Successful endovascular repair of aortic aneurysms has ignited great enthusiasm because of the minimally invasive aspects of this therapeutic modality. Delivery of the endovascular device to the aneurysm from a remote site requires use of the iliac and femoral arteries for access. These vessels are frequently diseased and may impede the device navigation through diseased iliac arteries. Auxiliary techniques used to extend or enhance implantation sites were elephant trunk graft (n = 2), the construction of renovisceral bypass grafts (n = 1), and subclavian artery transposition (n = 2). Plication of the common iliac artery at its bifurcation was performed in conjunction with femorofemoral bypass graft in nine patients to allow preservation of pelvic circulation by avoiding internal iliac artery sacrifice. Construction of a bypass graft to transpose the internal iliac artery orifice was performed in one patient. The auxiliary techniques used to facilitate device navigation were iliac artery angioplasty or stenting (n = 8), external iliac artery endovascular endarterectomy or straightening (n = 14), endoluminal iliofemoral bypass conduit (n = 5), and the construction of an open iliofemoral bypass conduit (n = 8).

**Results:** Successful deployment of the endovascular devices was achieved in 49 (98%) of 50 patients. Auxiliary techniques were successful in providing access for endovascular device deployment in all 35 patients (100%). Mean follow-up for techniques to facilitate device navigation was 26 months for endovascular procedures and 42 months for the open bypass graft construction patients; no occlusions were observed at this moment. There were five patients with incisional hematomas that did not necessitate intervention. Fourteen (94%) of 15 patients underwent successful device implantation after the auxiliary maneuvers to enhance implantation site. Mean follow-up for implantation site manipulation is 28 months. One of the subclavian transpositions had a new onset of Horner’s syndrome, two of nine patients who had common iliac artery ligated had retroperiitoneal hematomas that did not necessitate interventions, and no colon ischemia was seen. The patient who underwent nonanatomic bypass grafting of visceral-renal arteries had a retroperiitoneal hematoma that necessitated reexploration.

**Conclusions:** Significant coexisting arterial disease may be encountered in patients with aortic or iliac aneurysms. Identification of coexisting arterial disease is essential to help tailor the appropriate surgical procedure to allow the performance of endovascular aneurysm repair in patients who would otherwise require open surgical repair. (J Vasc Surg 2001;34:69-75.)
Table I. Maneuvers to facilitate device insertion/navigation: results and complications

<table>
<thead>
<tr>
<th>Procedural outcome</th>
<th>Actual no.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence</td>
<td>35/50</td>
<td>70</td>
</tr>
<tr>
<td>Device navigation success rate</td>
<td>35/35</td>
<td>100</td>
</tr>
<tr>
<td>Complications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematoma</td>
<td>5/15</td>
<td>33</td>
</tr>
<tr>
<td>Reexploration</td>
<td>0/15</td>
<td>0</td>
</tr>
<tr>
<td>Iliac artery rupture</td>
<td>0/15</td>
<td>0</td>
</tr>
<tr>
<td>Iliofemoral occlusion</td>
<td>0/15</td>
<td>0</td>
</tr>
</tbody>
</table>

PATIENTS AND METHODS

Demographics

From January 1, 1993, to December 31, 1999, 390 patients with aortic and aortoiliac artery aneurysms were treated with endovascular stent-grafts. Of the 390 patients, 50, or 12%, required adjunctive vascular procedures to enable endovascular exclusion of their aneurysm. All data about each patient were recorded prospectively in a vascular registry. The mean age was 76 years; 85% were men.

Endovascular devices

The devices used in patients requiring adjunctive surgical procedures were Talent (WorldMedical, Fort Lauderdale, Fla), Gore Excluder–Thoracic and Abdominal (Gore Inc, Sunnyvale, Calif), Vanguard (Boston Scientific, San Jose, Mass), AneuRx (Medtronics, Calif), and Parodi-type (custom-made device described elsewhere). In addition, all devices under investigation were performed with industry-sponsored IDE protocol under the guidelines of our institutional review board committee.

Auxiliary therapeutic modalities

Facilitating endovascular device delivery. The main factors prompting the use of auxiliary techniques were access vessel tortuosity or the presence of occlusive disease. The following maneuvers are described according to the various arterial diseases and their corresponding interventions used to correct the lesion:

1. Iliac artery angioplasty. Eight patients with short segment stenotic iliac lesions were treated with balloon angioplasty of the iliac vessels before stent-graft insertion. After endograft deployment, a 10- to 12-mm Wallstent (Wallstent, Schneider; Boston Scientific Corp, Natick, Mass) was deployed in the predilated segment to prevent arterial recoil.

2. Endoluminal balloon endarterectomy. Extensive external iliac artery stenosis was treated with endoluminal balloon endarterectomy in five patients. The technique uses multiple balloon inflations throughout the occlusive external iliac arterial segment with removal of atheromatous debris through the femoral arteriotomy site (Figure, A). Subsequent stent insertion was used to prevent arterial restenosis.

3. Endoluminal conduit. An endoluminal polytetrafluoroethylene (PTFE) conduit was used in five patients with long-segment external iliac artery stenosis, in whom endoluminal endarterectomy carried a high risk for arterial rupture. A Palmaz stent (Cordis; Johnson and Johnson Interventional Systems, Warren, NJ) was sutured into a 6-mm PTFE conduit and backloaded into a 6F device system. The Palmaz stent was deployed over the orifice of the internal iliac artery with the graft extending to the external iliac artery. The entire length of the external iliac artery was then dilated from within the PTFE graft with noncompliant (6-8 mm in diameter [Diamond, Boston Scientific]) (Figure, B). The endoluminal conduit was implanted into the distal external iliac artery in two cases, and an endoluminal handsewn anastomosis in the common femoral artery was used in the remaining three cases.

4. External iliac artery straightening. For tortuous external iliac arteries, manual retroperitoneal dissection was used to straighten the redundant arterial segment in nine cases. Once mobilized, the redundant and tortuous segment was excised.

5. Iliofemoral bypass conduit. In six patients, with severe occlusive disease associated with marked tortuosity involving the entire length of the iliac artery, an iliofemoral bypass graft was constructed through a retroperitoneal incision. The extraluminal iliofemoral bypass conduit served to improve lower extremity arterial flow and to allow device navigation to the aorta through the bypass conduit. An iliofemoral bypass conduit was also constructed in two additional patients with small caliber external iliac arteries (<5 mm in transverse diameter). In these patients, the bypass graft was removed after endovascular aneurysm exclusion by the stent-graft.

Implantation site modification. Modification of the proximal and distal implantation sites was categorized into two groups: manipulating directly to enhance the target site to achieve a complete seal of the aneurysm by the device or bypassing essential aortic branches, thereby extending the inadequate neck to a proximal, more favorable aortic segment. Each of the specific anatomic presentations and their corresponding maneuvers are described below:

1. Preservation of pelvic arterial blood flow in patients with bilateral iliac artery aneurysms. In nine patients with AAAs with extension to the common iliac arteries, an aortouniiliac endograft was performed with embolization of the ipsilateral internal iliac artery. This maneuver involves plication and division of the iliac bifurcation via the retroperitoneal approach to allow retrograde filling through the femorofemoral bypass graft to the patent internal iliac artery. Another patient had a bilateral internal iliac artery orifice relocated to a distal portion to allow stent-graft implantation in the external iliac artery segment. This patient had a history of descending aortic aneurysm repair before elective stent-graft repair of the AAA. The rationale to
perform bilateral internal iliac bypass grafts was to minimize the potential neurologic sequelae from cessation of arterial perfusion of the internal iliac artery.

2. Subclavian artery transposition. In two patients deployment of the thoracic endovascular device across the origin of the left subclavian artery orifice was necessary because of insufficient length for device implantation. After, with the confirmation that the left common carotid artery was free of significant occlusive disease, subclavian artery transposition to the left common carotid was performed before aneurysm repair to preserve L upper extremity perfusion.

3. Elephant trunk type aortic arch repair used as a proximal implantation site for endograft. In two patients elephant trunk repair had been performed previously for acute type A aortic dissections. Subsequently, both patients went on to have large descending aortic aneurysms necessitating intervention. In these cases the graft material from the arch reconstruction was used as a proximal implantation site or neck to anchor the stent-graft.

4. Staged extra-anatomic visceral vessel reconstruction and subsequent endovascular aortic grafting. Extra-anatomic bypass to superior mesenteric and renal arteries was performed in one patient before the aortic stent-graft repair. After a brief period of recovery the thoracoabdominal aneurysm was performed with exclusion of the aneurysm.

RESULTS
Fifty (12%) of the 390 patients undergoing endovascular repair of their aneurysms required adjunctive surgical procedures. Thirty-five (70%) underwent procedures to facilitate endovascular device delivery. Fifteen (30%) required modification of the proximal or distal implantation sites.

Facilitating endovascular device delivery. A summary of results and specific complications is displayed in Table I. All 35 procedures performed to facilitate device delivery were performed in the iliofemoral vessels. These procedures improved arterial access and permitted safe device navigation in all cases. The mean follow-up for endovascular iliofemoral interventions is 26 months. The mean follow-up for conduit bypass graft procedures is 42 months.

To date, all conduits remain patent. There were no episodes of iliac artery rupture during device navigation.
Access site hematomas were diagnosed in five (14%) of the 35 patients. All hematomas were controlled by manual compression of the access site. No patient required a return to the operating room for a second intervention.

**Implantation site modification.** A summary of results and specific complications is displayed in Table II. One patient who underwent subclavian artery transposition had a new onset of Horner’s syndrome, which spontaneously resolved 3 months postoperatively. No other peripheral nerve injuries were associated with this procedure.

Nine patients have undergone common iliac artery ligation with a mean follow-up of 23 months. Two patients went on to have retroperitoneal hematomas immediately after the procedure that were not hemodynamically significant. None of these patients required surgical reinterventions or blood transfusions. No symptoms of colonic ischemia were seen after this procedure. At the time of this report, no new onset of pseudoaneurysms or stump ruptures has been observed on follow-up imaging studies. Two patients previously treated with the creation of an elephant trunk graft for aortic dissection had descending aortic aneurysms. One patient underwent successful stent-graft repair by anchoring the proximal stent into the elephant trunk graft. The second patient had bilateral common iliac artery involvement by previous extension from an aortic dissection with subsequent development of aneurysm disease. Access to the iliofemoral arteries was not possible in this case, which constitutes the only failure of treatment on an “intent to treat” basis. The presence of complex vascular anatomy in combination with severe comorbidities in this frail patient precluded the performance of any other auxiliary maneuvers.

One patient with an extra-anatomic reconstruction of the visceral and renal vessels done before stent-graft repair for a thoracoabdominal aneurysm needed to undergo reexploration because of bleeding from the renal artery ligation. Currently, this patient is alive and doing well.

**DISCUSSION**

Because of its minimally invasive nature, endovascular stent-grafting constitutes an important therapeutic option, especially for the treatment of complex aortic disease. Endovascular treatment of arterial aneurysms requires normal arterial segments immediately adjacent to the aneurysmal area for adequate device anchoring. The presence of short-length attachment sites can complicate the choice of a proximal implantation site, which can potentially cause insufficient apposition of stent-graft to normal arterial wall, compromising the longevity of the repair. Wolf et al have published the eligibility rate of patients with aortic aneurysms to have endovascular repair on the basis of a large number of patients studied in the phase II AneuRx trial published in this journal. Inadequate proximal implantation site was the main cause for excluding patients for receiving endografting of AAA. However, in interpreting the data, one must take into consideration the fact that only one stent-graft was used in this cohort and patients were strictly controlled by rigid inclusion criteria of the trial.

It is well-known that patients with AAAs or thoracic aortic aneurysms have other concomitant arterial diseases that may complicate or even exclude them from receiving endovascular stent-graft therapy. Distal implantation sites can be problematic in the presence of common iliac artery aneurysms, which not only complicate the selection for an adequate implantation site but also present a challenge as to how to preserve the internal iliac arteries and prograde pelvic flow. Henretta et al have also reported their incidence of significant coexisting occlusive diseases of the access vessels, especially in regard to the iliofemoral segments, in 74 patients treated for aortic aneurysms with endovascular stent-grafting. Currently, the incidence of significant coexistent arterial disease initially impeding endovascular repair of their aortic aneurysms is unknown.

Coexisting atherosclerosis in the iliofemoral system is the most common problem encountered in these patients, which is also the most common access site used for device insertion. When an access site is chosen, the arteries must be relatively free of disease, thus allowing navigation of the delivery system through them to the aneurysmal aorta. However, currently available devices have large and non-steerable delivery systems, which can cause iliofemoral...
Most of these patients did not have significant injuries during insertion of the device at a rate of 5% to 17%.

Adequate proximal arterial circulation by the stent-graft requires exclusion of the aneurysmic sac from the main conduit, which was constructed through a retroperitoneal eased iliac segment was avoided by allowing device navigation of the delivery system. Several modalities were used in the treatment of the iliofemoral disease, including balloon angioplasty, endarterectomies, and the construction of extraluminal and endoluminal conduits to facilitate device navigation.

The simplest treatment modality for focal iliac artery stenosis is balloon angioplasty, which can sufficiently dilate the vessel to allow the device to safely traverse the lesion. This was used in eight of the 35 patients. After stent-graft deployment, stenting can be performed to prevent recoiling of the lesion. Iliac stents were not placed before stent-graft insertion in this series because of the theoretical risk of the stent migration during the insertion of the delivery system.

Several supplemental maneuvers were used to correct more complex iliofemoral lesions. For mildly calcified arteries with significant tortuosity, digital dissection allowed full exposure and straightening of the redundant external iliac artery, thus decreasing the potential risk of perforation by the delivery system. Frequently, the iliac arteries are diffusely stenotic. Closed endarterectomy can be performed in these stenotic vessels with multiple segmental balloon dilations throughout the diseased segments. With the use of this technique, atherosclerotic debris is extracted from the femoral arteriotomy site. For patients with iliac arteries free of tortuosity but with long, circumferential, nearly occlusive disease, intraluminal iliofemoral bypass grafts were used to permit dilation of a long stenotic segment of the iliac artery. This supplemental maneuver eliminates the risk of iliac artery rupture by inadvertent angioplasty, because the severely diseased vessel is protected by the intraluminal bypass graft. The combination of severe occlusive disease with tortuosity can represent one of the most extreme disease presentations in the iliac artery system. For these patients, the entire diseased iliac segment was avoided by allowing device navigation through an extraluminal iliofemoral bypass conduit, which was constructed through a retroperitoneal approach.

Successful endovascular repair of aortic aneurysms requires exclusion of the aneurysmic sac from the main arterial circulation by the stent-graft. Adequate proximal and distal implantation sites must be present to allow the device attachment mechanisms to anchor at these sites to ensure long-term repair durability. Insufficient length of a normal-caliber artery or accentuated angulations of the implantation site may make endovascular repair impossible. Ancillary procedures that were performed to allow implantation of the endovascular device can be conceptually subdivided into (1) procedures applied directly on the implantation site to enhance arterial anatomy and (2) procedures that allowed relocation of the implantation site to a more favorable anatomy.

For AAAs extending into the iliac arteries, endovascular repair may be performed with an aortouniiliac device. An occluder device is used to prevent aneurysm perfusion through the contralateral common iliac artery after a construction of a femorofemoral bypass graft to establish circulation to the contralateral lower extremity. However, this approach is not feasible when both common iliac arteries are aneurysmal. In our series, 11 patients had bilateral coil embolization of their internal iliac arteries to allow device deployment into the external iliac arteries distal to the iliac aneurysms. This maneuver carried an incidence of pelvic ischemia as high as 51%. Thus, it has been our policy to preserve at least one of the internal iliac arteries by performing ligation with subsequent disconnection of one common iliac artery at the iliac bifurcation to preserve pelvic circulation from the remaining internal iliac artery. This supplemental procedure makes the anatomy suitable for treatment with an aortouniiliac or femoral device. In these cases, both arterial stumps are oversewn with reinforcing pladgets. No signs of stump pseudoaneurysm have been detected in these patients; however, continued observation is needed to assess the integrity of the remnant common iliac artery stump. Recently, our preferred method of preserving prograde pelvic arterial flow is by relocating the internal iliac artery inflow to a segment of the external iliac artery, as described by Parodi and Ferreira.

Another supplemental technique that was used to treat a large thoracoabdominal aortic aneurysm involved the construction of an extra-anatomic renovisceral bypass graft to allow ligation of these vessels. This maneuver can simplify the operative strategy in patients who require reoperations by avoiding technical difficulties of exposing the aorta. In addition, viscero-renal ischemia does not occur, thus reducing the overall cardiovascular disturbances and end-organ ischemia. After recovery from this initial staged treatment, a stent-graft was deployed to treat a long-segment aorta involved by aneurysm with inconsequential graft coverage of otherwise essential aortic branches.

Subclavian artery transposition was used in patients whose thoracic aneurysms began close to the subclavian artery. In two cases in which this supplemental technique was performed the endovascular stent-graft covered the original orifice of the artery to ensure sufficient apposition of the stent-graft to the proximal neck. The patency rate for occlusive lesions of these vessels treated by constructing subclavian-carotid bypass grafts carries an excellent
REFERENCES


Submitted Nov 15, 2000; accepted Feb 26, 2001.

DISCUSSION

Dr O. William Brown (Southfield, Mich). I certainly want to congratulate you on some of these most innovative techniques in facing these very difficult problems. I guess my question would be, certainly in high-risk patients with a great deal of medical problems, we would use these. Have you extended this now to try to use these techniques, such as an iliofemoral graft, in all patients regardless of their preoperative medical status?

Dr Osvaldo Yano. I think that is a very broad question. It goes back to technology, if the repairs are durable or not. I think that is a topic of its own right there. We have used actually retroperitoneal approaches and iliofemoral bypass constructions for patients who had small access vessels. The vessels do not have to be necessarily diseased, but if you have a thoracic aneurysm and because the stent-graft device is quite large and if you have somewhat small iliac vessels, the stent-graft device may not be able to pass safely. Dr Hollier’s philosophy is to go ahead and operate in patients who have very low medical comorbidities and reserve aorto-endografts for the high-risk patient population. Just last week we removed a stent-graft because the distal graft migrated, and that was 3 years after repair. Clearly, durability at this point is the main issue with technology.

Dr Roy Greenberg (Cleveland, Ohio). I enjoyed your paper, and we actually share many of your beliefs in terms of how to manipulate the iliac arteries prior to or during an endovascular repair. My question relates to the timing of changing your approach. Our feeling is that when we start on the procedure, our
first shot is our best shot. Otherwise, if we damage the iliac artery while we are trying to do an endovascular repair, you are backpedaling, and your ability to save a hypogastric artery or do another procedure is lost. Are you attaching a conduit for most of these procedures, or are you deploying another stent-graft so that you can angioplasty the iliac system with impunity? Are you performing this procedure as a planned procedure, to be done prior to attempted passage of the stent-graft, or is it being performed as a bailout procedure when you cannot pass your device safely through the iliac arteries?

Dr Yano. As you can see the anatomies that we showed in this presentation have quite severe occlusion and tortuosity associated with the access vessels. All of these maneuvers were done before any problems happened. I think that is the key message of this talk. If you have a patient who had coexistent severe arterial disease, number one, you should know the anatomy, and number two, you should know the limitation of the device. If the device is not steerable and you know that, you should not go ahead and push the device capabilities to negotiate a very tortuous occlusive disease vessel. You should go ahead and do this before you have a problem.