Surgical versus endovascular treatment of traumatic thoracic aortic rupture

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Objectives: **Blunt traumatic thoracic aortic rupture is a life-threatening surgical emergency associated with high mortality and morbidity. The recent development of endovascular stent-graft prostheses offers a potentially less invasive alternative to open chest surgery, especially in patients with associated injuries. We sought to compare the results of conventional surgical repair and endovascular treatment of traumatic aortic rupture in a single center.**

Methods: **From July 1998 to January 2004, 20 patients with acute blunt traumatic aortic rupture underwent treatment at our institution. All patients had a lesion limited to the isthmus, and associated injuries. Initial management included fluid resuscitation, treatment of other severe associated lesions, and strict monitoring of blood pressure. Eleven patients (9 men, 2 women; mean age, 32 years) underwent surgical repair, including direct suturing in 6 patients and graft interposition in 5 patients. Ten patients were operated on with cardiopulmonary support (left bypass with centrifugal pump, n = 2; extracorporeal circulation, n = 8). The delay between trauma and surgery was 2.6 days (range, 0-21 days). Nine patients (8 men, 1 woman; mean age, 32 years) underwent endovascular treatment with commercially available devices (Excluder, n = 2; Talent, n = 7). In all patients 1 stent graft was deployed. In 2 patients the left subclavian artery was intentionally covered with the device. The delay between trauma and endovascular treatment was 17.8 days (range, 1-68 days).**

Results: **One patient in the surgical group (9.1%) died during the intervention. Three surgical complications occurred in 3 patients (27%), including left phrenic nerve palsy (n = 1), left-sided recurrent nerve palsy (n = 1), and hemopericardium 16 days after surgery that required a repeat intervention (n = 1). No patient in this group had paraplegia. In the endovascular group successful stent-graft deployment was achieved in all patients, with no conversion to open repair. No patient died, and no procedure-related complications, including paraplegia, occurred in this group. Control computed tomography scans obtained within 7 days after endovascular treatment showed exclusion of pseudoaneurysm in all cases. Length of follow-up for endovascular treatment ranged from 3 to 41 months (mean, 15.1 months). Computed tomography scans obtained 3 months after endovascular treatment showed complete disappearance of pseudoaneurysm in all patients.**

Conclusion: **In the treatment of blunt traumatic thoracic aortic rupture, the immediate outcome in patients who receive endovascular stent grafts appears to be at least as good as observed after conventional surgical repair. Long-term follow-up is necessary to assess long-term effectiveness of such management. (J Vasc Surg 2004;40:873-9.)**

Blunt traumatic aortic rupture is a life-threatening surgical emergency usually related to a violent crash involving sudden deceleration. Other life-threatening injuries are commonly associated; therefore more than 80% of patients with such trauma die at the scene of the accident.[1] Treatment remains controversial in surviving patients who reach the hospital.[2] Surgical procedures include simple aortic suture or graft interposition with the clamp-and-sew technique or the use of an adjunct to maintain distal aortic perfusion. Despite significant improvements in medical management, the results of early surgical repair are disappointing. Mortality remains at about 20%, and seems to be related to the severity of other associated injuries. Circulatory assistance techniques have decreased the incidence of postoperative medullary ischemia to 3%; however, the necessity of systemic heparinization increases the risk for fatal hemorrhage, particularly in patients with coexisting brain or pulmonary contusion.[3,4]

Delayed surgical treatment has recently been advocated to overcome these drawbacks of early surgical repair.[5,6] Nevertheless, even with careful blood pressure monitoring, approximately 2% to 5% of patients experience aortic rupture, most within the first week after the trauma.[7-10] The recent development of endovascular stent-graft prostheses offers a potentially less invasive alternative to open chest surgery for treatment of thoracic aortic disease.[11] As a result, there is an increasing number of reports of successful endovascular treatment of acute traumatic aortic rupture.[12-16]

The purpose of this retrospective study was to compare the results of conventional surgical repair and endovascular treatment of traumatic aortic rupture in a single center, to better define the role of stent grafts in management of traumatic aortic rupture.

PATIENTS AND METHODS

Between July 1998 and January 2004, 20 patients with acute traumatic rupture of the descending aorta received

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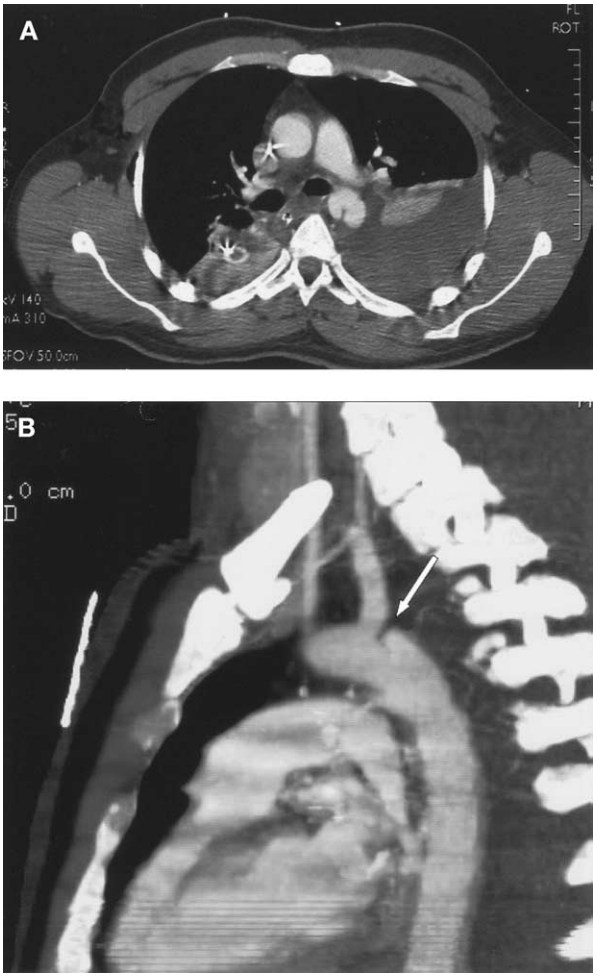

Fig 1. A, Computed tomography scan shows acute contained rupture of aortic isthmus. **B,** Same patient as in **A**. Two-dimensional computed tomography scan shows a pseudoaneurysm just distal to the left subclavian artery. Note short proximal neck *(arrow)*. Partial coverage of the subclavian artery was mandatory to prevent a proximal type I endoleak.

treatment at our institution. All patients had sustained a violent traumatic injury involving sudden deceleration (3 falls from great height, 17 road accidents) within 3 months before treatment. The group included 3 female patients and 17 male patients aged 15 to 51 years (mean, 31.7 years).

In all patients the diagnosis of traumatic rupture was made at computed tomography (CT) of the aorta when they were admitted to the emergency department. CT was usually indicated because of the severity of the traumatic injury, the clinical signs, or findings on chest x-ray studies (Fig 1, *A* and *B*).

We progressively changed the way our group manages traumatic rupture of the descending aorta during the study period. At the beginning of the study all patients underwent surgical therapy, and those in whom thoracotomy or circulatory assistance was contraindicated underwent delayed surgery after treatment of the associated injuries. The development of aortic stent grafts has enabled us to accelerate management in these patients and to treat in a less invasive manner immediately after diagnosis. Currently we have at our disposal a range of stent grafts (Talent; Medtronic/AVE) in all available diameters (22-36 mm).

Surgical treatment. The procedure was performed either with cross-clamping alone or with circulatory assistance (left-sided heart heparin-coated bypass or cardiopulmonary bypass). The thoracic aorta was approached through a posterolateral thoracotomy, with an incision in the fourth left intercostal space, excluding the left lung. After the pericardium was opened, the aortic arch was controlled as the dissection progressed, and was clamped between the left common carotid artery and the left subclavian artery or distal from the left subclavian artery. The descending thoracic artery was controlled distally immediately after the traumatic injury to avert sacrifice of the intercostal arteries. The aorta was repaired with direct suturing or graft interposition.

Patients underwent clinical evaluation, and CT or magnetic resonance imaging (MRI) at 3 or 6 months, and yearly thereafter, for graft surveillance.

Endovascular treatment. All procedures were performed in the operating room with the patient under general anesthesia and with tracheal intubation and mechanical ventilation. Patients were placed in the dorsal decubitus position. Drapes were arranged to include the abdomen and both groins in the operative field, thus affording access to the common femoral arteries and, if needed, the iliac arteries or the abdominal aorta. The right common femoral artery was approached surgically. The arteries were catheterized with a 0.035-inch hydrophile guide wire (Terumo Medical Corporation), with the Seldinger method. A graduated angiography catheter was then placed in the ascending aorta. A mobile digital substraction radiography unit (Philips BV-300) was used for image acquisition. An arteriogram of the whole of the aortic arch was taken from a left, anterior oblique view, and the remaining healthy portion of the aorta was measured proximal from the false aneurysm to determine the best position in which to deploy the stent graft. The hydrophile guide wire was then replaced with a 260-cm-long 0.035-inch superstiff guide wire (Amplatz; Boston Scientific). If an Excluder (W. L. Gore & Associates) stent graft was used, a 24F Cook introducer sheath was inserted. The Talent stent graft was contained inside a sheath, which served to insert it. The dimensions used for stent-graft sizing were determined on the basis of findings on the initial CT scan. The diameter of the stent graft was oversized by 20% in relation to the diameter of the native aorta, to ensure a satisfactory seal. The stent graft was then positioned inside the thoracic aorta under fluoroscopic monitoring and with mean arterial pressure less than 70 mm Hg during implantation. Arteriography was performed after the stent graft had been deployed, to ensure that the false aneurysm had been properly excluded. Finally, after removing the introducer delivery system, the femoral arteriotomy was repaired with interrupted 5-0 polypropylene sutures. An aortic

Table I. Data on 11 patients with traumatic rupture of the thoracic aorta treated by surgery

Age and Gender	*Comorbidity and associated lesions*	*Time of repair*	*Mechanical circulatory support*	*Repair*	*Outcome*
M 34 yrs	Closed head injury, hepatic contusion, fracture of the ulna	Immediate	Yes	Graft interposition	Alive
M 31 yrs	Fractured pelvis	Delayed (4 days)	Yes	Suture	Alive
M 37 yrs	Extradural hematoma, fractured femur and ulna	Delayed (21 days)	Yes	Graft interposition	Alive
M 33 yrs	Spleen contusion	Immediate	Yes	Suture	Alive
M 20 yrs	Spleen and pulmonary contusion, anterior flail chest	Immediate	Yes	Graft interposition	Alive
M 36 yrs	None	Immediate	Yes	Suture	Alive
M 38 yrs	Fractured tibia	Immediate	Yes	Graft interposition	Alive
M 37 yrs	Multiple compound fractures	Immediate	Yes	Suture	Alive
M 24 yrs	Pseudocoarctation, paraplegia, acute mesenteric ischemia	Immediate	No	Graft interposition	Dead
F 15 yrs	Ruptured spleen, ruptured diaphragm, fractured radius and pelvis	Immediate	Yes	Suture	Alive
F 51 yrs	Ruptured diaphragm	Immediate	Yes	Suture	Alive

CT scan was obtained before the patient was discharged from the hospital, then at 3 months and 6 months, and yearly thereafter, for stent-graft surveillance. Conventional radiographic examination of the stent graft in the anteroposterior, oblique, and lateral views was performed at the same intervals, to detect wire fractures.

Data regarding patient population, symptoms, associated lesions, and results of treatment were collected retrospectively from hospital records, consultation data or patient case histories, and telephone calls to the patients.

RESULTS

In all patients the aortic rupture was located in the isthmus. In the surgical group, 9 patients were operated on within 24 hours of the traumatic injury. Two patients underwent delayed surgery 4 days and 21 days, respectively, after the initial injury, because of severe orthopedic injuries in 1 patient and extradural hematoma in the other patient. The mean interval before surgery was 2.6 days (range, 0-21 days). In the group treated with stent grafting, 6 patients had delayed treatment and 3 patients were treated within 24 hours of the traumatic injury. Treatment was delayed in 6 patients because of associated injuries and because the stent graft was not available. The mean interval before stent-graft placement was 17.8 days (range, 1-68 days).

All data for the patients who underwent surgery and those who received endovascular treatment are provided in Tables I and II, respectively.

Surgical group. Ten patients were operated on with circulatory assistance. In 1 patient with aortic thrombosis distal from the rupture on the isthmus only cross-clamping was used. The aorta was subsequently repaired with direct suturing in 6 patients, and the damaged portion of the aorta was replaced with a prosthetic graft in 5 patients. One patient died after surgery, of ischemia-related multiple-organ failure, as a result of preoperative thrombosis of the distal thoracic aorta with a dissected intimal flap. The surgical mortality rate was 9.1%. No postoperative paraplegia occurred in this group.

Except for complications related to the associated injuries, 1 patient had left phrenic paralysis; 1 patient had left-sided recurrent nerve injury; and 1 patient had tamponnade, which was treated with surgical drainage of the pericardium.

Endovascular group. A right femoral approach was used in all the procedures. The mean diameter of the aorta proximal from the rupture was 21.4 mm (range, 16-26 mm), and distal from the rupture was 21 mm (range, 16-26 mm). The distance between the posterior edge of the left subclavian artery and the rupture was, on average, 14.5 mm (range, 3-29 mm). We used the Excluder thoracic endoprosthesis in 2 patients, and the Talent stent graft in 7 patients. Mean diameter of the stent grafts was 25.3 mm (range, 22-28 mm). Mean length of the stent grafts was 119.2 mm (range, 75-132 mm). In all patients a single stent graft was deployed to cover the rupture.

We partially covered the ostium of the left subclavian artery in 2 patients, because of insufficient length of the neck (3 and 5 mm, respectively), with no clinical effect. No patient died after endovascular treatment. No complications occurred during the procedure in this group, and, more important, no patients had paraplegia as a result of the endovascular repair, nor did we have to convert to open surgery.

Follow-up. Mean follow-up in all patients was 26.3 months (range, 3-68 months). In the surgical group 1 patient was lost to follow-up 4 months after surgical treatment. For the mean duration of follow-up of 36 months (range, 4-68 months) there were no complications (Fig 2).

In the stent-graft group no patients were lost to follow-up. Mean duration of follow-up was 15.1 months (range, 3-41 months). On CT scans at 3-month follow-up the aortic rupture had completely healed, and no change occurred during the subsequent follow-up period (Fig 3). No

Table II. Data on 9 patients with traumatic rupture of the thoracic aorta treated by stent-graft

Age and Gender	*Comorbidity and associated lesions*	*Time of repair*	*Device diameter/ length (mm)*	*Outcome*
M 31 yrs	Closed head injury, fractured pelvis, spleen and pulmonary contusion	Immediate	Talent 24/130	Alive
M 30 yrs	Closed head injury, Paraplegia, spinal fracture	Delayed 29 days	Excluder 28/75	Alive
M 26 yrs	Hepatic, spleen, kidney and pulmonary contusion, fractured pelvis, sepsis	Delayed 42 days	Talent 26/130	Alive
F 51 yrs	Fractured pelvis and femur	Delayed 15 days	Talent 26/132	Alive
M 37 yrs	Fractured ankle and multiple rib fractures	Delayed 5 days	Talent 26/130	Alive
M 31 yrs	Fractured pelvis, retroperitoneal hematoma with internal iliac embolization	Immediate	Talent 22/116	Alive
M 19 yrs	Bilateral femoral fractures, fractured tibia, right pneumothorax	Delayed 3 days	Talent 24/130	Alive
M 33 yrs	Fractured femur, pulmonary contusion	Immediate	Talent 26/130	Alive
M 20 yrs	Closed head injury, C2 spinal fracture	Delayed 68 days	Gore 26/100	Alive

damage to the stent-graft materials was detected. The 2 patients with partial coverage of the ostium of the left subclavian artery reported no symptoms.

DISCUSSION

We undertook a retrospective analysis of 20 patients who underwent treatment of traumatic rupture of the descending aorta. Eleven patients underwent surgery, and in 9 patients an aortic stent graft was placed. In the surgical group 1 patient died, for an operative mortality rate of 9.1%; none of the patients in this group had postoperative paraplegia. In the stent-graft group no patient died, and none had postoperative paraplegia. The overall mortality rate for the study was 5%.

The standard treatment for aortic rupture is surgical repair. When surgery is performed in an emergency setting, mortality and morbidity are high. In a recent review of the literature, the surgical mortality rate ranged between 8% and 15%, whether or not circulatory assistance was used to maintain satisfactory perfusion pressure in the aorta distal from the clamp.[4] Risk factors that explain the increase in postoperative mortality include severity of the associated traumatic lesions, preoperative shock (only 25% of which was related to aortic rupture), and cardiac risk factors.[17] Paraplegia was the main complication of surgical treatment. When aortic repair was achieved without circulatory assistance, the postoperative paraplegia rate can be as high as 19%, and this risk increases significantly when the aorta is clamped for more than 30 minutes.[3] With circulatory assistance, this rate remains at about 2%.[4] Surgery is sometimes contraindicated if the associated lesions are life-threatening (eg, extradural hematoma) and their treatment is the priority or if the patient has serious multiple traumatic injuries for which circulatory assistance and thoracotomy are contraindicated. In these situations, as long as the rupture remains contained and there is no pseudocoarctation, surgical repair can be delayed until the patient's status has improved and is compatible with major surgery, provided the patient's arterial pressure is strictly monitored and controlled. The satisfactory results obtained with this type of surgical management have led some authors to systematically propose delayed surgery. Although this attitude is justified by objective data,[5,18] it is not entirely risk-free, inasmuch as 4% of patients awaiting surgery die of a ruptured aorta, usually within 1 week of the traumatic injury.[7-10]

Recently the emergence of endovascular treatment has enabled us to find solutions to some of the controversies in the debate on surgical management. By nature, endovascular treatment is less invasive than standard surgery, and is associated with decreased mortality and morbidity, as the results of our study demonstrate. There is no need for thoracotomy, and this reduces morbidity related to single-lung ventilation in patients who often have lung contusions and fractured ribs. The absence of circulatory assistance, and thus of high systemic doses of heparin, limits the hemorrhagic complications of the procedure. It also helps to avert onset of a systemic inflammatory response, which can have a deleterious effect if it is amplified by an underlying trauma-related inflammatory status. Placement of a stent graft does not require aortic cross-clamping, which reduces the distal risk for visceral and medullary ischemic complications. The potential risk for medullary ischemia remains if the intercostal arteries opposite the stent graft are occluded, but it is limited in that rarely does the spinal artery arise from the aortic isthmus. To our knowledge, this complication has not been reported in the literature,[12-16,19-22] but similar to ours, these studies included a small number of patients, and it is difficult to make a reliable comparison with larger surgical series.

With respect to the delay between the traumatic event and surgery, again stent-graft treatment shows a considerable advantage. It can be performed before or immediately after treatment of other life-threatening injuries and in

Fig 2. Magnetic resonance image obtained 1 year after primary surgical repair. *Arrow* indicates suture line.

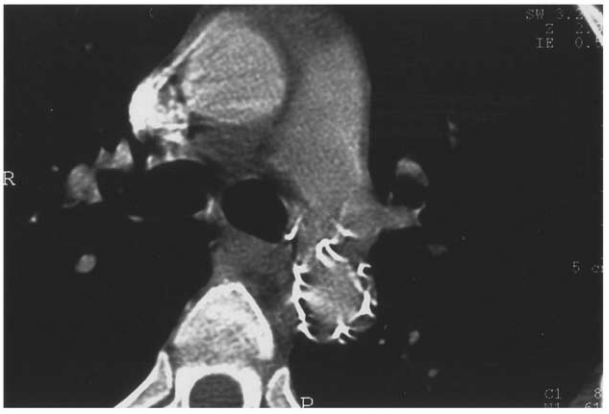

Fig 3. Computed tomography scan obtained at 6-month follow-up demonstrates complete healing of the aortic wall.

patients for whom conventional surgery is contraindicated, because the procedure is short and has little physiologic effect. We now have a complete range of stent grafts at our disposal, so as to avert undue delay in management of traumatic rupture of the descending aorta.

Successful endovascular treatment in these cases depends partly on strict evaluation of the patient's anatomic features, as in treatment of aneurysms of the abdominal aorta. The length of the healthy remaining portion of the aorta proximal from the rupture must measure at least 15 mm to achieve a satisfactory seal and to exclude the false aneurysm. If need be, we do not hesitate to cover the left subclavian artery to lengthen the proximal neck, as we did in 2 of our patients. When the left subclavian artery must be covered, it rarely causes upper limb ischemia; thus transposition of the subclavian artery onto the carotid artery before thoracic stent-graft implantation is not mandatory.[11] On the basis of this approach, endovascular treatment has not been contraindicated in any of our patients, and we did not observe any type I endoleaks in this series. The 3-month follow-up CT scan showed complete healing of the aortic wall, without any residual pseudoaneurysm. These results are identical to those in the literature (Table III).[12-16,19-22] They can probably be explained in that the aorta is usually healthy proximal and distal from the rupture, which means that a satisfactory seal can be achieved with no type I endoleaks; the rupture was always limited to the aortic isthmus in length, with few intercostal arteries to feed the false aneurysm; and use of a single stent graft reduced the risk for type III endoleaks. As a result of these factors, it is probable that the aortic wall is completely restored after healing, thus limiting the likelihood of arterial remodeling.

Apart from the problem of managing the proximal neck, several factors can contribute to limit the feasibility of endovascular treatment. Extension of the lesions to the aortic arch proximal from the left subclavian artery is a contraindication to deployment of the stent graft for the moment. The curve of the distal arch can be highly angulated, and that can be a problem with devices too rigid to negotiate such a curve. The arterial approach can be difficult in some cases, because of the size and stiffness of the delivery sheath. Last, it is essential to ensure that a whole range of diameters of stent grafts is available, to treat the largest possible number of patients. A single length of stent graft is sufficient, because in most cases the rupture is short and limited to 1 site, which limits the amount of stock required. It is clear that a single type of stent graft cannot be used to treat all diseases of the descending aorta. For traumatic injuries the ideal stent graft should be flexible, to fit the curve of the aortic arch, with a noncovered proximal stent that can be safely deployed on the ostium of the left subclavian artery and a suitably shaped, flexible introducer sheath as small in diameter as possible.

A key issue is the future outcome in these patients with stent grafts, because they are often young. Patient surveillance must therefore be strict. We obtain a thoracic CT scan within a week after the stent graft has been implanted, to ensure that the false aneurysm is properly excluded. Thereafter we obtain a follow-up CT scan and plain x-ray studies from several angles at 3 months and 6 months, then once a year, to monitor the initial good result and to detect any fracture or damage to the stent graft. There are reports of deteriorated stent grafts.[23] We had no experience with deteriorated prosthetic materials in our series, nor were any reported in other series in the literature. This could be

Table III. Endovascular treatment: results of literature review

	n	*Mortality*	*Paraplegia*	*Complications (n)*
Thompson et al[14]	5	0	0	0
Marty-Ané et al[19]	9	0	0	0
Orford et al[16]	9	1	0	Arm ischemia (1)
Scheinert et al[20]	10	0	0	Renal failure (1)
Melnitchouk et al[26]	15	1	0	Type I endoleak (1)
Personal experience	9	0	0	0

explained by a limited follow-up period, but long-term surveillance seems mandatory. It must also be remembered that surgical treatment itself is not entirely devoid of late complications, mainly, false aneurysms, anastomotic stenosis, or, more rarely, infected prosthetic materials, for which the prognosis is catastrophic and equally imposes long-term follow-up.[24]

This retrospective study shows that endovascular treatment is a safe method for repair of traumatic rupture of the descending thoracic aorta, with immediate and short-term results that are at least comparable with those of standard surgery. In the future, prospective studies will confirm these data, which must be considered with all due reservations for the moment, because there were only a few patients in each group. However, the preliminary results are interesting because they are comparable with those in the literature, that is, low postoperative mortality, no neurologic complications, and stability of the results over the short term. Although some authors[19] reserve endovascular treatment for patients in whom standard surgery is contraindicated, one might raise the issue of extending the stent-graft indication to all patients with traumatic injury who have rupture of the thoracic aorta, even the most favorable cases for surgical treatment, that is, those with no associated injuries. If the stent graft were to deteriorate during follow-up, a possible solution would be elective endovascular or surgical conversion in a far safer setting.

Studies must be carried out to determine the precise place of endovascular treatment in management of acute rupture of the thoracic aorta. Taking into account the small number of patients who received treatment in each center,[9] even a multicenter randomized study comparing the 2 treatment methods is illusory. We propose that an international register, similar to that kept for aortic dissection,[25] should be created to compile the results of endovascular treatment and to clearly define its indications.

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DISCUSSION

Dr Edward Diethrich (Phoenix, Ariz). What was the indication for the intervention, either operation or endoluminal grafting? Was this continued pain, pseudoaneurysm, or do you think just the presence of the lesion is indication for treatment?

What was the difference in delay, because there was a difference between the operation and the endoluminal graft, the endoluminal graft being delayed somewhat longer after the initial trauma. I wonder if this was a problem with availability of grafts?

And how were patients selected for either arm? This study went from 1998 to 2003, and I wonder if you had selected patients on the basis of availability or for some other reason.

You are known to be a conservative group. We have known you for a long time, and I think you're making a conservative conclusion here. But the data in this small series do seem to reflect that the endoluminal approach may have lower morbidity and lower mortality. Do you think that this should be encouraging for people who have the availability of these grafts to use them as the first intervention rather than operation?

Dr Philippe Piquet. The indication for treatment was the presence of the aortic rupture on the initial CT scan.

At the beginning of the study all patients underwent surgical treatment. Those with severe associated lesions were treated later because of contraindication to surgery. The development of aortic stent grafts has enabled us to progressively move to a less invasive technique and to treat patients considered at high risk for surgery. When we started our study with stent grafts the problem was essentially the availability of thoracic devices. We had to closely monitor blood pressure, and wait to receive the right aortic stent graft, usually within 24 hours. Now we have in the operating room a complete range of stent grafts in all diameters.

We definitely think that the endovascular approach is safer and less invasive than the surgical approach, and should be offered to all patients with traumatic aortic rupture.

Dr Richard Cambria (Boston, Mass). I agree with Dr Diethrich that you're being conservative in your conclusions. I won't be. This will clearly be the treatment of choice for traumatic aortic rupture in the very near future. You were fortunate to have the availability of thoracic devices in Europe. On this side of the Atlantic we end up using pieces and constructs designed for the abnormal aorta, and dealing with the restrictions of delivery systems meant to deliver devices in the abdominal aorta. We have recently treated 2 patients.

And my question really relates to follow-up and durability, not so much for your patients who received stent grafts but for those who underwent open surgery. I must say that primary suture repair without graft interposition seems a unique method of treatment for this. We've also treated a number of late aneurysms in middle-aged patients after failed surgical repair at a younger age. So my question is, where does this method of primary suture repair, as opposed to graft interposition, come into play?

Dr Piquet. In our series, 6 patients underwent primary suture repair. This type of reconstruction is well-described in the literature, and can be performed in as many as 50% of patients, when the aortic tear is limited. The arguments for such an approach are shorter cross-clamp times and reduced risk for prosthetic graft infection. All of our patients are closely monitored, and no pseudoaneurysm or pseudo-coarctation have yet developed.