Natural history of minimal aortic injury following blunt thoracic aortic trauma

Biniam Kidane, MD*
Daniel Abramowitz, MD
Jeremy R. Harris, MD
Guy DeRose, MD
Thomas L. Forbes, MD

From the Division of Vascular Surgery, London Health Sciences Centre and the University of Western Ontario, London, Ont.

Presented at the Annual Meeting of the Canadian Society for Vascular Surgery, Sept. 24–25, 2010, in Vancouver, BC

*Recipient of the 2010 MacLean–Mueller Prize for resident research from the *Canadian Journal of Surgery*.

Accepted for publication
Aug. 16, 2011

Correspondence to:
T.L. Forbes
Division of Vascular Surgery
London Health Sciences Centre
800 Commissioners Rd. E, E2-119
London ON N6A 5W9
Tom.Forbes@lhsc.on.ca

DOI: 10.1503/cjs.007311

Background: Endovascular repair of blunt traumatic thoracic aortic injuries (BTAI) is common at most trauma centres, with excellent results. However, little is known regarding which injuries do not require intervention. We reviewed the natural history of untreated patients with minimal aortic injury (MAI) at our centre.

Methods: We conducted a retrospective database review to identify all patients with a BTAI between October 2008 and March 2010. The cohort comprised patients initially untreated because of the lesser degree of injury of an MAI. We reviewed initial and follow-up computed tomography (CT) scans and clinical information.

Results: We identified 69 patients with a BTAI during the study period; 10 were initially untreated and were included in this study. Degree of injury included intimal flaps (n = 7, 70%), pseudoaneurysms with minimal hematoma (n = 2, 20%) and circumferential intimal tear (n = 1, 10%). Six (60%) patients were male, and the median age was 40 years. Duration of clinical follow-up ranged from 1 month to 6 years (median 2 mo) after discharge, whereas CT radiologic follow-up ranged from 1 week to 6 years (median 6 wk). Seven (70%) patients had complete resolution or stabilization of their MAI, 1 (10%) with circumferential intimal tear showed extension of the injury at 8 weeks postinjury and underwent successful repair, and 2 (20%) were lost to follow-up.

Conclusion: There appears to be a subset of patients with BTAI who require no surgical intervention. This includes those with limited intimal flaps, which often resolve. Radiologic surveillance is mandatory to ensure MAI resolution and identify any progression that might prompt repair.

Contexte : La plupart des centres de traumatologie ont souvent recours à la réparation endovasculaire des traumatismes fermés de l'aorte thoracique (TFAT), et cette dernière donne d'excellents résultats. Toutefois, on en connaît peu sur le type de blessures qui ne requièrent pas d'intervention. Nous avons passé en revue l'histoire naturelle des patients qui ont été vus dans notre centre pour un traumatisme léger de l'aorte, mais qui n'ont pas été traités.

Méthodes : Nous avons analysé rétrospectivement une base de données pour recenser tous les patients victimes de TFAT au cours des 11 dernières années. La cohorte comprenait des patients non traités initialement en raison de la relative légèreté de leur traumatisme à l'aorte. Nous avons passé en revue les tomographies initiales et de suivi, de même que les signes cliniques.

Résultats : Nous avons relevé 69 cas de TFAT au cours de la période de l'étude; 10 n'ont pas été traités initialement et ont été inclus dans l'étude. Les degrés d'atteinte incluaient lambeaux de l'intima (n = 7, 70 %), pseudoanévrisme avec hématome minime (n = 2, 20 %) et déchirure circonférentielle de l'intima (n = 1, 10 %). Six patients (60 %) étaient de sexe masculin et l'âge médian était de 40 ans. La durée du suivi clinique a varié d'un mois à 6 ans (médiane 2 mois) après le congé, tandis que le suivi radiologique par tomographie a été d'une semaine à 6 ans (médiane 6 semaines). Sept patients (70 %) présentaient une résolution complète ou une stabilisation de leur lésion bénigne de l'aorte; la blessure du patient qui avait été victime d'une déchirure circonférentielle de l'intima (10 %) s'est aggravée 8 semaines après le traumatisme et a bien répondu à la réparation; et 2 patients (20 %) ont été perdus au suivi.

Conclusion : Une catégorie de patients victimes de TFAT ne semble pas nécessiter d'intervention chirurgicale. Cela inclut les cas de lambeaux restreints de l'intima, qui rentrent souvent dans l'ordre spontanément. La surveillance radiologique est indispensable pour vérifier que les traumatismes légers se résolvent et observer, le cas échéant, toute progression nécessitant une réparation.

Injuries to the proximal descending thoracic aorta can result in complete transection and immediate fatality following blunt trauma, most commonly in the setting of motor vehicle collisions. If the patient has an injury of lesser extent and survives to reach an appropriate treatment facility, repair can be attempted to prevent exsanguination. These patients often have multiple injuries requiring coordination to determine the optimal timing and sequence of therapy.[1]

In the last decade, a major paradigm shift has occurred in the surgical treatment of these blunt thoracic aortic injuries (BTAI). Endovascular repair has replaced open repair in many trauma centres,[2] including ours,[3,4] except in occasional cases where it is not possible because of a more proximal injury location. In appropriately selected patients, this adoption of endovascular stent grafts has resulted in a reduction in perioperative mortality, stroke and paraplegia compared with open repair.[5] However, information regarding longer-term durability of endovascular repair in these often younger patients is lacking, with reports of device-specific complications[6] and concerns of aortic dilatation.[7]

With the higher mortality and paraplegia rates with open repair and the unknown durability of endovascular repair, attention is being refocused on the nonoperative management of selected patients with lesser degrees of BTAI, or minimal aortic injury (MAI).[8–11] The purpose of the present study was to review our centre's experience with nonoperative management of BTAIs and determine the natural history of these nonoperatively managed MAIs.

Methods

We performed a retrospective review of our level 1 trauma centre's database to identify patients who had a BTAI between October 1998 and March 2010. Computed tomography (CT) scans of those who were initially treated nonoperatively were reviewed to determine the extent of BTAI as either MAI (intimal flap with minimal or no periaortic hematoma[8]) or more severe injuries (pseudoaneurysm and greater periaortic hematomas). We reviewed follow-up CT scans and clinical information to determine the natural history of these lesions and the clinical outcomes related to their nonoperative management. All CT scans were assessed by 2 reviewers (B.K. and T.L.F.), and there was 100% agreement between them.

The classification used in this study was proposed previously by other investigators: type I (intimal tear), type II (intramural hematoma), type III (pseudoaneurysm) and type IV (rupture).[12]

This study received approval from the University of Western Ontario's Research Ethics Board for Health Sciences Research Involving Human Subjects.

Results

During the 11-year study period, 69 patients presented to our centre with a BTAI (Fig. 1). Of these, 23 (33%) were managed nonoperatively. We excluded 13 of 23 from further analysis, as they died from extensive injuries before any operative management could be considered or because they had such extensive injuries (in addition to the BTAI) that their families opted for comfort measures only. These 13 patients died shortly after hospital admission from these massive injuries that were incompatible with survival. The final study cohort comprised 10 patients with a BTAI who were initially and deliberately treated nonoperatively.

These were young patients (median age 40 yr), and most were men (6 of 10, 60%). The mean injury severity score was 43.2 (standard deviation [SD] 13.4, median 44.5). On review of the initial CT scans, 7 (70%) patients had intimal flaps of varying lengths (Fig. 2), 2 (20%) had pseudoaneurysms with minimal mediastinal hemorrhage (Fig. 3), and 1 had a circumferential intimal tear. According to the grading system[12] 7 patients underwent type I repair, 1 type II, 2 type III, and none had type IV repair. All injuries were located in the proximal descending thoracic aorta just distal to the left subclavian artery. Clinical characteristics are summarized in Table 1.

Nonoperative management involved the use of antihypertensives and negative inotropes (when necessary), with the goal of reducing aortic shear forces. The degree and aggressiveness of this medical management was often influenced by the extent of other injuries, specifically closed head injury. Medical management was attempted in all

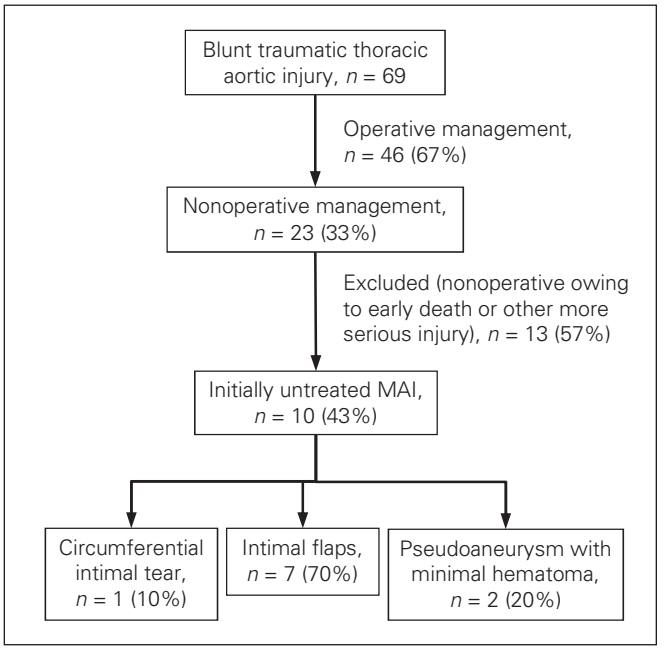

Fig. 1. Study selection and summary of patient clinical characteristics. MAI = minimal aortic injury.

patients, including the single patient who progressed to open repair. There was no specific predefined protocol of pharmacologic manipulation, other than that dictated by the patients' individual situations and injury patterns.

The duration of clinical follow-up, in those who were followed, ranged from 1 month to 6 years (median 2 mo) after hospital discharge, whereas CT radiologic follow-up ranged from 1 week to 6 years (median 6 wk). During this period, 5 (50%) patients with limited intimal flaps (type I) had complete resolution of aortic injury. An additional 2 (20%) patients demonstrated stable aortic injury at their last follow-up; 1 of these patients had an intimal flap (type I), whereas the other had a pseudoaneurysm (type III) with minimal hematoma. Finally, 2 (20%) patients, 1 with an intimal flap and another with a pseudoaneurysm, were lost to follow-up. The patient with a circumferential intimal tear (type II) was found to have extension at 8-week radiological follow-up and underwent open repair (Table 2). Six years after surgery, this patient remained well.

There were no other known early or late complications or deaths with the nonoperative management of these injuries. However, we caution that this does not preclude their possibility, as long-term follow-up was less than optimal, as is often the case with the relatively young and mobile trauma population.

Discussion

The concept of nonoperative management of selected BTAIs originated during the era of open repair in response to the concerning risks of major morbidity and mortality. It is the perception of many that with the introduction of endovascular repair, physicians have become less selective and have elected to treat most patients with this less invasive therapy, prompted by low rates of paraplegia and procedure-related mortality.[11] More recently, with concerns regarding the durability of these repairs[7] some groups have urged a re-evaluation of the selection of patients who require treatment.

The Society for Vascular Surgery (SVS) has recently

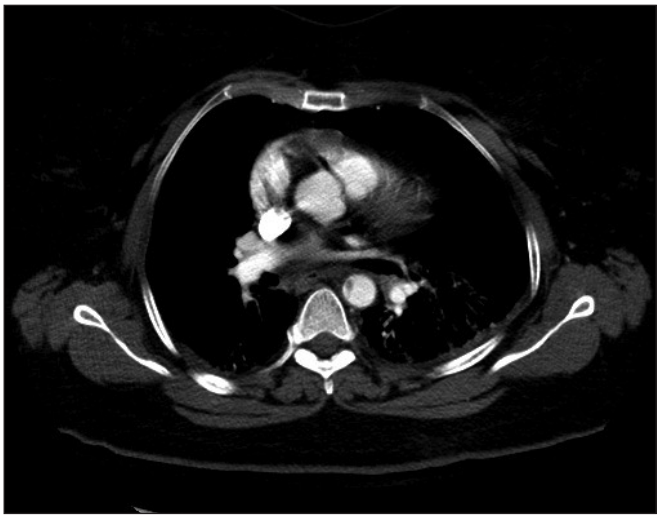

Fig. 2. Computed tomography scan of an intimal flap (in the proximal descending thoracic aorta).

Fig. 3. Computed tomography scan of a pseudoaneurysm (just distal to the left subclavian artery).

Table 1. Patient demographic and baseline clinical characteristics

Patient	Age, yr	Sex	BTAI grade[12]	BTAI type	ISS	Injuries
1	79	Male	III	Pseudoaneurysm	30	Multiple thoracic injuries, liver laceration
2	35	Female	III	Pseudoaneurysm	25	Multiple extremity fractures
3	47	Female	I	Intimal flap	41	Head injury, spine fractures, splenic laceration
4	24	Female	II	Circumferential tear	50	Head injury, spine fractures, multiple extremity fractures
5	38	Male	I	Intimal flap	48	Splenic laceration, pelvic crush
6	42	Male	I	Intimal flap	41	Multiple thoracic injuries, spine fractures, splenic laceration, pelvic crush
7	23	Male	I	Intimal flap	66	Head injury, multiple abdominal injuries, urethral injury, multiple pelvic/spine/extremity fractures
8	33	Male	I	Intimal flap	26	Spine fractures, pelvic fractures
9	43	Female	I	Intimal flap	48	Head injury, multiple thoracic injuries, pelvic/extremity fractures
10	57	Male	I	Intimal flap	57	Multiple thoracic/intra-abdominal injuries, iliac vein laceration, pelvic/extremity fractures

BTAI = blunt traumatic thoracic aortic injury; ISS = injury severity score.

published clinical practice guidelines regarding endovascular repair of BTAIs.[13] Using a recently developed grading system,[12] the SVS recommends conservative management with serial imaging for type I injuries (intimal tear) and repair of type II, III and IV injuries. Our retrospective review generally supports this guideline and reinforces the requirement for serial imaging.

Our experience further validates these SVS recommendations regarding type I injuries, as 5 of 7 patients with intimal tears in our series experienced complete resolution of their injuries. One patient had a stable intimal tear at last follow-up, and 1 patient was lost to follow-up. One patient with a type II injury (circumferential intimal tear with mediastinal hematoma) was found to have progression of her aortic injury at 8-week radiological follow-up and thus underwent successful repair. After a lengthy clinical and radiological follow-up she was still alive and had experienced no morbidity associated with her aortic injury. This limited experience with the failure of conservative management of type II injuries offers further evidence to support the SVS guidelines recommending repair of these lesions. Two patients with type III injuries (pseudoaneurysms) were included in our expectantly managed cohort. Neither underwent repair, as 1 was stable at last follow-up and 1 was lost to follow-up. This provides a cautionary note and reinforces the mandatory requirement for serial imaging when conservative therapy is chosen. With these limitations, our retrospective series does not provide sufficient evidence to contradict the SVS guidelines recommending repair of type III injuries or pseudoaneurysms.

A small number of recent studies have explored nonoperative management of BTAI.[8,9,11,14–17] Most involved patients who were not surgical candidates for various reasons. An even smaller subset of studies involved the purposeful adoption of nonoperative management in MAI.[8,9,11,15] Although all these studies had limited follow-up, most patients demonstrated either resolution or stabilization of their MAI. Furthermore, progression of MAI requiring repair did not occur in all studies. When progression did occur, it ranged from 3.7% to 16.7%.[8,9,11,14–17] The most recent study, from Stanford, represents the largest case series to date (27 patients) and looked specifically at MAI deliberately managed nonoperatively.[11] The results of our study reflect similar findings. Although only 1 patient's MAI progressed and required open repair in the Stanford study, the authors observed that another 2 patients went on to have an endovascular repair at other centres for unknown reasons.[11] Assuming that the indications for those repairs were related to the MAI, the rate of progression to repair in that study would be 11%, mirroring our rate of 10%.

Although the limited number of studies of nonoperative management of MAI have shown that it can be applied safely, at least in the short term, there is variability among studies in the definition of MAI. Most definitions encompass intimal flaps or injuries of less than 2 cm in length.[8] The Stanford study included many patients with pseudoaneurysms, but under the label of significant aortic injury (SAI). Because of the variability of the definition of MAI and because of its somewhat arbitrary nature, we allowed a broader definition of MAI. Thus, our MAI group also included patients with pseudoaneurysms with minimal mediastinal hematoma, although most patients had intimal flaps. In the future, it will be important for all investigators to use a common grading system of injuries,[12] as in the SVS treatment guideline.[13]

To fully determine whether minimal aortic injuries can be safely managed nonoperatively in the long term, 2 major factors are necessary: adequate duration of follow-up and good radiologic surveillance tools. At the therapeutic level, our study and most of the others also demonstrate that radiologic surveillance is mandatory to identify progressive aortic injury and thereby apply the appropriate therapy.[8,9,11,14–17] Over the years, great advancements in imaging modalities have allowed for better definition of aortic injury and MAI.[8] Computed tomographic angiography has become the screening test of choice.[8] Thus, imaging modalities are not a limiting factor. However, follow-up is notoriously difficult in trauma patients who are often young and mobile. In our study, median radiologic follow-up was 6 (range 0–300) weeks, while in the Stanford experience the median was 4 (range 0–92) weeks.[11] Given the lack of long-term follow-up in some of our patients, we

Table 2. Patient follow-up clinical characteristics

Patient	BTAI grade[12]	BTAI type	Radiologic follow-up, wk	Clinical follow-up, wk	Outcome
1	III	Pseudoaneurysm	8	0	Stable disease at last follow-up
2	III	Pseudoaneurysm	1	0	Lost to follow-up
3	I	Intimal flap	1	0	Stable disease at last follow-up
4	II	Circumferential tear	300	300	Open repair at 8 weeks; stable at 6-year follow-up
5	I	Intimal flap	28	0	Resolved at last radiologic follow-up
6	I	Intimal flap	4	208	Resolved at last radiologic follow-up
7	I	Intimal flap	4	4	Resolved at last radiologic follow-up
8	I	Intimal flap	12	8	Resolved at last radiologic follow-up
9	I	Intimal flap	8	8	Resolved at last radiologic follow-up
10	I	Intimal flap	0	0	Lost to follow-up

BTAI = blunt traumatic thoracic aortic injury.

view the inability to perform serial radiologic surveillance as a contraindication to expectant management of most of these injuries.

Although follow-up is clearly an issue in this population, especially when managed nonoperatively, most type I intimal tears in our study resolved radiologically within 4 weeks. The 1 progressive type II injury was also early and was identified at the 2-month radiologic follow-up. It is not clear how long it took the MAIs in other studies to progress to a point requiring intervention. Nevertheless, it may be that MAIs destined to progress to more severe injury do so early. Interestingly, histologic studies on animal models of intimal injury have shown that maximal vessel wall thickening and cellular activity tend to occur at 3–4 weeks.[18,19] Thus, it may be less likely for MAIs involving intimal flaps that have not started progressing at 4 weeks to suddenly start progressing at a later time. More basic science and clinical research with larger numbers and longer follow-up is needed to clarify these issues.

Limitations

Limitations of the present study include its small sample size. As with all the other studies exploring the natural history of MAI, our data were retrospectively collected and thus present increased potential for bias. Limited and variable duration of follow-up offers limited natural history information, but, at least with type I injuries, is sufficient to support a conservative therapeutic regimen. Future studies will include the analysis of clinical outcomes associated with the prospective adoption of the SVS guidelines, as well as a cost–benefit analysis comparing conservative versus endovascular therapy.

Conclusion

A subset of patients with BTAIs can be successfully treated expectantly while being followed with serial radiologic studies. Our retrospective review of patients with MAIs supports the recent treatment guidelines recommending conservative management of type I injuries (intimal tears). There are insufficient data to contradict the recommendation for repair of injuries of greater degree. Regardless of the therapy chosen, serial imaging is a mandatory component of the treatment regimen. Prospective, multicentred studies with adequate follow-up are required to further elucidate the long-term safety and success of surgical and expectant management of the various grades of thoracic aortic injuries.

Competing interests: None declared.

Contributors: B. Kidane, G. DeRose and T.L. Forbes designed the study. B. Kidane, D. Abramowitz and T.L. Forbes acquired the data, which B. Kidane, J.R. Harris, G. DeRose and T.L. Forbes analyzed. B. Kidane and T.L. Forbes wrote the article. All authors reviewed the article and approved its publication.

References

1. Maggisano R, Nathens A, Alexandrova NA, et al. Traumatic rupture of the thoracic aorta: Should one always operate immediately? *Ann Vasc Surg* 1995;9:44-52.
2. Dunham MB, Zygun D, Petrasek P, et al. Endovascular stent grafts for acute blunt aortic injury. *J Trauma* 2004;56:1173-8.
3. Ott MC, Charyk-Stewart T, Lawlor DK, et al. Management of blunt thoracic aortic injuries: endovascular stents versus open repair. *J Trauma* 2004;56:565-70.
4. Lawlor DK, Ott M, Forbes TL, et al. Endovascular management of traumatic thoracic aortic injuries. *Can J Surg* 2005;48:293-7.
5. Tang GL, Tehrani HY, Usman A, et al. Reduced mortality, paraplegia, and stroke with stent graft repair of blunt aortic transections: a modern meta analysis. *J Vasc Surg* 2008;47:671-5.
6. Demetriades D, Velmahos GC, Scalea TM, 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.
7. Forbes TL, Harris JR, Lawlor DK, et al. Aortic dilatation following endovascular repair of blunt traumatic thoracic aortic injuries. *J Vasc Surg* 2010;52:45-8.
8. Malhotra AK FT, Croce MA, Weiman DS, et al. Minimal aortic injury: a lesion associated with advancing diagnostic techniques. *J Trauma* 2001;51:1042-8.
9. Kepros J, Angood P, Jaffe CC, et al. Aortic intimal injuries from blunt trauma: resolution profile in nonoperative management. *J Trauma* 2002;52:475-8.
10. Hirose H, Gill IS, Malangoni MA. Nonoperative management of traumatic aortic injury. *J Trauma* 2006;60:597-601.
11. Caffarelli AD, Mallidi HR, Maggio PM, et al. Early outcomes of deliberate nonoperative management for blunt thoracic aortic injury in trauma. *J Thorac Cardiovasc Surg* 2010;140:598-605.
12. Azizzadeh A, Keyhani K, Miller CC III, et al. Blunt traumatic aortic injury: initial experience with endovascular repair. *J Vasc Surg* 2009; 49:1403-8.
13. Lee WA, Matsumura JS, Mitchell RS, et al. Endovascular repair of traumatic thoracic aortic injury: clinical practice guidelines of the Society for Vascular Surgery. *J Vasc Surg* 2011;53:187-92.
14. Akins CW, Buckley MJ, Daggett W, et al. Acute traumatic disruption of the thoracic aorta: a ten-year experience. *Ann Thorac Surg* 1981;31: 305-9.
15. Fabian TC, Davis KA, Gavant ML, et al. Prospective study of blunt aortic injury: helical CT is diagnostic and antihypertensive therapy reduces rupture. *Ann Surg* 1998;227:666-76, discussion 76-7.
16. Fabian TC, Richardson JD, Croce MA, et al. Prospective study of blunt aortic injury: Multicenter Trial of the American Association for the Surgery of Trauma. *J Trauma* 1997;42:374-80, discussion 80-3.
17. Holmes JH, Bloch RD, Hall RA, et al. Natural history of traumatic rupture of the thoracic aorta managed nonoperatively: a longitudinal analysis. *Ann Thorac Surg* 2002;73:1149-54.
18. Hsiang YN, Fragoso M, Lundkist A, et al. The natural history of intimal flaps caused by angioscopy. *Ann Vasc Surg* 1992;6:38-44.
19. Neville RF, Padberg FT Jr, DeFouw D, et al. The arterial wall response to intimal injury in an experimental model. *Ann Vasc Surg* 1992;6:50-4.