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Emergency aortic stent grafting for traumatic rupture of the thoracic aorta

緊急移植胸主動脈帶膜支架治療因創傷引致的胸主動脈破裂

Objective. To investigate the role of aortic stent grafting in emergency treatment of traumatic rupture of the descending thoracic aorta in patients with multiple injuries.
Design. Retrospective study.
Setting. Cardiothoracic surgery facility of a tertiary referral hospital, Hong Kong.
Patients. Between September 2001 and September 2002, four patients who had sustained a blunt injury to the chest after high-speed deceleration injury were recruited. Three patients were treated with stent grafting because concomitant head injury and multiple other injuries precluded the use of open thoracic surgery. One patient had no head injury and was offered stent grafting as a less invasive treatment.
Intervention. The pseudoaneurysm was covered with an aortic stent graft under fluoroscopic and angiographic guidance.
Main outcome measures. Technical success of treatment, complications, and treatment outcome.
Results. Three patients recovered and were discharged from hospital. The computed tomography scan at 3 months to 6 months after surgery showed resolution of the pseudoaneurysm. The final patient was still in the hospital. Follow-up computed tomography 2 weeks later showed exclusion of the pseudoaneurysm. There was one external iliac artery thrombosis on the side of femoral arteriotomy, which was recanalised with thrombectomy. There was another unintentional partial coverage of the left subclavian artery, which was asymptomatic. No other major complication was present and there was no paraplegia after the stent grafting.
Conclusion. Aortic stent graft is useful for emergency treatment of descending thoracic aortic injury. In the short term, it causes less morbidity and mortality than does open surgery, and can be life-saving when there is no surgical alternative. The long-term effect is still unknown.

目的：研究對於多重創傷下胸主動脈創傷破裂的病人，使用胸主動脈帶膜支架移植作為緊急治療方法的效用。
設計：回顧性研究。
安排：香港一所附設心胸外科服務的第三層轉介醫院。
患者：於 2001 年 9 月至 2002 年 9 月期間，接收了 4 名病人，他們全部因減速意外而遭受到猛烈的胸部創傷。其中3名病人，在意外中頭部受傷及多重其他創傷，無法進行切開性胸部手術，因而接受帶膜支架治療。另一名病人的頭部沒有受傷，他接受帶膜支架移植作為低創傷性的療法。
療法：在X光透視及血管造影術引導下，植入主動脈帶膜支架以遮蓋假動脈瘤。
主要結果測量：治療技術是否成功、併發症及治療結果。
結果：3 名病人康復出院。術後 3 個月至 6 個月所進行的電腦斷層掃瞄顯示假動脈瘤已經萎縮。最後一名病人仍然留院。手術後兩週的跟進電腦斷層掃瞄顯示假動脈瘤已經萎縮。其中一名病人在股動脈切開的同一邊出現骼外動脈血栓，以血栓移除術重新開通血管。另外一名病人的左下鎖動脈被無意地遮蓋了一部分，但並無症狀。沒有發生其他主要併發症，病人在接受帶膜支架後亦無下身癱瘓的情況。
結論：帶膜支架對緊急治療胸主動脈創傷是有用的。短期而言，帶膜支架的併發症發生率及死亡率較切開性手術低，而且在缺乏其他外科治療選擇時，這種方法可以保住病人性命。但長期的影響仍然未確定。

Key words:
Aorta, thoracic;
Aortic rupture;
Multiple trauma;
Stents

關鍵詞：
主動脈，胸部；
大動脈破裂；
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Introduction

Traumatic rupture of the thoracic aorta is a devastating injury. More than 80% of patients die of uncontrolled bleeding before they reach a hospital. In a small proportion of patients, the aortic adventitia is intact and the rupture is contained by the surrounding mediastinal structures. However, they still require emergency or early surgery. Open thoracic surgery, cardiopulmonary bypass support, and systemic heparinisation often complicate and sometimes endanger the overall management of these patients, because they often have concomitant conditions such as head injury. Aortic stent grafting is one procedure used to treat this high-risk group.[1-4] In this study, we reviewed our experience in aortic stent grafting for the management of traumatic rupture of the descending thoracic aorta in four patients.

Patients and methods

Between September 2001 and September 2002, we treated four patients with traumatic aortic rupture using aortic stent grafts.

All patients had sustained blunt injury to the chest: two patients had fallen from a height and two had been involved in traffic collisions. All four patients had the diagnosis of traumatic aortic rupture first detected in chest X-rays, which showed a widened mediastinum. Their diagnoses were confirmed by contrast computed tomography (CT) of the thorax (Fig 1) and finally by aortography before the insertion of the stent graft (Fig 2). The symptoms related to the aortic injury were inconspicuous. Clinical profiles of the patients are shown in Table 1.

Aortic stent grafting was offered to three patients because of severe concomitant injuries, and open surgery would have imposed a much higher risk to the patients; it was offered as an alternative to one patient (patient 3). A covered stent graft (Talent; Medtronic AVE, Minneapolis, US) was used in each case. The diameter of the stent graft required was estimated from the CT scan, and was about 20% larger than the diameter of the native aorta.

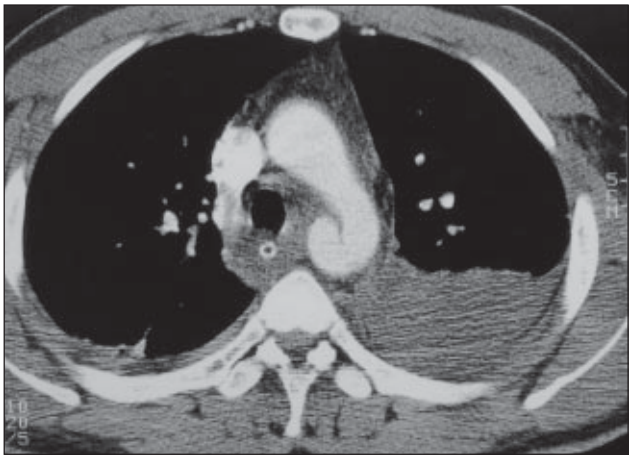

Fig 1. Contrast computed tomogram of the thorax showing a pseudoaneurysm at the medial side of the descending thoracic aorta, mediastinal haematoma, and left haemothorax

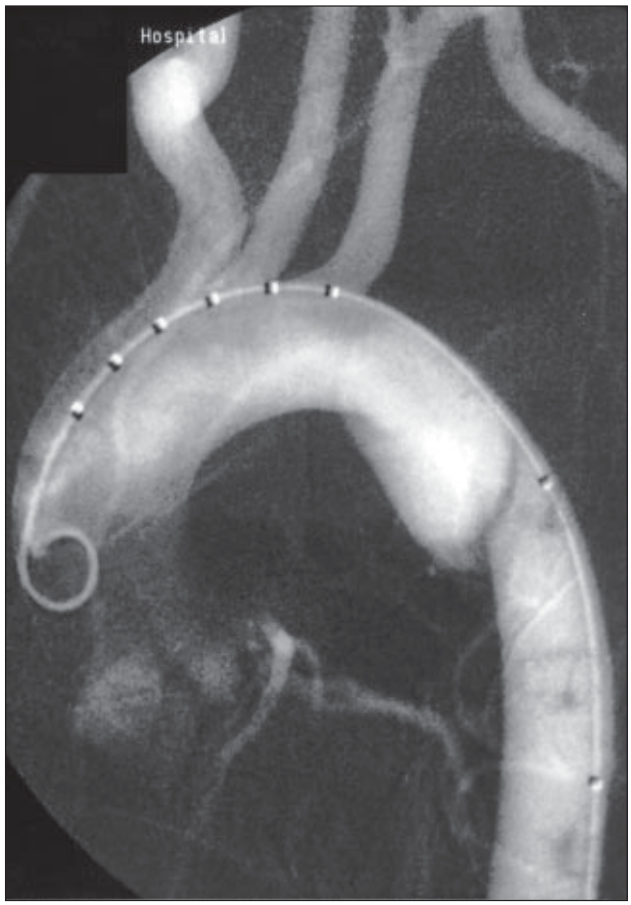

Fig 2. Thoracic aortogram was taken with a calibrated pigtail catheter inserted via the left femoral artery. The rupture was identified and a pseudoaneurysm was present. The distance between the rupture site and the origin of the left subclavian artery was about 2 cm

The procedure was performed in the angiographic suite for the first two patients and in the operation theatre in the other two. Immediately before surgery, thoracic aortography was performed using a calibrated pigtail catheter (Cook, Bloomington [IN], US) to confirm the diagnosis. Pelvic angiography was performed if it was uncertain whether the femoral artery could accommodate the introducer system of the stent graft (8 mm or 24 French in diameter).

After preparing the stent system with heparinised saline, the right common femoral artery was exposed, and the sheath containing the unexpanded stent graft was introduced under fluoroscopic and angiographic guidance. The location of the proximal end of the covered stent was determined by measuring the distance between the aortic tear and the left subclavian artery. If the distance was 2 cm or more, the covered end was placed distal to the left subclavian artery. If the distance was less than 2 cm, the left subclavian artery was intentionally covered.

Table 1. Patient characteristics

Patient No.	Sex/Age (years)	Mode of injury	Concomitant injury	Interval between initial injury and stent grafting
1	M/33	Fell from three storeys	Head injury with frontal bone fracture, left frontal contusion and subdural haematoma; left femoral fracture and patellar fracture	4 days
2	M/27	Driver of high-speed deceleration car accident	Left intracerebral haemorrhage; bilateral lung contusion and haemothorax, ruptured diaphragm; left renal infarction; fracture right superior pubic ramus and acetabulum	Same day (<12 hours)
3	F/44	Car accident, sat in the back seat with seat belt buckled	Deep facial laceration; fracture of left ulna and radius	Next day (<24 hours)
4	M/28	Fell from seven storeys	Pelvic fracture; mandibular fracture; splenic rupture; subdural haematoma and cerebral oedema; fat embolism; rhabdomyolysis; C2 fracture with C2/3 subluxation, C6 fracture; paraplegia; fracture of the left first rib; fracture of the right elbow, both femora, left fibula, right calcaneus, metatarsals	6 days later after the chest condition has improved and the cerebral status better defined

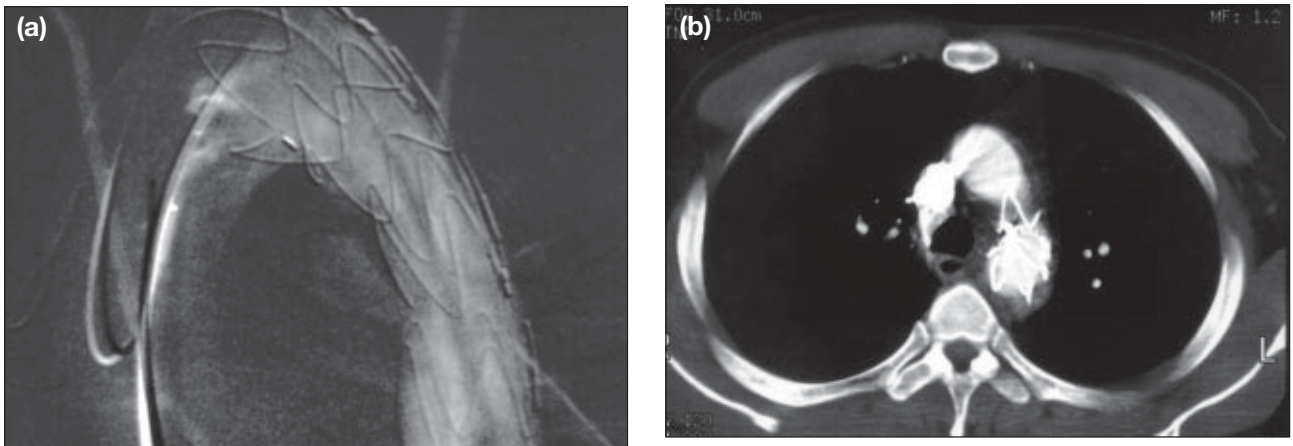

Fig 3. (a) The rupture was sealed off and the pseudoaneurysm was not opacified immediately after stent graft implantation. (b) Contrast computed tomogram of the thorax 2 weeks later showed no pseudoaneurysm and reduction in the size of the mediastinal haematoma

No systemic heparin was given in the first two patients because of the possibility of intracranial haemorrhage. In patient 3, systemic heparin was given after arteriotomy, and the dosage was adjusted according to the activated clotting time, which was kept at 2.5 times the baseline value. Patient 4 also received heparin, despite having an intracranial injury; the activated clotting time was kept at twice the baseline value.

Results were assessed by using immediate post-procedural angiography (Fig 3a) and then contrast CT of the thorax 2 to 3 weeks after the procedure (Fig 3b). Follow-up CT was performed after 3 and 6 months in three patients (Fig 4).

Results

The mean age of the patients (three men and one woman) was 33 years (range, 27-44 years). All four aortic ruptures presented as aortic pseudoaneurysms, which were visible in CT scans and aortograms. All pseudoaneurysms were successfully excluded from the systemic circulation. The interval between the injury and stent graft implantation was less than 24 hours in two cases, 4 days in one case, and 6 days in the fourth. In three patients, the distance between the aortic tear and the left subclavian artery was 2 cm or more, and the covered portion of the stent graft was placed distal to the left subclavian artery (Table 2). In patient 2, the estimated distance was 1.5 cm, and the left subclavian artery was intentionally covered to provide a sufficiently long landing zone for the stent. Angiography after the procedure showed incomplete coverage of the left subclavian artery, but the pseudoaneurysm was excluded. The patient's systolic blood pressure in the left arm was 30 mm Hg lower than that in the right arm, but there was no clinical symptom or sign attributed to the partial coverage.

Table 2. Treatment and complications

Patient No.	Location for procedure	Site of rupture as shown in aortogram	Duration of operation* (hours)	Estimated blood loss (mL)	Size of stent graft	Complications of stent grafting
1	Angiographic suite	2 cm distal to the left subclavian artery	3.0	500	30 mm diameter, 101 mm covered length	None
2	Angiographic suite	1.5 cm distal to the left subclavian artery	3.5	200	32 mm diameter, 100 cm covered length	Acute thrombosis of right external iliac artery (side of arteriotomy), thrombectomy performed
3	Operation theatre	2 cm distal to the left subclavian artery	3.0	100	34 mm diameter, 100 cm covered length	Partial coverage of the left subclavian artery, asymptomatic
4	Operation theatre	2 cm distal to the left subclavian artery	2.5	200	32 mm diameter, 100 cm covered length	None

* From incision for arteriotomy to skin closure

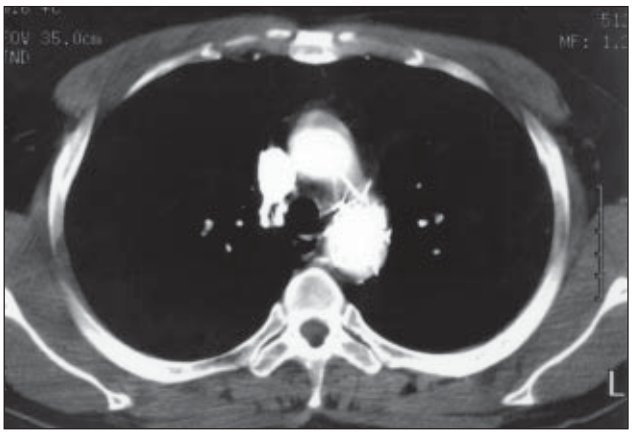

Fig 4. Contrast computed tomogram of the thorax 3 months later showing complete absorption of the pseudoaneurysm and mediastinal haematoma

There was no major complication related to the procedure, such as paraplegia, severe blood loss, aggravation of haemorrhage, stroke, cardiac events, pulmonary insufficiency, or renal failure. However, external iliac artery thrombosis on the side of the femoral arteriotomy developed 1 day after the procedure for patient 2; thrombectomy was performed and the artery was recanalised successfully. In patient 3, the left subclavian artery was only partially covered, but this was asymptomatic. In the three patients with intact preprocedural spinal function, there was no paraplegia. The remaining patient, who had cervical spine injury, experienced loss of power and sensation in the lower limbs before any treatment. The first three patients were discharged from hospital and had a good recovery. Patient 4 remained hospitalised because of multiple severe injuries; he underwent other operations and his condition is currently stable.

Discussion

Traumatic aortic rupture is a potentially lethal injury. If the condition is left untreated, 30% of affected individuals will die within 6 hours, 40% to 50% within 24 hours, and 90% within 4 months.[5] Chest X-rays may show a widened mediastinum and possibly a left pleural cap, which represents mediastinal haematoma and pleural effusion, respectively. Physicians need to bear in mind the possibility of traumatic aortic rupture in such cases. Contrast CT can be conducted to confirm the diagnosis, by detecting the mediastinal haematoma—a pseudoaneurysm arising from the aorta or a dissecting flap in the aorta.[5]

Conventional aortic repair is done by open thoracic surgery, which involves thoracotomy and aortic cross-clamping with or without cardiopulmonary bypass support.[6,7] A meta-analysis by von Oppell et al[8] showed that the risk of postoperative paraplegia can be minimised if some form of active distal perfusion is used. Cardiopulmonary bypass protects the heart and provides distal perfusion to the spinal cord and kidneys during cross-clamping. However, this procedure requires heparinisation, which is clearly a major disadvantage in the presence of closed head injury. Partial bypass using heparin-coated surfaces is another option, but this technique is not widely available, including in our institution.

With the development of the covered aortic stent graft and its improvement in design, thoracic stent grafting is starting to have a role in the repair of traumatic aortic injury. The aortic stent graft was first designed to treat abdominal aortic aneurysm. It was then used to treat thoracic aortic aneurysm, thoracic aortic rupture, and type B aortic dissection. The advantage of endovascular repair is its minimal invasiveness; thoracotomy, cross-clamping or bypass is not required. In typical patients, heparinised saline should be used to prepare the equipment so that clotting in the femoral artery and around the deployed stent is prevented.

However, in patients with contra-indication for high dose of heparin, systemic heparinisation may be avoided if the procedure is performed rapidly; alternatively, low-dose heparin may be used to prevent thrombosis in the access artery. The role of systemic heparinisation in aortic stent grafting for patients with intracranial haemorrhage has not been fully studied. We did not use systemic heparinisation in the first two patients with head injury, and one of these two patients developed a thrombosis in the access vessel.

The third patient with head injury received a lower dose of heparin, so that the activated clotting time was maintained at only twice the baseline value. There was no obvious thrombosis or severe haemorrhage. In addition, because the thoracic aortic stent graft is straight and it is easier to deploy a straight graft than a bifurcated abdominal aortic stent graft, the procedure time and time of systemic heparinisation can be shortened. Reduction or avoidance of full heparinisation is one of the most important benefits of stent grafting.

We deliberately covered the left subclavian artery in patient 2 to increase the length of the proximal landing zone. Although the site of injury is usually in the isthmus of the descending thoracic aorta, at a short distance distal to the left subclavian artery, occlusion of the left subclavian artery usually does not cause significant damage, because the basilar artery is usually supplied by both vertebral arteries, and perfusion to the left upper limb is maintained through collaterals from the other arterial branches.[9,10]

The femoral artery was used to gain access to the stent site in all four patients in our series, and there was no difficulty in inserting the stent. One important issue for stent grafting in Chinese patients is the size of the access artery. The diameter of the thoracic stent graft used is larger than that of the abdominal aortic stent graft; hence, the sheath containing the unexpanded stent is also larger: the diameter may be 24 French or larger. This issue may not be a significant problem for patients living in Europe or the US, because they generally have a larger body build and bigger arteries than do patients in Asia. However, if the patient is old and the body build is small, the atherosclerotic femoral artery may not be able to accommodate the large equipment, and forceful insertion may cause intimal tearing and even arterial rupture. One may have to expose the external iliac artery or the aorta to insert the stent. This alternative route of entry will increase the risk of the procedure. Thus, the body size of the patient should always be measured to determine which procedure is appropriate; in cases of doubt, pelvic angiography or CT of the pelvis before the procedure is advisable to measure the diameter of the common femoral artery or iliac arteries.

Thoracic aortic stent grafting is rarely performed in this locality; all reports that have been published so far are from other countries. The largest series was reported by Dake et al,[11] who used 'first-generation' stent grafts among a mixed group of 103 patients, including 64 with thoracic aortic aneurysm, eight aortic dissection, eight traumatic rupture, 10 penetrating ulcer, and 13 others. Major complications were stroke (7% of patients), paraplegia or paraparesis (3%), myocardial infarction (2%), and respiratory insufficiency (12%). Reports from other centres showed lower complication rates, perhaps because they used a newer generation of stent design, which has a smaller profile and is more flexible. In papers reporting on aortic stent grafting for traumatic aortic rupture, the complication rates were also low: complications included missed ascending aortic rupture and cardiac tamponade,[2] occlusion of the left subclavian artery and left main bronchus atelectasis that required stent grafting,[3,12] and perigraft leakage that required coil embolisation.[12] There were no reported cases of paraplegia among these aortic stent graft procedures for traumatic aortic rupture. We also did not encounter paraplegia in the three patients with intact preprocedural spinal function; this was probably related to the use of a short stent, thereby sparing the lower thoracic aorta, where the artery of Adamkiewicz usually arises. Our complication of delayed external iliac thrombosis may be related to the lack of systemic heparinisation in the patient. This may be a problem in the presence of severe head injury and intracranial haemorrhage. Furthermore, the left subclavian artery was partially covered in two patients, one intentionally and the other unintentionally. Although this situation does not affect the final outcome, the goal of very precise deployment is not achieved. The design of the stent has still to be improved to allow exact deployment. It is difficult to compare our result with those from other centres, because all have few study participants. However, most centres seem to have very few complications.

The long-term result of stent grafting for traumatic rupture is not yet known. The available literature was published quite recently, and no centre has an experience of more than 10 years. This observation may be important for patients with traumatic rupture, because this group tends to be young and, if they recover, these patients may have a long life expectancy. The effect of strong cardiac and aortic pulsation on the stent is still not fully studied; it may cause metal fatigue, fracture, or graft breakage. One case report describes leakage through the graft material,[13] although no metallic fracture has been reported. We do not know the effect on the traumatic rupture after the stent fails; probably, the traumatic defect will heal over time and the stent will have fulfilled its role. Long-term effects nevertheless need to be studied, and affected patients should be warned of this if they opt to receive a stent graft.

Stent grafting is also used to treat other thoracic aortic diseases, such as thoracic aortic aneurysm and Stanford type B aortic dissection. In thoracic aortic aneurysm, the main concern is the endoleak after stent grafting. The average rate is about 14% and is probably higher when compared with traumatic aortic rupture. This might be related to the length of aortic involvement as well as the generalised atherosclerosis in the aorta.[14,15] Another concern is paraplegia after stent grafting, the average rate of which is about 3%. In Stanford type B aortic dissection, the indication for stent grafting is completely different, and the discussion is outside the scope of this paper.[16]

Stent grafts have also been used to treat the coronary arteries, aortocoronary venous graft, iliac arteries, femoropopliteal arteries, and other arteries. The diameter of these arteries is much smaller than that of the aorta. Their

long-term complication is restenosis and occlusion, which is not a primary concern in the thoracic aorta.

Although the number of cases is small in our series, we have shown that the covered aortic stent graft is useful in the emergency treatment of descending thoracic aortic injury, at least in the short term. It causes less morbidity and mortality, when compared with open surgery. It is especially useful when concomitant head injury is present.

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