Immediate Versus Delayed Endovascular Treatment of Post-Traumatic Aortic Pseudoaneurysms and Type B Dissections: Retrospective Analysis and Premises to the Upcoming European Trial

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Background—Stent grafting has been reported as a viable therapeutic option for the delayed treatment of traumatic rupture of the aortic isthmus as well as reconstruction of thoracic aortic dissections. We tested the hypothesis of whether immediate endovascular management offers clinical and pathological advantages over a delayed approach in patients with post-traumatic aortic pseudoaneurysms (PAPs) and Stanford type-B dissections (TBDs).

Methods—Thirty-one consecutive patients who were admitted with diagnosis of either PAP (n=11; 33.4±8.7 years) or TBD (n=21; 58.2±8.4 years) were respectively divided into 2 groups according to the timing of diagnosis and endovascular treatment after the traumatic or pathologic event: immediate ([lteq]2 weeks; PAP=6 and TBD=7) and delayed (>2 weeks; PAP=4 and TBD=14). Excluder®-Gore (11 in PAP and 8 in TBD) and Talent™-Medtronic (1 in PAP and 7 in TBD) endovascular stent grafts were deployed. Follow-up was performed at 3 months, 6 months, and 1 year and based on laboratory tests; chest angio-computed tomography scans of chest, abdomen, and pelvis; and transesophageal echocardiography.

Results—The endovascular procedure proved uneventful in all PAP patients who underwent either immediate or delayed treatment. In 1 PAP patient with delayed treatment, surgical removal of the pseudoaneurysm was still necessary because of further compression of the airway stem. All immediately treated TBD patients were also successful. However, in 8 of 13 TBD patients with delayed treatment (61.5%), a stent graft deployment was not possible because of complicated progression of the false lumen and multiple intimal entry tears: 1 patient benefited by fenestrations of the false lumen and 7 patients underwent medical therapy. One patient (8.3%) died because of retrograde dissection involving the aortic arch. All patients treated with endovascular stent grafts were discharged within 5 days.

Conclusions—An immediate endovascular management of PAP and TBD patients offers important advantages such as avoidance of high-risk surgical procedures and postoperative complications with short hospital stay. Moreover, it has been observed that an immediate endovascular treatment allows a safe management of all patients with complete healing of the aortic wall and regression of the pseudoaneurysm in the PAP group and thrombosis of the false lumen in TBD patients. (Circulation. 2002;106[suppl I]:I-234-I-240.)

Key Words: aorta ■ prosthesis ■ stents ■ grafting ■ surgery

Both post-traumatic injuries and dissections of the descending thoracic aorta represent conditions burdened with high mortality risk. Traumatic rupture of the thoracic aorta causes sudden death in 75% to 90% of patients, with only 15% to 20% of the victims able to enter the hospital in stable condition.1,2 Aortic dissections originating after the left subclavian artery, also known as Stanford type-B dissections (TBDs), remain a dilemma concerning their correct management because of a postoperative mortality ranging from 6% to 67%, with no significant improvement when compared with medical treatment.3 For decades, an immediate surgical resection of either the aortic segment involved in the trauma or containing the dissection entry tear, followed by interposition of a tubular prosthesis, represented the preferred therapeutic option.4 However, despite both the advent of new surgical techniques and cumulated experience, postoperative mortality and morbidity remain remarkable.5–8

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The timing of repair is still controversial.9,10 Unless a life-threatening hemothorax follows the trauma, a deliberately delayed surgical repair has been mostly reported.10 The rationale behind this trend is that in the majority of those patients that make it to the hospital alive, the adventitia and surrounding mediastinal structures remain partially intact, thus preserving the integrity of the disrupted aorta and preventing a massive intrathoracic bleeding (Fig. 1A and 1B).4

On the other hand, despite disappointing results, medical management represents the main option for TBDs, with an average mortality of 20%.5,11–12 Surgery is generally reserved for cases of persistent communication between true and false lumen without any spontaneous thrombosis of false lumen. However, the intermediate and long-term prognoses remain poor, with unpredictable risk of rupture or progression of the dissection.3,5

The technique of endoluminal aortic stent graft placement has recently been introduced for repair of abdominal and thoracic aneurysm.6,8,13 In high-risk settings such as aortic dissections or traumatic injuries of the aorta, endoluminal repair is now reported as a promising therapeutic strategy that yields encouraging results.7,12,16–19 Reported findings have so far confirmed the effectiveness of this technique for the treatment of aortic lesions on condition that an adequate level of chronicization will first be achieved. However, there are no reports in literature describing use of endovascular stent grafts in acute scenarios, that is, a few hours or days after a traumatic or pathologic event (ie, intimal tear).

We retrospectively analyzed our series to test the hypothesis whether an immediate endovascular management offers long-term clinical and pathological advantages over a delayed approach in patients with post-traumatic aortic pseudoaneurysms (PAPs) and TBDs.

**Methods**

**Selection of Patients**

Between March 1999 and October 2001, 10 consecutive patients (Group A, 9 males and 1 female, 33.4±8.7 years) admitted with clinical and instrumental diagnosis of either acute (n=6) or chronic (n=4) post-traumatic PAP of the thoracic aorta and, 12 of 20 consecutive patients (Group B, 9 males and 3 females, 58.2±8.4 years) with either acute (n=7) or chronic TBD (n=5) underwent elective transluminal endovascular stent graft placement. The remaining 8 patients of Group B underwent similar pre operative imaging studies that revealed complicated dissections in each case and, therefore, were respectively treated with beta-blockers (n=7) and fenestration of the intima (n=1). Selection criteria for endovascular treatment in both groups are reported in Table 1.

Based on the lapse of time occurring between pathologic event (trauma or dissection) and diagnosis followed by treatment, patients underwent what we termed immediate ([≤q]2 weeks) or delayed (>2 weeks) endovascular approach. In particular, 3 out of 10 patients in group A underwent treatment in emergency conditions (<24 hours from traumatic event) based on both a promptly obtained hemodynamic stability and in-house availability of stent grafts. Patients who underwent immediate treatment numbered 13 (6 PAP and 7 TBD), whereas 9 patients (4 PAP and 5 TBD) were delayed beyond 2 weeks. Demographic and technical characteristics of treated patients are reported in Table 2A, whereas a few main anatomical features are listed in Table 2B.

**Stent Graft Procedure**

All procedures were performed in the angiography suite under general anesthesia and controlled hypotension (mean arterial pressure of 70 mm Hg). An operative room equipped with a cardiopulmonary bypass machine was on stand-by in every case. The common femoral artery was surgically exposed and controlled proximally and distally. If the femoral artery appeared inadequate, the common femoral artery was surgically exposed and controlled proximally and distally. If the femoral artery appeared inadequate, the iliac artery was used for vascular access. One hundred IU/Kg of heparin were administered in each case. According to vascular anatomy, a percutaneous left and/or right brachial artery approach was selected, allowing a catheter to be inserted over a guide wire to localize the subclavian artery and the celiac axis and to be used for aortograms (Fig. 2 A and 2B). We have used 2 different stent graft devices: Talent™ (Medtronic, World Medical Manufacturing Corp, Sunrise, FL) and Excluder® (Gore, Sunnyvale, CA). Technical features and deployment of both systems have already been described in detail.16

Once the stent graft has been released, an arteriogram is made to verify a complete exclusion of the PAP or dissection and the correct perfusion through the graft without perigraft leakage (Fig. 2C). The placement system is then removed and the arteriotomy is closed in the usual manner. In all patients, a transesophageal color-Doppler echocardiogram was performance as a guide to the site of interfascial communication. A further element to consider is a short proximal neck close to the left subclavian artery. We favored the exclusion of the artery itself in all those situations (1 in group A and 4 in group B) in which a more...
proximal treatment of the aortic lesion was feasible. The left subclavian artery was promptly grafted to the left carotid artery with no immediate or long-term sequelae.

In 1 patient, we opted for the contemporary stenting of the left renal artery as a result of an inconsistent collapse of the tunicae and persistent compression exerted by the false lumen with kidney failure. Creatinine and blood urea nitrogen levels returned to baseline in 72 hours and the patient avoided dialysis.

All patients who underwent endovascular stent graft treatment were discharged in overall good condition within 5 days of the procedure.

Follow-Up
The follow-up was based on blood tests, transesophageal echocardiography (TEE), and serial 3-mm angio-computed tomography (CT) scans of the chest, abdomen, and pelvis. The first control was performed within 72 hours from the procedure to assess the position of the graft, the optimal sealing with complete exclusion of aneurysm and, in patients with dissection, the extent of thrombosis of the false lumen with perfusion of the branch vessels. New scans were then obtained at 3 (Fig. 3A), 6, and 12 months (Fig. 3B) from the procedure and scheduled once a year, with the goal of monitoring changes in the aorta and the graft.

Early mortality and morbidity included events occurring within 30 days after stent graft deployment, either in hospital or after discharge. Information about patients was obtained both from retrospective chart review and by contacting patients or their primary physicians.

The follow-up (range 1 to 30 months) was 100% complete, and its mean duration was 14.8 ± 7.8 months (Group A) and 9.7 ± 8.5 months (Group B).

Limitations of the Study
As for any study involving the application of new techniques, quite a few limitations affected our conclusions, one of which was a shorter-term follow-up, a result of the relatively recent introduction of endovascular stent grafting in the treatment of pathologies of the thoracic aorta. The short length of this follow-up did not allow us to outline an opinion regarding the resistance of the materials and their adaptability to the altered anatomy and hemodynamics.

Nonetheless, it is not possible to treat by endoprostheses the aortic arch beyond the takeoff of the left subclavian artery. Further studies are necessary to identify pitfalls related to the available materials. As a matter of fact, the possibility of treating the aortic arch and its branches, whether involved in the dissecting or aneurysmatic processes, remains obscure. The actual compounds (eg, Nitinol) are outstanding in terms of adaptability of a straight segment of diseased aorta; however, they frequently fail when the vessel geometry dramatically changes.

As for what we would have done in case of lacking “landing zones” beyond the left subclavian artery takeoff, there is not so much ground for this hypothesis. The models of stent graft that we have available do not have enough flexibility to be deployed within the aortic arch without causing consistent damages to the aortic wall or to the graft structural integrity itself. At the same time, they would not preserve the treatment from possible perigraft leakage.

### TABLE 1. Selection Criteria for Stent Graft Treatment in Patients With Aortic Post-traumatic Pseudoaneurysm or Type B Dissection

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
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<tr>
<td>1. Patients of age ≥ 18 who have undergone endotracheal intubation and general</td>
<td>1. Patients with ongoing pregnancy or malignancy.</td>
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<tr>
<td>anesthesia.</td>
<td>2. Complex dissection and course of the false lumen at preoperative angiogram.</td>
</tr>
<tr>
<td>2. Lack of vascular anomalies that interfere with stent graft insertion and</td>
<td>3. Severe respiratory failure that might preclude a possible thoracotomy.</td>
</tr>
<tr>
<td>deployment.</td>
<td>4. History of myocardial infarction or cerebrovascular accident in the last 6 weeks.</td>
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<tr>
<td>3. Diameter of the aortic segment immediately proximal to flap dissection or</td>
<td>5. Use of drugs in the last 6 months.</td>
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<tr>
<td>pseudoaneurysm &lt; 37 mm.</td>
<td></td>
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<tr>
<td>4. Maximal transverse diameter of the descending thoracic aorta &lt; 45 mm.</td>
<td></td>
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<tr>
<td>5. Patients with overall stable hemodynamic parameters.</td>
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Results
The endovascular stent graft treatment has been technically successful in all cases of post-traumatic PAPs treated either with the immediate (n = 6) or delayed approach (n = 4). Only 1 patient required conversion to elective surgery because of a large, calcified aneurysm that was still causing compression on the trachea and left main bronchus, even if totally excluded by the stent graft.

Immediate endovascular graft treatment also was successful in all 7 patients with TBD. However, in 8 of 13 patients (61.5%) with TBDs who were referred more than 2 weeks after the acute tearing of the intima, the deployment of a stent graft was aborted because of the complex course of the false lumen or because of multiple entry tears that made it impossible to distinguish the true from the false lumen. Seven of these patients were managed with an appropriate antihypertensive regimen based on beta- and calcium-channel blockers. In 1 patient, it was necessary to create endoluminal fenestrations of the false lumen that was completely obstructing the true one to re-establish an homogeneous pressure distribution throughout the aorta.

One patient (4.5%) died 72 hours after the stent graft deployment because of retrograde progression of the dissection. This individual had a past medical history of TBD, with replacement of the ascending aorta (Bentall’s technique) performed 3 years previously. He was referred to our institution with a diagnosis of asymptomatic redissection after having developed a new entry tear 2.5 cm beyond the origin of the left subclavian artery that was detected during a routine follow-up visit. This new lesion was diagnosed by the service that performed the previous intervention at least 3 months before our diagnostic survey. Despite the fact he appeared to be an excellent candidate for endovascular completion of a previous surgical procedure, the patient developed a retrograde dissection during the graft deployment and eventually succumbed 72 hours later to a massive cerebral ischemia. At the autopsy, a new false lumen was observed with complete involvement of the aortic arch and both common carotid arteries, and stopping at the distal anastomosis of the Dacron prosthesis previously implanted to replace the native ascending aorta.

The use of the stent graft systems had the following distribution: 9 patients with post-traumatic PAP and 7 with TBD received an Excluder® stent-graft whereas 1 patient with PAP and 5 with aortic dissection received a Talent™. The selection of the device was based on the vascular anatomy, course and, in some cases, the type of aortic lesion.
In 1 patient with post-traumatic PAP and 2 patients with aortic dissection who underwent delayed treatment, it was necessary to deploy more than a 1st stent graft in a "telescope" fashion. In brief, a second or even a third graft was positioned proximally to and within the first during the same procedure. This is a feasible and handy solution when some persistent leakage is observed and has already been described.17 None of the patients died during the follow-up, and no cases of perigraft leakage or aortic rupture have been detected thus far. It is also interesting to note that no structural damages, changes in position, or configuration of the graft have been observed.

**Discussion**

If a patient is candidate for stent graft treatment, 3 main factors have to be considered. For the aortic lesions we have treated, it is fundamental to locate either the wall disruption or intimal tear and the subsequent developed aneurysm. Thereafter, it is necessary that there is a distal vascular access of sufficient size and, last but not least, a limited tortuosity of the abdominal and thoracic aorta must be observed. During the preoperative assessment, we gave much attention to the determination of the proximal and distal "landing" zones of the stent graft because they serve as friction anchors at each end. As a matter of fact, grafts are generally oversized in diameter by 3 to 4 mm to allow sufficient radial force for fixation.

Our findings indicate that an immediate endovascular management of both post-traumatic aortic injuries and TBDs is not only possible but also advantageous over the generalized trend of deliberate waiting.

**Post-Traumatic PAP**

Because the isthmus is involved in more than 85% of traumatic aortic lesions, it is generally believed that managing...
these injuries with stent grafts can be impracticable because of anatomic and technical hurdles (ie, rigid devices, consistent angulation of the aortic arch, insufficient proximal anchoring length, post-traumatic instability of the aortic wall, etc). In our series, the endovascular stent graft treatment was successful in 100% of post-traumatic PAP patients in which a correctly sized and deployed device was placed within 2 weeks after the event, with complete restitutio ad integrum of the aortic wall confirmed by the regression of the PAP during the 1-year follow-up (Fig. 3C).

It has to be emphasized that the majority of patients belonging to group A were admitted with serious coexisting injuries (ie, liver laceration with intraparenchimal hematoma, hemothorax, pleural effusion, multiple fractures, head concussion) that greatly decreased the chances for surgical resection, repair, or replacement of the injured aortic as a result of the high risks associated with systemic heparinization.

In our opinion, an immediate instead of a delayed stenting of post-traumatic PAPs eliminates the risk of the lesion itself. Indeed, this process is characterized by long-term anatomic and clinical repercussions as a result of development of a calcified mass at the isthmic level. This area represents not
just a locus minoris resistentiae resulting from the constant pressure exerted from the blood, but the progressive dilation of the involved aortic segment may also lead to the development of a hard shell, exerting compression on the surrounding viscera itself. In patient 3 of group A, the PAP had to be surgically removed 2 weeks later. Despite the good sealing of the stent graft, he developed unremitting respiratory failure as a result of compression of the left main bronchus and trachea that did not resolve even after their own stenting. This situation represents a suboptimal candidate selection, hardly preventable unless it is considered that both fibrosis and heavy calcification intervene in the aortic healing process.

The evolution of the tissue processes involved in the chronic post-traumatic PAP leads to the creation of a fibrous and calcified connective within the aortic wall itself, followed by tenacious adhesions to lung parenchyma with pleural thickening.

Therefore, the natural history of untreated chronic post-traumatic PAPs is fatally destined to sudden rupture, sometimes not preceded by any clinical sign or symptom, within an indefinite number of years. In these cases, the deployment of an endovascular stent graft might save the patient from fatal complications but, at the same time, neither eliminates the possibility of compression on adjacent organs nor reduces the risks related to a persistent locus minoris resistentiae.

**TBD**

Although nonsurgical interventional techniques have been successfully introduced in the past 3 years,\textsuperscript{11,12,16} medical or surgical management remain the chosen treatment for dissections, with overall disappointing results.\textsuperscript{20,21} We have also found evident advantages relatively to an immediate endovascular approach to TBD. All 7 patients treated within 2 weeks after the diagnosis and onset of symptoms were successfully managed. In this group of patients, once the entry tear was located and the course of the false lumen carefully analyzed, the deployment of the stent graft has been performed proximally to the intimal entry tear.

There were no life-threatening complications in patients with both acute and chronic dissection included in this study. However, 3 of 20 patients showed some major complications like acute renal failure (n=1) and left lower extremity ischemia (n=2). In the first case, the origin of the left renal artery was involved in the progression of the false lumen with critical narrowing of the true lumen and significant increase of the creatinine level (2.2 mg/dL). Those 2 patients with severe left lower extremity ischemia required different management, as described ahead.

A post-operative angiogram verified the complete closure of the false lumen with progressive normalization of the blood supply to branches involved in the dissection. A CT-scan of chest, abdomen, and pelvis, performed during the follow-up at 3 months, documented a diffuse shrinking and thrombosis of the false lumen all along the dissected aortic wall.

The chance to manage all patients with chronic TBD immediately was poor. In 8 of 14 cases (57.1%) admitted with onset of dissection more than 2 weeks before admission, both the CT scan and the preoperative angiogram showed established complicated lesions such as diffuse progression of the false lumen, multiple entry tears, and hemodynamic predominance of the false over the true lumen that hampered any possibility of success. One of these patients was successfully treated with endovascular fenestration of the intima. A second patient with limb ischemia benefited from closure of the entry site achieved with a stent graft.

The remaining 7 patients who did not receive a stent graft were started on beta-blockers and periodically re-examined every 6 months.

Deployment of a stent graft in a dissected descending thoracic aorta is more challenging and potentially hazardous than repairing a PAP. Most of the problems derive from the anatomic variability with which the dissection flap can propagate distally. Therefore, the true and false lumen may appear in any of numerous complex configurations with unpredictable pattern of distribution for what concerns the origin of the branch vessels. Indeed, 1 of the main pitfalls is that the perforation of the flap caused by the passage of the stiff guide wire. However, our experience,\textsuperscript{16} as well as those of others,\textsuperscript{11,12} suggests that this technique can now be considered as an effective alternative to open surgery. The final goal, similarly to surgical obliteration, is to cover the entry tear and redirect the blood flow exclusively into the true lumen. Once the stent graft has been correctly positioned, aortic stability is achieved by both thrombosis of the false lumen and the endoprosthesis itself within approximately 3 months.\textsuperscript{12} Even if only partial thrombosis of the false lumen is obtained, the stent graft may protect the false lumen from enlarging over time, therefore avoiding the risk of aortic rupture or visceral ischemia.

It has to be noted that no cases of paraplegia were encountered in both groups of our series. It is known that the sudden deployment of the stent followed by the occlusion of the intercostal branches does not produce a steal syndrome in the perfusion of the spinal cord.\textsuperscript{13} In patients with TBD, the use of short stent grafts and placement far from the vertebrae T8–L2 further minimizes the risk of paraplegia as compared with risk related to surgical aortic replacement.

Data gathered in our retrospective study represent a first step toward a new frontier. The concurrent advancement of technology, the minimally invasive treatment of more complex pathologies, and the biocompatibility of materials will inevitably involve emergency situations that were exclusively managed with surgery in the recent past. The use of endovascular prostheses is definitely progressing in that direction, with the concrete possibility to definitely treat primary lesions of the aorta and prevent further evolution toward rupture or visceral ischemia. We are confident that larger series and prospective randomized trials will confirm this trend. Therefore, these preliminary data constitute the basis of an upcoming randomized European academic trial about the acute endovascular treatment of thoracic aortic pathologies.

**References**


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