



Transcaval Access for Large Bore Devices

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Abstract

Purpose of Review Examine the latest data and techniques regarding transcaval access and closure.

Recent Findings Transcaval access was proven to be a feasible and a translatable skill in a 100 patient open-label prospective study. No late complications from fistulas occurred and of all patients alive at 1 year, one fistula remained open.

Summary Transcaval is a viable access route for large bore devices. With adequate planning, bleeding and vascular complications are minimal. It should be integrated into the rubric of transcatheter large bore access.

Keywords Alternative access · Transcatheter aortic valve replacement · Transcaval

Introduction and Background and Proof on Concept

Transcaval access was developed as an alternative to femoral access based on the hypothesis that larger distensible femoral veins and venous decompression would decrease access-related complications and avert aortic confined hemorrhage respectively [1•]. Rationale for the approach was based on several observations: (1) femoral veins are larger than arteries and more distensible, (2) aortic-caval fistulas from trauma are not immediately life-threatening, (3) patients with these

fistulas survive because the blood preferentially flows into the low-pressure venous system instead of the retroperitoneal space, and (4) the inferior vena cava (IVC) and infrarenal abdominal aorta are juxtaposed and rarely have interposed structures. Use of monopolar electrosurgical energy to facilitate transeptal puncture served as the inspiration for development of the technique of channeling electricity into a 0.014" coronary wire for crossing [1•].

In vivo swine experiments demonstrated transcaval crossing feasibility using an energized coronary wire supported by a serial telescoping system of a 0.014" microcatheter and a 0.035" support catheter [1•]. After crossing the aorta in a graded fashion, exchange for a stiff wire enabled delivery of an 18Fr sheath to the aorta. Closure was done either immediately or in a delayed fashion, the latter to prove the concept of venous decompression serving as the mechanism of survival for subjects with patent aortic-caval fistulas (Fig. 1). Successful caval-aortic access and closure was achieved, with four animals undergoing closure 1 week later by re-crossing the caval-aortic tract.

The cornerstone of transcaval success is the physiology of venous decompression. The predicate for not exsanguinating is that the pressure in the retroperitoneal space exceeds venous pressure and aortic blood preferentially shunts into the inferior vena cava (Fig. 1). If there are impediments to venous decompression such as venous obstruction, bleeding into the retroperitoneal space will result. Conversely, if the venous pressure exceeds the retroperitoneal space pressure as seen in aortic injuries from external trauma, patients will exsanguinate. Ultimately, safety of transcaval technique hinges on proper application of this concept and allowing pressurized aortic

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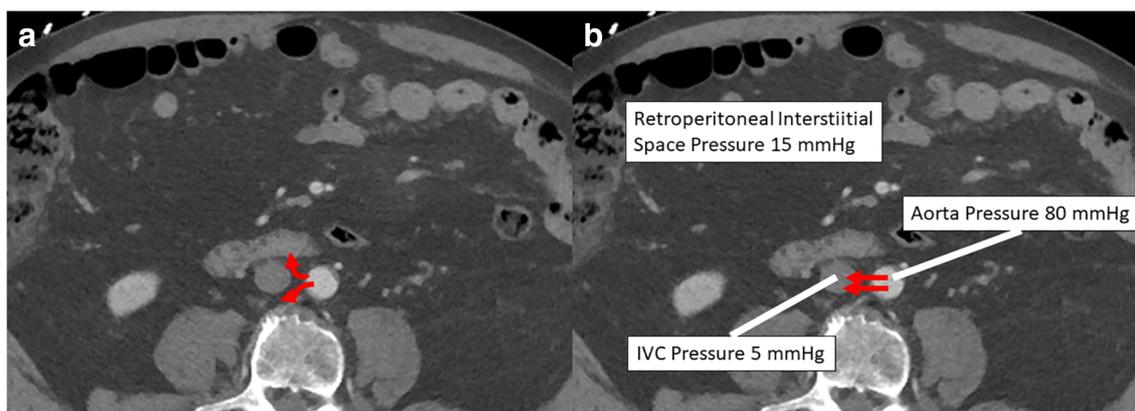


Fig. 1 Pathophysiology of an iatrogenic aortic-caval fistula. **a** Intuitively, most would believe that patients should exsanguinate from a rent in the aorta (red arrows). **b** Since a breach is present in both the aorta and vena

cava and the interstitial pressure of the retroperitoneal space exceeds the venous pressure, blood preferentially shunts from the aorta to the vena cava (red arrows)

blood to preferentially flow into the IVC until the tract is occluded from the arterial side [2].

Translation to human use was first done in a patient with severe aortic valve stenosis without other access options

including a failed attempt of transapical access. Initial experience at a single center was reported in 2014 where 19 patients underwent successful transcaval access and closure for TAVR. This series confirmed human feasibility of caval-aortic access

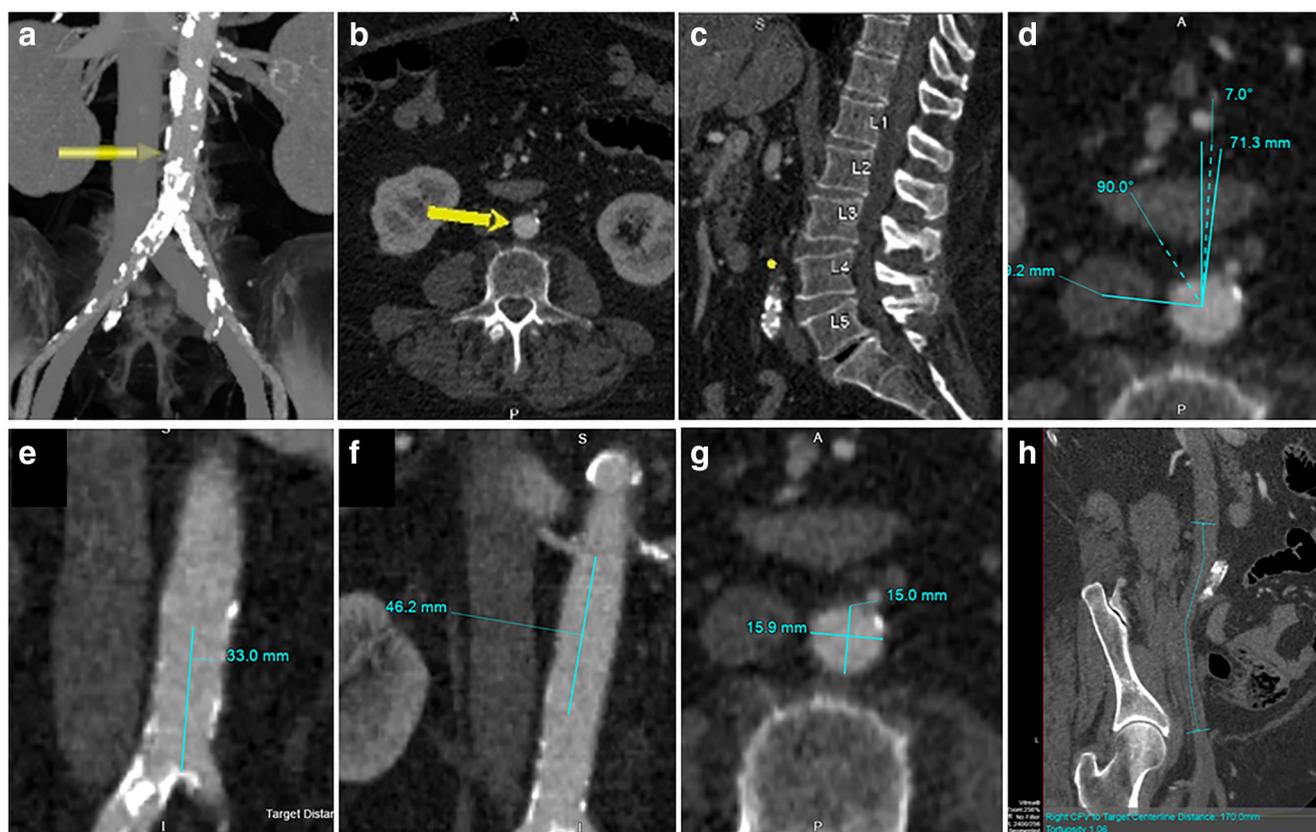


Fig. 2 Computed tomography for assessment of transcaval access. **a** 3D reconstruction of the abdominal aorta and the inferior vena cava to find a calcium-free window on the medial surface of the infrarenal aorta. The yellow arrow depicts a candidate crossing site. **b** Axial image of abdominal aorta confirming a calcium-free target for crossing. **c** Sagittal image depicting the abdominal aorta and vertebrae. The bony landmark for the crossing site appears to be at the top half of L4. **d** Coplanar angle for determining the crossing trajectory is 7.0° off the vertical plane, the

coplanar angle is 83.0° left anterior oblique (LAO). **e** Distance of the proposed crossing site from the aortoiliac bifurcation. **f** Distance of the crossing site from the renal arteries. **g** Measurement of the cross-sectional diameter of the abdominal aorta in planning for possible bailout covered stent selection. **h** Centerline distance from the bottom of the femoral head to the crossing site at the aorta to ensure selected sheath length is sufficient

with a 31.6% VARC-2-defined major vascular complications, 2/19 (11%) patients required treatment with covered endografts for bleeding despite use of a nitinol-based plug [3].

Subsequently, a 100 patient open-label, prospective, multi-center, single-arm study was designed to evaluate the risks and benefits of transcaval access [4•]. The study was complete with independent computed tomography (CT)-corelab analysis and endpoint adjudication by a clinical events committee. Transcaval crossing was successful in 99% of cases; a total of 98% of cases achieved the primary endpoint of successful access and closure. Thirty-day survival was 92% and no deaths were attributed to transcaval access or closure. VARC-2-defined major/life-threatening bleeding was observed in 12.1% of patients, and aortic stent grafts were deployed in eight patients. A median of 2 units (2.0–4.0) of packed red cells were infused in 35 patients. Small or moderate retroperitoneal hematomas were observed in 24% of patients prior to discharge and in only 5% of patients at 30 days. More experienced centers were found to have fewer vascular complications, major/life-threatening bleeding, and acute kidney injury in this registry. Including the competing risk of death, estimates of fistula occlusion rates were 33%, 49%, 66%, and 86% at procedure complete, pre-discharge, 30-day visit, and 12-month visits, respectively [5•]. Only one fistula was proven patent at 1-year in a patient with a mal-deployed occluder. Small tract-related aortic dissections were evident during procedural angiography, but none were seen at the pre-discharge CT scan.

Screening and CT-plan development

A contrasted CT scan is essential to safe and successful transcaval access and closure. A well-developed methodology for determining patient eligibility and access planning was implemented for the prospective registry and proven effective (Fig. 2; Tables 1, 2, and 3) [7].

Performing Transcaval Access

First, proper patient consent for alternative access and all necessary equipment for crossing, closure, and bailout should be assembled prior to beginning (Table 4). The electrosurgical pad should be attached to the patient prior to sterile preparation with care not to place the pad over metallic prostheses or implants (e.g., hip replacement). Otherwise, a standard set-up for a transfemoral procedure will suffice. The room set up must allow for the image intensifier to rotate to the lateral position if necessary and at times, the upper extremities can obscure the lateral crossing view; therefore, the arms must be allowed to be repositioned in transcaval crossing. Since TAVR is the most frequent reason for transcaval access, we will use this as the template for standard set up.

Table 1 Computed tomography for planning transcaval access rationale and caveats

| |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Objective: Identify a calcium-free crossing target (Fig. 2a, b) |
| Rationale: A heavily calcified aorta cannot be traversed and a window must be large enough to accommodate the intended sheath. The window should be larger than the outer diameter of the sheath in at least one dimension. |
| Example: 18Fr sheath for Medtronic Evolut R ≥ 7 mm 14-16Fr e-sheath for Edwards Sapien 3 ≥ 7.6 –8.6 mm |
| Objective: Identify high-risk anatomy for caval-aortic traversal and large sheath insertion |
| Rationale: Several extra- and intravascular anatomic variations have been identified that jeopardize safe traversal |
| Interposed structures: Arterial branches, interposed bowel and major veins (e.g., renal) cannot be traversed for obvious reasons. |
| Pedunculated atheroma: Pedunculated aortic atheroma may embolize during catheter or closure device manipulation. |
| Abdominal aneurysms: Ectasia and aneurysms are not contraindications, but the large size of the aorta may make endovascular bailout challenging. |
| Dissections: Chronic dissections can extend with large bore sheath insertion and should be avoided. |
| Leftwards aorta: Aortas with a cephalad leftward trajectory may result in a tangential trajectory if a sheath is inserted and result in leftwards translation of the abdominal aorta while crossing. 20° leftward aortas should be avoided. |
| Prior device implants: IVC filters, polyester aortic grafts, and even pacemakers have impeded transcaval access. Although crossing an aortic graft is possible, it should be performed in experienced centers [6]. |
| Objective: Identify vascular structures at risk during closure of possible endograft rescue |
| Rationale: The crossing site should be at least 15 mm away from the aortoiliac bifurcation (Fig. 2e) and renal arteries (Fig. 2f). Important vessels including accessory renal arteries and lumbar collaterals in patients with important iliac disease should be noted as endograft implantation will compromise these branches. |
| Objective: Select preferred iliofemoral access for possible endograft insertion |
| Rationale: Endograft implantation at minimum requires a vessel than accept a 12Fr access. Should femoral arterial access be inadequate, and then the patient will require appropriate risk/benefit counseling if operators decide to proceed. |
| Objective: Perform measurements for equipment selection and corresponding bony landmarks for crossing plan (Fig. 2) |
| Rationale: Once a safe traversal point has been determined, measurements for selecting a snare, guide, and bailout equipment. |
| Key findings include: |
| - Crossing site(s) and correlating lumbar spinous level for crossing (Fig. 2c) |
| - Distance from femoral vein puncture site to crossing site (Fig. 2h) |
| - Distance from aortoiliac bifurcation (Fig. 2e) |
| - Distance from renal arteries (Fig. 2f) |
| - Abdominal aorta size at the crossing, 30 mm cephalad and 30 mm caudad (Fig. 2g) |
| Aortocaval distance does not appear to be important. |

Femoral arterial access should be established in the limb with the largest lumen should there be a need for bailout stenting of the abdominal aorta. Right venous access should be reserved for the large bore sheath. Many operators decide

Table 2 Transcaval planning report

| Feature | Example value and detail |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Recommendation | Favorable (no high-risk features) Feasible (features that increase difficulty or risk) Unfavorable (features that contraindicate or significantly increase risk) |
| Basis for recc. | Detail such as “poor-quality CT for planning” |
| Target entry site lumbar vertebra | L3 = center of lumbar vertebra L3.5 = midway between L3 and L4 |
| Projection angles | Coplanar angle = RAO 10° Orthogonal angle = LAO 80° |
| Interposed and nearby structures | Example: bowel anterior |
| Aortic lumen diameter (+ 3 cm/0/− 3 cm) | 16.1 × 14.6 mm above/15.9 × 15.0 mm at crossing/16.0 × 7.1 mm below |
| Target distance to renal artery | 46.2 mm |
| Target distance to aortoiliac bifurcation | 33.0 mm |
| Femoral vein to target distance | 20 cm |
| Cover-stent bailout limb access | R minimum diameter 3.7 mm L minimum diameter 4.0 mm |
| Mesenteric arteries | Celiac and superior mesenteric artery are patent |
| Other caveats | Miscellaneous findings that may be relevant: accessory renal artery present; patient rotated on CT-table; leftward aorta 15°; lumbar compression fractures present |

to use the Perclose Proglide device (Abbott Vascular, Santa Clara, CA) and deploy at least one suture prior to dilating to a large bore catheter, but venous hemostasis can also be achieved using external suture-based techniques such as “figure of eight” at the end of the case [8]. Once vascular access is complete, the patient should be anticoagulated to achieve an activated clotting time > 250 s prior to attempted transcaval access.

Next, identification of aortic valve coplanar view should be done so that operators can proceed with valve implantation immediately after transcaval access. Subsequently, the pigtail catheter should be retracted to the level of the upper lumbar spine (L1) to perform a scout abdominal aortogram under digital subtraction angiography (DSA) at ~ 32 cm magnification using the coplanar angle identified on the CT scan. An injection of 10 ml over 1 s will be sufficient to opacify if using digital subtraction. No angiography of the venous system is necessary but “dry” x-ray cine is useful to illuminate the calcium pattern in the abdominal aorta.

Afterwards, the pigtail catheter is exchanged for a 6Fr JR4 guiding catheter for positioning a snare. A single-loop snare (Amplatz Gooseneck, Medtronic, Minneapolis, MN) that is ~ 5 mm larger than the aortic lumen should be opened and oriented orthogonal to the coplanar view. Then, the crossing catheter, either a 6-7Fr Renal Double Curve-1 (RDC-1) or internal mammary (IM) guide should be situated at the corresponding lumbar spinous level. A graded, serial telescoping crossing system should be assembled that includes the 0.014”

crossing wire, a 0.014” microcatheter, and a 0.035” braided catheter (Table 4).

Once the system is assembled and the 0.014” wire is connected to the electro-surgical pencil via a hemostat, the crossing catheter should be aligned to point at the aorta at the planned lumbar spinous level. To optimize transmission of electricity, our center removes the paint and gel coating of the coronary wire and electro-surgical pencil respectively using a surgical blade. Then, the image intensifier is maneuvered to the orthogonal plane of the coplanar crossing angle (example: coplanar angle 5° RAO, orthogonal view 85° LAO). This image determines if the crossing catheter trajectory is headed straight into center of the snare. After confirmation of the crossing trajectory with orthogonal views, the wire should be advanced towards the aorta while applying 50 W of pure electro-surgical cutting. Only a short burst of energy should be emitted, and it should halt once the wire appears to be across the aortic wall near the snare. If the patient is not under general anesthesia, analgesia should be administered as traversal in the retroperitoneal space is painful. Snaring of the wire further confirms aortic intraluminal location, and then the snared 0.014” wire is dragged cephalad to the thoracic descending aorta. Using the snared wire for countertraction, the 0.014” catheter is advanced to the descending aorta followed by the 0.035” catheter in a telescoping fashion. Once the 0.035” catheter is across, the 0.014” wire is released from the snare and the 0.014” wire/catheter exchanged for a 0.035” Lunderquist

Table 3 Classification for transcaval eligibility

| Classification | Features |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Favorable | <p>All of the following:</p> <ul style="list-style-type: none"> • A calcium-free window > 10 mm in diameter • No important interposed structures (hemiazygous or lumbar plexus veins OK; renal vein, bowel or arterial branches not OK). • Centerline distances from femoral vein at lower femoral head to aortic entry at least 7 cm shorter than working length of the proposed sheath • Target > 15 mm below lowest renal artery and > 15 mm above aortoiliac bifurcation |
| Feasible | <p>Any of the following:</p> <ul style="list-style-type: none"> • Circumferentially calcified window (as long as diameter is ≥ 2 mm than expanded outer diameter of the intended valve and sheath) or non-circumferential calcified window (if its smallest dimension is ≤ 2 mm less than expected diameter of intended valve and sheath) • Centerline distance from femoral vein at lower femoral head to aortic entry 5–7 cm less than working length of intended sheath • Aortic fabric graft • Non-contrast computed tomography |
| Unfavorable | <p>Any of the following:</p> <ul style="list-style-type: none"> • Confluent calcification of the abdominal aorta without a calcium-free target window larger than the proposed sheath • Centerline distance from femoral vein at lower femoral head to aortic entry point < 5 cm difference than the working length of the intended sheath • Proximity to the renal arteries ≤ 15 mm • Pedunculated abdominal aortic atheroma that might embolize • Bilateral iliofemoral artery occlusion • Celiac and superior mesenteric artery obstruction that could result in bowel ischemia if the inferior mesenteric artery is occluded by a covered stent • Leftward aortic angle with regard to vertical approximal $> 20^\circ$ that would impede catheter and sheath placement • Other high-risk features (e.g., permanent IVC filter, aortic stent graft at target) |
| Not important | <ul style="list-style-type: none"> • Aortocaval distance • Aortic aneurysm or ectasia, even with lamellated thrombus • Interposed lumbar venous structures |

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wire. Afterwards, the small venous sheath can be exchanged for a larger dilator or the large bore sheath. Sheath crossing should be observed under high-resolution x-ray to ensure the edges of the sheath do not splay and damage the aorta. If using an Edwards Lifesciences E-Sheath, the seam of the sheath should be oriented towards the most inferior lip of the tract to provide the greatest margin of safety should the split at the seam dissect or lacerate the aorta.

Difficulty crossing should trigger caution to avoid inadvertent damage to vascular structures and prompt troubleshooting steps. Firstly, wire buckling should be avoided since if a slit like orifice is formed on the aortic wall from penetration, but it is not matched on the caval side, there may be retroperitoneal bleeding. Also, multiple attempts may inadvertently cause an aortic breach to go undetected and result in bleeding. Unexplained hemodynamic changes in the context of multiple crossing failures should prompt angiography of the abdominal aorta.

Otherwise, failure to cross should prompt rechecking of the connections to the electrosurgical unit, review that electrosurgical monopolar cutting at least 50 W is being activated, and the contact point between the coronary wire and electrosurgical pencil is clean. The crossing wire should not be looped; otherwise, a short circuit will result. Additionally, several failed traversal attempts will cause charring of the wire tip and it may need to be replaced; otherwise, energy will not channel. An alternate crossing point can be selected based on calcium distribution. If an alternative crossing location is selected, intimate knowledge of aortic lumen size, interposing structures, proximity to vessels, and coplanar angles must be available or reassessed. Operators should remain mindful of the risks of multiple crossing attempts in elective cases such as TAVR.

The aortic wall may be unyielding and sometimes resistant to catheter crossing. Occasionally, balloon angioplasty is required to facilitate microcatheter traversal and a 2.5–3.0-mm

Table 4 Equipment for transcaval access, closure, and bleeding management

Transcaval access

- Electrosurgical unit and pen (Bovie)
- 6Fr Judkins Right guide
- Amplatz Gooseneck snares (~5 mm larger abdominal aortic diameter) (Medtronic, Minneapolis, MN) (example 20 mm diameter use a 25 mm snare)
- 6–7 Fr Renal Double Curve-1 guide catheter or 6-7Fr Internal Mammary guide catheter (renal length)
- 0.014" microcatheters:
 - 0.014" Finecross 135 cm (Terumo, Ann Arbor, MI)
 - 0.014" Piggyback 120 or 150 cm (Teleflex Medical, Morrisville, NC)
 - 0.014" Advance Microballoon 150 cm (Cook Medical, Bloomington, IN)
- 0.035" catheters:
 - 0.035" CXI catheter 90 cm (Cook Medical, Bloomington, IN)
 - 0.035" Navicross catheter 90 cm (Terumo, Ann Arbor, MI)
 - 0.035" Lunderquist Wire (Cook Medical, Bloomington, IN)
- 0.014" crossing wires
 - 0.014" Astat XS 20 wire 300 cm (Asahi Intecc, Tustin, CA)
 - 0.014" Confianza Pro 12,300 cm (Asahi Intecc, Tustin, CA)

Transcaval closure:

- Small curl Agilis (Abbott Structural, Santa Clara, CA)
- Amplatz Duct Occluder I 8/6 mm or 10/8 mm (Abbott Structural, Santa Clara, CA)
- 0.014" Balance Middle Weight 300 cm

Bleeding Complication Rescue:

- Reliant Aortic Occlusion Balloon (Medtronic, Minneapolis, MN)
- Coda Aortic Occlusion Balloon (Cook Medical, Bloomington, IL)
- 14–28 × 45 mm Endologix Ovation iX Iliac Limb Extender stents (Endologix, Irvine, CA)

non-compliant coronary balloon should work. If angioplasty is being performed, ensure dilation of both the aortic and caval side of the tract to facilitate venous decompression. A case of using a laser to cross the caval-aortic tract was previously reported [9]. Lastly, if an Edwards Lifesciences e-sheath is delivered across the aortic wall and hypotension occurs after removal of the sheath dilator, bleeding from sheath collapse should be considered. The flexible nature of the sheath may cause it to collapse at the seam when the lumen is empty. If angiography confirms this phenomenon, rapid dilator or valve catheter insertion to fill the sheath lumen will stop the bleeding and prompt aortic-caval closure should be performed once the valve delivery is complete.

Transcaval Access Closure

Once the intended procedure is complete (e.g., TAVR, Impella placement), the team should be alerted for transcaval access closure. First, all transcaval access emergency bailout equipment should be assembled and available in the room prior to closing. This includes requisite aortic occlusion balloons, corresponding sheaths, and covered stents (Table 4). Next, protamine should be delivered to normalize the activated clotting time. A 0.014" 300-cm safety wire is inserted through the

large bore sheath in case the nitinol-based closure device pulls through the tract, and the fistula needs to be recrossed. To close the tract, an Amplatz Duct Occluder I (ADO) (Abbott, Minneapolis, MN) is delivered via a deflectable catheter, in this case, a small curl Agilis catheter (Abbott, Minneapolis, MN). In general, for sheath outer diameters (ODs) less than 18 Fr, an 8:6 ADO I occluder should be sufficient and for sheath $OD \geq 18$ Fr, a 10:8 ADO I occluder is appropriate. For the sake of simplicity, most proctors recommend using the 10:8 ADO I occluder device for all cases. If the abdominal aorta is relatively small and the hole is small enough, the smaller retention skirt of an 8:6 ADO I (12 mm) may be easier to deploy.

The ADO I device is deployed through a deflectable catheter, and a small curl Agilis catheter is used to deflect the retention disc so that it is oriented vertically (Fig. 3). First, the large bore transcaval sheath is withdrawn close to the crossing site. Next, the distal end of the device is passively exposed in the aorta into the "ball" position and the catheter flexed into the ready position. The transcaval sheath is retracted to the IVC carefully to ensure the venous side is not obstructed to maintain venous decompression; otherwise, there will be significant bleeding. Finally, the retention disc should be fully formed and the deflectable catheter flexed to 90° and pulled back towards the cava with sufficient tension to appose the aortic wall but avoid pulling through the tract. Once apposed to the wall, the remaining device can be passively exposed. The aortic pigtail catheter is then used to perform angiography, typically with digital subtraction angiography. Generally, there are four patterns of closure: occluded (type 0), funneled (type I), cruciform (type II), and extravasation (type III) (Fig. 4) [2]. Generally, the types 0–2 can be observed without intervention, but obvious extravasation requires intervention. Transient blood pressure drops of 10–15 mmHg are typical should there be shunting; however, if there is concern for bleeding, prolonged observation and repeat angiography can be performed to re-assess for bleeding. Sometimes, bowel artifact can make DSA pictures difficult to interpret; therefore, coronary mode cine-angiography can be done to assess for bleeding. Also, if there is persistent hypotension, consider obtaining oblique views to exclude extravasation. Once satisfied, the remaining vascular access can be closed.

In the event of extravasation, rapid exchange for an aortic occlusion balloon and tamponade of the transcaval tract is performed. Occlusion of the tract for 3–5-min cycles can be done for several times, but if there is no improvement, operators should proceed with covered stent implantation. In rare occasions, patients with right ventricular cardiomyopathy can experience hemodynamic embarrassment from the inability to accommodate aortic-caval shunting. To manage extravasation or arterial-venous shunting, occlusion of the tract using a covered stent is sometimes necessary. A covered stent approximately 20% larger than the aortic lumen is recommended, and

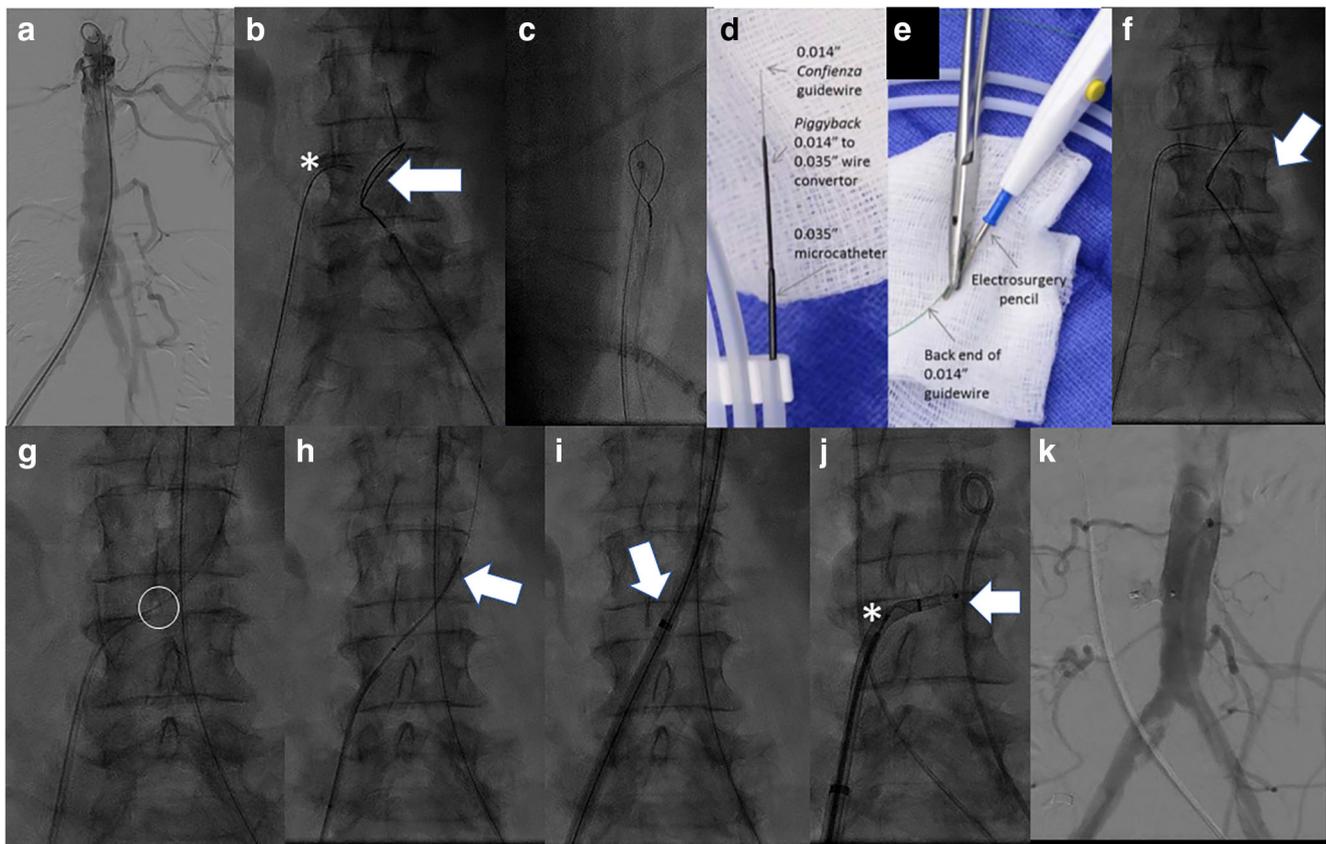


Fig. 3 Stereotypical case of transcaval access and closure. **a** Scout angiogram using digital subtraction angiography (DSA) of the abdominal aorta in the coplanar view. **b** A 6Fr internal mammary (*) (IM) guide is oriented in the inferior vena cava (IVC) pointed towards the abdominal aorta. A 6Fr JR4 guide with a 25-mm Gooseneck snare (*arrow*) oriented orthogonally to the coplanar angle in preparation for wire crossing. **c** The image intensifier is rotated 90° to the coplanar angle and the IM catheter trajectory into the open snare in the abdominal aorta. **d** Assembly of a coaxial, serial telescoping system composed of a 0.014" Confianza Pro 12 within a 0.014" Piggyback, all nested inside a 0.035" Navicross. **e** The end of the of Confianza Pro 12 wire is clamped to an electrosurgical pencil with a hemostat. **f** With the

application of 50 W of "cut" electrosurgical energy, the 0.014" wire (*arrow*) traverses the IVC and abdominal aortic wall to the level of the snare. **g** The 0.014" wire is captured and towed to the thoracic aorta. A 0.014" Piggyback catheter (*circle*) crosses into the abdominal aorta. **h** Using the Piggyback 0.014" → 0.035" wire converter enables passage of a 0.035" Navicross (*arrow*) to facilitate delivery of a 0.035" Lunderquist wire, a 14 Fr Edwards Lifesciences E-sheath (*arrow*) is delivered to the abdominal aorta. **j** Using a small curl Agilis catheter (*), an Amplatzer Duct Occluder 10/8 (*arrow*) is deployed with the retention disc against the abdominal aortic wall. **k** Final DSA aortogram demonstrating minimal flow (type 0) across the transcaval fistula

the stent of choice is an Ovation iX aortic limb extender stent (Endologix, Irvine, CA).

Transcaval Access Peripheral to TAVR

A multitude of large bore devices have entered the heart and vascular space, and unique circumstances have sometimes prompted the need for transcaval access. For instance, axial flow hemodynamic support devices (Impella, Abiomed, Danvers, MA) for either 3.5 or 5.0 L devices and thoracic endografts have been placed using transcaval access [10, 11].

Transcaval Access Without CT-Planning

In the event large bore access is needed emergently, for instance Impella 5.0 placement, transcaval access can be

performed without antecedent CT-planning. This technique is reserved for highly experienced operators, and the clinical scenario must warrant the risk of possibly unintentionally traversing bowel or an arterial vessel. The most important information to ascertain is a transcaval crossing site and the coplanar angle for crossing. Vascular access as described previously is established, and pigtail catheters are placed in both the IVC and abdominal aorta respectively. The pigtails should be oriented so that the curve points anterior-posterior and both pigtails match. Subsequently, the fluoroscopic image intensifier should be rotated until the pigtails are superimposed to identify the coplanar and its orthogonal angle. Once established, DSA angiography can be performed to confirm the distances from the aortoiliac bifurcation and renal arteries prior to crossing. High-intensity x-ray is used to confirm a calcium-free zone. Otherwise, transcaval access is performed as previously



Fig. 4 Classification system of angiographic patterns in transcaval closure. **a** Complete occlusion of the transcaval tract after closure (type 0). **b** Patent, funnel-shaped fistula (*circle*) flowing into the inferior vena cava (type 1). **c** Patent fistula with a “cruciform” pattern of contrast flow

(*arrow*) at the occluder (type 2). **d** Extravasation (*arrow*). Note that there is superimposed flow into the vena cava but the contrast staining pattern without clearance should be interpreted as retroperitoneal bleeding

described. Caveats to closing a transcaval tract with a long sheath dwell time include vigorous shunting, and the tract may be larger due to the sheath size used (22–24Fr). If the abdominal aorta is able to accommodate, the use of an ADO I 12/10 has been useful in achieving closure.

Comparative Alternative Access for TAVR

Established alternative access for TAVR includes transapical, transaortic, transcarotid, transaxillary, and transcaval (Table 5). While there are no prospective comparative studies for alternative access, the relative morbidity with respect to

bleeding, myocardial injury, and pain have downgraded the appeal of transapical and transaortic access [12–14]. Furthermore, chest invasion from transthoracic access appears to stimulate higher rates of atrial fibrillation [15]. Transaxillary access is most frequently used alternative access in the USA (49%) and has a low vascular complication rate (2.5%) [16]. However, a relative high stroke rate (6.3%) was observed casting concern over its use. Transcarotid access is gaining popularity despite some reservations against complete occlusion of a carotid vessel. Single-center retrospective comparison found no differences in hospital or 1-year outcomes for transcarotid, transcaval, and transfemoral approaches [17].

Table 5 Comparison of alternative access

| Alternative access | Advantages | Disadvantages |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Transthoracic | <ul style="list-style-type: none"> • Simulates aortic cannulation, a well-established surgical procedure • Excellent catheter control during prosthesis deployment | <ul style="list-style-type: none"> • Thoracic invasion increases bleeding, pain and rates of atrial fibrillation • Patients with chronic lung disease tolerate thoracic invasion poorly |
| Transapical | <ul style="list-style-type: none"> • Excellent catheter control during prosthesis deployment | <ul style="list-style-type: none"> • Thoracic invasion increases bleeding, pain, and rates of atrial fibrillation • Patients with chronic lung disease tolerate thoracic invasion poorly • Myocardial injury has been reported • Some cases of compromised myocardial integrity have resulted in aborted cases due to the inability to place pledgeted sutures |
| Transaxillary | <ul style="list-style-type: none"> • Relatively generalizable to most centers • Can be performed percutaneously or with surgical exposure | <ul style="list-style-type: none"> • Increased stroke rate observed in a self-reported US registry • Increased operator radiation exposure |
| Transcarotid | <ul style="list-style-type: none"> • Well-established surgical techniques for carotid exposure and repair • Low rates of bleeding and vascular complication | <ul style="list-style-type: none"> • Suboptimal ergonomics for valve delivery • Increase operator radiation exposure |
| Transcaval | <ul style="list-style-type: none"> • Optimized ergonomics for TAVR | <ul style="list-style-type: none"> • Increased cost of procedure • Decreased generalizability due to increased requirements for operator experience and repertoire |

The main disadvantage appears to be operator radiation exposure and limited experience across centers. Transcaval access optimizes cathlab ergonomics and facilitates TAVR the most; however, it does increase the expense of the procedure and requires a diverse range of skills and expertise. While the single-arm NIH registry did show the ability to disseminate the technique, the transcaval access and closure should be reserved for experienced operators.

Conclusion

Transcaval is a viable alternative arterial access for large bore devices and while it poses risks of bleeding and vascular injury, with proper planning and experience, it is safe and effective. Understanding and applying the concept of venous decompression is critical to success of transcaval technique. Experience in a proof-of-concept single-arm registry demonstrated immediate safety without long-term adverse consequences. Iterative advances in technique, increased experience, and use of a dedicated closure device may further improve outcomes.

Compliance with Ethical Standards

Conflict of Interest Marvin H. Eng is a clinical proctor for Edwards Lifesciences.

Pedro Villablanca has no conflicts to report.

Tiberio Frisoli is a clinical educator for Edwards Lifesciences.

Adam B. Greenbaum is a proctor for Edwards Lifesciences, Medtronic, and Abbott Vascular; holds equity in and has been a scientific advisor for Transmural Systems; and has received institutional research support from Edwards Lifesciences, Abbott Vascular, Medtronic, and Boston Scientific.

William W. O'Neill is a consultant to Abiomed, Medtronic, and Boston Scientific.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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