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Traumatic aortic injury score (TRAINS): an easy and simple score for early detection of traumatic aortic injuries in major trauma patients with associated blunt chest trauma

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Abstract

Purpose. To develop a risk score based on physical examination and chest X-ray findings to rapidly identify major trauma patients at risk of acute traumatic aortic injury (ATAI).

Methods. A multicenter retrospective study was conducted with 640 major trauma patients with associated blunt chest trauma classified into ATAI (aortic injury) and NATAI (no aortic injury) groups. The score data set included 76 consecutive ATAI and 304 NATAI patients from a single center, whereas the validation data set included 52 consecutive ATAI and 208 NATAI patients from three independent institutions. Bivariate analysis identified variables potentially influencing the presentation of aortic injury. Confirmed variables by logistic regression were assigned a score according to their corresponding beta coefficient which was rounded to the closest integer value (1–4).

Results. Predictors of aortic injury included widened mediastinum, hypotension less than 90 mmHg, long bone fracture, pulmonary contusion, left scapula fracture, hemothorax, and pelvic fracture. Area under receiver operating characteristic curve was 0.96. In the score data set, sensitivity was 93.42 %, specificity 85.85 %, Youden’s index 0.79, positive likelihood ratio 6.60, and negative likelihood ratio 0.08. In the validation data set, sensitivity was 92.31 % and specificity 85.1 %.

Conclusions. Given the relative infrequency of traumatic aortic injury, which often leads to missed or delayed diagnosis, application of our score has the potential to draw necessary clinical attention to the possibility of aortic injury, thus providing the chance of a prompt specific diagnostic and therapeutic management.

Keywords: Aorta, Trauma, Imaging, Risk prediction, Acute aortic syndrome

Introduction

Acute traumatic aortic injury (ATAI) usually occurs in patients with major trauma and has devastating consequences [*1*]. Nowadays, the way of managing ATAI has evolved thanks to the advent of multidetector computed tomography (MDCT) [*2*], the clinical management with aggressive blood pressure control and cardiac contractility [*3*, *4*], the shift toward the use of aortic endovascular repair techniques [*5*], and the institution of delayed surgical treatment after the associated critical injuries have been stabilized [*6*]. Nevertheless, an important number of patients may not completely benefit from all the advances achieved in ATAI management as a result of a delay in the aortic injury diagnosis which may lead to catastrophic aortic-related complications [*7*]. Furthermore, the imaging diagnosis of some ATAI requires a specific arterial MDCT scan with multiplanar reconstructions (MPR) [*2*, *8*]. On the other hand, if every major trauma patient undergoes an arterial MDCT scan with MPR for a potential ATAI, the cost and level of radiation exposure would be prohibitive.

A combination of data from initial physical examination and on admission chest X-ray (CXR) to determine the probability of ATAI may allow the prompt establishment of a specific therapeutic management of ATAI to avoid aortic-related complications and a better determination of what imaging is appropriate and how it should be interpreted. As a tool like this is lacking, the purpose of this study was to determine whether a simple and easy score to determine a patient’s probability of having an ATAI could be developed and validated and, if so, to estimate its diagnostic accuracy.

Patients and methods

Patient recruitment

This retrospective study population included 646 major trauma patients with associated blunt chest trauma divided into two data sets: a score data set provided by one institution, and an independent validation data set provided by three other institutions. All the participating institutions are level-one trauma centers. Major trauma patients with associated blunt chest trauma were classified into ATAI (associated acute traumatic aortic injury) and NATAI (no associated acute traumatic aortic injury) groups.

For the purpose of the study, a major trauma patient was defined as a victim of trauma of sufficient energy to put him at risk of important injury, with associated blunt chest trauma, transported to a level-one trauma center presenting with an injury severity score (ISS) [*9*] greater than 15 according to published literature [*9*, *10*].

The severity of the associated chest trauma was not itself an inclusion/exclusion criterion. Indeed, the severity of the associated blunt chest trauma could span from mild findings of chest trauma (i.e., local pain) to the most severe chest injuries such as bilateral lung contusion or multiple rib fractures and flail chest.

The score data set initially included 82 ATAI patients admitted to our institution from January 1980 to December 2010. However, six patients (7.3 %) in the ATAI group were excluded from the analysis because of deficient documentation and/or in extremis status on arrival. To achieve four control subjects in the NATAI group per patient with ATAI, we selected 324 consecutive patients who presented to our emergency department with major trauma with thoracic involvement but without traumatic aortic injury between January 2009 and December 2010.

In the validation data set, the ATAI group included 52 consecutive major trauma patients with aortic injury admitted between January 2000 and December 2010 at the emergency departments of three independent hospitals from different regions of the country. The validation data set also included 208 consecutive major trauma patients with thoracic involvement but without aortic injury who presented to these three collaborating centers' emergency departments between January 2009 and December 2010.

Penetrating trauma was an exclusion criterion in the study.

Figure 1 depicts a flow diagram describing the design of the study and the flow of patients. There was not a specific matching process for control patient selection apart of the aforementioned criteria.

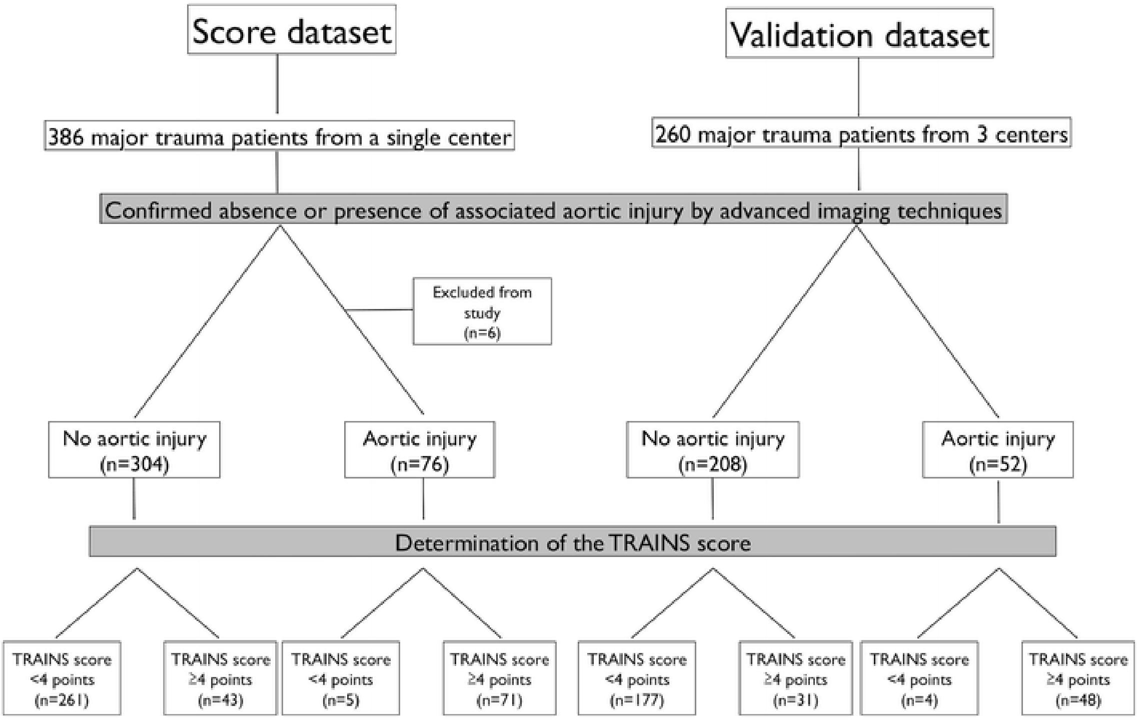


Fig. 1. Study design for recruitment of both the score and validation data sets. Exclusion criteria were penetrating trauma, deficient documentation, and/or in extremis status on arrival. *TRAINS* traumatic aortic injury score

Acute traumatic aortic injury diagnosis was based on imaging CT scan, angiography, and/or transesophageal echocardiogram (TEE).

All participating centers used the same CT scan acquisition protocols for trauma patients requiring advanced imaging from January 2000.

All institutions received institutional review board (IRB) approval to participate in the study; each IRB waived the requirement for written patient consent.

Variables collected

Data on 96 variables were recorded on a standardized form that included information on patient demographics, mechanism of injury, clinical status on hospital admission (blood pressure, respiratory rate, need of endotracheal intubation at the site of the trauma or during transport, Glasgow coma scale (GCS)), injury severity score (ISS) [*9*], abbreviated injury score (AIS) for each body area (head, chest, abdomen, extremities), revised trauma score (RTS) [*11*], trauma injury severity score (TRISS) [*12*], associated injuries, findings in simple CXR taken on admission and other performed diagnostic imaging tests (CT scan, angiography, TEE).

When present, aortic injury was classified according to its severity, i.e., type I (intimal tear), type II (intramural hematoma), type III (pseudoaneurysm), or type IV (rupture) [*13*], and the site of injury was also recorded.

Mechanism of injury was classified as motor vehicle crash (MVC), motorcycle collision (MCC), auto versus pedestrian (AVP), fall, crush under weight, and others.

For the purpose of the study, the definitions of other analyzed variables, i.e., widened mediastinum [*14–17*], hemothorax [*18*], lung contusion [*19*], pelvic fracture-deformity [*20*], long bong fracture, left scapula fracture [*21*], hypotension, abnormal respiratory rate, and head injury, are included as Online Resource 1.

Statistical analysis

Data are expressed as mean and standard deviation or median and range, when appropriate. For bivariate analysis, proportions were compared with contingency tables by means of chi-square or Fisher exact tests and the Student’s t test or Mann–Whitney rank-sum test was used to compare continuous variables.

The relation between the severity of the trauma, defined by the TRISS, RTS, and ISS values, and the different degrees of aortic injury was tested using one-way analysis of variance (ANOVA). One-way ANOVA was also used to determine whether there was association between the TRAINS value and the degree of severity of the ATAIs.

A bivariate analysis was used to identify variables potentially influencing the probability of presenting with an ATAI among major trauma patients. A stepwise forward logistic regression was used to confirm or reject these clinically relevant variables as predictors of aortic injury. Odds ratio (OR), 95 % CI, and p values were derived. A p value of less than 0.05 was considered significant.

Subsequently, a prediction score to determine the probability of aortic injury from clinical and CXR data was developed. Predictive variables confirmed by logistic regression were assigned a score according to their corresponding beta coefficient (provided by logistic regression), which was rounded to the closest integer value (1–4).

The receiver operating characteristic (ROC) curve and the Hosmer–Lemeshow goodness-of-fit statistic were calculated to assess the performance and calibration of the model. The DeLong method [*22*] was employed to compare areas under ROC curves.

The Youden index was used to measure the effectiveness of the test to select an optimal threshold value (cutoff point) for the test [*23*].

We performed both an internal and external-multicenter validation of the score. Internal validation of the aortic injury predictive score was accomplished using the bootstrap technique.

The study adheres to the standards for reporting of diagnostic accuracy (STARD) initiative [*24*].

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

A more extensive description of the statistical methods is included as Online Resource 2.

Results

Clinical and radiological data were available for all the patients in the score data set (Table 1).

Table 1. Epidemiological, clinical, and diagnostic characteristics of patients in the score data set

Variable	ATAI group	NATAI group	*p* value
Sex (male)	82.9 %	85.2 %	0.61
Age	41.33 ± 18.14	43.62 ± 18.30	0.32
Age ≥55 (years)	26.3 %	29.3 %	0.61
Mechanism of injury			
MVC	61.8 %	39.2 %	0.002
MCC	14.5 %	14.8 %	
Fall	10.5 %	26 %	
AVP	6.6 %	11.5 %	
Crush under weight	5.3 %	7.2 %	
Others	1.3 %	1.3 %	
Diagnostic tests on admission			
CT scan	68.4 %	91.7 %	<0.001
Angiography	42.1 %	12.2 %	<0.001
TEE	63.1 %	26.9 %	<0.001
ISS	40.45 ± 14.32	29.95 ± 11.03	<0.001
RTS	5.98 ± 1.71	6.97 ± 1.34	<0.001
TRISS	38.06 ± 36.44	18.54 ± 24.91	<0.001
Type of aortic injury			
Type I (intimal tear)	25 %	NA	NA
Type II (intramural hematoma)	22.4 %		
Type III (pseudoaneurysm)	22.4 %		
Type IV (rupture)	30.2 %		
Location of aortic injury			
Aortic isthmus	64.5 %	NA	NA
Mid-distal descending aorta	19.7 %		
Aortic arch	11.9 %		
Ascending aorta	3.9 %		

The *p* value of proportions analysis was obtained with the χ^2 test, whereas *p* value mean analysis corresponds to Student's *t* test
ATAI acute traumatic aortic injury, *NATAI* no associated acute traumatic aortic injury, *MVC* motor vehicle crash, *MCC* motorcycle collision, *AVP* auto versus pedestrian, *CT* computed tomography, *TEE* trans-esophageal echocardiography, *ISS* injury severity score, *AIS* abbreviated injury score, *RTS* revised trauma score, *TRISS* trauma injury severity score, *NA* not applicable

Bivariate analysis suggested 18 variables potentially influencing the probability of presenting with an aortic injury in major trauma patients (Table 2). Eleven other analyzed variables were not statistically significant in bivariate analysis (Table 2).

Table 2. Results of the univariate analysis for the patients in the score data set

Variable	ATAI group (%)	NATAI group (%)	*p* value
First rib fracture	17.1	8.2	0.021
Left ribs fracture	69.7	47	<0.001
Right ribs fracture	31.6	43.4	0.061
Sternal fracture	9.2	5.9	0.301
Left clavicle fracture	11.8	8.6	0.375
Right clavicle fracture	2.6	4.9	0.385
Left scapula fracture	28.9	7.9	<0.001
Right scapula fracture	2.6	5.6	0.290
Pelvic fracture	51.3	15.5	<0.001
Long bone fracture	21.1	4.6	<0.001
Head injury	21.1	18.7	0.61
Spine fracture	24.3	23.7	0.905
Lung contusion	93.4	59.9	<0.001
Diaphragmatic rupture	9.2	2.3	0.004
Cardiac injury	23.7	5.6	<0.001
Liver injury	27.6	16.4	0.025
Spleen injury	21.1	14.5	0.159
Bowel injury	10.5	5.3	0.092
Kidney injury	18.4	7.9	0.006
Bladder injury	3.9	0.7	0.024
Hemoperitoneum	43.4	17.8	<0.001
Pneumoperitoneum	1.3	3.3	0.359
Hemothorax	77.6	44.7	<0.001
Pneumothorax	38.2	39.5	0.834
Widened mediastinum	78.9	24	<0.001
Hypotension	76.3	19.1	<0.001
Altered respiratory rate	59.2	30.6	<0.001
Need of ETI	65.8	32.2	<0.001
GCS <9	34.2	21.7	0.023

ATAI acute traumatic aortic injury, *NATAI* no associated acute traumatic aortic injury, *ETI* endotracheal intubation, *GCS* Glasgow coma score

Of the 18 potentially influencing variables suggested by the bivariate analysis, the stepwise forward logistic regression only confirmed seven variables as risk factors for the presence of associated traumatic aortic injury in major trauma patients (Table 3). These variables were assigned a score between 1 and 4 points according to their corresponding beta coefficient provided by logistic regression, which was rounded to the closest integer value (1–4), as shown in Table 3. Thus, the obtained score could rank from 0 to 12 points.

Table 3. Results of the binary stepwise forward logistic regression and the corresponding score assigned to each significant variable according to its OR

Variable	Beta coefficient	OR	95 % CI for OR	*p* value	Score points
Widened mediastinum	3.42	30.82	12.05–78.81	<0.001	4
Hypotension	1.76	5.85	2.26–15.15	<0.001	2
Long bone fracture	2.15	8.60	2.15–34.31	0.002	2
Lung contusion	1.41	4.12	1.11–15.20	0.033	1
Left scapula fracture	1.34	3.81	1.24–11.69	0.019	1
Hemothorax	1.24	3.47	1.19–10.09	0.023	1
Pelvic fracture-deformity	1.08	2.96	1.15–7.60	0.024	1

OR odds ratio, *CI* confidence interval

The ROC curve had an area under the curve of 0.96 (0.94–0.98) (Fig. 2). There was no statistically significant difference by the DeLong method between this ROC curve and the ROC curve obtained using the non-rounded original beta coefficients, which had an area under the curve of 0.97 (0.95–0.98) ($p < 0.001$) (Fig. 2).

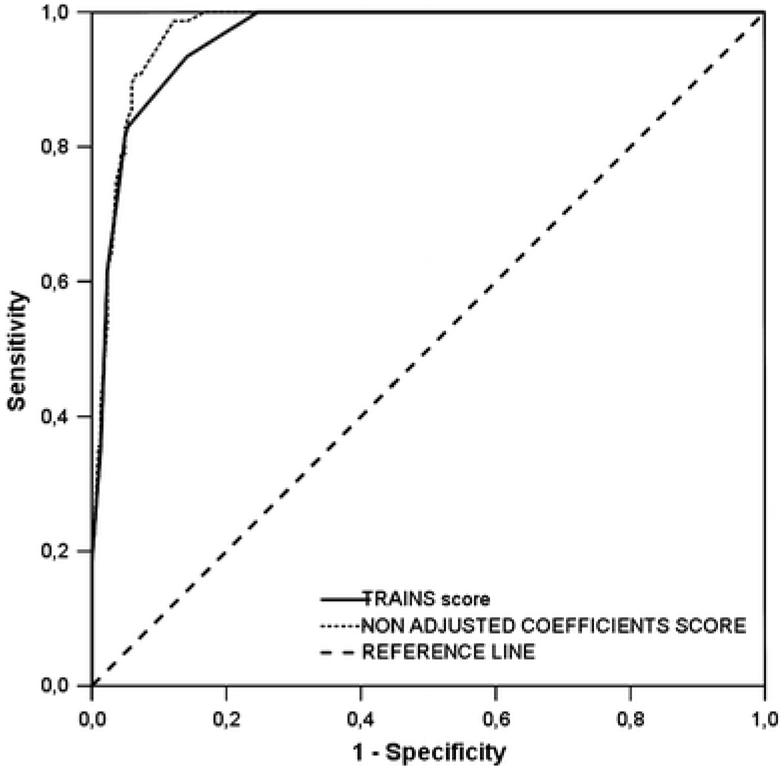


Fig. 2. ROC curve in the score data set had an area under the curve of 0.96 (0.94–0.98). There was no statistically significant difference by the DeLong method between this ROC curve and the ROC curve obtained using the non-rounded original beta coefficients, which had an area under the curve of 0.97 (0.95–0.98) ($p < 0.001$)

The Hosmer–Lemeshow goodness-of-fit statistic across groups of risk was not statistically significant ($p = 0.07$, Online Resource 3), indicating little departure from a perfect fit.

A score of at least 4 points was calculated as the threshold value which maximized sensitivity and specificity. It provided a sensitivity of 93.42 % (87.19–99.65) and a specificity of 85.85 % (81.77–89.94). The Youden’s index for a score of at least 4 was 0.79 (0.72–0.86), whereas the positive likelihood ratio was 6.60 (4.98–8.77) and negative likelihood ratio was 0.08 (0.03–0.18).

Other tested cutoff values were a score of at least 3 points, which provided a sensitivity of 97.2 % (95.2–100) and a specificity of 53 % (47.34–58.65), and a score of at least 5 points, which had a sensitivity of 74.68 % (64.46–84.9) and a specificity of 94.74 % (92.06–97.41).

One-way ANOVA revealed that there was no relation between the severity of the trauma defined by either TRISS ($p = 0.77$), ISS ($p = 0.59$), or RTS ($p = 0.73$) values and severity of aortic injury (types I to IV). Nonetheless, the ANOVA test demonstrated that there was a significant relation between TRAINS value and severity of aortic injury ($p = 0.005$). Additional data are given as Online Resource 4.

Data for the patients of the validation data set are shown in Table 4.

Table 4. Epidemiological, clinical, and diagnostic characteristics of patients in the validation data set

Variable	ATAI group	NATAI group	*p* value
Sex (male)	78.8 %	73.1 %	0.395
Age	37.4 ± 18.1	47.5 ± 19.4	<0.001
Age ≥ 55 (years)	15.4 %	37 %	0.003
Mechanism of injury			
MVC	50 %	36.5 %	0.013
MCC	23.1 %	13 %	
Fall	11.5 %	33.7 %	
AVP	5.8 %	7.2 %	
Crush under weight	5.8 %	7.7 %	
Others	3.8 %	1.9 %	
Diagnostic tests on admission			
CT scan	94.4 %	93.7 %	0.9
Angiography	30.7 %	6.7 %	<0.001
TEE	57.7 %	16.3 %	<0.001
ISS	38.7 ± 18.29	31.8 ± 14.5	0.004
RTS	6.2 ± 1.8	7 ± 1.3	<0.001
TRISS	31.5 ± 34.6	21.4 ± 29.2	0.055
Type of aortic injury			
Type I (intimal tear)	15.4 %	NA	NA
Type II (intramural hematoma)	15.4 %		
Type III (pseudoaneurysm)	28.8 %		
Type IV (rupture)	40.4 %		
Location of aortic injury			
Aortic isthmus	55.8 %	NA	NA
Mid-distal descending aorta	23.1 %		
Aortic arch	19.2 %		
Ascending aorta	1.9 %		

The p value of proportions analysis was obtained with the χ^2 test, whereas p value mean analysis corresponds to Student's t test
ATAI acute traumatic aortic injury, *NATAI* no associated acute traumatic aortic injury, *MVC* motor vehicle crash, *MCC* motorcycle collision, *AVP* auto versus pedestrian, *CT* computed tomography, *TEE* trans-esophageal echocardiography, *ISS* injury severity score, *AIS* abbreviated injury score, *RTS* revised trauma score, *TRISS* trauma injury severity score, *NA* not applicable

In the validation data set, the score provided a sensitivity of 92.31 % (86.1–100) and a specificity of 85.1 % (80.02–90.18). The Youden's index for a score of at least 4 was 0.77 (0.69–0.86), whereas the positive likelihood ratio was 6.19 (4.43–8.65) and negative likelihood ratio was 0.09 (0.04–0.23).

The one-way ANOVA also confirmed that there was a significant relation between TRAINS value and severity of aortic injury ($p = 0.002$) in the validation data set.

Discussion

This research presents for the first time in the literature a predictive scoring method for ATAIs in major trauma patients with associated blunt chest trauma. The method, which was externally validated in a multicenter study, is based on simple variables easy to obtain in the emergency room and has remarkable proven sensitivity and specificity.

The score and the associated algorithm were designed to rapidly identify major trauma patients at high risk of suffering an ATAI and to provide a framework to optimize resources use and to initiate the prompt medical management to prevent potentially lethal aortic-related complications.

In daily practice, CXR on admission is used to provide data to guide suspicion of ATAIs in major trauma patients. A widened mediastinum [*17*] and variations such as a left mediastinal width of 6 cm or more and a mediastinal width ratio of at least 0.60 [*25*] and other CXR findings [*26*, *27*] are frequently associated with the diagnosis of an ATAI and used in the decision to proceed to more advanced imaging tests. Nonetheless, although combining the most sensitive radiographic signs may improve sensitivity up to 90 % in certain series, there is a simultaneous decrease in specificity (even <50 %) which fails to provide a sufficient negative predictive value [*17*]. In addition, it has been reported in the literature that up to 30 % of patients with ATAIs may not present mediastinal abnormalities [*27*]. The vast majority of major trauma patients (97.9 % of the patients in our study) had a CXR taken in the supine position using portable imaging equipment. Thus, in a significant number of cases, the interpretation of CXR findings in major trauma patients may be difficult because of the poorer technical quality of supine radiographs taken using portable equipment [*15*, *17*].

We developed a highly predictive but easy scoring method based on clinical and CXR data with a sensitivity of 93.42 % (87.19–99.65) and a specificity of 85.85 % (81.77–89.94) in our center's population (score data set) and with a sensitivity of 92.31 % (86.1–100) and a specificity of 85.1 % (80.02–90.18) after an independent external multicenter validation process (validation data set). The process of external validation is of paramount importance to check the validity of the model across other geographic areas [*28*].

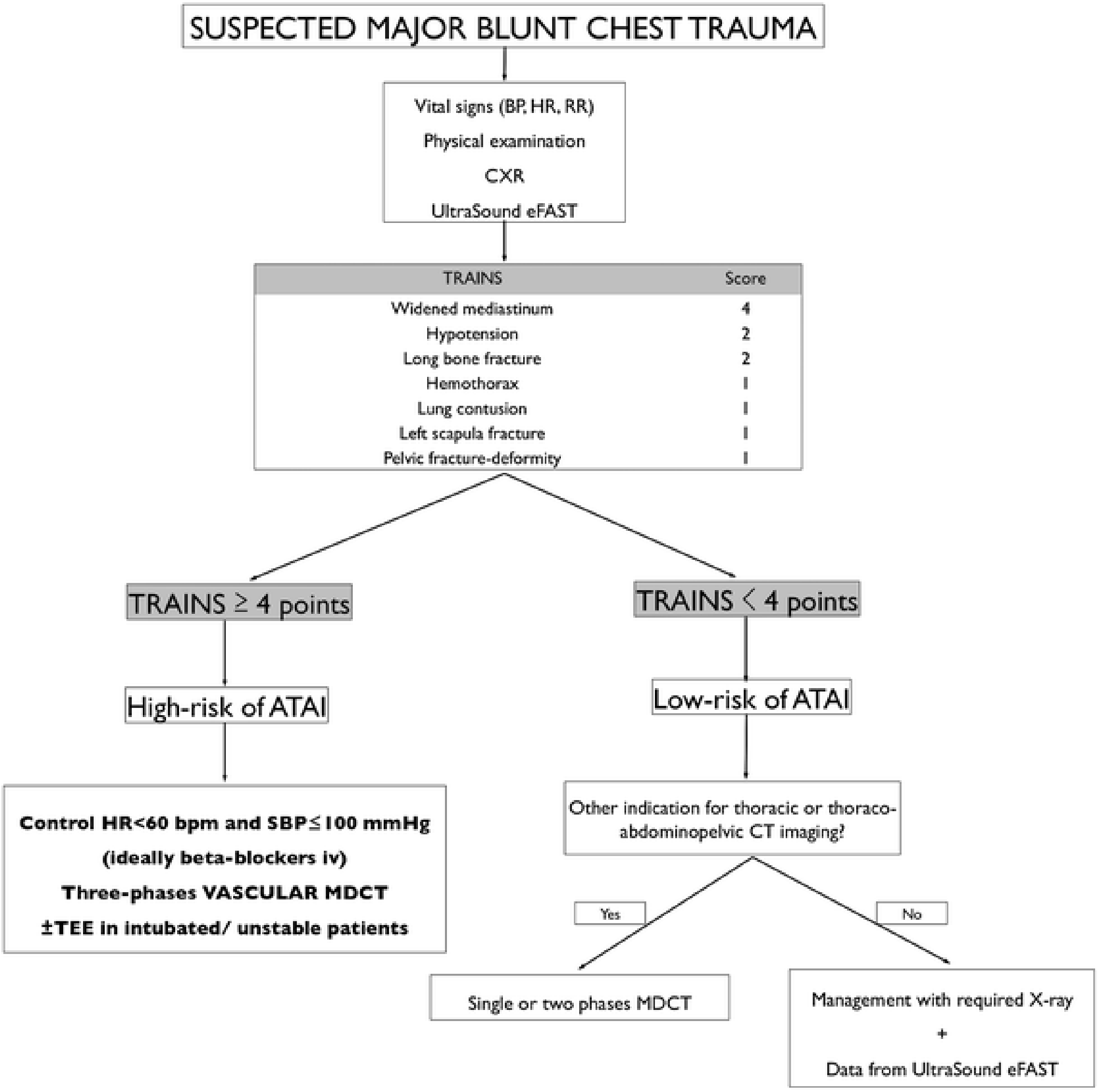
In order to allow the prompt identification of major trauma patients at risk of suffering a potentially lethal aortic injury, we currently recommend in all patients with a TRAINS of at least 4 to initiate an optimal medical control [*3*, *4*] and we advocate for performing a specific aortic MDCT protocol combined with a TEE, especially in unstable and/or intubated patients [*7*]. The speed and portability of TEE, combined with its ability to obtain high-resolution images of the aorta make this technique an attractive diagnostic modality, especially in an unstable patient in whom it can be performed without interrupting ongoing measures to stabilize the patient [*29*, *30*].

In addition, patients with a score of at least 4 (high risk of ATAI) should undergo a three-phase vascular MDCT including an unenhanced phase, an arterial contrast-enhanced phase from the thoracic inlet to the symphysis pubis, and a delayed phase. Whenever the score is at least 4, it is mandatory to generate oblique reconstructions, resembling the images obtained in conventional angiography, as well as sagittal, coronal, and MPR [*31*]. In such cases, we recommend to perform an MDCT using 100 mL of intravenous iodinated contrast medium at 4 mL/s to maximize arterial enhancement, acquisition of axial images at 0.625 mm collimation, and reviewing images at a section thickness of 5 mm.

In contrast, patients with a score of less than 4 (low risk of ATAI) are managed with simple CXRs, data from extended focused assessment with sonography for trauma (eFAST) [*32*], and, when indicated because of a suspected non-aortic thoracic injury, a thoracic or thoraco-abdominopelvic less aggressive protocol of two phases MDCT. In that protocol, axial images are acquired at 1.25 mm collimation during the portal venous phase, after injection of 80 mL of iodinated contrast medium at 2 mL/s. This approach minimizes the contrast and radiation exposure of the patient compared to a three-phase vascular MDCT.

The use of a standard trauma (nonspecific arterial) MDCT scan protocol without MPR allows many high-degree ATAIs to be diagnosed, but up to 10 % of less severe aortic injuries [*33*] can be missed. Although low-degree aortic injuries usually do not pose a life-threatening risk at the moment of trauma admission, their long-term natural history is not well known and may lead to potential adverse consequences [*13*, *33*, *34*].

Our current algorithm for managing major trauma patients with associated blunt chest trauma is depicted in Fig. 3.



TRAINS	Score
Widened mediastinum	4
Hypotension	2
Long bone fracture	2
Hemothorax	1
Lung contusion	1
Left scapula fracture	1
Pelvic fracture-deformity	1

Fig. 3. Proposed algorithm for managing major trauma patients with associated blunt chest trauma according also to the international recommendations for advance imaging test [*2*, *8*] and medical therapy [*3*, *4*] in patients at high risk of ATAI. *BP* blood pressure, *HR* heart rhythm, *RR* respiratory rate, *CXR* chest X-ray, *eFAST* extended focused assessment with sonography for trauma, *MDCT* multidetector computed tomography

Other alternative cutoff values such as a score of at least 5 points were rejected because, despite providing a higher specificity (94.74 %), the decrease of sensitivity (74.68 %) would probably lead to missed diagnosis of a significant number of traumatic aortic injuries, which is not affordable from a clinical point of view. Conversely, a cutoff value of at least 3 points with a higher sensitivity (97.2 %) had an unacceptably low specificity (53 %), which would involve an overutilization of advanced thoracic imaging tests in an important number of patients without aortic injury (false positives). Thus, a score with a low specificity might entail an unnecessary increase in hospital resources and financial costs and, moreover, an unnecessary deleterious exposure to nephrotoxic contrast and radiation.

As other authors have found [*33*], the conventional trauma risk scores (ISS, RTS, and TRISS) failed to show a statistical relationship between the severity of the trauma and the degree of severity of the aortic injury. Thus, the conventional trauma severity scores are useless in raising diagnostic suspicion of ATAI. In contrast, the TRAINS value was proven to be related to the severity of the aortic injury in both data sets. In fact, the greater the TRAINS value was, the more severe the aortic injury was.

Apart from the previously mentioned CXR findings suggestive of ATAI, clinically relevant correlations between non-mediastinal injuries and ATAI have been reported [*16*, *35*–*37*].

Blackmore et al. [*38*] published a traumatic aortic injury prediction rule based on a single-center retrospective case–control study. Although innovative, the number of cases was very low. Besides, that study lacked an external validation in other populations to ensure generalizability. In fact, a more recent re-evaluation of those clinical predictors by Kirkham and Blackmore [*39*] showed that only four factors were actually predictive [*39*].

To the best of our knowledge, TRAINS is the first predictive score of ATAI in major trauma patients externally validated in a multicenter study.

Limitations

There are limitations with our model that need to be considered, including the limitations inherent in any retrospective study. The score data set was obtained from a long time period during which substantial diagnostic and therapeutic advances were incorporated. The applicability of the score is limited to major trauma patients (ISS > 15) with associated chest trauma. The rounding of the variable "widened mediastinum" to 4 points might jeopardize the score from a pure statistical point of view, but this modification improves the applicability of the score in the everyday clinical practice.

The simplicity of the scoring method, the fact that it does not depend on the result of complex diagnostic tests, and its validation in a contemporaneous multicenter population overcome these shortcomings. An extended comment of the limitations of the study is given as Online Resource 5.

Conclusions

We have developed a multivariate prediction model for traumatic aortic injury after major trauma with associated blunt chest trauma. TRAINS may be used in daily practice to easily and rapidly identify major trauma patients with associated blunt chest trauma at risk of aortic injury, thus avoiding unnecessary cost and radiation exposure in low-risk trauma patients. This tool may also be useful for planning of resource allocation, enabling clinicians to refer patients at high risk of traumatic aortic injuries to specialized units and providing the chance of a prompt specific diagnostic and therapeutic management of this critical subset of trauma patients to avoid potentially lethal aortic-related complications. TRAINS is able to raise suspicion of ATAI even in trauma cases with low-degree aortic injuries, thus recommending the performance of a specific arterial MDCT scan with MPR and avoiding the misdiagnosis of aortic injuries.

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