

# TEVAR Access, Delivery, and Fixation

Key considerations and new developments to achieve optimal endograft placement.

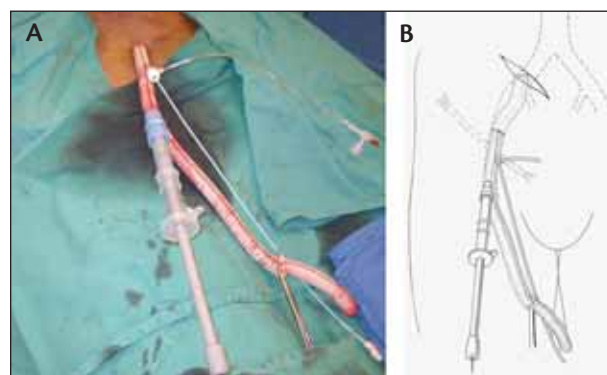
BY FRANK J. CRIADO, MD

**T**horacic endovascular aortic repair (TEVAR) has impressively become one of the most remarkable success stories in modern-day cardiovascular medicine. Rapid advances in technology and procedural breakthroughs have contributed to the achievement of a near-complete transformation of the whole field of thoracic aortic surgery less than 15 years after the first report by Dake et al<sup>1</sup> on stent graft repair of thoracic aortic aneurysms (TAAs). TEVAR promises to replace the traditional surgical standard of care for treatment of most—if not all—thoracic aortic pathologies in the not-too-distant future. The horizon is broad and limitless, and tomorrow promises to become even brighter. Having said that, it is only fair to state that there remain several unmet needs and unconquered areas, mainly on the device technology side, such as branched endografts and solutions for the ascending aorta and total arch.

TEVAR procedures can be challenging and, at times, extraordinarily difficult. They require seasoned endovascular experience and refined skills. Of all endovascular procedures, assessment of anatomy and preoperative procedure planning are absolutely paramount to produce optimal outcomes in TEVAR. Impeccable technical execution is, of course, of great importance. This article discusses some of the fundamental technical steps that have been found to be critical to achieve optimal thoracic endograft placement in the author's 10-year experience with more than 400 TEVAR procedures.<sup>2</sup>

## ACCESS

Access strategies and techniques are crucial. The reasons are twofold. First, TEVAR devices require a large-profile delivery system—often 22 F to 27 F (outer diameter). This



**Figure 1.** Iliac conduit technique. This 10-mm-diameter Dacron graft allows introduction of the TEVAR delivery system and (via a second more proximal puncture) a 5-F sheath for the diagnostic pigtail catheter (A). Exiting the conduit through a small stab incision just above the inguinal ligament provides for a smoother angle of entry (B).

reason clearly necessitates the presence of large, femoral-iliac arteries and represents a significant contributor to the risks of access-vessel injury. Vessel-access injury continues to be the most significant cause of serious morbidity and even mortality related to thoracic endovascular procedures. Second, unlike abdominal stent graft repair, female patients make up >30% of TEVAR subjects. Notoriously, they tend to have small arteries, which compounds the first set of problems described.

Although a small-incision femoral artery cutdown is obviously desirable and sufficient to achieve satisfactory endovascular access in at least 70% to 80% of the cases, it is not unusual to have to tap into a larger, more proximal vessel (ie, the common iliac artery) to achieve an adequate



**Figure 2.** Probing of access arteries with graduated Coons dilators.



**Figure 3.** The thoracoabdominal aorta can be geometrically difficult to navigate with TEVAR devices.

entry for introduction of the thoracic endograft device. The common iliac artery conduit technique is well established and tends to be safe and effective, but attention to detail is paramount to produce best results and avoid complications (Figure 1).<sup>3</sup> I can certainly endorse adhering to the dictum, “The best time to opt for an access conduit is when you think you might need one.” Attempts at forceful device introduction through small-caliber and often diseased external iliac arteries are fraught with danger. Access-related arterial rupture (most frequently at the proximal external iliac) is at best messy, highly morbid, and always potentially fatal. One additional technique I have used extensively in my experience is the probing of proposed access vessels with Coons dilators (Cook Medical, Bloomington, IN) (Figure 2). It is a safe and very useful maneuver that can easily clarify the issue of whether the interventionist should attempt transfemoral introduction or go straight to an iliac conduit. Another dictum to keep in mind is, “When in doubt about adequacy of access arteries, probe with Coons dilators first.” They come in a set, in 2-F increments, up to 24 F in diameter. There is no point in going further if, for instance, a 22-F Coons dilator will not pass without excessive force while planning to use a 22-F or 24-F thoracic device. Probing with the endograft itself is foolish, dangerous, and may result in the waste of a very expensive device.

## DELIVERY

*Delivery* refers to the advancement of the endograft-car-

rying catheter or sheath from the entry site to the intended target zone in the thoracic aorta. As such, delivery and access are essentially inseparable, with considerable overlap of the various considerations. However, there are some specific issues beyond access that apply to delivery. Unlike those used by some interventionists in the early days of TEVAR 6 to 10 years ago, present-day thoracic systems, both approved and investigational, tend to negotiate the aortic anatomy quite well and are

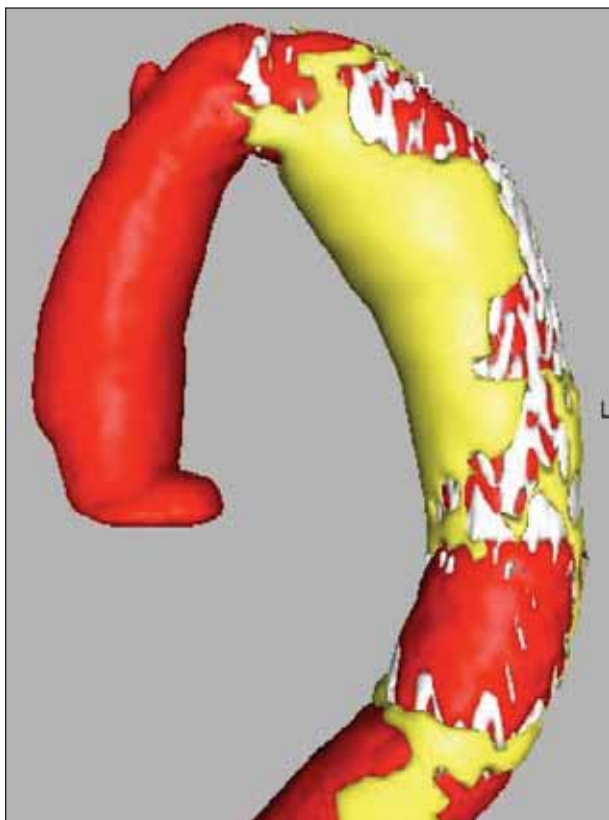
deliverable to the arch without much difficulty. Only extreme cases of unfavorable anatomy would prevent deliverability of a TEVAR device at the present time; such situations are relatively infrequent. Beware of marked S-shaped configurations in the thoracoabdominal aorta because they can be quite tricky and, at times, impossible to pass with TEVAR systems (Figure 3).

## DEPLOYMENT

Deployment issues tend to be device specific and will not be discussed in this article, but it is pertinent to review a few general principles. The induction of hypotension, or even asystole, continues to be practiced by a few experts in the field. However, there is little, if any, evidence that this is necessary at all. In fact, some experts would argue that the use of vasodilators to induce hypotension might be counterproductive because of the resultant increased flow that may be more likely to displace the device downstream during initial deployment. I tend to use hypotension only at the time of balloon dilatation (of the fixation and modular overlap zones).

With one exception, all TEVAR systems that I am aware of call for gradual uncovering and release of the endograft as the sheath is pulled back. Care must be exercised to avoid an unnecessary windsock effect that may, in some cases, lead to instability or even migration or displacement of the proximal end of the device.

The absolute need for continuous fluoroscopic visualiza-



**Figure 4.** Sharp arch knuckle with device placement just below it.

tion throughout these maneuvers is a key consideration from one end to the other.

## FIXATION

Fixation of the endograft to the aortic wall is, of course, what this procedure is all about. There is near-universal agreement on a few fundamental principles. Length is crucial. Two centimeters of normal (or near-normal) healthy cylindrical aorta (neck) is the absolute minimum for optimal results, and 3 cm is even better. Appropriate oversizing of the endograft (in relationship to the diameter of the native aorta) is believed to be very important. Generally, 15% to 30% oversizing is often advised in the context of TAA treatment. Practically speaking, this amounts to 4 mm or occasionally more. Treatment of acute aortic dissection, on the other hand, should be performed with minimal (2 mm) or no oversizing (using the nondissected distal aortic arch as the target segment for measurements and device sizing).

Both fixation length and degree of oversizing should increase correspondingly with increasing aortic diameter at the neck. Although fixation and seal go hand in hand, they are two different functions, and one can exist without the



**Figure 5.** Nonconformity to arch bend.

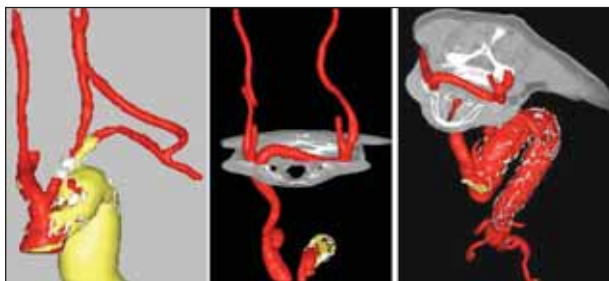
other. There is no consensus or evidence on the real need for providing TEVAR devices with active fixation (ie, hooks or barbs).

## PROXIMAL FIXATION

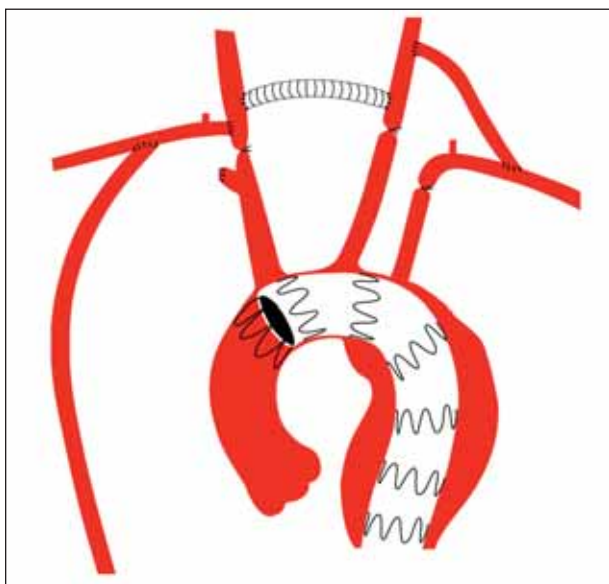
The proximal fixation target in the majority of TEVAR procedures will be adjacent to or within the aortic arch, which is perhaps the biggest challenge of all. The aortic arch has been appropriately termed the *Achilles' heel* of TEVAR. The reasons are multiple and relate mainly to anatomy. The aortic arch is geometrically challenging and contains critical branches. Additionally, worsening anatomy and disease tend to occur increasingly with advancing age, which is a common feature of many patients with TAA.

## Geometric Challenges

The *arch knuckle* refers to the area in the distal arch that transitions into the descending thoracic aorta (Figure 4). It represents a significant potential problem because presently available devices cannot conform to such geometry, especially along the lesser curve. Landing or fixating in this area can lead to potentially fatal disaster in the worst-case scenario or, at a minimum, an unsatisfactory cosmetic appearance (Figure 5). Resolution of these issues will be forthcoming in the future as new device iterations address such limitations by creating more flexible and conformable designs, or even precurved endografts. Until then, we should strive to avoid these potentially serious problems by not landing within or across the knuckle. Fixating the endograft below the bend is simplest. However, more frequently, the better option will be a more proximal landing within the transverse portion of the arch. The implications of such a strate-



**Figure 6.** Left carotid-axillary bypass (left side) and crossover carotid-carotid retropharyngeal bypass.

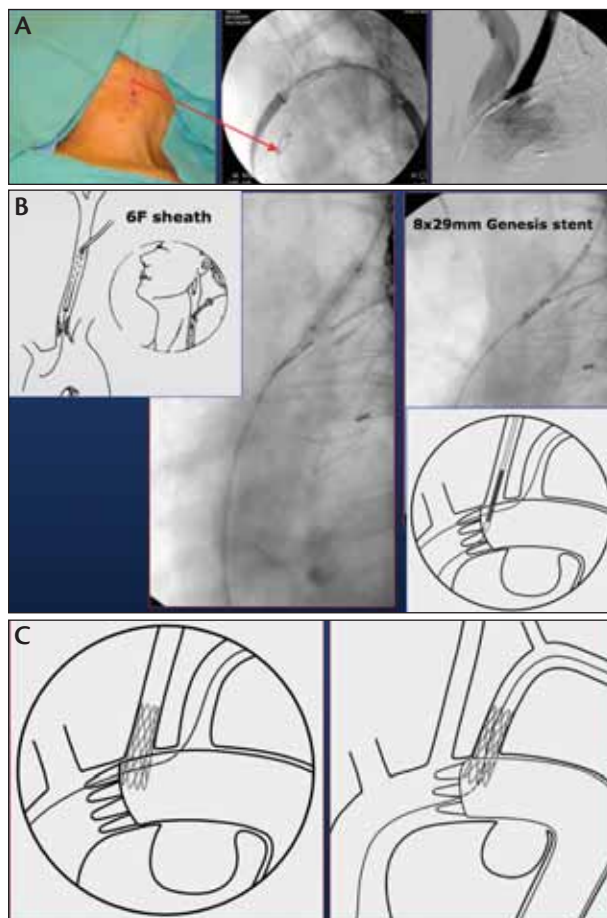


**Figure 7.** Right femoral artery-based bypass to all arch branches for total extrathoracic debranching.

gy are significant because important branches will need to be addressed.

## Branch Challenges

Arch branch issues have been present in >30% of all procedures and represent some of the biggest issues in TEVAR, in my experience.<sup>2</sup> Adherence to the important principle of achieving a minimum 2-cm-long proximal fixation neck often implies the need for debranching—that is, the performance of preliminary, or occasionally simultaneous, bypass/transposition cervical operations to produce a longer and more suitable segment of nonaneurysmal aorta within the arch for endograft fixation and seal. The most common procedures relate to the left subclavian and left common carotid arteries (Figure 6). Total arch debranching is also possible but implies the need for a transsternotomy ascending aorta-based bypass to all (or at least two) of the arch branches, followed during the same operation or subsequently by retrograde endograft placement across the



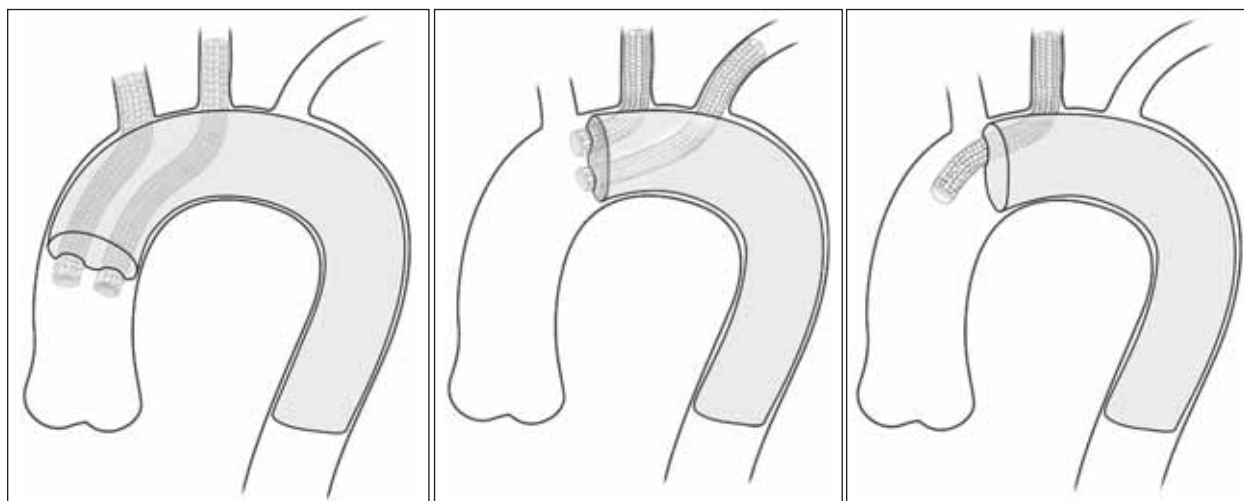
**Figure 8.** Near-total coverage of the left common carotid artery after stent graft placement. Retrograde catheterization of the artery performed as a preemptive move with placement of a micropuncture wire into the ascending aorta (A). Balloon-mediated dilatation and sizing at the vessel origin followed by advancement of balloon-expandable stent (B). Stent deployed to restore patency and normal antegrade flow (C, left); a similar technique can be used for the left subclavian artery (C, right).

entire arch. There have also been anecdotal reports of one-session operations with antegrade deployment of the thoracic endograft.<sup>4</sup> Lastly, there is a technical option to achieve total arch debranching, which can be performed completely extrathoracic (without opening the chest) (Figure 7). I have had the opportunity to perform this femoral artery-based bypass to all arch branches only twice, on rather unusual patients who could not have or tolerate a median sternotomy or partial clamping of the ascending aorta.<sup>5</sup>

## Branch Preservation

This is a new option that we first considered in 2002 in two cases where percutaneous retrograde catheterization





**Figure 9.** Various endobranching technical options using covered stent devices, with or without additional endoluminal bare-stent reinforcement for additional compression resistance.

and stenting of the left common carotid artery became necessary as a troubleshooting strategy to re-establish normal antegrade flow after unintentional endograft coverage. My experience has grown to 14 cases at present, and I now use it preferentially in most procedures in which arch branch coverage (one or two vessels) or significant encroachment seems likely or unavoidable. The techniques have been described in some detail and are relatively straightforward because they use standard interventional maneuvers and devices.<sup>6</sup> They are based on the placement of a balloon-expandable bare-metal stent that breaks the seal and apposition of the endograft in a small focal area, restoring normal vessel patency and flow (Figure 8). Although a theoretical possibility, endoleak has not occurred in any of these cases. The concept has now been expanded to the creation of “chimney” grafts,<sup>7</sup> whereby the operator can conceptually expand the reach of these techniques to exciting new horizons. For instance, a covered stent, such as a Gore Viabahn (Gore & Associates, Flagstaff, AZ) or a Bard Fluency (Bard Peripheral Vascular Inc., Tempe, AZ), can be deployed transluminally across the arch or even into the ascending aorta via retrograde catheterization of the left brachial subclavian artery and/or left common carotid artery and potentially the right carotid innominate arteries as well. This is followed during the same procedure by the deployment of a thoracic endograft in the arch, achieving partial or total endovascular arch replacement with preservation of antegrade flow into one, two, or all branches (Figure 9).

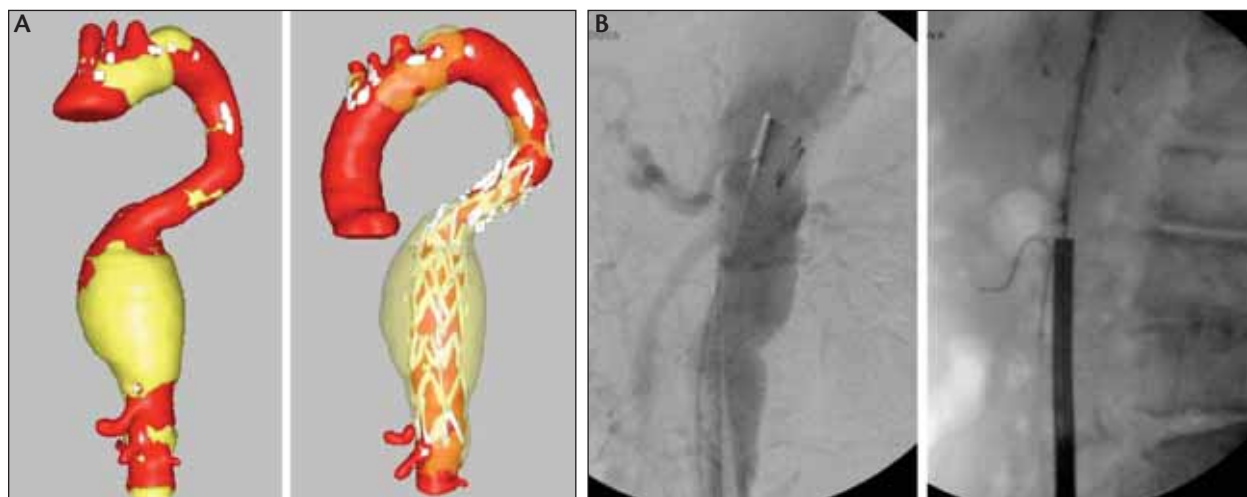
If necessary, the interventionist may consider adding a bare-metal self-expanding stent inside the covered stent device to enhance its compression resistance as it lies trapped between the aortic wall and the adjacent thoracic endograft—likely posterior or posterosuperior. My experi-

ence with chimney arch grafts is rather limited because I have performed only two such cases so far, but it is clear these new techniques have great potential. I propose *endoconduits*, *branch internalization*, and *endobranching* as possible names for such emerging techniques for preserving normal antegrade branch flow in the context of endograft repair of the aortic arch.

Although it is undeniable that the concept of true branched endografts is the most appealing as an endovascular solution to the total arch, formidable technological and procedural challenges must be overcome before such devices become widely available—likely several years into the future. In the meantime, more traditional cervical debranching techniques and perhaps other creative hybrid techniques<sup>8</sup> will serve many patients well. The new and emerging endobranching options herein described may also provide useful and even exciting interim solutions to expand the reach of endograft intervention in the aortic arch and beyond. Before considering adoption, the reader is forewarned that significant unanswered questions surround these new approaches. They relate to important areas such as safety and effectiveness, the potential for seal disruption and endoleak, and mainly perhaps the untested potential for adverse events related to possible graft integrity problems caused by device interaction over the long term.

#### DISTAL FIXATION

Although much less attention has been paid to this aspect of TEVAR procedures, distal fixation is an important technical step because there can be no durable success without secure and stable fixation and seal at the distal end of the repair. The general principles in terms of fixation



**Figure 10.** Pre- and post-TEVAR 3D images of a large juxtaceliac TAA with limited distal neck for fixation and seal (A). Retrograde catheterization of the SMA with placement of an indwelling catheter performed to help with anatomic outlining during device deployment and to provide ready access for vessel stenting in case of unintentional SMA coverage after deployment (B).

length and other aspects are identical to those already discussed. However, additional consideration must be given to the visceral segment of the aorta where the need for vessel branch exclusion and extra-anatomic bypasses are now emerging as an innovative and frequent option at the present time. A complete discussion of visceral debranching would be well beyond the scope of this article. However, I will discuss coverage of the celiac artery. Exclusion without revascularization of this vessel is probably well tolerated by most patients.

Nonetheless, this is not universally true; there have been several anecdotal reports of serious and even catastrophic and fatal complications resulting from celiac artery coverage. So, the undertaking of such a maneuver should not be decided upon without serious consideration of potential complications, and performed only when deemed absolutely necessary to achieve an optimal TEVAR result. In such a context, and particularly when there is only a short distance between the celiac and superior mesenteric artery (SMA) origins, I have found it prudent to use an adjunctive technique that may enhance safety and provide an avenue for troubleshooting should imprecise distal deployment result in encroachment of the SMA in addition to celiac coverage. Preliminary transfemoral catheterization of the SMA with placement of an indwelling 4-F or 5-F catheter within the vessel during thoracic device deployment is helpful as an anatomical guide during the procedure. More crucially, it can provide a readily available troubleshooting avenue for rapid retrograde insertion of a stent into the SMA to restore flow should the vessel become occluded or encroached upon by the endograft (Figure 10).

## MULTIPLE MODULAR COMPONENTS

Use of a single-graft system that is long enough to address the entire diseased segment in the thoracic aorta is ideal and frequently possible at present thanks to the availability of longer thoracic stent-graft devices. When choosing or having to use two or more grafts, however, the operator must adhere to certain principles and learned lessons, mainly to provide sufficient overlap of at least 5 cm in length between the segments for long-term stability and avoidance of disconnections. Also, oversizing (2 to 4 mm) of the inner component in relation to the outer is generally recommended, but the guidelines vary somewhat with the various devices. ■

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