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Different Sites of Vascular Access for Transcatheter Aortic Valve Implantation (TAVI)

Mohd Shahbaaz Khan

Abstract

Aortic valve stenosis is a common valvular heart disease and its incidence is increasing day by day as the life expectancy is increasing gradually. It can be of congenital or acquired variety but in old ages aortic stenosis is acquired mostly and main reasons rheumatic heart disease or senile calcification of aortic valve. Aortic valve replacement with mechanical tissue valves is the surgical management of aortic valve stenosis but some of the patients are not suitable for the surgery based on their physical status and associated comorbidities. These patients are high risk for surgical complications or they have prohibitive risks for surgery. Transcatheter aortic valve implantation is the new technique developed to implanting aortic valve mostly without opening the sternum and without using cardiopulmonary bypass machine. This procedure is mostly done via transfemoral access but in case of contraindications to use femoral artery for access some other different accesses are used to implant the aortic valve, that is, transsubclavian/transaxillary access, transapical access, transaortic access, transcarotid and transcaval accesses. In this chapter we are going to discuss all accesses in details.

Keywords: TAVI, transfemoral access, transsubclavian access, transaxillary access, transapical access, transaortic access, transcarotid and transcaval access

1. Introduction

Aortic valve is present between left ventricle and aorta. It opens during ventricular systole and closes at ventricular diastole.

Aortic stenosis (AS) represents obstruction of blood flow across the aortic valve due to congenital or acquired narrowing. Etiology can be bicuspid aortic valve, rheumatic aortic stenosis and senile aortic stenosis due to calcification of aortic valve.

It is a progressive disease that presents after a long subclinical period with symptoms of decreased exercise capacity, exertional chest pain (angina), syncope, and heart failure.

Echocardiography helps in diagnosis and grading of the aortic stenosis (Table 1).

Most of the patients usually undergo open surgical aortic valve replacement with mechanical or bioprosthetic aortic valve, but some patients may not be suitable

Table1-Grading of aortic stenosis			
Grade	Aortic Jet velocity (m/s)	Mean gradient (mmHg)	Valve area (cm2)
Normal	≤2	<5	3.0-4.0
Mild	≤3	<25	>1.5
Moderate	3.0-4.0	25-40	1.0-1.5
Severe	>4.0	>40	<1.0

Table 1.
Grading of aortic stenosis.

candidate for the open surgical aortic valve replacement because of their associated comorbidities or risk of adverse outcome.

Transcatheter aortic valve implantation (TAVI) is the procedure of implanting the prosthetic aortic valve through intravascular route. First transcatheter aortic valve implantation was done by Cribier et al. [1].

It is the preferred procedure for the severe aortic stenosis patients who are being considered as non-operable [2] or high risk procedure [3] for open surgical aortic valve replacement.

It has become a well-established procedure over the years and since its invention over hundreds of thousands of valves has been deployed. This number is gradually increasing day by day.

There is a basic idea of a crimped aortic bioprosthetic valve and its transcatheter implantation in aortic valve position.

Followings (Table 2) are the aspects to be considered by the heart team to take decision for management of severe aortic stenosis in high risk patients for surgical aortic valve replacement or TAVI.

There are many ways of implanting the aortic valve (Figure 1) by TAVI but most commonly used route is retrograde transfemoral arterial access. This is less invasive and the only percutaneous way of implanting the aortic valve. Even it can be done without general anesthesia. Other routes need surgical cut down for the arterial access.

Peripheral vessels must be assessed for the size, tortuosity, and calcification of the iliac and femoral arteries. Vascular assessment is most commonly performed using contrast angiography or CT angiography. By default transfemoral access is considered to be vascular access site for TAVI.

Other retrograde transcatheter aortic valve implantation (TAVI) is currently performed through an alternative access in 15% of patients. Existing data does not favor one route over another one. All the routes have different advantages and disadvantages.

This chapter will review the different accesses for aortic valve implantation.

Most common vascular access for TAVI is transfemoral artery by default. As the technology has improved, the options for the vascular access for TAVI has increased and may include transfemoral, transsubclavian (transaxillary), transapical, trans-aortic, and transcaval.

With the availability of the lower profile aortic valves for implantation, these valves are mostly deployed via transfemoral route but in case of contra-indication to use femoral artery for TAVI other vessels are used for access; as in case femoral arteries are of small size, tortuous or heavily calcified.

Before proceeding for TAVI, patient should undergo full work up with coronary angiography, CT angiography scan of heart, aorta and peripheral vessels, transthoracic and transesophageal echocardiography, lab investigations and other radiological investigations.

	Favors TAVI	Favors SAVR
Clinical Characteristics		
STS/Euro SCORE II <4% (Logistic Euro SCORE I <10%)		+
STS/Euro SCORE II ≥4% (Logistic Euro SCORE I ≥10%)	+	
Presence of severe comorbidity (not adequately reflected by scores)	+	
Age <75 years		+
Age ≥75 years	+	
Previous cardiac surgery	+	
Frailty	+	
Restricted mobility and conditions that may affect the rehabilitation process after the procedure	+	
Suspicion of endocarditis		+
Anatomical and technical aspect		
Favorable access for trans femoral TAVI	+	
Unfavorable access(any) for TAVI		+
Sequelae of chest radiation	+	
Porcelain aorta	+	
Presence of intact coronary artery bypass grafts at risk when sternotomy is performed	+	
Expected patient-prosthesis mismatch	+	
Severe chest deformation or scoliosis	+	
Short distance between coronary Ostia and aortic valve annulus		+
Size of aortic valve annulus out of range for TAVI		+
Aortic root morphology unfavorable for TAVI		+
Valve morphology (bicuspid, degree of calcification, calcification pattern) unfavorable for TAVI		+
Presence of thrombi in aorta or LV		+
Cardiac condition in addition to aortic stenosis that require consideration for concomitant intervention		
Severe CAD require revascularization with CABG		+
Severe primary mitral valve disease, which could be treated surgically		+
Severe tricuspid valve disease		+
Aneurysm of ascending aorta		+
Sepal hypertrophy requiring myectomy		+

Table 2.
 Factors to be considered in severe Aortic stenosis in high risk patients for Surgical AVR or TAVI.

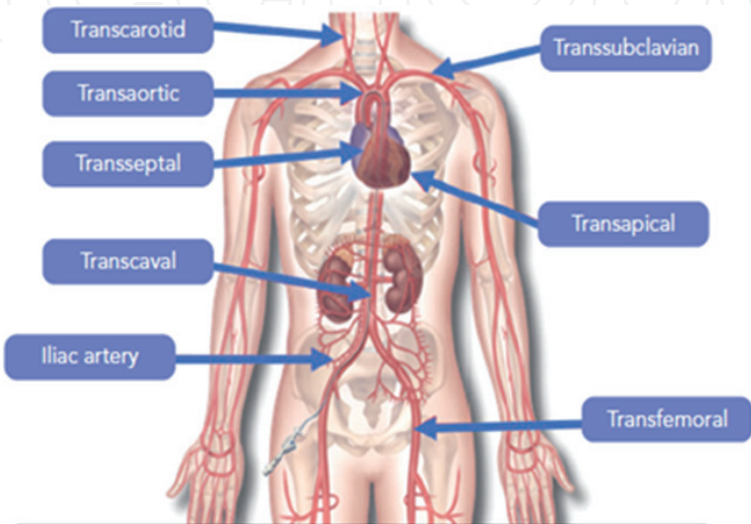


Figure 1.
 Different routes of aortic valve implantation by TAVI.

Although in most of the TAVI procedures, Cardiopulmonary bypass (CPB) is not required but patient should have a full informed consent with possibility of emergency midline sternotomy and use of CPB in case of complications.

While it is difficult to predict which patients will need temporary CPB support during or after valve deployment, usually patients with ejection fraction (<25%) with severe pulmonary hypertension, especially those requiring significant inotropes during and after anesthetic induction are at higher risk.

2. Preoperative assessment and planning

Potential TAVI patients must undergo full evaluation with

- Coronary angiography
- Transthoracic echocardiography (TTE)
- Transesophageal echocardiography (TEE)
- Cardiac computed tomography
- CT angiography of aorta and peripheral vessels

Initial TAVI evaluation should include an assessment of the following variables also:

1. Severity of aortic stenosis.
2. Anatomy of the aortic valve.
3. Aortic valve calcification.
4. Annular, sinotubular, and sinus of Valsalva dimensions.
5. Ventricular function.
6. Coronary artery disease.
7. Height of coronary ostia from aortic annulus.
8. Iliofemoral vessel size, calcification, and tortuosity.

Patients with severe coronary artery disease and lesions which are treatable by percutaneous coronary intervention should get stents prior to the procedure. We keep patients on dual anti platelets therapy for about 6 weeks and then take them for TAVI.

The aortic annulus is sized at mid-systole, and the valve size is selected based upon 10% over-sizing of the annular diameter.

If the annulus is not adequately sized, there would be risk of improper valve size selection that could lead to paravalvular leak, valve embolization, coronary obstruction if the sinus of Valsalva is small or the distance between the annulus and the coronary ostia is less (<10 mm).

3. Transfemoral access

3.1 Introduction

Transfemoral access (**Figure 2**) is the most preferred route in majority of the TAVI procedures world over [4] unless there is an increased risk of vascular complications depending on vascular size, tortuosity and calcification [5].

3.2 Planning

- All patients should undergo a CT-angiographic scan with 3D reconstruction of aorta and femoral vessels
- Aorta should be assessed for tortuosity, presence of aneurysms, atherosclerotic plaques and aortic arch calcifications
- Minimum size of femoral and iliac arteries should be more than 5.5 mm (ideally more than 6.5 mm) and it should be free of calcification
- A circumferential calcification could be a potential contraindication for transfemoral approach
- Some studies shown that a sheath to femoral artery ratio of greater than 1.05 is predictive of a vascular complication [6]
- Bifurcation of femoral artery and its relation with the femoral head should be evaluated properly
- Site of needle entry may be altered based on CT scan or ultrasound findings of high bifurcation of the common femoral artery and presence of significant calcium.

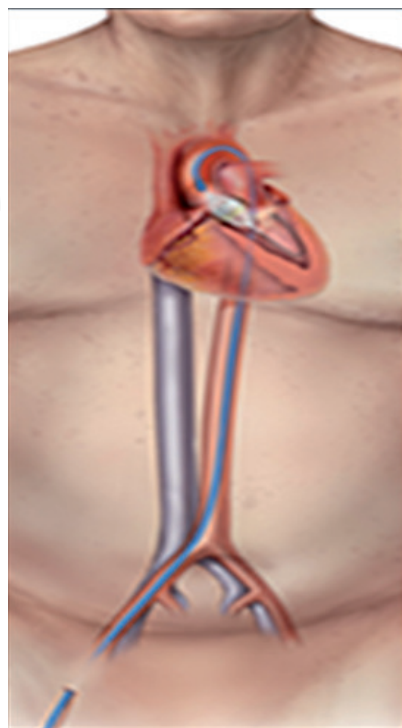


Figure 2.
Transfemoral access for TAVI.

3.3 Technique

- Patient lies supine on operating table
- Endotracheal intubation, arterial line and central line with temporary pace maker lead through right internal jugular vein and placed
- Surgical part painted and draped from neck down till mid-thigh
- Femoral arteries are accessed percutaneously under vascular ultrasound or fluoroscopic guidance
- Surgical cut down can be considered in obese patients with deep femoral arteries
- 6Fr sheath is inserted in one femoral artery and then a 5 Fr pigtail catheter is placed in non-coronary sinus of aorta as a marker for aortic valve placement and positioning.
- These days routinely we are using right radial artery for placing Pigtail catheter in non-coronary sinus of aorta instead of femoral artery
- IV heparin is given to keep activated clotting time (ACT) around 200–250 s.
- Another femoral artery is used to insert 18 Fr valve deployment sheath. First a 6 Fr sheath is inserted and then a soft, J-tipped wire is placed into the descending thoracic aorta (DTA).
- Two percutaneous sutures based vascular closure devices (Per close devices) are placed, which are used to control the bleeding after the procedure.
- The soft J-tipped wire and an exchange catheter are inserted into the aorta
- A soft wire is exchanged for a super-stiff Amplatz wire
- Then catheter and 6-Fr sheath are removed
- 18 Fr sheath is inserted after making a small nick with 11 blade at the puncture site in order to facilitate entry of bigger sheath
- Valve deployment is done through the 18-Fr sheath
- Contra lateral pigtail catheter should be pulled out a little before the opening the valve fully; to prevent the entrapment of the pigtail catheter in device
- Rapid ventricular pacing is done to decrease the blood pressure and valve is deployed under fluoroscopic and transesophageal echocardiographic guidance
- At completion of the procedure we reverse the ACT by giving protamine and then remove the deployment sheath first and control bleeding by per close devices.
- In case of doubtful control of bleeding or suspicion of femoral artery stenosis, we do check angiography using cross over from the contralateral femoral artery
- We usually extubate the patient in operating room

4. Transsubclavian/axillary access

4.1 Introduction

The subclavian artery has recently become a site of access for TAVI [7]. Right axillary or subclavian artery is rarely used for TAVI because of anatomic restrictions and unfavourable angle for valve implantation. The proximal third of the left axillary artery (between the lateral border of the first rib and the medial border of the pectoralis minor) represents the ideal target for both surgical and percutaneous approaches.

A study suggested that subclavian access is not advisable in patients with subclavian artery diameter <7 mm, significant tortuosity, or prior coronary artery bypass grafting (CABG) and patent in situ internal mammary artery grafts [8].

4.2 Disadvantages

There is a higher risk of stroke due to interruption of blood flow to the vertebral arteries in patients with carotid disease who depend on the vertebral arteries for cerebral perfusion.

4.3 Planning

- CT angio scan with 3D reconstruction of the subclavian and axillary arteries.
- Vessel size should be >6.5 mm without calcifications and tortuosity
- It is more prone for vascular complications (especially in old age) because of anatomical differences between subclavian/axillary (more elastic fibers and less muscular wall) and femoral arteries.
- Post CABG patients in whom LIMA was used for LAD anastomosis, this approach can be lethal due to acute graft occlusion.

4.4 Technique

- A femoral artery and vein access is obtained, 6 Fr sheath is inserted and then pigtail catheter is placed in the aortic sinus and a femoral transvenous temporary pacing lead inserted through femoral vein.
- Surgical cutdown for the left axillary artery is done in deltopectoral groove (6–7 cm in size and 1 cm below and parallel to the clavicle from the mid clavicular line to the axillary line) (**Figure 3**)
- Axillary artery is exposed by dissection of pectoralis major and lateral retraction of the pectoralis minor
- Purse string suture is placed on the artery
- The patient is heparinized to maintain an ACT 200–250 s
- A sheath is inserted by direct puncture Using the Seldinger technique

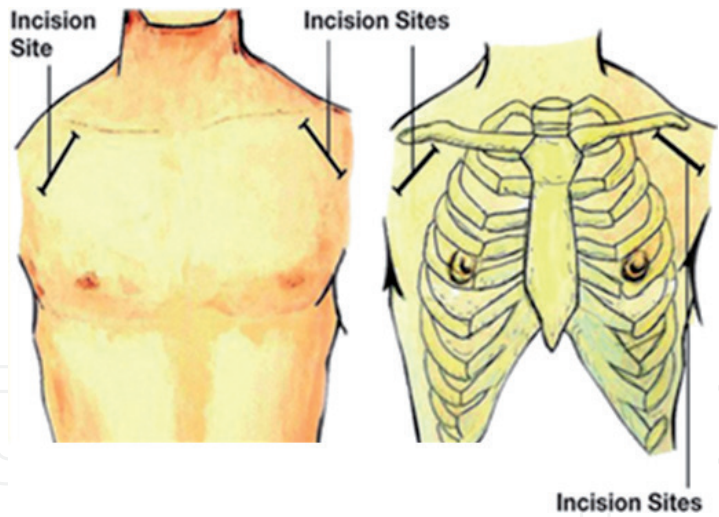


Figure 3.
Transsubclavian artery access.

- In some selected cases an 8–10 mm sized Dacron graft can be anastomosed in an end-to-side fashion and then cannulated with the valve deployment sheath
- A fully percutaneous approach was described in 2012 as the “*Hamburg Sankt George Approach*” [9]
- Once the sheath is in place, aortic valve is deployed in same manner as for previously described transfemoral access
- Heparin reversal, sheath removal and control of vascular bleeding are done in same way as transfemoral approach.

5. Transapical access

5.1 Introduction

Transapical access (**Figure 4**) is the alternative approach for TAVI in patients in whom transfemoral or transsubclavian/transaxillary approach is not feasible.

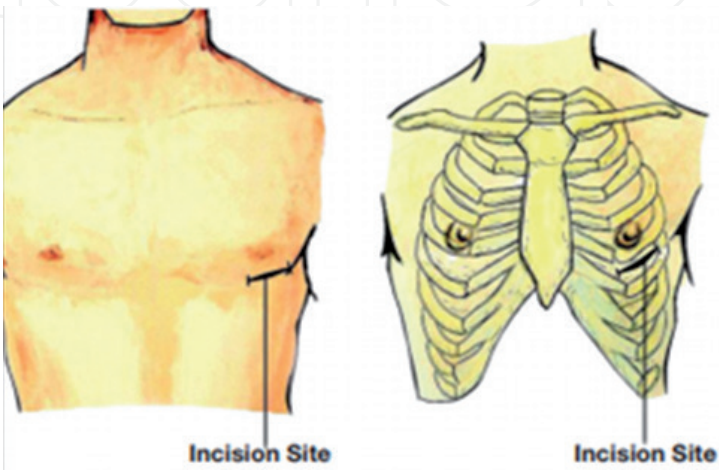


Figure 4.
Transapical access for TAVI.

5.2 Advantages

The transapical approach has the following advantages over other approaches:

1. Peripheral vascular anatomy and size are not limitation
2. The valve is easily crossed in the antegrade direction (vs. retrograde)
3. Less paravalvular leaks
4. Shorter time for insertion and lesser contrast use

5.3 Disadvantages

1. Longer recovery due to thoracotomy
2. Bleeding
3. Not suitable for patients with significant lung disease (forced expiratory volume in 1 s <35%) or low ejection fraction (<15–20%) [10]
4. It could be a source of postoperative Left ventricular (LV) pseudoaneurysm, and may impair left ventricular function

5.4 Planning

- Preoperative CT scan chest is needed to identify both the rib space over the apex of the heart and the distance from the sternum to the LV apex
- CPB should be standby, to use in case of emergent conversion to open AVR
- Cannulation sites for CPB must be planned
- Common femoral artery and vein are used for cannulation usually
- Access to femoral vessels must be done in beginning of case, if femoral vessels are supposed to be used as a bailout CPB cannulation (on the contra lateral side, other than from the femoral arterial access for pigtail aortogram and venous access for ventricular pacing)
- Axillary artery can also be cannulated in case femoral artery is small in size
- A final bailout for CPB is transapical cannulation itself putting a long arterial cannula across the aortic valve. The obvious advantage of this approach is that area will already be readily accessible. The disadvantage of the transapical CPB cannulation is that it gives up the site of access for valve deployment
- It need to be careful while tying the sutures as LV can tear due to friable myocardium

5.5 Technique

- It is done under general anesthesia
- The procedure should be performed in a hybrid operative room

- Supine position with both arms tucked at the sides and a small roll under the left chest
- It is important to prep patient widely to include all potential CPB cannulation sites and for an antero lateral thoracotomy
- Femoral artery and vein access is achieved as routinely
- A femoral transvenous pacing lead is inserted in right ventricle and a pigtail catheter is placed in aortic root via femoral artery
- Anterolateral thoracotomy is made in the fifth or sixth intercostal space
- Dissection is carried down to the pleura and a rib retractor is placed
- After identifying the phrenic nerve, the pericardium is opened
- In cases of a previous sternotomy, adhesions are released between the pericardium and epicardium for adequate exposure of the LV apex
- Two apical concentric pledgeted 3–0 PROLENE purse-string sutures are placed just cephalad to the apex and lateral to the LAD coronary artery
- The purse-string sutures must be deep into the myocardium as they are prone to tear through the ventricular tissue.
- The patient is heparinized to maintain an ACT 200–250 s
- Fluoroscopy is used to align all three aortic cusps in the same plane as in transfemoral approach
- The Left ventricle is punctured with a needle and a 0.035" J wire is passed into the LV, across the aortic valve and into the ascending aorta
- The needle is exchanged for a 7-French sheath
- The 0.035" guide wire is then exchanged for an Amplatz super-stiff wire
- The 7-French sheath is exchanged for the appropriate transapical delivery sheath
- If there is bleeding around the sheath, the purse-string sutures can be snared
- The bioprosthetic valve is delivered through the sheath and positioned across the aortic valve
- The valve is aligned parallel to the long axis of the aorta and perpendicular to the aortic annulus [11]
- Both transesophageal echocardiography (TEE) and aortic root angiogram under fluoroscopy are used to confirm the position of the valve

- Once the optimal position is confirmed, the valve is deployed during rapid ventricular pacing
- The valve delivery apparatus is then removed leaving the stiff wire across the bioprosthesis
- TEE and angiography are used to assess valve position and paravalvular leak
- Balloon dilation may be performed if there is $\geq 2+$ paravalvular leak
- Once satisfactory valve function and position is confirmed, all catheters and wires are removed from the apex, and purse-string sutures are tightened during rapid ventricular pacing
- Protamine is given, and additional pledgeted sutures may be placed for adequate hemostasis
- The pericardium can be closed partially and a flexible Blake drain is placed in the left pleural space with part of it in the pericardium as well for the drainage
- Thoracotomy wound is closed in layers.

6. Transaortic access

6.1 Introduction

The transaortic approach was originally reported by Bapat et al. [12, 13]. The concept behind this first report was the use of the short transapical TAVI delivery system for the retrograde TAVI implant through the ascending aorta. Since then it has become a valid option in case of severe peripheral vascular disease [14].

6.2 Advantages

It has many practical advantages compared to other approaches:

1. It avoids thoracotomy which could potentially impede pulmonary function in COPD patients
2. It avoids cannulation of the left ventricular apex
3. It is easier to achieve hemostasis in aorta than in LV due to fragile myocardium
4. If needed, direct visualization of the aorta permits rapid cannulation and initiation of cardiopulmonary bypass for support

6.3 Disadvantages

1. It is technically challenging in case of previous sternotomy and internal mammary artery or saphenous vein grafts for CABG
2. It cannot be used in patients with porcelain aorta [15]

6.4 Planning

- Preoperative CT scan is done to show the relationship of the distal ascending aorta to the sternum, calcification, and the distance from the distal aortic cannulation site to the aortic root
- This distance should be ideally >7 cm allowing enough space for the valve implantation.
- CPB should be standby for any intra operative complication

6.5 Technique

- It needs a hybrid operating room where fluoroscopy and TEE
- Supine position with the lower neck remaining exposed for a counter incision for the delivery sheath
- Femoral arterial access is obtained as routine for placing a pigtail catheter in the aortic sinus
- A femoral transvenous pacing lead is placed in the right ventricle
- It can be performed by two approaches. The first is through mini-sternotomy (**Figure 5**) and the second is by a right mini-thoracotomy (**Figure 6**).
- An upper ministernotomy is performed with extension to the second intercostal space, where the “J” is completed
- The pericardium is opened
- Pericardial stay sutures are placed for retraction. The aorta is then inspected to find a suitable place for catheter insertion
- It should be free from calcification and at least 6–8 cm from the aortic valve for valve deployment
- Two aortic purse strings are placed

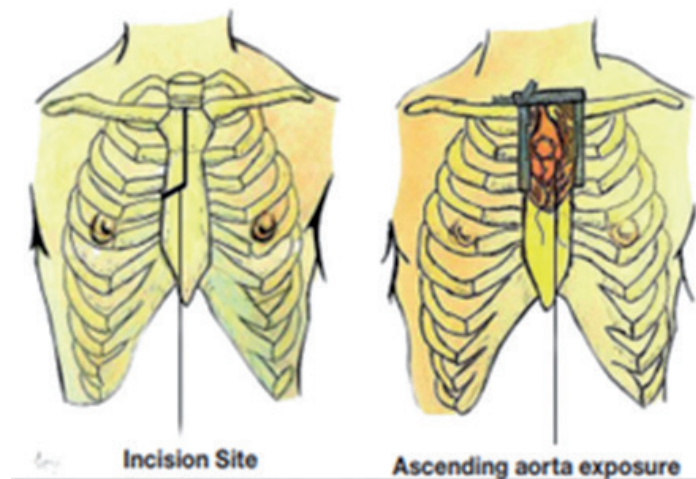


Figure 5.
Transaortic access by upper “J” ministernotomy for TAVI.

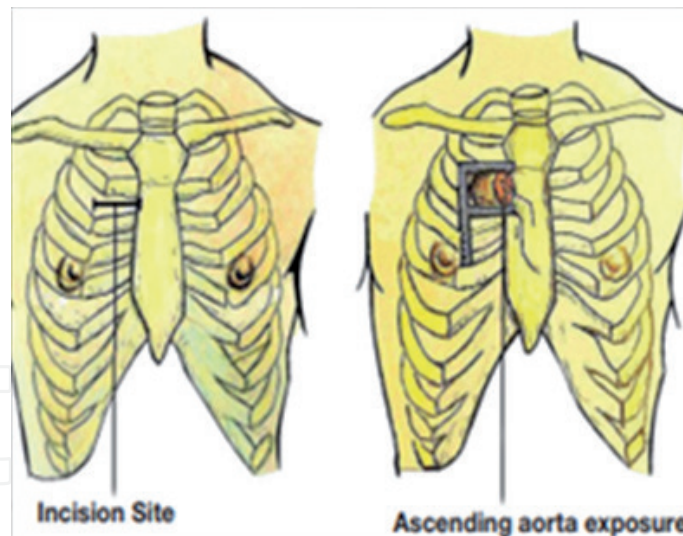


Figure 6.
Transaortic right anterior minithoracotomy for TAVI.

- The patient is heparinized to maintain an ACT 200–250 s
- An 18-gauge needle with a 0.035" soft J guide wire is passed through the counter incision in the lower neck and used to puncture the aorta through the purse strings
- The needle is exchanged for a 7-F sheath, and a multipurpose catheter with a straight soft wire is used to cross the valve
- This is exchanged for a 0.035" Amplatz extra-stiff J wire
- The appropriate valve sheath is placed 2–4 cm into the aorta
- An aortic root aortogram is performed to align all the three leaflets of the aortic valve in same plane
- The valve is placed through the delivery sheath and positioned across the valve
- Once optimal positioning of the valve is confirmed, rapid ventricular pacing at 160–200 beats/min is started
- When the valve is positioned correctly, the valve is deployed
- Aortograms and TEE is used to assess position and presence of any paravalvular leaks and patency of coronary ostia
- After full assessment, all catheters and wires are removed and the aortic sutures are tightened
- Protamine is administered
- A small flexible chest tube is placed in the mediastinum
- Sternum is closed with stainless steel wires
- A right mini-thoracotomy (through second intercostal space) is an option if a surgeon wants to avoid sternotomy or improve visualization in the case of a horizontal or a right-sided aorta

7. Transcarotid approach

7.1 Introduction

This approach is used rarely and required in only for the patients who have contraindications to all other accesses. Modine reported a successful series of 12 patients who underwent CoreValve TAVI with no access site complications, no stroke, and only 1 TIA contralateral to the accessed side [16].

Mylotte et al. [17] reported the feasibility and the safety of this transcarotid approach in 96 patients enrolled in 3 different French sites. In their series, no major bleedings nor vascular complications related to the access site occurred, while only three transient ischemic attacks and no strokes were reported.

7.2 Planning

- Common carotid artery diameter must be >8 mm without any calcification, stenosis or tortuosity
- CT angio carotid and brain to rule out significant atherosclerotic disease and to assess patency of the circle of Willis and cerebral circulation
- MRI brain is done assess the patency of circle of Willis.

7.3 Technique

- A 6-F sheath is placed in the femoral artery and an angled pigtail catheter is utilized for ascending aortography
- A transvenous pacing lead is placed via the femoral vein
- The right common carotid artery is exposed by vertical lower neck incision
- After proximal cross-clamping of the common carotid artery, it is opened longitudinally for 2.5 cm
- The de-aired bypass shunt is placed through the arteriotomy into the distal carotid to maintain cerebral perfusion
- Cerebral oximetry is monitored for both the cerebral hemispheres during the whole procedure
- Through the proximal portion of the arteriotomy, a 0.035-inch J-tipped wire and 7-F introducer are placed in the ascending aorta
- A multipurpose catheter is then inserted and a straight wire is used to cross the aortic valve
- The straight wire is exchanged for an Amplatz extra-stiff wire
- Under TEE and fluoroscopic guidance bioprosthetic valve is deployed as in other approaches
- After the procedure the wires, catheters, and sheath are removed, and the carotid artery is repaired with a pericardial patch.

8. Transcaval approach

8.1 Introduction

The transcaval approach, described by Greenbaum et al. [18] is considered as the last resort in patients not qualifying for any other vascular access. In the transcaval approach (**Figure 7**), the delivery system is inserted through the femoral vein and crossed to the arterial system by creating an aortocaval fistula, which is closed with an Amplatzer device after the valve is deployed.

A case series demonstrated the feasibility of the transcaval TAVI, revealing a successful valve deployment in 17 of 19 patients despite a 79% rate of transfusion and a 33% rate of vascular complications [18].

8.2 Planning

The location of the fistula is determined by a careful evaluation of the CT abdomen and pelvis prior to the procedure.

8.3 Technique

- A baseline CT-scan to identify a calcium free target on the right abdominal aortic wall allowing for a safe passage from the inferior vena cava to the aortic lumen of the large bore sheath
- After having obtained a femoral venous access, the inferior vena cava is punctured by means of a stiff CTO wire mounted over a microcatheter and a standard RCA or IMA guiding catheter
- The caval and aortic walls are perforated by using electrocautery applied at the distal end of the wire.
- Once the access is obtained to the aortic lumen, the wire is snared and both the microcatheter and the guiding catheter are advanced into the abdominal aorta.

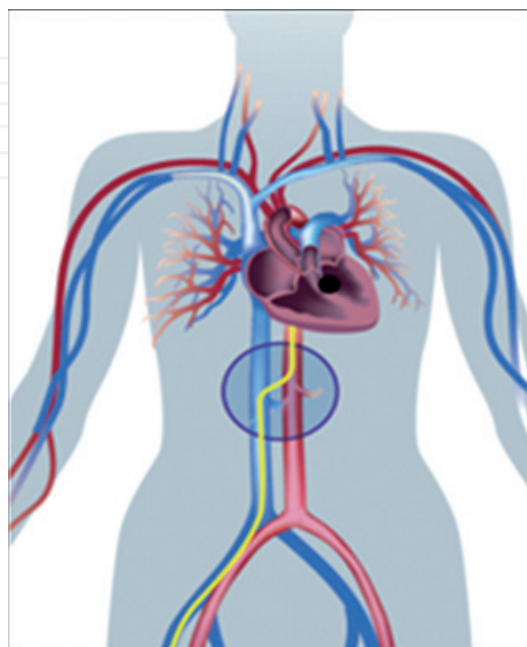


Figure 7.
Transcaval access for TAVI.

- This allows for the placement of a stiff “0.035” wire and the advancement of a large introducer sheath from the femoral vein into the aortic lumen for conventional retrograde aortic valve replacement
- At case completion, heparin is reversed, and the aortic perforation is closed using a conventional vascular, duct or ventricular septal defect occluder device.

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