($P = 0.81$).

After hospital discharge, clinical and imaging follow-up was available in all patients at a median time of 27 months (range 0–143 months). MAI patients survival estimated by the Kaplan–Meier method, including early mortality, was 77.8% at 1 and 5 years. Only two patients in the MAI group have reached a 10-year follow-up. There was no late mortality in MAI patients after hospital discharge. The survival of SAI patients was 69.7% at 1 year, 63.6% at 5 and 10 years (Fig. 2). There were no statistically significant differences between groups' survival ($P = 0.46$). During follow-up, none of the seven surviving trauma patients with MAI after discharge presented a progression of the aortic injury. In six patients, the intimal tear had completely healed by 12 months in serial imaging controls using CT (Patients 1, 2, 4, 6, 7 and 9), whereas one patient (Patient 5) developed a small saccular pseudoaneurysm (1 cm in diameter) diagnosed during the first year of imaging control at the level of the aortic isthmus. It has not reached indication for surgical repair and undergoes strict yearly imaging surveillance⇓.
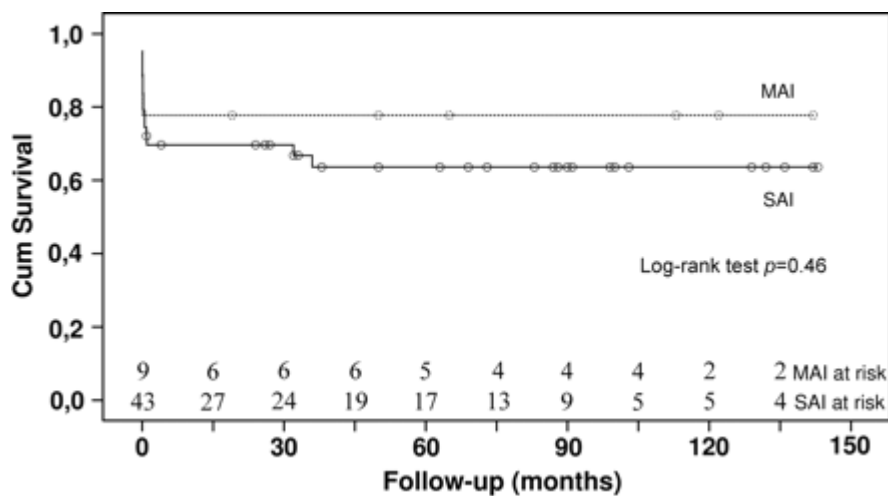
Figure 2. Kaplan–Meier survival curves of major trauma patients with SAI or MAI, including in-hospital mortality.

Discussion

Our results suggest that blunt traumas presenting with MAI are, at least, as severe as those with associated SAI. Likewise, the overall in-hospital mortality of both types of traumas seems to be similar. However, in contrast to SAI traumas, in-hospital mortality in MAI is not usually related to the aortic injury. Our results also suggest that MAI management must be more conservative than with SAI, but close imaging surveillance should be performed for the early detection of any potential adverse evolution of the MAI.

Our experience is consistent with the literature to date, yet provides some new insights about major trauma patients with MAI. In our series, we found 17.3% of MAI among the overall 52 ATAIs in major trauma patients admitted to our institution from January 2000 to December 2011. This proportion is higher than the 10–13% of MAI among overall ATAIs reported by other authors in smaller series of MAI [7, 9, 18]. We may explain this difference because our series is more recent and includes the results of the widespread use of MDCT for trauma emergencies since 2006 at our institution. In fact, four cases were diagnosed using dual-slice helical CT during the period 2000–2006, whereas the MDCT diagnosed five patients in the period 2006–2011. The MDCT has a sensitivity of 96.0%, a specificity of 99.8%, a positive predictive value of 92.3% and a negative predictive value of 99.9% in the diagnosis of ATAIs [18]. In spite of the remarkable accuracy of MDCT in diagnosing ATAIs, there are anatomic variants that may mimic an aortic injury including aortic spindle, ductus diverticulum, ductus remnant and branch vessel infundibula [16]. Breathing, arterial pulsation and other motion artefacts may also be misinterpreted as ATAIs [16].

On the other hand, the speed and portability of TEE, combined with its ability to be performed without interrupting ongoing measures to stabilize the trauma patient and to obtain high-resolution images of the aorta, makes this technique an attractive diagnostic modality [19]. Besides imaging ATAIs, TEE is an invaluable tool in the evaluation of all cardiovascular abnormalities in chest trauma patients, such as myocardial contusion, pericardial effusion, valvular abnormalities and hypovolemia. Transoesophageal echocardiography may be especially useful for providing a safe and rapid method for examining mediastinal structures and evaluating the haemodynamic status of intubated major trauma patients, as reported by Catoire *et al*. [20]. With the advent of MDCT and in combination with the invaluable data provided by TEE, especially in intubated patients, we currently perform an accurate stratification and monitoring of the aortic injury according to the risk of aortic complication [8].

In our series, the severity of major trauma was not lower in MAI patients. On the contrary, major trauma patients with MAI presented a worse prognosis and a higher expected mortality on admission than SAI patients, as estimated by ISS, RTS and TRISS data. Aortic injuries with other associated traumatic injuries must be evaluated altogether in the context of the multisystem impairment of major trauma patients, given that these associated injuries can be just as lethal as the ATAIs. This emphasizes the fact that treatment priorities should be modulated on an individual basis. In our series, in-hospital mortality in major trauma patients with SAI (30.2%) was slightly higher than in major trauma with MAI (22.2%), although this difference did not reach statistical significance. In both groups of major trauma patients, observed in-hospital mortality tended to be lower than expected in-hospital mortality estimated by TRISS (59.3% in MAI and 47.3% in SAI). Among SAI patients, five (38.5%) of the 13 in-hospital deaths were due to aortic-related complications, whereas none of the in-hospital deaths occurred in MAI patients were related to the aortic injuries. In case of multiple associated injuries, a conservative management of the ATAIs may be selected, especially in low-risk aortic injuries (small intimal tears or intramural hematoma without intimal tear) [7–9, 21].

The anatomic structure of the aortic wall may explain the amenability of limited intimal injuries to conservative treatment. The aortic wall is composed of an internal layer, the intima, a middle layer, the media, an outer layer, and the adventitia. The media is composed of sheets of elastin interspersed with smooth muscle cells and provides most of the structural strength and elastic properties of the aorta. Therefore, injuries limited to the intimal layer should not compromise the resistance of the aortic wall and may be suitable candidates for non-operative management, provided that aortic wall stress and cardiac contractility is appropriately controlled with beta-blockers. Besides, animal studies support that aortic wall injuries limited to the intimal layer are successfully repairable by endothelization in nearly all subjects [22].

Currently, it is well known that the natural history of patients sustaining an ATAI, which is non-operatively managed presents a marked trend to develop late aortic-related complications [8]. We must keep in mind that up to 40% of ATAIs in which a conservative approach is selected may develop a life-threatening aortic-related complication. The initial type of aortic lesion and a TRISS score of >50% on admission have been identified as risk factors for a worse long-term prognosis [8]. Besides, the potential for rapid progression even of MAI in major trauma patients [7, 8, 21] mandates serial radiological controls during the first 3 months after injury and diagnosis and then annually. Some authors have identified the potentially adverse evolution of MAIs as the formation, enlargement and rupture of a

pseudoaneurysm; embolism of loose intima, or thrombus; and progressive dissection of the aortic wall [7, 9]. In our series, 85.7% of surviving patients with MAIs have spontaneously healed and only one patient has developed a small pseudoaneurysm without reaching an indication for surgical repair [23].

These satisfactory outcomes obey a multidisciplinary approach and the combination of a strict control of cardiac contractility and aortic wall stress with a close imaging surveillance. Nevertheless, the abuse of high-radiation imaging tests in imaging surveillance must be avoided. A typical patient with traumatic injury who undergoes irradiation at a young age incurs an increased cumulative lifetime risk of developing cancer [24]. The potentially detrimental effects of serial high-radiation tests during a long period of time must be weighed up, especially in young patients. Therefore, we currently advocate the combination of MDCT and echocardiography data to perform the imaging monitoring of MAIs during the in-hospital stay. Subsequently, we chose magnetic resonance imaging (MRI) for the yearly imaging surveillance after the first year of hospital discharge and did not perform MDCT surveillance unless a new aortic anomaly was detected in MRI.

Conclusions

Blunt traumas with associated MAIs are as severe as traumas with associated SAI and both groups present similar in-hospital mortality. However, in contrast to SAI traumas, in-hospital mortality in MAIs is not usually related to the aortic injury. Management of MAIs must be conservative, but close imaging surveillance for the early detection of potential adverse evolution of the MAI, highlighting the risk of development of an aortic pseudoaneurysm, should be performed. Nevertheless, caution must be exercised to avoid exceeding patient exposure to diagnostic radiation during imaging surveillance. Hence, a balance must be struck between performing a close serial imaging surveillance and the potentially detrimental effects of obtaining high-resolution additional images, especially in young trauma patients.

Supplementary material

Supplementary material is available at *ICVTS* online.

Conflict of interest: none declared.

References

1. Parmley LF, Mattingly TW, Manion WC, Jahnke EJ Jr. Non-penetrating traumatic injury of the aorta. Circulation 1958;17:1086-101.
2. Fabian TC, Davis KA, Gavant ML, Croce MA, Melton SM, Patton JH Jr., et al. Prospective study of blunt aortic injury: helical CT is diagnostic and antihypertensive therapy reduces rupture. Ann Surg 1998;227:666-76. discussion 676–667.
3. Pate JW, Fabian TC, Walker W. Traumatic rupture of the aortic isthmus: an emergency? World J Surg 1995;19:119-25. discussion 25–6.
4. Tsai TT, Nienaber CA, Eagle KA. Acute aortic syndromes. Circulation 2005;112:3802-13.
5. Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma Multicenter Study. J Trauma 2008;64:561-70. discussion 70–1.
6. Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Blunt traumatic thoracic aortic injuries: early or delayed repair—results of an American Association for the Surgery of Trauma prospective study. J Trauma 2009;66:967-73.
7. Malhotra AK, Fabian TC, Croce MA, Weiman DS, Gavant ML, Pate JW. Minimal aortic injury: a lesion associated with advancing diagnostic techniques. J Trauma 2001;51:1042-8.
8. Mosquera VX, Marini M, Lopez-Perez JM, Muniz-Garcia J, Herrera JM, Cao I, et al. Role of conservative management in traumatic aortic injury: comparison of long-term results of conservative, surgical, and endovascular treatment. J Thorac Cardiovasc Surg 2011;142:614-21.
9. Kepros J, Angood P, Jaffe CC, Rabinovici R. Aortic intimal injuries from blunt trauma: resolution profile in nonoperative management. J Trauma 2002;52:475-8.
10. Arthurs ZM, Starnes BW, Sohn VY, Singh N, Martin MJ, Andersen CA. Functional and survival outcomes in traumatic blunt thoracic aortic injuries: an analysis of the National Trauma Databank. J Vasc Surg 2009;49:988-94.
11. Hong MS, Feezor RJ, Lee WA, Nelson PR. The advent of thoracic endovascular aortic repair is associated with broadened treatment eligibility and decreased overall mortality in traumatic thoracic aortic injury. J Vasc Surg 2011;53:36-42. discussion 43.

12. Baker SP, O'Neill B, Haddon W Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96.
13. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the trauma score. J Trauma 1989;29:623-9.
14. Champion HR, Sacco WJ, Copes WS. Injury severity scoring again. J Trauma 1995;38:94-5.
15. Soreide K. Epidemiology of major trauma. Br J Surg 2009;96:697-8.
16. Berger FH, van Lienden KP, Smithuis R, Nicolaou S, van Delden OM. Acute aortic syndrome and blunt traumatic aortic injury: pictorial review of MDCT imaging. Eur J Radiol 2010;74:24-39.
17. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr., et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with Thoracic Aortic Disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation 2010;121:e266-369.
18. Steenburg SD, Ravenel JG. Acute traumatic thoracic aortic injuries: experience with 64-MDCT. AJR Am J Roentgenol 2008;191:1564-9.
19. Smith MD, Cassidy JM, Souther S, Morris EJ, Sapin PM, Johnson SB, et al. Transesophageal echocardiography in the diagnosis of traumatic rupture of the aorta. N Engl J Med 1995;332:356-62.
20. Catoire P, Orliaguet G, Liu N, Delaunay L, Guerrini P, Beydon L, et al. Systematic transesophageal echocardiography for detection of mediastinal lesions in patients with multiple injuries. J Trauma 1995;38:96-102.
21. Holmes JHt, Bloch RD, Hall RA, Carter YM, Karmy-Jones RC. Natural history of traumatic rupture of the thoracic aorta managed nonoperatively: a longitudinal analysis. Ann Thorac Surg 2002;73:1149-54.
22. Chemnitz J, Christensen BC. Repair in arterial tissue 2 years after a severe single dilatation injury: the regenerative capacity of the rabbit aortic wall. The importance of endothelium and of the state of subendothelial connective tissue to reconstitution of the intimal barrier. Virchows Arch A Pathol Anat Histopathol 1991;418:523-30.
23. Svensson LG, Kouchoukos NT, Miller DC, Bavaria JE, Coselli JS, Curi MA, et al. Expert consensus document on the treatment of descending thoracic aortic disease using endovascular stent-grafts. Ann Thorac Surg 2008;85:S1-41.
24. Brenner DJ, Hall EJ. Computed tomography–an increasing source of radiation exposure. N Engl J Med 2007;357:2277-84.