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Vancouver simplified grading system with computed tomographic angiography for blunt aortic injury

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Objective: Delineation of blunt aortic injury by computed tomographic angiography guides management of this potentially fatal injury. Two existing grading systems are problematic to apply and not linked to outcomes. A simplified computed tomographic angiography–based grading system, linked to clinical outcomes, was developed, and feasibility and reliability were evaluated.

Methods: Retrospective review was performed of all blunt aortic injury cases presenting to a single provincial quaternary referral center designated for blunt aortic injury management between 2001 and 2009. Management, associated injuries, hospital survival, and cause of death were determined. Initial computed tomographic angiography was reviewed, and injuries were graded according to the new Vancouver simplified grading system by 2 study authors. Three additional trauma radiologists then graded the aortic injuries with the 2 existing systems and the simplified system. Interrater reliability was determined.

Results: Forty-eight patients were identified. Two had minimal aortic injury (grade I), 7 had an intimal flap larger than 1 cm (grade II), 32 had traumatic pseudoaneurysm (grade III), 6 had active contrast extravasation (grade IV), and 1 could not be rated. Survivals were 100%, 90%, and 33% for grades I and II, III, and IV, respectively. Of grade III injuries, 14% were medically managed, 68% repaired endovascularly, and 18% repaired with open surgery. Interrater correlation was best with the simplified score, with only 0.5% of cases unable to be classified.

Conclusions: The Vancouver simplified blunt aortic injury grading system is easy to use and correlates with clinical outcomes. Prospective external validation is required. (J Thorac Cardiovasc Surg 2012;144:347-54)

Supplemental material is available online.

Blunt aortic injury (BAI) occurs in high-velocity trauma and is a life-threatening injury, with reported in-hospital mortalities reaching 31%.[1] Different approaches have traditionally been advocated to diagnose and treat BAI, all aiming to avoid potential rupture and exsanguination. Diagnostic tools include chest radiography, transesophageal echocardiography, chest computed tomographic (CT) angiography, endovascular ultrasonography, and digital subtraction angiography.

The technical advances of multidetector CT scanners have allowed a much better description of traumatic aortic injury. CT angiography has now replaced digital subtraction angiography as the modality of choice to exclude traumatic aortic injury, with better insight into concomitant injuries related to the mediastinum and beyond.[2,3] Open aortic repair by thoracotomy, either immediate or delayed, is the traditional management of BAI in patents selected for repair and can be performed with excellent outcomes.[2,4] Urgent open repair may be associated with high morbidity and mortality, particularly in severely injured patients.[5] Delayed repair carries an additional low but real risk of rupture in the preoperative period.[6] Recently, endovascular aortic repair (EVAR) through placement of an endovascular covered self-expanding stent–graft has provided a rapid and apparently safe alternative that avoids complications of an unrepaired aorta in patients unsuitable for open repair, because more than 70% of injuries involve the aortic isthmus and the descending thoracic aorta.[7] EVAR has replaced open surgery in patients with favorable anatomy in many centers.[5,8]

A classification of severity of BAI was described in 1958 by Parmley and colleagues.[7] This anatomic classification was based on the layers of the aortic wall disrupted by injury. Intimal lesions included intimal hemorrhage and intimal laceration and hemorrhage. Medial lesions were described as traumatic medial laceration. Lesions to the tunica adventitia included traumatic false aneurysm formation, complete aortic laceration, and periaortic hemorrhage.

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Abbreviations and Acronyms

BAI = blunt aortic injury
CT = computed tomography
EVAR = endovascular aortic repair

Despite potentially including all aspects of the spectrum of injury, the diagnostic modalities to identify the type of lesions were limited, with many of the findings described only at autopsy. Because BAI was identified only at surgery or autopsy, Parmley and colleagues[7] could not identify predictors of poor prognosis in their series.

More recently, Gavant and associates[9] and Simeone and colleagues[10] have reported classification systems for traumatic aortic injuries (Table 1). Unlike Parmley and colleagues' classification system,[7] the 2 newer classifications systems were based on multidetector CT imaging. Gavant and associates[9] described 4 grades and 7 subcategories of BAI, ranging from normal (grades Ia and Ib) to complete aortic disruption (grade IV). Simeone and colleagues' classification system[10] focused on isthmic aortic injuries. Their 4 categories described the extent of the disease, from intimal injury to active contrast extravasation. Neither of the 2 clinical classification systems available have been linked to outcomes, however, and most management strategies have been based on local experience and extrapolations from aortic dissection. Intimal lesions too small to be identified with earlier imaging techniques are now described as minimal aortic injury. The management of these lesions is currently being debated.[11] Although patients with expectantly managed lesions may have progression to aortic rupture and exsanguination, aggressive management in other cases may lead to surgical complications or implantation of intravascular devices of unknown longevity. For most patients with concomitant injuries, managing minimal aortic injury expectantly while other major life-threatening injuries are dealt with is common and appears safe.[12,13] Medical management of nontraumatic aortic dissection not involving the ascending aorta has been recognized as the standard of care and leads to good short-term and midterm outcomes.

In this context, a reassessment of the prognostic significance of the severity of BAI as imaged by high-resolution CT angiography is timely, particularly with regard to survival, complications, and associated injuries. The objective of this study was to characterize all retrospectively BAI diagnosed by multidetector CT angiographic scanning in patients being treated at a single center to create a new, simplified classification of BAI. The new classification was then compared with the 2 existing clinical classification systems. The clinical outcomes and comorbidities of patients with BAI are also described here.

MATERIALS AND METHODS

All patients presenting to the Vancouver General Hospital from 2001 through 2009 for management of traumatic aortic injury were identified by searching the provincial trauma registry and reports from the hospital radiology information system. All patients who received the diagnosis of traumatic aortic injury, diagnosed by any modality or identified post mortem, were included in the provincial trauma registry. The presenting contrast-enhanced multidetector CT scan images were imported from local digital archive storage. Information was collected on patient demographic characteristics, mechanism of injury, associated injuries, injury severity score (ISS), management, and outcomes. Clinical factors influencing our treatment approach to BAI were anatomic, associated injuries, and availability of technology. For patients with intimal injuries without adventitial deformity, medical treatment was offered. Tight blood pressure control and close CT scan follow-up were done in all cases. Endovascular treatment was offered to patients in stable condition with pseudoaneurysms with proximal and distal landing zones larger than 2 cm and absence of active contrast leakage. Finally, patients in unstable condition, patients with contraindications to EVAR, and patients with active contrast leakage on CT underwent immediate open repair.

Surgical Technique

Open surgery consisted of a posterolateral thoracotomy, exposure of the aorta, administration of heparin (unless contraindicated), and cannulation of the left atrial appendage or left inferior pulmonary vein and of the femoral artery or distal thoracic aorta. Left heart bypass was achieved with a coated circuit and a Bio-Medicus (Medtronic, Inc, Minneapolis, Minn) pump with flows of 2.5 to 3.5 L/min. The aorta was clamped proximal and distal to the injured zone. The area of aortic injury was resected and replaced by a tubular woven Dacron polyester fabric graft.

Endovascular repair was performed with the Talent thoracic stent–graft (Medtronic) in 2001 through 2009, the Zenith stent–graft (Cook Medical Inc, Bloomington, Ind) in 2005 through 2009, or the Relay stent–graft (Bolton Medical Inc, Sunrise, Fla) since 2009. Exposure of the common femoral artery was performed. Heparin was administered at a dose of 5000 units. The prosthesis was inserted and deployed under fluoroscopic guidance. Control angiography was performed to rule out endoleak, and subsequent balloon dilatation was added if necessary.

Follow-up included CT scan at 48 to 72 hours in patients with EVAR and medical treatment. If endoleak or persistent minimal injury was present, CT was controlled at 1 week and discharge. Patients undergoing EVAR were followed up in the long term with yearly contrast CT scans.

Outcomes of interest were treatment method, length of stay, and correlation of radiologists with respect to grade of injury.

Imaging Technology

During the 8-year study period, a variety of CT scanners were used, including the following: Somatom Cardiac Sensation Dual-Source CT scanner (64-slice; Siemens AG, Medical Solutions, Forchheim, Germany), Definition Dual-Source CT scanner (64-slice; (Siemens AG, Medical Solutions), HiSpeed CT/i scanner (1-slice; GE Healthcare, Milwaukee, Wis), LightSpeed Plus CT scanner (4-slice; GE Healthcare), and LightSpeed Ultra CT scanner (8-slice; GE Healthcare). All patients were scanned with 120 mL Optiray 320 intravenous contrast (ioversol 320; Mallinckrodt Inc, Hazelwood, Mo) injected at 4 mL/s with a 40-mL saline solution chaser. Depending on the scanner used, either a bolus triggering technique (Siemens systems) or a standard 30-second delay (GE systems) was used. Collimations and reconstructed slice thicknesses used varied from 0.6 mm to 2.5 mm and 1 mm to 3 mm, respectively.

Twenty-three patients were scanned with a GE LightSpeed Ultra scanner (reconstructed slice thicknesses, 14 patients, 2.5 mm; 6 patients, 1.25 mm; and 3 patients, 1 mm), 16 patients were scanned with a Siemens Definition Dual-Source 64-slice scanner (reconstructed slice thickness, 14 patients, 1 mm; 1 patient, 2 mm; and 1 patient, 3 mm), 3 patients were

TABLE 1. The Vancouver simplified, Simeone,[10] and Gavant[9] classification systems

Grade	Vancouver simplified	Simeone[10] (isthmus only)	Gavant[9]
I	Intimal flap, thrombus, or intramural hematoma <1 cm	Intimal irregularity <1 cm with minimal periaortic hematoma	A, normal aorta, no mediastinal hematoma; B, normal aorta, mediastinal hematoma (para-aortic)
II	Intimal flap, thrombus, or intramural hematoma >1 cm	Intimal flap >1 cm with or without pseudoaneurysm	A, minimal aortic injury, small (<1 cm) pseudoaneurysm, flap, or thrombus, no mediastinal hematoma; B, minimal aortic injury, small (<1 cm) pseudoaneurysm, flap, or thrombus, mediastinal hematoma (para-aortic)
III	Pseudoaneurysm (simple or complex, no extravasation)	Circumferential or near-circumferential disruption, "shattered" isthmus	A, >1 cm easily identified regular, well-defined pseudoaneurysm with intimal flap or thrombus; no ascending aorta, arch, or great vessel involvement; mediastinal hematoma present; B, >1 cm easily identified regular, well-defined pseudoaneurysm with intimal flap or thrombus; ascending aorta, arch, or great vessel involvement present; mediastinal hematoma present
IV	Contrast extravasation (with or without pseudoaneurysm)	Active contrast extravasation, pseudocoarctation, dissection, ischemia	Total aortic disruption; easily identified, irregular, poorly defined pseudoaneurysm with intimal flap or thrombus; mediastinal hematoma present

scanned with a Siemens Somaton Cardiac Sensation 64-slice scanner (reconstructed slice thickness, 2 mm), 3 patients were scanned with a GE LightSpeed Plus scanner (reconstructed slice thickness, 2.5 mm), and 3 patients were scanned with a GE HiSpeed CT/i scanner (reconstructed slice thickness, 3 mm). Which scanner was used depended on availability at time of presentation and which models were installed at that time in the department. For the earlier scanners, the collimation depended on the scan range that needed to be covered, with the thinner collimation reserved for CT scans of the chest only and thicker collimation used for scans of the chest, abdomen, and pelvis. Most patients after 2005 were scanned with the Siemens Definition Dual-Source CT scanner, which allowed a reconstructed slice thickness of 1 mm in most cases regardless of scan range.

Imaging was reviewed with Impax software (version 4.5; Agfa Healthcare, Mortsel, Belgium). Window and level settings could be changed to preference. For size measurements, radiologists were required to identify the largest dimension in multiplanar reconstructions done with the imaging software's 3-dimensional multiplanar reconstruction tool (see Online Data Supplement 1).

To gauge image quality, the attenuation values as measured in Hounsfield units were obtained of the aortic lumen at the aortic root, at the site of BAI, and at the diaphragmatic crux. In addition, a subjective visual interpretation of scan quality was scored, defining scans as nondiagnostic, poor quality, or adequate quality. Both the Hounsfield unit measurements and the subjective value were determined by a single radiologist (F.H.B.).

Scoring System

The proposed Vancouver simplified CT-based classification of BAI was drafted after review of the literature with input from the cardiothoracic surgical, trauma, and radiology services (Table 1). The 3 available classification systems (Gavant classification, Simeone classification, and the new Vancouver simplified classification) were detailed on a data collection form (Online Data Supplement 2). The study's lead radiologists (S.N. and F.H.B.) served as a reference group; they reviewed all imaging individually and graded injuries according to all 3 classification systems. The reference radiologists were required to agree on all cases (reference read).

A self-administered tutorial was then designed to instruct radiologists on application of the 3 grading systems (Online Data Supplement 1). This tutorial was completed by 3 certified trauma radiologists (validation group, L.L., A.-M.B., J.R.I.), who then reviewed all imaging and scored the injuries with all 3 systems. All CT scans were also reviewed separately for associated thoracic injuries by a single radiologist (F.H.B.). Injuries were described according to the classification presented in Figure 1.

Statistical Analysis

Descriptive statistics are presented as mean ± SD and median with interquartile range for normal and nonnormal distributions, respectively. Statistical analyses were computed with SAS statistical software (version 9.2; SAS Institute, Inc, Cary, NC). The κ statistic was used to assess the agreement on multicategory ratings by multiple raters; the 3 validation radiologists were therefore compared on their observations for the 3 classifications.[14,15] Each radiologist from the validation group was also compared individually against the reference group with the κ statistic. The project was reviewed and accepted by the University of British Columbia and Vancouver General Hospital Research Ethics Board.

RESULTS

During the study period, 48 patients were found to have BAI on initial CT angiography. Thirty patients came directly to our level 1 trauma referral center, and 18 patients were transferred from secondary centers. The mean initial injury severity score was 41.9. The Abbreviated Injury Scale scores for head and chest were 2.1 ± 2.1 and 4.5 ± 0.5, respectively (Table 2). Median time from injury to level 1 trauma center arrival was 262 minutes (interquartile range, 41–588 minutes).

Thirty-three percent of patients were treated nonoperatively (n = 16), EVAR was used in 24 (50%) at an average of 33 hours after hospital admission, and 8 (17%) underwent open repair at an average of 16 hours after hospital admission. Table 3 details the use of each treatment modality according to the Vancouver simplified grade of injury. Overall hospital survival was 82%. The hospital survivals after open repair, EVAR, and nonoperative management were 100%, 88%, and 62%, respectively. Twenty of the 40 patients discharged alive from the hospital were confirmed alive at 1 year, and we have had no reports of late deaths or complications from referral centers regarding the 20 other patients. No cases of new-onset paraplegia or stroke were observed in the EVAR and open repair groups. There was no conversion from any given initial treatment strategy

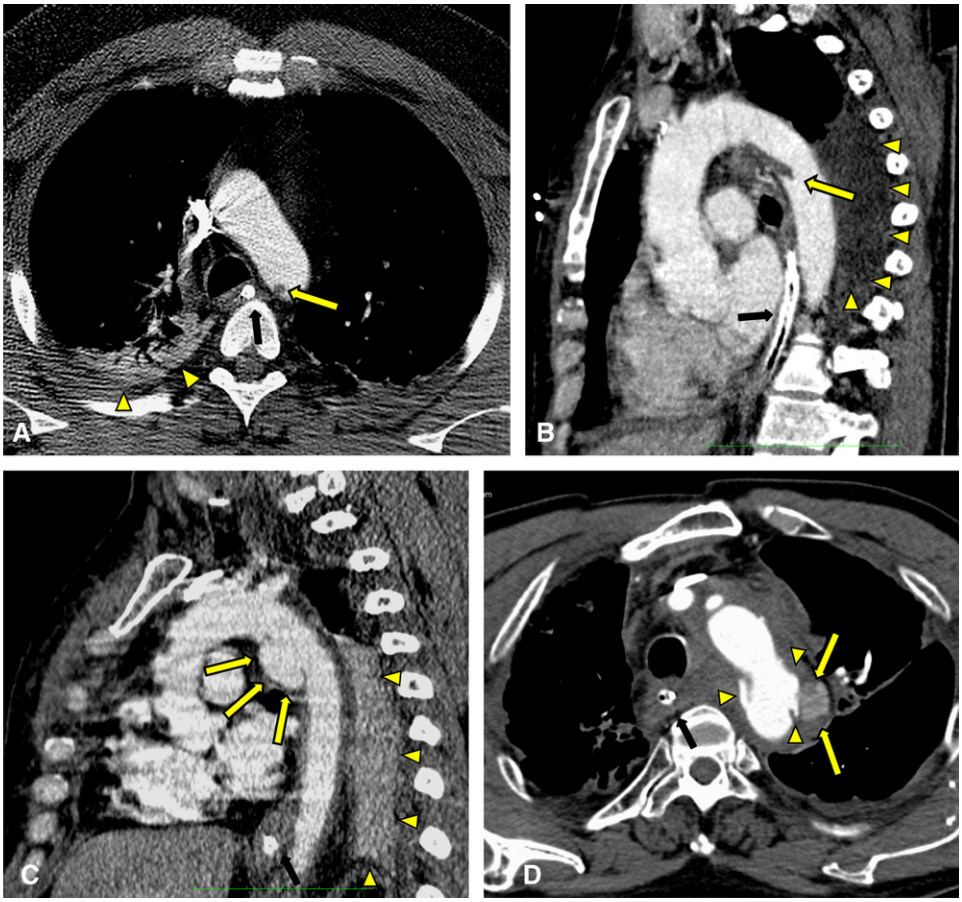

FIGURE 1. A, Vancouver simplified grade I blunt aortic injury (thrombus, intimal flap, or intramural hematoma <1 cm). A small thrombus (<1 cm) is seen in the aortic lumen just distal to the left subclavian artery branch *(yellow arrows)* in this axial slice of a postcontrast CT scan. A zone of lung consolidation is seen in the right lung *(yellow arrowheads),* and a nasogastric tube is present in the esophagus (*solid arrow* in A). B, Vancouver simplified grade II blunt aortic injury (thrombus, intimal flap or intramural hematoma >1 cm). A large thrombus (>1 cm) is seen in the aortic lumen at the site of the aortic isthmus *(yellow arrow)* in this oblique sagittal reformat of a postcontrast CT scan. Pleural effusion and hemothorax is seen *(arrowheads),* and a nasogastric tube is present in the esophagus (*solid arrow*). C, Vancouver simplified grade III blunt aortic injury (pseudoaneurysm, simple or complex, without extravasation). A large pseudoaneurysm is seen bulging from the aortic lumen at the site of the aortic isthmus *(yellow arrows)* in this oblique sagittal reformat of a postcontrast CT scan. A zone of lung consolidation is seen in the left lung *(arrowheads),* and a nasogastric tube is present in the esophagus *(solid arrows)*. D, Vancouver grade 4 blunt aortic injury (active contrast extravasation). A large irregular pseudoaneurysm is seen bulging from the aortic lumen at the site of the aortic isthmus *(yellow arrowheads)* in this axial slice of a postcontrast CT scan. Active contrast extravasation from the irregular pseudoaneurysm is seen to extend into the mediastinum *(yellow arrows),* which is obliterated by hematoma. A nasogastric tube is present in the esophagus *(solid arrow),* and the trachea and esophagus are clearly displaced.

to another in this series of patients. The cause of death was multiple organ failure in 4 patients. Two patients died of refractory intracranial hypertension, 1 of sepsis, 1 of refractory respiratory failure, and 1 of massive hemothorax, with the last being a patient with advanced directives of no resuscitation with grade 4 injury.

Extent of Injury According to Vancouver Simplified Grading System

All patients with grade I and II injury (no pseudoaneurysms or contrast extravasation) were discharged alive. Patients with grade III injuries (pseudoaneurysm) had 90% hospital survival. Patients with grade IV injuries (extravasation of contrast medium with or without pseudoaneurysm) had 33% survival.

Treatment strategy used for patients with grade I injuries (n = 2) was nonoperative in all cases. All patients with a grade II injury (intimal flap or thrombus ≥1 cm but no pseudoaneurysm, n = 7) except for 1 were treated medically. The patient with grade II injuries treated with open repair had bilateral hemothoraces and an intimal flap of 15 mm in the mid descending thoracic aorta. Patients with pseudoaneurysms were treated most commonly with EVAR (68%), with 5% mortality. Patients with pseudoaneurysms treated medically had 50% mortality, and all patients treated with open repair (18%, n = 6) survived to discharge.

TABLE 2. Baseline characteristics (n = 48)

Age (y, mean ± SD)	45.2 ± 20.4
Sex (% male)	75%
Severity of injury (mean ± SD)	
ISS	41.9 ± 13.0
AIS score, chest	4.5 ± 0.5
AIS score, head	2.1 ± 2.1
Time from injury to level 1 hospital (min, median and IQR)	262 (41–588)

ISS, Injury severity score; *AIS,* Abbreviated Injury Scale; *IQR,* interquartile range. Adapted from: Rating the severity of tissue damage. I. The abbreviated scale. *JAMA*. 1971;215:277-80.

Patients with active contrast extravasation (grade IV, n = 6) had a 66% mortality and had the highest mean injury severity score (49.8). Fifty percent of these patients underwent no repair procedure and died of their injuries (2 in the first hours after presentation and 1 at day 5). Fifty percent of the patients treated with EVAR (1/2) survived, as did the only patient with grade IV injury treated with open repair (1/1). One patient could not be classified in any of the classification systems, including the Vancouver simplified grading system, by the reference read.

All patients who received medical management for minimal aortic injury survived, and none required secondary procedures. All injuries had healed at the 1 year follow-up CT scan. In patients for whom the trauma team deemed the severity of the trauma and of the injuries not survivable, no aortic intervention was done regardless of the aortic injury grade, and mortality was 100%. Two patients treated with EVAR had technical complications: 1 patient had a small type I endoleak that had resolved completely at the 3-month follow up CT scan, and 1 patient had partial collapse of his stent–graft that subsequently deteriorated and led to an acute coarctation syndrome, hypoperfusion, and multiple organ failure that was ultimately fatal.

Table E1 illustrates the anatomic locations of aortic injuries. BAI most frequently occurred at the isthmus level. In all patients with grade II injuries, the isthmus was involved; 1 patient also had a concomitant descending aortic injury. Grade III and IV injuries involved the aortic isthmus in 88% and 83% of cases, respectively. The arch was involved in 33% of grade IV injuries. The ascending aorta, arch, and descending aorta were involved in 1, 2, and 1 cases, respectively, in patients with grade II injuries. The mean age was highest for patients with grade IV injuries.

Associated Injuries

The associated injuries to the thoracic and bony structures are reported in Table E2. Thoracic spine and clavicular fractures were present in a quarter of the patients. Rib fractures were found in most patients, with at least 1 fracture of the first 3 ribs in 57% and 83% of grade III and IV injuries (high grade), respectively. Sternal fracture was less frequent, being present in 40% of all cases. Pneumomediastinum was identified in 25% of cases. A pneumothorax or hemothorax was identified in most patients with any grade of aortic injury.

BAI Grading Systems Interobserver Correlation

All 5 trauma radiologists reviewed the imaging of all patients. Agreement among the 3 validating radiologists for the Vancouver simplified, Gavant, and Simeone classifications were 0.51, 0.55, and 0.44, respectively (Table 4). Agreement between each individual radiologist and the reference read was better for the Vancouver simplified classification than for either the Gavant or the Simeone grading system (κ= 0.85, κ= 0.64, κ= 0.42, respectively). One patient (2%) had an aortic injury that could not be classified according to either the Vancouver simplified or the Gavant classification by the validation radiologists. That patient could be classified as class III by the Simeone grading system by the reference radiologists; however, 2 other radiologists rated that patient as indeterminate by the Simeone classification system. Five patients (10%) had aortic injury that did not involve the aortic isthmus and therefore could not be classified according to the Simeone classification system. The indeterminate category was used by the 3 validation radiologists in 0.5%, 2.7%, and 15% of cases in the Vancouver simplified, Gavant, and Simeone classification systems, respectively.

DISCUSSION

The diagnostic and treatment approach to traumatic aortic injury has evolved significantly in the past 2 decades.

TABLE 3. Characteristics and outcomes according to Vancouver simplified classification (n = 47*)

			AIS score		Treatment			Stay (d, median and IQR)		Hospital
Grade	No.	ISS	Head	Chest	Medical	EVAR	Open	ICU	Hospital	survival (%)
I	2	46.5	4.0	4.5	100%	0	0	10 (7–13)	27 (21–34)	100%
II	7	38.0	2.0	4.0	86%	0	14%	13 (6–25)	21 (3–72)	100%
III	32	40.9	1.8	4.5	14% (50% survival)	68% (95% survival)	18% (100% survival)	11 (6–20)	15 (6–30)	90%
IV	6	49.8	2.8	4.7	50% (0% survival)	33% (50% survival)	17% (100% survival)	9 (1–21)	4 (1–21)	33%
Total	47	41.9	2.1	4.5	33%	50%	17%	9.5 (5–20.5)	14 (3–35.5)	82%

ISS, Injury severity score; *AIS,* Abbreviated Injury Scale; *EVAR,* endovascular repair; *ICU,* intensive care unit; *IQR,* interquartile range. *One patient could not be classified into a specific extent.

TABLE 4. Performance of grading systems (n = 48)

	Multirater κ (A, B, C)	Rater A vs reference	Rater B vs reference	Rater C vs reference
Vancouver simplified	0.51	0.85	0.64	0. 42
Simeone et al[10]	0.44	0.63	0.47	0. 51
Gavant et al[9]	0.55	0.39	0.54	0.45

Multi-rater κ comparing the 3 validating radiologists against each other and κ statistics comparing the 3 validating radiologists versus the reference read.

The initial approach to patients with significant chest trauma has changed from a simple chest radiography, followed or not by digital subtraction angiography, to a multidetector CT scan with contrast medium in most cases. This approach is likely to lead to an increased sensitivity to previously possible occult aortic injuries missed by the former approach. It has been suggested that 2% to 7% of patients with traumatic aortic ruptures may present with normal chest radiography.[16] The early diagnosis of aortic injury allows for early decision on the treatment plan, which may be medical, endovascular (EVAR), or surgical. The treatment approaches to traumatic aortic injuries vary widely among centers. Some groups suggest EVAR for most patients with thoracic aortic injuries,[17,18] whereas others suggest open surgical repair for some patients and EVAR for others.[19] Finally, for aortic injuries that are not severe, multiple groups suggest that aggressive medical treatment alone may be an alternative to invasive repair.[13,20-22] Despite the broad range of treatment options for traumatic aortic injury, few efforts have been devoted to the characterization of the extent of injury and therapeutic approaches in those different groups. The objectives of this study were to characterize the findings associated with thoracic aortic injury, the extent of aortic injury, and the outcomes, as well as to define a simple classification system.

The 4-category system described here as the Vancouver simplified classification system was able to discriminate patients with varying severity of aortic injury, from a minimal intimal tear to an aortic transection. The outcomes of the patients were progressively worse for patients with higher levels of aortic injuries, and all 3 treatment options were used in different clinical scenarios. The severity of injury in this series (injury severity score of 41.9) was similar to levels in other reports.[17,22] The other lesions found on chest CT scan were also reported and correlated with the extent of thoracic aortic injury. The use of a common classification system could lead to more refinement in the understanding of the physiopathology and natural history of traumatic aortic injury. In this series, the Vancouver simplified classification system could characterize 98% of the injuries; furthermore, the interrater correlation of the 3 validating radiologists was acceptable. The 3 validating radiologists also correlated more closely with the reference read than in the 2 previously known classification systems. The fact that the Simeone classification system could only characterize injuries to the aortic isthmus confused many radiologists. Two radiologists allocated an injury grade despite the absence of isthmic injury, whereas others did not use the classification for arch or descending aortic pathology. Because the treatment modalities, mainly medical and EVAR, are very similar for the aortic isthmus and the descending aorta, the classification system used should incorporate all sites of thoracic aortic injury. Similarly, the Gavant classification with its 7 categories was precise but more difficult to use. The correlations between the individual raters and the reference were poor, and more patients were classified as having indeterminate grade of injury than with the Vancouver simplified classification (3% vs 0.5%).

The new classification system proposed here was initially inspired by the pathoanatomic classification of Parmley and colleagues,[7] with the addition of the 2 existing classifications.[9,10] The publication of those 2 later classifications was not associated with patient series or outcomes. Furthermore, only a minimal description of the CT findings was available, and interpretation by the radiologist or surgeon was therefore necessary to report grades of injury according to those systems. The proposed Vancouver simplified classification system for aortic injury was initially designed with 5 categories including a category of pseudoaneurysm with extravasation of contrast medium (IV) and a category of extravasation of contrast without pseudoaneurysm (V). The classification was then simplified to 4 categories, regrouping any case of active contrast leakage as a grade IV injury. This allowed the inclusion of 1 patient with extensive aortic injury and contrast extravasation without pseudoaneurysm. All the authors were in agreement that any patient with active contrast extravasation should be in the highest risk category, regardless of the presence or absence of a pseudoaneurysm. The choice of a cutoff point at 1 cm between the grade I and grade II injuries was arbitrary. Despite some groups using 1 cm[11] and some using 2 cm[20] for the threshold to describe an aortic injury as being minimal, however, we agreed that the 1-cm threshold was closer to the limit of the imaging modality and that it would be appropriate to study those lesions further in future studies. The Stanford group also recently reported results of medical management for 29 patients with traumatic aortic injuries characterized as being minimal aortic injury.[13] Their retrospective study included patients with intimal and mural injuries as well as pseudoaneurysms. The early outcomes were excellent, with only 10% undergoing secondary invasive intervention. All 3 patients with interventions had pseudoaneurysms of various sizes at presentation. Their findings illustrate the possibility that the minimal aortic injury group may be heterogeneous and require subcategorization before recommendations regarding treatment modalities can be suggested. Mosquera and colleagues,[23] however, reported a prevalence of as much as 38% for aorta-related complications in patients with conservative treatment after BAI.

The future use of a common, simple classification system for the description of traumatic aortic injury could allow refinement of the indications for each treatment modality. Although aortic injuries have been treated for several decades, no system has been widely adopted, and the strategies used are mostly anecdotally derived or based on level III evidence. The adoption of the blunt carotid artery injury grading system described by Biffl and coworkers[24] paved the way to a better understanding of the extent of injury and of a tailored treatment approach, as well as opening discussions on treatment strategies based on extent of injury. The adoption of a similar system for BAI could help to define when to use medical treatment, EVAR, and open repair.

Limitations

This retrospective, single-center study involved only the known proportion of patients with BAI who could reach the hospital and had the injury correctly diagnosed. The decision to use CT as the initial diagnostic test and as a criterion to enter the study may have led to inappropriate exclusion of some patients who would have had the diagnosis made with different modalities; however, the patients identified in the provincial trauma registry could undergo diagnosis by any treatment modality. All patients identified for the study period underwent a CT angiogram in the course of the evaluation, which limits the probability that many patients were missed by the chosen selection strategy. The different types of CT technology from referring centers necessitated a simplification of our criteria to ensure that all types of multidetector CT could be included. The timing of presentation also varied widely, as did the treatment modalities offered to the patients, which were not standardized. One patient had an injury that could not be classified by any of the grading systems, including the Vancouver simplified grading system. That patient had multiple mid descending thoracic aortic injuries not involving the isthmus, including a circumferential intimal tear, a pseudoaneurysm, and a circumferential intramural hematoma. Although a formal grade could not be assigned in any of the classifications for that patient, all radiologists agreed it was a high-severity lesion that should not be considered a minimal injury. That patient died hours after arrival to the hospital as result of severe brain injury. Despite those limitations, the facts that data were captured prospectively in a province-wide database and that patients with this type of injury are routinely transferred to the provincial level 1 trauma center reduced the chance of missing a significant proportion of the patients with a diagnosis of traumatic aortic injury. The systematic approach to evaluation of the CT scans allowed a precise description of the population. Finally, the complete follow-up provided by the provincial data allowed better description of the natural history of the patients after aortic injury.

CONCLUSIONS

Patients with a diagnosis of BAI can be categorized into low- and high-risk groups. The use of the Vancouver simplified traumatic aortic injury grading system was reproducible among multiple trauma radiologists. It compared favorably with other existing grading systems and correlated with associated injuries and outcomes. A multicenter validation of this grading scale could provide more perspective on the outcomes with different treatment approaches in patients with traumatic aortic injury.

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TABLE E1. Site of aortic injury stratified by Vancouver simplified grade of aortic injury

Grade	Isthmus	Ascending	Arch	Descending
I	1 (50%)		1 (50%)	
II	7 (100%)	0	0	1 (14% associated)
III	28 (88%)	1 (3%)	2 (6%)	1 (3%)
IV	5 (83%)	0	2 (33%)	0

TABLE E2. Associated thoracic injuries according to Vancouver simplified grade of aortic injury

		Bone fractures					Chest		
Grade	Age (y, mean)	Clavicle	Thoracic spine	Sternum	Rib	Rib 1–3	Pneumomediastinum	Pneumothorax	Hemothorax
I	48	0	0	50%	100%	100%	50%	50%	100% (2)
II	37	43%	14%	29%	60%	40%	0	29%	57% (4/7)
III	43	22%	25%	34%	89%	57%	31%	69%	75% (24/32)
IV	64	33%	33%	83%	83%	83%	17%	66%	83% (5/6)