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Review Article

Detailed Description of Alternative Access Route Options for Trans catheter Aortic Valve Implantation – PART 2

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Abstract

This subsequent review to the first Mini-Review(Schäfer, Burgdorf, 2026) describes the most relevant details for preparation and execution of alternative access techniques (i.e. direct aortic, transapical, transcarotid, transcaval and transaxillary implantation techniques), their limitations, procedural results in comparison to transfemoral (TF) transcatheter aortic valve implantation (TAVI).

Introduction

Peripheral vascular disease is a common finding in patients who are candidates for TAVI [1,2]. For transvascular TAVI sheath/introducer sizes range between 14F and 20F, depending on the valve size and the transcatheter heart valve (THV) delivery system. Thus, for most devices a minimal vessel diameter of 5 to 6 mm is required. Nevertheless, in at least 10 to 15% of TAVI patients a transfemoral approach seems to be not advisable due to significant peripheral artery disease or severe vessel tortuosity. Hence, the direct aortic (Tao), transcarotid (TC), transcaval (TCav), and transaxillar (TAX) implantation routes have been developed and applied to a broader extent over the last decade [3-7]. According to BiBa MedTech Research, the counts demonstrated a continuous rise between 2013 to 2025 for TF access utilization (in 2025: Europe 96%, Germany 94%)(Schäfer, Burgdorf, 2026) Conversely, the largest decrease was found for the TA access route (2015 vs. 2025: 15% vs. 1% in Europe and 18% vs. 3% in Germany) with similarly stable counts for the TAX access route (2015 vs. 2025: Europe 2% vs. 2%, Germany 2% vs. 1%), TC/TCav access route (2015 vs. 2025: Europe 2% vs. 1%, Germany 1% vs. 1%), whereas the TAO access route seems no longer to be utilized in Europe and Germany (2015 vs. 2025: 1% vs. 0.5% and 1% vs. 0.5%, respectively). (Schäfer, Burgdorf, 2026).

Transaxillar access

Compared to the other non-transfemoral approaches for TAVI, a strong argument in favor of the transaxillary approach is its lower invasiveness. Similar to the transfemoral approach, it allows a truly percutaneous insertion of the THV system and this approach has been used for all commercially available THV systems [8]. It also offers the possibility to perform the procedure without general anesthesia, which may reduce the rate of anesthesia-related complications such as failure of ventilator weaning or postoperative delirium and shorten the length of hospital stay and procedure [9]. In the experience of the authors and many other interventionalists, the following criteria must be met for safe introduction of THV via the axillary artery and subclavian artery:

- Vessel diameter ≥ 6 mm,
- Absence of severe calcification, excessive kinking or severe stenosis of the access vessel that cannot be treated by balloon angioplasty,

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- In patients with a patent coronary left internal mammary artery bypass graft (LIMA), a minimum subclavian vessel diameter of 7 - 8 mm and no significant atherosclerotic disease proximal to or at the ostium of the LIMA to prevent myocardial ischemia.

In cases with critical coronary oxygen supply via the LIMA, transaxillary TAVI should generally be considered as an absolute contraindication. In contrast, implanted pacemakers ipsilateral to the access site are not considered a contraindication for transaxillary access. In order to adequately assess the transaxillary access, a multislice computed tomography (MSCT) should always be performed prior to implantation. Angiography or duplex sonography of the axillary artery and the subclavian artery can provide additional useful information in borderline cases.

Vascular access techniques: The ideal access to the axillary artery is in its first segment at the lateral edge of the first rib, as there are no major side branches. The left axillary artery is preferred as it allows coaxial alignment of the THV system within the aortic annulus. An angle of more than 30° between the annulus plane and the horizontal axis should be considered as a major limitation for the right-sided approach, as the THV is then too vertically aligned (Figure 1). In general, the right axillary artery should only be chosen if the left side is not accessible.

The axillary artery can be accessed either by surgical cut-down or direct percutaneous puncture. Most centers prefer surgical exposure of the artery. In this case, the puncture site is prepared with a double purse-string suture. Alternatively, an arteriotomy and placement of a Goretex conduit is performed to create access to the vessel.

However, a purely percutaneous approach without vascular surgery is also possible and has been successfully performed in a larger series of patients [8].

For this purpose, a long safety wire is proposed, which is inserted into the axillary artery via the ipsilateral brachial artery (**Figure 2**). The wire is then snared through the femoral artery and externalized.

The wire serves as an orientation for the fluoroscopically guided puncture - usually at a point on the side of the chest to rule out the risk of pneumothorax. Adequate closure of the axillary artery is the most critical point when performing percutaneous access, as manual compression of the puncture site is not efficient in most cases due to the anatomical conditions. Vascular occlusion can usually be performed using a vascular closure device. Two ProGlide 6F devices (Abbott Vascular, Minneapolis, MN, USA) have been shown to be most effective for this purpose [10].

To avoid bleeding complications in the event of closure device failure, measures should always be taken to ensure an adequate endovascular bail-out maneuver. Placement of an uninflated PTA balloon via the femoral artery over the externalized long wire in the descending aorta prior to

access recommendation			
	left subclavia	right subclavcia	transfemoral
aortic root angle	< 70°	< 30°	no limitations

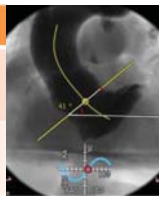


Figure 1:

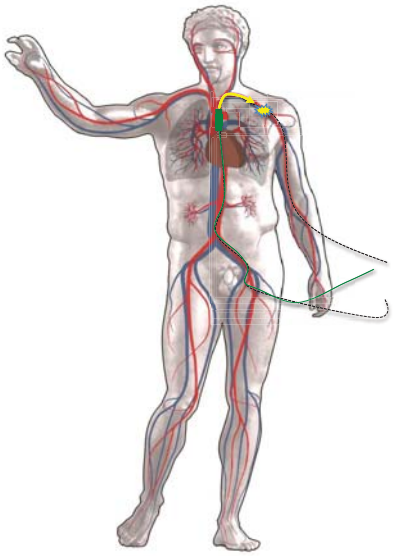


Figure 2:

insertion of the valve introducer sheath into the axillary artery is strongly recommended. The long wire can serve as an endovascular monorail access loop and enables vessel blockade with a balloon, stent graft treatment or both, either from the femoral or brachial side or in a rendezvous procedure, even in cases of severe vessel damage such as a rupture or severe dissection (Figure 3).

This technique is also recommended independently of surgical or percutaneous access to avoid inaccessible injuries to the proximal subclavian artery. After adequate preparation of the access site, the procedure is performed similarly to the transfemoral implantation technique as described previously [8,10].

Outcome: Data regarding patient outcome after transaxillary TAVI are still limited. Prospective, randomized studies comparing the transaxillar access with other approaches for TAVI are completely lacking. The first report of a successful transaxillary TAVI in three patients was published in 2009 by Fraccaro and co-workers. TAVI was performed with the CoreValve Revalving System (Medtronic Inc.; Minneapolis, MN, USA) [11]. The procedure was successful in all three cases and there were no adverse events at 3-month follow-up. In 2010, Petronio and colleagues published multicenter registry data of 54 high-risk patients in whom the CoreValve THV system was implanted via a transaxillary approach and surgical cut-down [12]. The procedural and clinical outcomes of transaxillary TAVI were excellent, with a device implantation success rate

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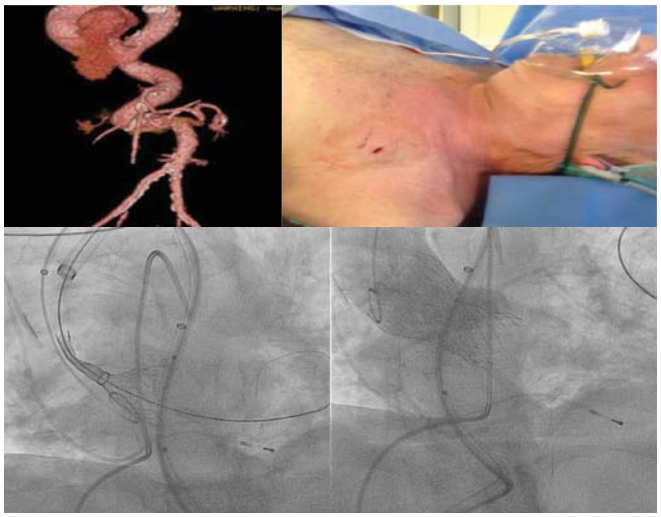


Figure 3:

of 100%, no reported deaths at 30 days and freedom from no serious adverse valve-related events at 6 months in 88.5%. In a propensity-matched comparison between the transaxillary and transfemoral approaches, similar 2-year outcomes were seen in the transaxillary group with even lower rates of acute kidney injury, minor vascular complications, and bleeding events [13]. Given these results, one could also conclude that the transaxillary approach is a viable alternative in cases with difficult but feasible transfemoral access.

In general, surgical cut-down contributes to a longer procedure time compared to a transfemoral approach, which was also observed in a German analysis of a single centre.[13] Nevertheless, a reduction in procedure time and invasiveness could be achieved by a true percutaneous transaxillary approach. The first publication on this topic included 24 high-risk patients and showed successful closure in 95.8% (23/24) of patients and a 30-day mortality rate of 8.4% with no serious adverse cardiac and cerebrovascular events and no serious vascular complications according to the Valve Academic Research Consortium (VARC)-1 criteria [10]. However, closure device failure was observed in 29.2% of patients who subsequently underwent stent graft implantation. In all cases with failed vessel closure, the ProStar system (Abbott Vascular, Minneapolis, MN, USA) was used, while the success rate of vessel closure was 100% when using the ProGlide system. Such a difference between the two closure systems appears to be specific to the transaxillary approach, as it has not been reported for the transfemoral approach, for which the use of both systems was recommended [10]. As mentioned above, the results 100 consecutive cases in which the true percutaneous approach was used was published with satisfactory outcomes [8].

Future perspectives: The direct aortic access for TAVI is technically feasible but clinical outcome seems to be inferior to most other alternative access routes possibly indicating a lower likelihood of utilization in the future.

Transcarotid access

The transcarotid approach is a simple approach to the aortic annulus, as with other short-distance approaches. It also offers the possibility of performing the procedure without general anaesthesia, but requires the full cooperation of the patient. According to the experience of some investigators, the carotid artery should provide the following criteria:

- Vessel diameter ≥ 6 mm,
- No severe calcification, excessive kinking or severe narrowing of the access vessel,
- Transcarotid access should be avoided in patients with critical contralateral cerebral perfusion (stenosed carotid or basal artery).

A MSCT, angiography and duplex sonography of the supraaortic branches should be performed to adequately evaluate the transcarotid access route in every case. In addition, the functionality of the arterial circle of Willis should be investigated, as it serves as an important collateral pathway to maintain cerebral perfusion in cases of diminished afferent blood supply through the internal carotid arteries. Cerebral magnetic resonance angiography (MRA) can accurately delineate the components of the circle of Willis and determine the adequacy of collateral blood flow.

Techniques of vessel access: Figure 4 illustrates the anatomy and steps of implantation. The proximal left common carotid artery is exposed via a small incision 2 cm above the left clavicle. The carotid artery needs to be carefully dissected to avoid injury to the vagus nerve, which is retracted from the immediate surgical field. Vascular clamps are used to achieve proximal and distal control of the carotid artery, and percutaneous access is subsequently achieved by insertion of a 5-F vascular access sheath.

After sequential dilation of the carotid artery a 16F or 18F introducer sheath is carefully advanced into the ascending aorta and standard TAVI implantation techniques are performed. After valve deployment, the introducer sheath is carefully retracted, and vascular clamps are used to minimize blood loss while the arterial access site is surgically repaired using a 6/0 Prolene suture. A control angiogram is usually performed to assess artery patency, and patients are transferred to the intensive care unit for over-night monitoring.

Outcome: The French transcarotid TAVI registry was a voluntary database that prospectively collected data from centers with transcarotid TAVI procedures [14]. Outcome data from 96 patients treated at 3 sites (2009 to 2013) in France was collected and analyzed in accordance to the updated Valve Academic Research Consortium criteria. Successful carotid artery access was achieved in all patients. Two THV, the Medtronic CoreValve (Medtronic Inc., Minneapolis, Minnesota, USA) (n = 89; 92.7%) and Edwards SAPIEN valves (Edwards Lifesciences, Irvine, California, USA) (n = 7; 7.3%) were investigated. Procedural complications included: valve

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embolization (3.1%), requirement for a second valve (3.1%), and tamponade (4.2%). There were no major bleedings or major vascular complications related to the access site. There were 3 (3.1%) procedural deaths and 6 (6.3%) deaths at 30 days. The 1-year mortality rate was 16.7%. There were 3 (3.1%) cases of cerebrovascular accidents (CVA; in-hospital stroke n = 0; transient ischemic attack n = 3). At 30 days, further 3 transient ischemic attacks (TIA) were observed, giving an overall stroke/TIA rate of 6.3%. The authors concluded that the transcarotid vascular access for TAVI is feasible and is associated with encouraging short- and medium-term clinical outcomes. Updated data regarding patient outcome from 2 centers in France comprises 174 transcarotid TAVI treated patients (between 2009 and 2014).[15] A minimally invasive strategy (MIS, local anesthesia and conscious sedation) was undertaken in 29.8% (n = 52) and general anesthesia (GA) was utilized in 70.1% (n = 122). Transcarotid vascular access and THV deployment was successful in all cases. Thirty-day mortality was 7.4% (n = 13) and 1-year all-cause and cardiovascular mortality were 12.6% (n = 22) and 8.0% (n = 14), respectively. According to the type of anesthesia, there was no difference in 30-day mortality (GA 7.3% vs. MIS 7.6%; p = 0.94), 1-year mortality (GA 13.9% vs. MIS 9.6%; p = 0.43), 1-month clinical efficacy (GA 85.2% vs. MIS 94.2%; p = 0.09), and early safety (GA 77.8% vs. MIS 86.5%; p = 0.18) between both groups. Nevertheless, there were 10 (5.7%) periprocedural cerebrovascular events: 4 strokes (2.2%) and 6 TIA (3.4%) among those treated with GA. There was neither a stroke nor a transient ischemic attack in the MIS group (p < 0.001). The authors concluded that the transcarotid approach for TAVI is feasible using general or local anesthesia, but the higher rate of perioperative strokes with GA should be investigated in more detail.

Future perspectives: The transcarotid access for TAVI is technically feasible and results in clinical outcomes comparable to those after transfemoral TAVI [16]. The signal of higher CVA needs to be further investigated. In this regard, it might be interesting to use an intra-procedural shunt (Figure 5) to prevent transient hypoperfusion of the brain.

Transcaval access

Transcaval access allows for unlimited access size with regard to the introducer sheaths. In addition, a similar room set up as with the regular set up for a transfemoral approach is possible and it provides the opportunity to perform the intervention without general anesthesia [17]. In general, any THV can be used for this access and in the experience of some investigators, the caval and abdominal anatomy should provide the following criteria:

A calcium-free target on the right aortic wall needs to be identified, that allows a safe passage of the TAVI sheath from the inferior vena cava (IVC) to the abdominal aorta.

The trajectory of the sheath has to be free of interposed obstacles (bowel), and the area of aortic entry has to be away from important arterial branches, which allows for provisional covered stent bailout if necessary.

Cases with a significant distance between the caval vein and the abdominal aorta should be avoided.

Most importantly, a MSCT needs to be performed prior to implantation in every case to evaluate the exact entry site at the abdominal aorta. Angiography or duplex sonography of the aorta may provide additional useful information in borderline cases. Figure 6 illustrates the anatomy and access point for transcaval TAVI.

Techniques of vessel access

Briefly, after heparin anticoagulation, a loop snare is placed into the aorta to serve as a target. A coaxial crossing system, consisting out of a 0.014-inch 300-cm coronary guidewire (Confienza Pro 12 or Astato XS20, Asahi, Abbott, Santa Clara, California, USA) inside a 0.035-inch x 145-cm locking wire convertor (Piggyback, Vascular Solutions, Minneapolis, MN, USA), inside a braided 0.035-inch x 90-cm microcatheter, inside a 6-F to 7-F renal-length IMA or RDC1 guiding catheter is positioned into the cava [18].

The crossing system is oriented towards the aortic snare and electrified using a monopolar electrosurgery pencil at 50 W. A brief guidewire burn is used for advancement across the vascular walls (Figure 7). Once the 0.014-inch guidewire is snared, counter-traction allows the wire convertor and 0.035-inch microcatheter to be advanced successively across the aortic wall and then to be exchanged for a rigid 0.035-inch x 260-cm guidewire (Lunderquist, Cook Medical, Bloomington, Indiana, USA). Subsequently, the TAVI introducer sheath is introduced from the femoral vein into the aortic lumen over a rigid guidewire. Pre-dilatation with a noncompliant coronary dilatation balloon (2 to 3 mm x 20 cm) can be performed when necessary to advance the microcatheter.

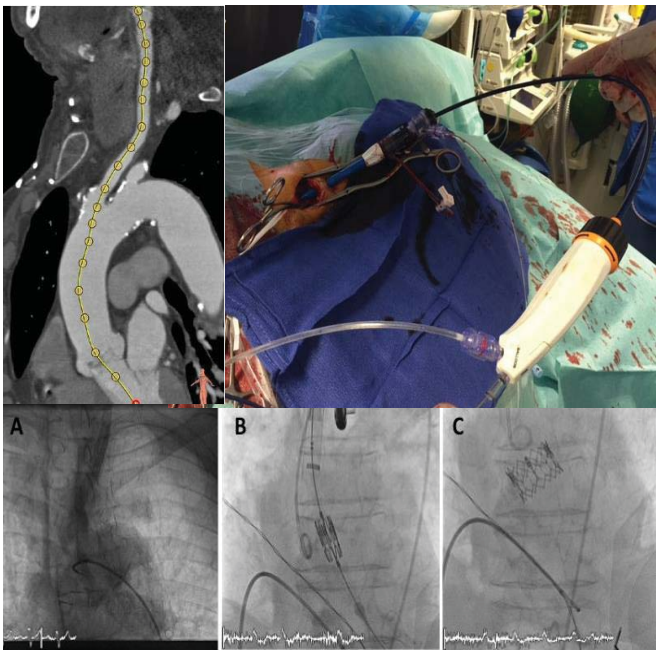


Figure 4:

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Retrograde TAVI is performed using the standard transfemoral technique. To close the access port after TAVI, heparin anti-coagulation is fully reversed with protamine and a nitinol cardiac occluder (Amplatzer Duct Occluder or Amplatzer Ventricular Septal Defect Occluder, Abbott Vascular; Minneapolis, USA) is positioned in the aorta through the TAVI introducer sheath. A 0.014-inch buddy guidewire can be placed alongside and rotated sideways using a deflectable catheter (Agilis NxT SML curl, Abbott Vascular, Minneapolis, USA). Pigtail aortic angiography guides the occluder device positioning. According to the inventors of this access technique, aortocaval fistulas can be accepted unless they cause heart failure from shunting. If retroperitoneal bleeding is evident, adjunctive balloon aortic tamponade or self-expanding covered stents (typically iliac limb ex-tenders, Endologix or Trivascular, Irvine, California, USA) can be deployed, at the discretion of the physician. Post-procedure antiplatelet and anticoagulation medications are administered according to local routine (Figure 7).

Outcome: This first use of caval-aortic access and closure to enable transcatheter aortic valve replacement (TAVI) was performed by Greenbaum and colleges [19]. All investigated 19 patients (79% women) lacked other access options. Caval-aortic access and tract closure were successful performed in all 19 patients and TAVI it-self was successful in 17 patients. Six patients experienced modified VARC-2 major vascular complications, 2 (11%) of whom required intervention. Most (79%) required blood transfusion. There were no deaths attributable to caval-aortic access. Throughout the follow up, there were no post-discharge complications related to tract creation or closure. All patients had temporary persistent aorto-caval fistulas post-procedure. Of the 16 patients who underwent repeat imaging after the first week, 15 (94%) had complete closure of the residual aorto-caval tract. The authors concluded that percutaneous transcaval venous access to the aorta offers a new access strategy for TAVI and other applications requiring large transcatheter introducers.

A subsequent paper described the outcome of 100 patients utilizing the transcaval approach for TAVI (multicenter, single-arm trial). All patients were ineligible for femoral artery access and had a high or prohibitive surgical risk (STS 9.6 ± 6.3%) for surgical aortic valve replacement[20]. Transcaval access was successful in 99 of 100 patients. Device success (access and closure with a nitinol cardiac occluder without death or emergency surgical rescue) was documented in 98 of 99 patients. Transcaval access ports were closed with nitinol cardiac occluders. One subject had closure with a covered stent. In-hospital survival was 96%, and 30-day survival was 92%. According to Valve Academic Research Consortium (VARC-2) criteria life-threatening bleeding and modified VARC-2 major vascular complications were likely related to the transcaval access in 7% and 13%, respectively. Median length of stay was 4 days (range 2 to 6 days). There were no vascular complications after discharge. The authors concluded that the transcaval access enables TAVI in patients who are not good candidates for transthoracic access. Nevertheless, bleeding and vascular complications, using nitinol cardiac occluder to close the access ports are relatively common, indicating that dedicated closure devices may be needed to simplify the procedure and to reduce bleeding.

Future perspectives: Transcaval TAVI access is technically feasible and ultimately leads to clinical outcomes comparable to those after transfemoral TAVI. Nevertheless, acceptance of this approach is limited, and many surgeons consider it an experimental access technique with a high risk of bleeding complications.

Direct transaortic access

The direct transaortic approach (TAo) is similar invasive as the transapical approach, but spares the heart from a muscular injury and seems to be better for cases with previous myocardial dysfunction. Similar as with the transapical approach, steering of the THV is very simple and allows for perfect control during the THV deployment, what is most likely the most supporting argument for the direct aortic access [21,22]. In the experience of some investigators, the direct aortic approach should provide the following criteria:

- Absence of calcification at the entry site,
- The necessary height of the entry site above the aortic annulus (usually a point that is at least 50 mm above the annulus) needs to be precisely investigated to allow

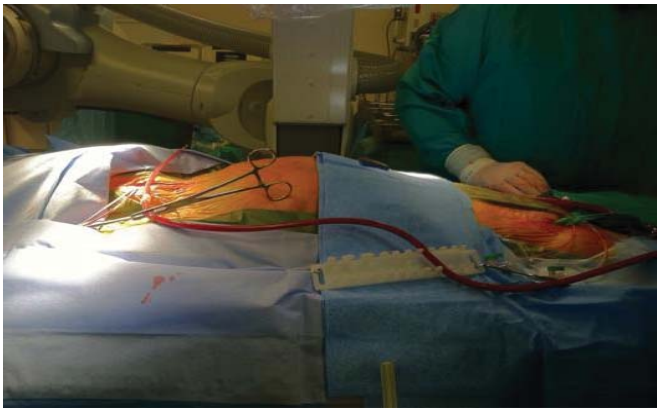


Figure 5:

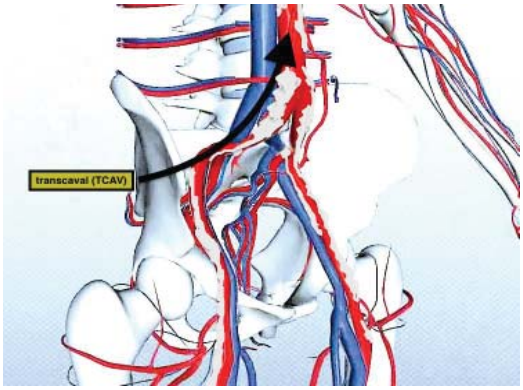


Figure 6:

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THV delivery (long stent designs) and to allow a sheath position in a straight line for device deployment,

- To adequately evaluate the access route, a MSCT should be performed prior to implantation in every case [23].

Techniques of vessel access: Figure 8 illustrates the anatomy of a patient who was treated with a Symetis Accurate Neo TF (Symetis SA, Ecublens, Switzerland) via a direct aortic approach (Figure 9). In general, every THV can be used for this access. The procedure is performed under general anesthesia with full hemodynamic monitoring under fluoroscopy and 3-dimensional (3D) transesophageal echo guidance (TEE).

Catheter laboratory setup differs from the transapical and transfemoral approach with the operator standing towards the head end of the patient or on the right site of the patient. The access route is usually depending on the relationship between the sternum and the ascending aorta.

The approach can be either 1.) a mini J-sternotomy, 2.) a mini right thoracotomy in the 2nd intercostal space, or 3.) a full sternotomy what allows for additional surgical procedures like simultaneous coronary bypass grafting (Figure 10). A mini J-sternotomy is usually preferred if the ascending aorta is in the midline or towards the left and >6 cm deep to the sternum. A mini right thoracotomy is preferred when the ascending aorta is right sided (i.e., more than 50% of the aorta is present on the right of the sternal boarder) at the level of 2nd intercostal space and is <6 cm deep to the sternum.

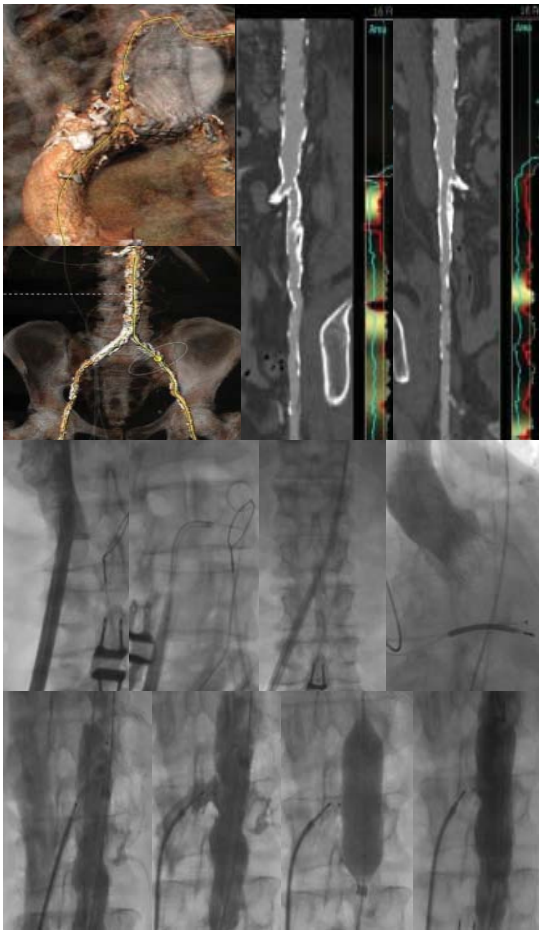


Figure 7:

A mini J-sternotomy is performed, usually through the right third intercostal space. The skin incision is performed in the midline extending from top of the sternum to the level of the third rib. The sternum is divided with an oscillating sternal saw. A mini-oscillating saw is used to extend the sternotomy into the third intercostal space. A mini-sternal retractor is used to open up the sternum.

A mini right thoracotomy is performed through the second intercostal space. A 4 cm skin incision is performed from the right sternal border, and the pleural space is entered. The right internal mammary vessels are either retracted or ligated. Exposure of the ascending aorta is achieved using either soft-tissue retractor alone or with a small rib spreader. Thymic tissue is dissected, and the pericardium identified. Pericardium is incised parallel to the incision and retracted with pericardial stay sutures to expose the ascending aorta. The site of the purse strings (TAo zone) is identified, and 2 circular purse strings are taken on the selected spot with Polypropylene 3-0 sutures. First purse string is non-pledgeted, and the second is pledgeted with 4 Teflon pledgets large enough to accommodate the sheath. The sutures are usually secured with snares. After aortic puncture, the aortic valve is crossed and an introducer sheath is inserted over a stiff guidewire and held at the 2-cm mark. To support the position of the sheath at its entry site we usually tie a small rubber band/ring to the distal end of the sheath (Figure 10). After balloon aortic valvuloplasty, the valve implantation can be performed in a slow stepwise manner, allowing controlled positioning during implantation. The short distance from the ascending aortic puncture and the aortic annulus allows precise valve implantation. After THV implantation, the sheath is removed and the purse strings are tied. Protamine is given to reverse the heparin. The closure of the access site after a mini J-sternotomy is performed with usually leaving open the pericardium, with a drain in place. The sternum is closed using 2-3 nitinol clips or sternal wires. Incision is closed in layers. Similarly, after a mini right thoracotomy, the pericardium is left open, and a drain is placed in the right pleural cavity. The incision is closed in layers. The patient is usually extubated immediately on the table or in the recovery unit.

Complications associated with this approach are ventricular perforation/injury due to stiff guidewires and aortic dissection. It is necessary to carefully watch the wire position and to avoid excessive manipulation due to the short distance of the wire between entry site and the ventricle. Dissection from the cannulation site is rare.

Outcome: Data regarding patient outcome has been investigated in the ROUTE registry with regard to Edwards SAPIEN XT or a SAPIEN 3 valves [24].

But similar with other access routes, any THV can be implanted utilizing the TAo approach. ROUTE was a multicenter, international, prospective, observational registry and data were collected from 18 centers across Europe

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starting in February 2013. A total of 301 high-surgical risk patients (STS: 9.0 ± 7.6%) were included. Valve success was documented in 96.7% and the 30-day mortality was 6.1% (18/293) (procedure-related mortality: 3.1%; 9 of 293). The Valve Academic Research Consortium-2 defined complications included myocardial infarction (1.0%), stroke (1.0%), transient ischemic attack (0.3%), major vascular complications (3.4%), life-threatening bleeding (3.4%), and acute kidney injury (9.5%). In 3.3% of patients, paravalvular regurgitation was classified as moderate or severe (10 of 300). Twenty-six patients (8.8%) required permanent pacemaker implantation. Hence the authors concluded that TAo access for TAVI seems to be a safe alternative to the transapical procedure. A second study investigated the self-expanding CoreValve prosthesis (Medtronic, Minneapolis, MN) by TAo access and compared it to the transfemoral access [25]. Propensity score matching was used to account for differences in baseline characteristics between groups. 394 matched pairs of transfemoral and TAo patients were compared with respect to their clinical outcomes at 30 days and 1 year. The all-cause mortality rate was significantly higher in the TAo group than in the transfemoral group at 30 days (10.9% vs. 4.1%, $p < 0.001$), but this difference was diminished at 1 year (28.1% vs. 23.2%, $p = 0.063$). All-cause mortality or major stroke was significantly higher for TAo vs. transfemoral access at 30 days (13.5% vs. 5.3%, $p < 0.001$) and at 1 year (30.4% vs. 24.2%, $p = 0.025$). Major/life-threatening bleeding and acute kidney injury were significantly greater in the TAo group at 30 days (66.7% vs. 35.4% and 19.7% vs. 10.0%, respectively, both $p < 0.001$). Hence, the authors concluded that a TAo access allows effective delivery of the valve but incurs an increased risk of death and adverse events being potentially the result of procedural differences. Thus, the TAo approach should be used only if the femoral access is not feasible. Similarly, a third study found also a difference with regard to patient outcomes between transfemoral and direct aortic TAVI [26]. The authors also compared their data to transapically treated patients. The patient population was treated between January 2011 and December 2014 and consisted out of 467 consecutive cases of transfemoral TAVI, 289 cases of TAo TAVI, and 42 cases of transapical TAVI. Balloon-expandable prostheses were used in 320 cases of transfemoral TAVI (69%), 209 cases of TAo TAVI (72%), and all cases of transapical TAVI. The remaining cases were performed using self-expandable prostheses. Patient age and Society of Thoracic Surgeons score (6.2% vs. 5.8% vs. 7.1%) were similar and among all groups. Although non-significant, a trend toward lower 30-day mortality (5% vs. 9%; $p = 0.057$) was observed with transfemoral TAVI compared with TAo TAVI [26]. Kaplan-Meier analysis revealed a trend toward a higher 1-year survival rate with transfemoral TAVI compared with TAo TAVI. There was no significant difference in 30-day mortality between TAo and TA TAVI (9% vs. 14%; $p = 0.283$). Kaplan-Meier analysis revealed a trend toward a higher 1-year survival rate with TAo TAVI compared with transapical TAVI. Although the 30-day mortality and 1-year survival rates were similar between transfemoral and TAo TAVI patients, a trend in favor of the transfemoral approach was observed.

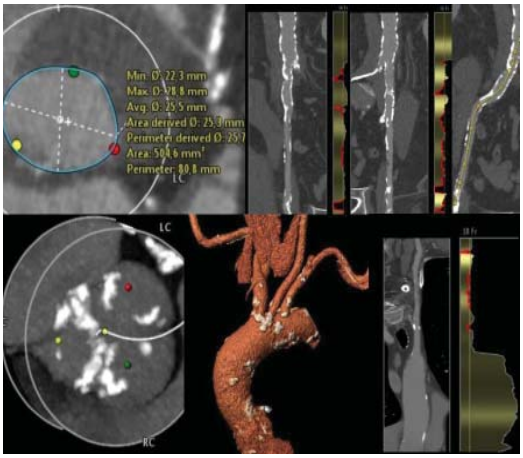


Figure 8:

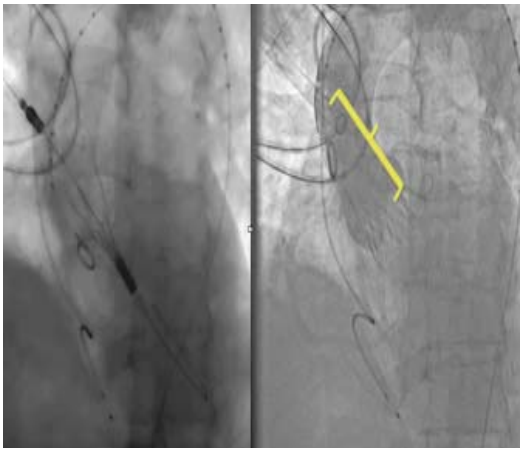


Figure 9:

Future perspectives: The direct aortic access for TAVI is technically feasible but clinical outcome seems to be inferior to most other alternative access routes possibly indicating a lower likelihood of utilization in the future.

Discussion

Alternative access strategies remain important options for patients undergoing transcatheter aortic valve implantation (TAVI) in whom transfemoral access is unsuitable or technically infeasible. The currently described alternative approaches include transaxillary, transcarotid, transcaval, and direct transaortic access, each of which has specific anatomical requirements, procedural considerations, advantages, and limitations. Previous reviews have summarized the evolution and clinical application of these alternative access strategies [3–7].

The increasing predominance of transfemoral TAVI has substantially reduced the use of alternative access routes. Contemporary procedural planning therefore requires careful assessment of the individual patient's vascular anatomy and identification of the safest feasible access route. Multislice computed tomography (MSCT) is particularly important for evaluating vessel diameter, calcification, tortuosity, aortic root orientation, and the relationship between the intended access

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Figure 10:

site and surrounding structures [2,23]. The market-analysis data presented in this manuscript further demonstrate the continuing predominance of transfemoral access and the declining utilization of several alternative approaches [1].

The transaxillary approach represents a relatively less invasive alternative to transthoracic access and can be performed using either surgical or percutaneous techniques. Published clinical experience has demonstrated the technical feasibility of transaxillary TAVI using different transcatheter heart valves, including experience with percutaneous access and contemporary closure strategies [8,10]. Earlier clinical studies also reported outcomes following subclavian/transaxillary implantation and provided comparative data with transfemoral access [11–13]. Nevertheless, careful assessment of vessel diameter, calcification, tortuosity, and the presence of a patent left internal mammary artery graft remains essential before selecting this route.

Transcarotid access provides a relatively short and direct route to the aortic valve and may be performed under general or selected minimally invasive anesthesia strategies. Initial clinical experience established the feasibility and safety of this approach, while subsequent studies examined outcomes according to the type of anesthesia used [14,15]. The transcarotid approach has consequently been described as an alternative access strategy when transfemoral access is not feasible. [16] However, careful evaluation of the carotid arteries, contralateral cerebral circulation, and collateral cerebral perfusion remains important during patient selection and procedural planning.

Transcaval access provides another alternative for patients in whom conventional arterial access is unsuitable. This technique enables large-bore transcatheter devices to be introduced through the venous system following controlled crossing from the inferior vena cava into the abdominal aorta [17,18]. Initial human experience demonstrated the feasibility of caval-aortic access and closure, while subsequent multicenter experience further evaluated its procedural feasibility and safety. [19,20] Despite these encouraging findings, bleeding and vascular complications remain important considerations, and appropriate pre-procedural imaging and a clearly defined bailout strategy are essential.

Direct transaortic access provides a short and relatively controlled route for valve delivery and has been described as an alternative when peripheral access routes are unsuitable. [21,22] Appropriate pre-procedural imaging is particularly important for determining the relationship between the ascending aorta, aortic annulus, sternum, and intended entry site. [23] Clinical experience from the ROUTE registry demonstrated the feasibility of transaortic TAVI in a high-risk population. [24] Additional comparative investigations have evaluated direct aortic access using self-expanding valves and have compared transaortic outcomes with transfemoral and transapical approaches. [25,26]

Overall, selection of an alternative access route should be individualized according to the patient's vascular and thoracic anatomy, previous surgical history, cerebral and coronary circulation, feasibility of transfemoral access, and local institutional expertise. The available evidence indicates that no single alternative access route is universally applicable to all patients. Instead, detailed anatomical assessment and multidisciplinary procedural planning remain fundamental to selecting the appropriate approach [2–7].

The available evidence should also be interpreted in the context of differences among published studies with respect to patient populations, surgical risk, access techniques, transcatheter heart valve generations, anesthesia strategies, closure methods, and institutional experience. [3–7,8,14,17,24–26] Direct head-to-head comparisons between all alternative access techniques remain limited, and much of the available evidence is derived from observational studies, registries, and selected high-risk populations. Consequently, reported procedural and clinical outcomes should be interpreted within the context of these methodological differences.

Limitations

This review has several inherent limitations. First, the manuscript was designed as a descriptive review to provide clinically relevant information regarding the feasibility and practical considerations of different alternative access techniques, including anatomical assessment using different imaging modalities and measures intended to improve procedural safety. Previous reviews have similarly described the heterogeneous development and application of alternative access techniques [3–7].

Second, many of the alternative access techniques discussed in this review were developed and evaluated in earlier eras of TAVI and have subsequently undergone substantial technical and technological evolution. [8,10–15,17–20,24–26] Consequently, outcomes reported in older studies may not fully reflect contemporary procedural techniques, transcatheter heart valve systems, vascular closure technologies, anesthesia strategies, or current patient-selection practices.

Third, the available evidence is heterogeneous. The published literature includes single-center experiences,

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observational studies, registries, propensity-matched analyses, and comparative studies involving different patient populations and procedural strategies. [8,11–15,19,20,24–26] Such differences make direct comparison of outcomes between alternative access routes difficult and may introduce selection and procedural biases.

Fourth, the utilization of alternative access routes has declined as transfemoral TAVI techniques and vascular management strategies have evolved. The market-analysis information presented in this manuscript indicates a substantial predominance of transfemoral access in contemporary practice. [1] Therefore, a considerable proportion of the available evidence for alternative access techniques originates from earlier clinical experience, when these approaches were used more frequently.

Fifth, direct head-to-head comparisons among all alternative access techniques are limited. Although some studies have compared individual alternative routes with transfemoral or other access strategies, [12,13,25,26] differences in baseline risk, anatomy, procedural technique, valve technology, and institutional expertise limit the extent to which these findings can be generalized across all access strategies.

Finally, the access-route utilization statistics presented in the manuscript are derived from the market-analysis information attributed to BiBa MedTech Research rather than from a conventional prospective clinical registry. [1] These data should therefore be interpreted according to their stated source and nature and should not be considered directly equivalent to registry-derived epidemiological data.

Accordingly, the findings and reported outcomes summarized in this review should be interpreted with appropriate caution, particularly when comparing different access strategies across different periods of TAVI development.

Summary and conclusion

In summary, all access routes have been successfully established and serve as important alternatives to transfemoral TAVR, if the transfemoral access is not indicated or impossible. As previously outlined, judgment of invasiveness varies among different investigators. It is important to note, that every access route (e.g. transapical and direct aortic) that is associated with even a small thoracotomy mandates for intubation and ventilation, whereas all other peripheral approaches allow for analgosedation and/or local anesthesia only Schäfer, Burgdorf, 2026. Due to the more aggressive vascular treatment strategies (e.g. calzium modification with high focused ultrasound, etc.) the frequencies of transfemoral implantations have largely surpassed all other access routes. According to BiBa, transfemoral TAVI accounts in 2025 for 96% of the cases in Europe and 94% of the cases in Germany, respectively Schäfer, Burgdorf, 2026. Each of the here described alternative access routes has advantages and disadvantages and needs meticulous analysis of the patients' anatomy.

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