The success of transcatheter aortic valve replacement (TAVR) is intimately tied to its less-invasive nature in comparison to surgical aortic valve replacement. TAVR should lead to faster patient recovery and ambulation, fewer bleeding and infectious complications, and eventually, shorter intensive care unit and in-hospital stays overall. The randomized PARTNER trial has emphatically demonstrated the value of TAVR with the balloon-expandable Sapien valve (Edwards Lifesciences, Irvine, CA) in patients with aortic stenosis who have escalating operative risk: transfemoral TAVR improves survival in inoperable patients (cohort B), and both transfemoral and transapical TAVR appear to be on par with surgical aortic valve replacement in patients at high operative risk (cohort A).1,2 Numerous national and multinational registries have illustrated safety and efficacy with use of the self-expanding CoreValve system (Medtronic, Inc., Minneapolis, MN).3-6 These registries have predominantly evaluated transfemoral access strategies, as many centers have adopted a transfemoral-first strategy.

Several key features limit the use of transfemoral access in the current 18-F–compatible, self-expanding systems: (1) a minimum common femoral artery vessel size of 6 mm, (2) excessive atherosclerotic disease, (3) severe tortuosity, (4) circular iliofemoral arterial calcification, (5) thoracoabdominal aorta pathology, and (6) unfavorable horizontal aortic root angulation.

Vascular access site complications are not trivial; their incidence varies between 6% and 14% when using the Valve Academic Research Consortium definitions.7 In the operable PARTNER cohort A, the incidence was 14%, and importantly, vascular complications affected survival.1

**ALTERNATIVE ACCESS STRATEGIES**

Alternative access strategies have emerged in recent years and have expanded TAVR technology to even more patients. Without exception, these approaches bypass the iliofemoral arterial tree and most often require surgical cutdown. With conventional and relatively straightforward surgical techniques, the access site is visibly exposed, and purse-string sutures are applied in the puncture region to guarantee adequate hemostasis during and after the procedure. The introduction of the 18-F sheath is then performed using a modified Seldinger technique. The surgical approach will generally allow for superior control of the artery and more guaranteed arteriotomy closure, yet potentially at the expense of patient comfort.
Transsubclavian/Transaxillary Access

The transsubclavian/transaxillary artery has a decent caliber (approximately 6–10 mm in diameter) and appears to be less prone to atherosclerotic disease. Ruge et al first reported a case of transsubclavian access for TAVR in 2008. Data from the Italian Registry on 54 consecutive subclavian cases in 13 Italian hospitals demonstrated excellent procedural success (100% implantation success rate) and no significant access site complications.

An additional report from the same Italian CoreValve registry presented a propensity-matched comparison between 141 subclavian versus 141 femoral TAVR cases and demonstrated similar procedural success (97.9% vs 5.7%; \( P = 0.47 \)), major vascular complications (5% vs 7.8%; \( P = .33 \)), and life-threatening bleedings (7.8% vs 5.7%; \( P = .48 \)). Of note, there were significantly fewer overall vascular complications due to the 18-F sheath (2% vs 11%; \( P = .003 \)) in the subclavian cohort, suggesting improved vascular access control. The shorter route from the access site to the aortic root may also allow for superior control of the device during valve deployment and release and may result in more secure valve positioning (Figure 1). However, this has not yet resulted in less conduction disturbances and the need for permanent pacemakers.

Conversely, the 90° angulation of the left and right subclavian arteries along their respective courses to the aortic arch may predispose to sheath kinking and complicate valve delivery. The risk of major intrathoracic bleeding or brachial neural plexus injury seems relatively small.

Recently, our group and others have published articles on transaxillary TAVR with a completely percutaneous approach (Figure 2). The Hamburg group reported on 24 patients with acute vascular closure success using percutaneous closure devices in 71%. In our experience of six patients, we encountered closure device failure requiring covered stent implantation in 50%; one patient experienced a major vascular complication. In our opinion, current-generation, suture-based closure devices are suboptimal for this approach, and newer closure systems are eagerly awaited.

Direct Aortic Access

Direct aortic access has gained momentum in the last few years (Figure 3). An upper mini- (or J) sternotomy or small thoracotomy at the level of the second right intercostal space exposes the ascending aorta and may offer an even closer and linear trajectory toward the aortic root. Key requirements are: (1) a calcium-free area...
in the upper quadrant of the ascending aorta, (2) at least 6 cm above the virtual aortic annulus, and (3) no overlying critical vessels (saphenous vein grafts, internal thoracic artery). Direct aortic access precludes the passage of the aortic arch and may thus be associated with less cerebral embolization. Furthermore, the incision for direct aortic access appears to be less painful than at the transapical access site, and the mini-sternotomy variant often will not require chest drainage (as opposed to the thoracotomy variant).

Sometimes, the introducer sheath will enter the ascending aorta at an acute angle, making it prone to kinking and mandating excessive sheath manipulations. In such instances, the sheath can be introduced transcatheter several centimeters cranial to the actual surgical incision site. After traversing the subcutaneous track, the sheath is then visualized in the surgical window to allow for controlled aortic entry under direct vision.

**Transapical Access**

The transapical approach is used with three self-expanding device platforms. The Engager device (Medtronic, Inc.) is 30-F compatible and has support arms that reside in the aortic sinuses upon aligning the prosthetic commissural posts with the native commissures and should aid in correct anatomical positioning.

The first clinical experience was hampered by aortic dissections in a significant number of patients and stimulated additional device modifications. The JenaValve system (JenaValve Technology GmbH, Munich, Germany) has a 32-F sheathless delivery catheter and is fully repositionable during the first step of its implantation. First, so-called feelers are released into the aortic sinuses followed by active clip fixation on the native aortic valve leaflets and final device valve release. The Symetis Accurate TA system (Symetis Inc., Geneva, Switzerland) is a 28-F sheathless system that contains stabilization arches and an upper crown to facilitate proper valve positioning. Risk of pericardial bleeding, ventricular (pseudo-) aneurysm formation, and cardiac muscle damage, although rare, are specific issues related to the transapical approach.

**ACCESS SITE STRATEGY SELECTION**

Patient selection for TAVR requires a multidisciplinary approach involving cardiac surgeons, interventional cardiologists, cardiac imaging specialists, anesthesiologists, and sometimes, geriatricians and neurologists. This dedicated heart valve team should vouch for rational patient selection for the TAVR technology but should also scrutinize the optimal access strategy. If kidney function permits, we favor the combination of conventional invasive contrast arteriography of the iliofemoral arterial tree in combination with three-dimensional multislice computed tomography scanning of the entire arterial vascular bed from the aortic root down to the femoral arteries, including the left brachiocephalic trunk, left and right subclavian/axillary arteries, and carotids (Figure 4).

With growing experience in alternative access sites, challenging iliofemoral anatomies can be avoided. In the Thorax Center, in Rotterdam, we maintain a transfemoral-first approach, given that is a reliable, completely percutaneous technique. In cases of unfavorable peripheral arterial anatomy (in approximately 10% of cases), the transaxillary/subclavian arteries are initially explored. When deemed inaccessible, either a transapical or direct aortic access route is contemplated. Improved postoperative patient well-being, illustrated by superior pain control, may shift our preference toward the direct aortic approach over the transapical route in the near future. A downside of both the direct aortic and transapical routes is the persistent require-
ment of general anesthesia and, especially, chest tubes for mediastinal and thoracic drainage, which frequently generate patient discomfort.

**CONCLUSION**

Growing experience and successful exploration of alternative access sites have made TAVR technology available to many more patients, even those with unfavorable iliofemoral anatomies. As the device platforms become smaller and newer closure devices become available, TAVR will progress further toward truly and completely percutaneous procedures regardless of the access site chosen.

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