

Endovascular management of traumatic thoracic aortic injuries

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Background: Endovascular surgery has recently been extended to the treatment of blunt traumatic aortic injuries. Since most of these injuries occur at the aortic isthmus, graft fixation in proximity to the origin of the left subclavian artery (LSA) has been a concern. Covering the LSA with graft fabric lengthens the proximal fixation site and should minimize proximal endoleaks. We therefore wished to evaluate the feasibility and safety of endovascular repair of thoracic aortic injuries after blunt trauma, both with and without deliberate coverage of the LSA. **Methods:** At a tertiary care teaching hospital in London, Ont., we reviewed our experience with endovascular repair of 7 traumatic aortic injuries. We reviewed the technical success rate and the incidence of left subclavian coverage. Major morbidity, including rates of paraplegia and death were noted. The patients were followed-up with serial CT to look for endoleaks, stent migration or aneurysm growth and to determine whether they had symptoms related to left subclavian coverage. **Results:** The time from injury to treatment ranged from 7 hours to 7 days (mean 36 h). The mean Injury Severity Score was 36. All injuries were at the aortic isthmus, and among the 7 patients treated, 6 had deliberate coverage of the LSA. One patient underwent carotid-to-subclavian artery bypass, but the other 5 did not. There were no cases of paraplegia; 1 patient had symptoms of claudication in the left arm but did not want revascularization. No procedure-related complications occurred, and all patients survived the event. Follow-up ranged from 2 to 30 (mean 13) months, and no endoleaks, stent migration or aneurysm expansion were noted in follow-up. **Conclusions:** Although long-term results are unknown, we conclude that endovascular repair of traumatic aortic injuries after blunt trauma can be performed safely with low morbidity and mortality and that coverage of the LSA without revascularization is tolerated by most patients.

Contexte : On a étendu récemment la chirurgie endovasculaire au traitement des traumatismes contondants de l'aorte. Comme la plupart de ces traumatismes se produisent au niveau de l'isthme aortique, la fixation du greffon à proximité de l'origine de l'artère sous-clavière gauche (ASG) préoccupe. La couverture de l'ASG par du tissu du greffon allonge le site de fixation proximal et devrait minimiser les endofuites proximales. Nous voulions donc évaluer la faisabilité et la sécurité d'une réparation endovasculaire de traumatismes contondants de l'aorte thoracique avec et sans couverture délibérée de l'ASG. **Méthodes :** À un établissement d'enseignement de soins tertiaires de London (Ontario), nous avons étudié nos expériences de la réparation endovasculaire de sept traumatismes contondants de l'aorte. Nous avons passé en revue le taux de réussite technique et l'incidence de la couverture de l'artère sous-clavière gauche. On a constaté une morbidité majeure, y compris des taux de paraplégie et de décès. On a suivi des patients en pratiquant des séries de tomodensitométries pour rechercher les endofuites, la migration de stents ou le grossissement de l'anévrisme et déterminer si les sujets avaient des symptômes reliés à la couverture de l'artère sous-clavière gauche. **Résultats :** Le temps écoulé entre le traumatisme et le traitement a varié de sept heures à sept jours (moyenne de 36 h). L'indice moyen de gravité de la blessure était de 36. Tous les traumatismes se situaient au niveau de l'isthme aortique et chez les sept patients traités, on a couvert délibérément l'ASG dans six cas. Un patient a subi un pontage entre l'artère carotide et l'artère sous-clavière, mais les cinq autres n'en ont pas subi. Il n'y a eu aucun cas de paraplégie. Un patient présentait des symptômes de claudication du bras gauche, mais il ne voulait pas subir de revascularisation. Il n'y a eu aucune complication reliée à l'intervention et tous les patients ont survécu à l'événement. Le suivi a varié de deux à 30 mois (moyenne de 13) et l'on n'a constaté au suivi aucune endofuite, migration de stent, ni dilatation de l'anévrisme. **Conclusions :** Même si l'on ne connaît pas les résultats à long terme, nous concluons qu'il est facile de pratiquer la réparation endovasculaire des traumatismes contondants de l'aorte sans danger, avec un faible taux de morbidité et de mortalité, et que la plupart des patients tolèrent la couverture de l'ASG sans revascularisation.

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Traumatic disruption of the thoracic aorta after blunt chest trauma remains a highly lethal injury. It is reported to occur in 0.8% of motor vehicle collisions (MVCs) and is responsible for up to 16% of MVC-related deaths.^{1,2} Mortality at the scene has been reported as 80% from autopsy series,³ and a 30% mortality has been reported within the first 6 hours without surgical treatment.⁴ Until recently, despite the lack of evidence for this approach, emergent, open surgical intervention had been advocated as the appropriate treatment for traumatic aortic rupture. Maggisano and colleagues¹ challenged this and reported an overall survival of 82% for patients having delayed management of their aortic injuries, and only 4.5% of these patients died as a result of their aortic rupture within 72 hours of admission. Despite controversy surrounding the timing of intervention, high mortality and morbidity are associated with open repair of traumatic aortic rupture. Death rates ranging from 10% to 35% are reported from larger series,^{5,6} with up to 10% associated paraplegia rates.⁷ Significant advances have been made in endovascular surgical techniques for elective aortic disease, and endovascular surgery has recently been extended to the treatment of blunt traumatic aortic injuries. Successful endovascular repair of aortic rupture has been described in a few small series.⁸⁻¹⁰ As the majority of blunt thoracic injuries occur at the aortic isthmus, proximal graft fixation in proximity to the origin of the LSA has been of concern. Intentional coverage of the LSA has been described^{11,12} in the management of traumatic injuries, both with and without LSA revascularization. Covering the LSA lengthens the proximal fixation site, provides better fabric coverage for aortic injuries at the isthmus and should minimize proximal endoleaks. We report our experience with the endovascular management of 7 traumatic aortic injuries and deliberate coverage of

the LSA in 6 of them. This is a technical description of the endovascular procedure and patient outcomes. We recently performed a comparative analysis of open versus endovascular repair of traumatic aortic injuries in our centre, which is awaiting publication.¹³

Methods

Patients

Between October 2000 and August 2002, 7 patients underwent endovascular treatment of aortic rupture. All injuries were a result of blunt trauma. Three patients received immediate management at our level I trauma centre; the remainder were referred from other institutions. The diagnosis was made by CT in all patients, with angiography being performed either preoperatively or intraoperatively. Surgery was delayed until all other life-threatening injuries were stabilized or managed definitively; this included intra-abdominal injuries in 2 patients and external pelvic fixation in 1 patient. Patients were managed medically to maintain a systolic blood pressure less than 120 mm Hg preoperatively.

Surgical protocol

Diameter and length of the endovascular prostheses were determined preoperatively with the use of CT or angiography, or both. All patients were treated with prefabricated Talent stent-grafts (Medtronic AVE, Santa Rosa, Calif.) kept in stock in our centre. These are fully supported nitinol, self-expanding, Dacron-covered stents with bare spring both proximally and distally. Grafts were oversized 4–8 mm greater than the proximal aortic diameter. Fabric length was determined by length of injury on CT and aimed for a 1- to 2-cm overlap proximally and distally. All procedures were performed under general anesthesia in the operating room, by a team consisting of a

vascular surgeon and an interventional radiologist. One patient underwent planned subclavian-to-carotid artery transposition following the aortic repair, which included planned coverage of the LSA. Complete angiographic and portable C-arm fluoroscopic equipment were available for each case. Patients were positioned in the left anterior oblique position to open up the aortic arch fluoroscopically. Six patients underwent open surgical exposure of the common femoral artery; 1 patient required retroperitoneal exposure of the left common iliac artery because of small calibre external iliac arteries. An 8-mm GORE-TEX (W.L. Gore & Associates, Flagstaff, Ariz.) graft was then sutured to the common iliac artery such that it could be used as a conduit for aortic access. All patients for whom anticoagulation was safe (4 of the 7) were given heparin intravenously. After femoral arterial puncture, a Benson (0.035) guidewire (Cook Inc., Bloomington, Ind.) was advanced into the ascending aorta under fluoroscopic guidance. A 7-French pigtail catheter was then advanced over the guidewire into the ascending aorta, and digital subtraction angiography was then performed using the breath-hold technique. The origins of the innominate, left subclavian and carotid arteries were marked. A decision was then made whether the subclavian artery would require coverage. The pigtail catheter was removed after insertion of a 260-cm Amplatz Super Stiff wire (Boston Scientific Medi-Tech, Boston, Mass.) into the ascending aorta. The access artery was then clamped and arteriotomy performed. With fluoroscopic guidance, the stent prosthesis was introduced over the wire and positioned in an appropriate position. Patients then received adenosine intravenously to induce momentary cardiac standstill for graft deployment. Graft position as well as the presence of an endoleak were then determined by post-procedural an-

giography. The grafts were not routinely ballooned after deployment unless there were concerns about a proximal or distal endoleak. This was done to avoid distal graft migration or displacement when the balloon is inflated under systemic aortic pressures.

Follow-up

CT was performed at 4 weeks after the procedure and then after 3 months and every subsequent 6 months. Patients were assessed postoperatively for clinical evidence of LSA insufficiency as well as in subsequent follow-up visits.

Results

All 7 patients received blunt trauma from MVCs. All but 1 were restrained with shoulder belts. The mean age was 42 years and the mean Injury Severity Score (ISS) was 36. The mean time from injury to treatment was 36 hours (Table 1).

All patients had successful exclusion of their thoracic aortic injury, and all were treated with a single intervention. There were no conversions to an open procedure. Preoperatively, all patients underwent CT,

which demonstrated extraluminal hematoma (4 with pseudoaneurysm, 1 intimal flap, 1 with active extravasation of contrast). Angiography was performed preoperatively on the first 2 patients, but on the subsequent 5, the procedure was planned on the basis of the findings from preoperative CT, and angiography was delayed to the beginning of the endovascular procedure in the operating room. Mean operating time was 153 minutes. All devices were accurately placed with coverage of the tear as determined by completion angiography. All grafts had 98-mm fabric length, and no patient required more than 1 graft for successful treatment.

The LSA was intentionally covered with fabric in 6 of the 7 patients because of proximity of the injury to its origin. The first patient underwent subclavian-to-carotid artery transposition after the repair due to young age and the patient's stable condition at the end of the aortic procedure. The remaining 5 patients did not have their LSA revascularized after its occlusion. None of the patients demonstrated endoleaks or persistent aneurysm filling on completion angiography. No procedurally related complications were noted. All the pa-

tients survived and were discharged from hospital to be followed as outpatients. No patients were paraplegic after the procedure. One 21-year-old man in whom the LSA was covered and not revascularized does have persistent claudication in the left arm but has not wanted revascularization after 24 months of follow-up. Three patients had pulmonary complications and pneumonia likely related to their significant chest and other injuries. Mean hospital stay was 21 days and mean stay in the intensive care unit was 10 days.

Mean follow-up was 18 (range 4–30) months. One patient had no follow-up as he returned to his home in Europe, and we were unable to coordinate imaging for him. All other patients were alive with no evidence of endoleak, graft migration or pseudoaneurysm expansion.

Discussion

Traumatic aortic injuries remain highly lethal, and traditional surgical repair is associated with significant morbidity and mortality. Early, open surgical intervention had been advocated as the appropriate treatment for traumatic aortic rupture, with death rates ranging from 10% to 35%^{5,6} and up to 10% associated paraplegia rates in larger series.⁷ Series have been reported in which patients had their aortic injuries managed in a delayed fashion with overall survival of 82% and only 4.5% mortality as a result of their aortic rupture within 72 hours of admission.¹ Our series supports this finding, with a mean time to intervention of 36 hours; 1 patient was successfully treated after 7 days. Despite controversy around the timing of intervention, high mortality and morbidity are still associated with open repair of traumatic aortic rupture.

Compared with open repair, our series was not associated with any deaths, and there were no cases of paraplegia. In comparison, the reported death rate for open repair is

Table 1

Characteristics of 7 patients who underwent endovascular treatment of blunt thoracic aortic trauma

Patient no.	Sex	Age, yr	Time from injury to repair, h	ISS	Associated injuries
1	M	21	170	41	Head, thoracic spine, rib fractures, diaphragm, hemopneumothorax, spleen, pancreas
2	M	70	8	33	Pelvis, thoracic spine, femoral fracture, rib and sternal fractures, hemopneumothorax
3	F	36	12	45	Head, liver, rib fractures, bilateral pneumothoraces
4	M	49	16	20	Pneumothorax, spleen
5	M	53	7	24	Pelvis, thoracic spine, tibia, radius, rib fractures, pneumothorax, spleen
6	M	38	12	41	Head, pelvis, rib fractures
7	M	29	30	50	Head, liver, rib fractures, pneumothorax, pelvis

All injuries occurred at the aortic isthmus.
F = female; ISS = Injury Severity Score; M = male.

10%, with a rate of neurologic deficit of 16%: 11% paraplegia and 5% paraparesis.⁵ One might attribute this lower mortality and risk of spinal cord ischemia to avoiding aortic cross-clamping and the significant blood loss and hemodynamic changes associated with traditional open repair.

Owing to the common location of these injuries at the aortic isthmus, endovascular treatment requires the surgeon to decide whether intentional coverage of the LSA will be necessary. Gorich and associates¹¹ reported on intentional LSA coverage in 23 patients having thoracic grafts placed for multiple aortic disorders and found that 78.5% of patients were asymptomatic after the procedure. Our experience supports this finding, with only 1 patient out of 5 who had subclavian coverage without revascularization having symptoms of claudication in the left arm. This patient's symptoms were not so severe that he requested a revascularization. If the need did arise, however, this could be safely accomplished electively once the patient had completely recovered from the initial event. The one patient who did have a subclavian-to-carotid artery transposition had this done at the completion of the aortic procedure due to his hemodynamic stability, relatively young age and our relative inexperience with this technique. It seems that the majority of patients will tolerate LSA coverage without revascularization in the acute setting, and this is a useful

adjunct to treating this injury.

Endovascular treatment of infrarenal and thoracic aortic aneurysms is rapidly becoming the treatment of choice for many elective and some emergency cases. This has involved extensive clinical and laboratory trials, and significant debate still exists as to whether this technique should replace traditional open repair when technically feasible. This controversy exists because the traditional open repair is a safe, durable and effective alternative to endovascular treatment. In a recent commentary,¹⁴ Sullivan stated that this is not the case for the treatment of traumatic aortic rupture where a safe, low-risk surgical procedure does not exist and endovascular therapy offers a viable, low-risk alternative.

There is concern about the durability of the procedure in a young person (our youngest patient was 21 yr) and the lack of follow-up to determine long-term outcomes (our longest follow-up was 30 mo). Despite this many are now willing to accept this uncertainty in exchange for a procedure that is much safer with lower morbidity than the traditional repair and virtually eliminates the risk of paraplegia. A report of an endovascular aortic repair in a 12-year-old has recently been described and it will be critical to follow-up these patients to determine long-term outcomes.¹⁵ Until recently, all traumatic aortic injuries in our centre have been managed with

traditional open repair; however, over the past 3 years, endovascular repair has become the treatment of choice when technically possible, and open repair is reserved for those who are not candidates for an endovascular procedure due to unsuitable anatomy or hemodynamic instability.

Conclusions

Our experience demonstrates that endovascular repair of traumatic aortic injuries is possible and that it can be done with low mortality and morbidity. The technique of LSA coverage appears to be well tolerated by most with no need for arm revascularization. Although better long-term follow-up is needed to determine the procedure's durability in what is typically a younger patient population, early results are most impressive and offer a much better alternative to open repair.

Competing interests: Drs. Lawlor and Kribs attended and spoke at an endovascular symposium in Lake Louise, Alta., in April 2005, supported by Medtronic Canada. The topics of their presentations did not relate to the content of this article.

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Table 2

Operative results

Patient no.	Proximal diameter, mm	OR time, min	Heparin, IU	LSA coverage	LOS in hospital or ICU, d	Follow-up, mo
1	30	180	5000	Yes*	27/20	30
2	42	170	3000	Yes	12/3	24
3	26	180	5000	No	45/16	19
4	28	150	5000	Yes	8/5	12
5	28	120	0	Yes	22/2	20
6	28	120	0	Yes	16/8	4
7	28	150	0	Yes	16/12	—†

The prefabricated Talent stent-graft (98 mm long) was used in all cases. There were no instances of endoleak, pseudoaneurysm or graft migration.

*Subclavian-to-carotid transposition

†This patient was living in Europe and follow-up was not available.

ICU = intensive care unit, LOS = length of stay, LSA = left subclavian artery, OR = operating time.

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