

Transapical implantation of the Intrepid device: Case planning and operative technique



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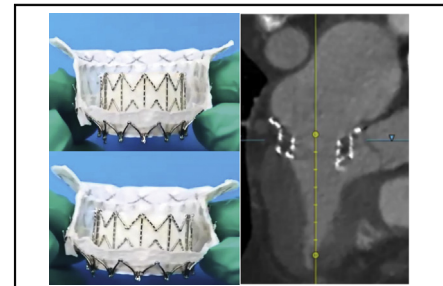
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Intrepid transcatheter mitral valve replacement with 2-frame design and postimplantation cross-sectional computed tomography scan after 12 months.

CENTRAL MESSAGE

The transapical approach provides a safe and direct route for implantation of transcatheter mitral valve replacement devices. Early results have been encouraging. Modifications to facilitate a less invasive transeptal implantation are underway.

See Commentary on page 34.

Video clip is available online.

Transcatheter aortic valve replacement (TAVR) has shown astounding success, resulting in its rapid adoption and widespread use.¹ Given the positive impact of TAVR, efforts unsurprisingly shifted to address mitral valve pathology with transcatheter techniques. Untreated severe symptomatic mitral regurgitation (MR) reaches a mortality rate of 50% at 5 years of follow-up and has an estimated prevalence of 2-4 million people in the United States.^{2,3} MR is age-dependent, with global prevalence increases from 1.7% to 10% in individuals age >75 years.⁴ A large proportion of patients with MR are not ideal candidates for surgical intervention and may benefit from transcatheter options.

Emerging options to address MR can be divided into transcatheter mitral valve repair (TMVr) and transcatheter mitral valve replacement (TMVR) technologies. TMVr addresses abnormalities of one of the components of the mitral valve apparatus, such as correcting annular dilatations, abnormal leaflet coaptation, and chordae pathology. Among the TMVr technologies, the greatest clinical experience is with the MitraClip device (Abbott Vascular, Santa Clara, Calif), which is approved for high-risk primary and secondary MR patients.^{5,6} However, TMVr generally reduces MR rather than eliminates MR. Alternatively, TMVR can eliminate MR independent of the pathology and may offer a

promising alternative for patients with contraindications to surgery.⁵

Although attractive in concept, the development of TMVR faces many challenges—atomic and physiological, pathological, and device design and access routes.

ANATOMIC AND PHYSIOLOGICAL CHALLENGES

Compared with the aortic valve, the mitral valve is a large, noncircular and dynamic structure (Figure 1, A). Unlike in aortic stenosis, the mitral annulus is typically not calcified and contains sections of myocardial and fibrous tissue that limit structural support to secure the device. With exposure to higher pressure during closure (systolic blood pressure), secure fixation of the device is critical (Figure 1, B). Once the TMVR is implanted, the anterior mitral leaflet can become pinned open toward

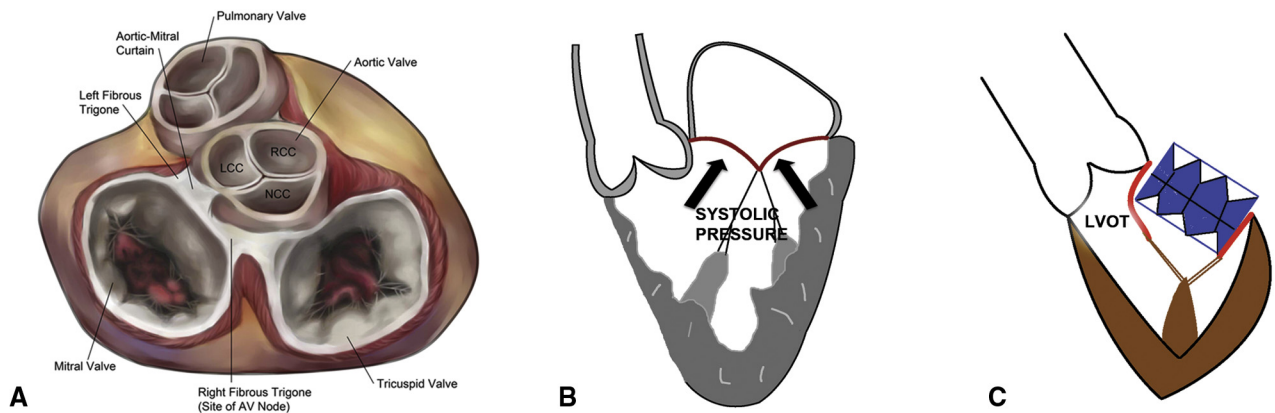


FIGURE 1. Mitral valve anatomy and physiology. A, Shape and relationship of the mitral valve. B, Closing pressure is higher on the mitral valve compared with any other valve (*black arrows*). C, Once a transcatheter mitral valve device is implanted, the anterior leaflet is hinged open toward the left ventricular outflow tract (LVOT), resulting in varying degrees of reduction in the LVOT area. AV, .

the left ventricular outflow tract (LVOT), potentially resulting in LVOT obstruction (neo-LVOT) (Figure 1, C).⁷ LVOT obstruction remains one of the major limiting factors of this therapy.

the left ventricle. Within each group, there is a spectrum of pathology; for example, degenerative disease can vary from a simple P2 prolapse to the more complex Barlow's disease. Thus, a single design of TMVR might not be able to address all pathologies.

PATHOLOGICAL CHALLENGES

Unlike aortic stenosis, MR is of multifactorial etiology (ie, primary or secondary MR).^{8,9} Primary MR is a result of changes in the mitral valve apparatus, including mitral valve leaflets, chordae, and papillary muscle. Secondary MR is a result of geometric and/or functional changes in

DEVICES AND ACCESS ROUTES

There are currently several devices at different stages of development and testing (Figure 2).⁵ Each device has a unique design and positioning and delivery method (Figure 2, E); however, a common feature of all devices is

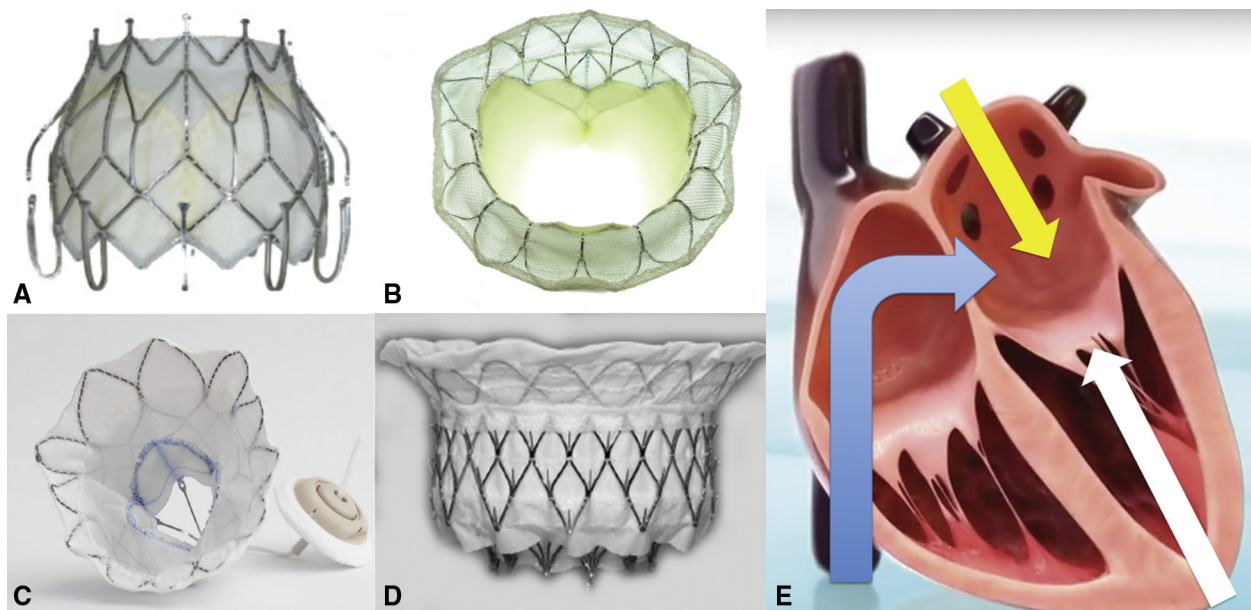


FIGURE 2. Examples of transcatheter mitral valve replacement devices currently in use and possible access for implantation. A, CardiaQ device, implanted via transapical (TA) and transseptal (TS) routes. B, Tiara device, implanted by the TA route. C, Tendyne device, implanted by the TA route. D, Intrepid device, implanted by the TA route. E, Access routes for implantation: The *blue line* represents the TS route; the *white line*, the TA route; the *yellow line*, the transatrial route.

large size, resulting in larger crimp profiles and delivery systems. Thus, for the majority of TMVR devices, the transapical (TA) route is preferred for implantation. Furthermore, proximity to the mitral valve allows better control and precision for implantation using a TA approach. However, the TA approach is invasive, especially with large-caliber delivery systems, and can result in left ventricular (LV) injury and tear.¹⁰ In certain patient subgroups, such as those with severe lung disease and kyphoscoliosis, a TA approach may be contraindicated. Although the transseptal (TS) approach is less invasive, it is technically more challenging owing to the large delivery systems and small maneuvering space in the left atrium.

The greatest clinical experience in the TMVR space is with 2 devices: Tendyne (Abbott Vascular, Santa Clara, Calif) (Figure 2, C) and Intrepid (Medtronic, Minneapolis, Minn) (Figure 2, D).^{11,12} Both of these devices are implanted via the TA approach and although not commercially available, are available through clinical trial enrollment.

In the discussion that follows, we focus on device description, case planning, and the step-by-step procedure for Intrepid device implantation.

Intrepid TMVR Device

The bioprosthesis is being investigated in 42-mm and 48-mm outer diameters and is built around a 27-mm inner valve structure with an effective orifice area of 2.4 cm² (Figure 3, A and B). Fixation and sealing are achieved through a combination of design features. The outer fixation ring of larger circumference than the native mitral valve annulus with varying degrees of radial stiffness along its axial length. The atrial portion of the outer fixation ring is flexible where the frame and native annulus engage, allowing for

conformation to the native annulus; in contrast, the ventricular portion is stiffer and resists compression, producing a “champagne cork-like” conformation (narrow neck and wider body) to resist migration under systolic pressure (Figure 3, C). Three circumferential rings of frictional elements further aid fixation through their interaction with the native leaflets (Figure 3, A and C). The outer and inner stent frames are covered by a polyester fabric skirt to facilitate tissue ingrowth for long-term fixation and sealing.

Given that the device's circular anatomic orientation is not essential for device placement, thereby simplifying device implantation. The prosthesis has minimal protrusion downstream of the annulus to help maintain LVOT patency.

The Intrepid Delivery System

The Intrepid delivery system is currently designed for a TA access only and consists of an apical sheath and a hydraulically actuated delivery catheter (Figure 3, D and E). The Intrepid device is loaded into a 33 Fr delivery catheter and then advanced through the sheath into the mitral position without a wire.

Patient Screening and Case Planning

Given that TMVR is still in the early phases of development, careful preprocedural planning is necessary to determine patient suitability and successful outcome. Multimodality imaging is an indispensable tool for TMVR planning. Echocardiography provides physiological data, such as MR severity, MR etiology, intracardiac thrombus, left ventricular (LV) function and morphology, and mitral valve annulus size, shape, and calcification. Transesophageal echocardiography (TEE) is essential, including 3D TEE to aid patient selection. In a suitable

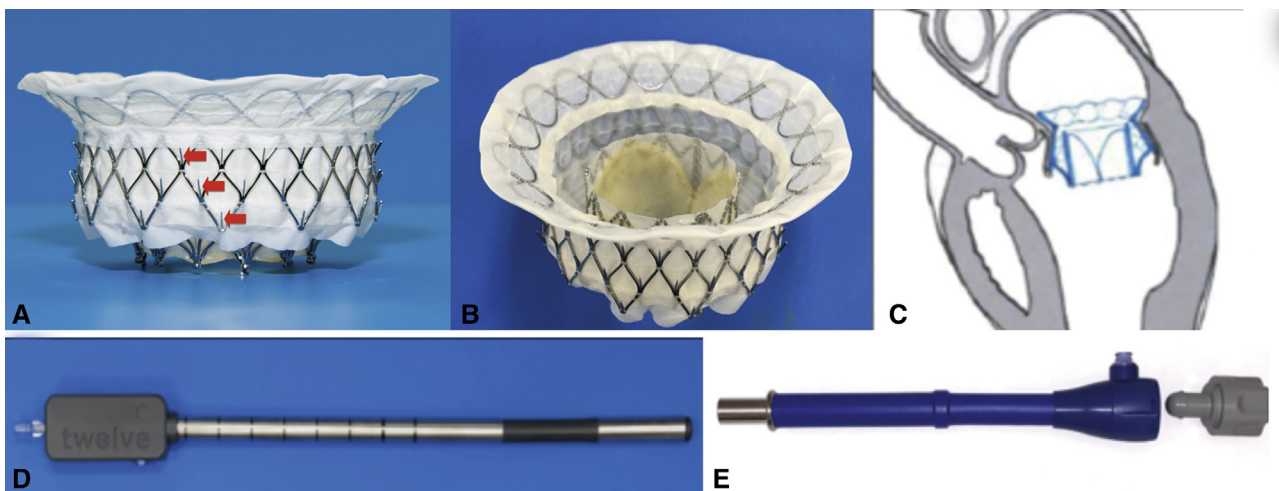


FIGURE 3. Intrepid transcatheter mitral valve replacement device and delivery system. A, Exterior of the Intrepid device highlighting the atrial brim and frictional elements on the outer stent frame. B, Dual stent frame design highlighting the inner circular 27-mm functional stent with 3 bovine pericardial leaflets. C, Diagram highlighting the interaction of the Intrepid device when implanted with the native mitral annulus. D, Hydraulic delivery system. E, Sheath.

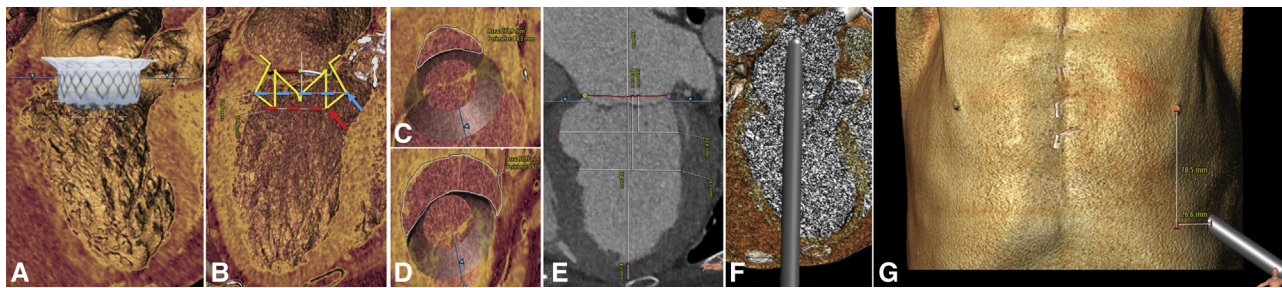


FIGURE 4. Intrepid sizing and implantation planning with multislice computed tomography. A, Sizing of the device is done after measuring the mitral annular perimeter and area and simulating a device implant. B, Neo-left ventricular outflow tract (LVOT) calculation and LVOT obstruction risk. A virtual device is implanted, and the cross-sectional area of the LVOT is calculated at 2 points (blue and red arrows). C, Neo-LVOT area at level of blue arrow. D, Neo-LVOT area at level of red arrow. E, and F, A virtual line/sheath is drawn perpendicular to the mitral annulus to provide an ideal point for a left ventricular purse-string suture. Ventricular thickness is measured at the entry point and should be >5 mm. G, The same virtual sheath is extended outside the chest wall to provide location of the incision on the chest wall.

candidate, case planning can proceed with computed tomography (CT) scanning, including retrospectively obtained electrocardiography (ECG)-gated cardiac CT.

Device size. Using dedicated software, the mitral annular area and circumference are calculated, and device size is selected depending on a 10%–20% perimeter oversize (Figure 4, A). CT scanning also helps assess interaction of the device with mitral annular calcification. Presence of severe mitral annular calcification is a surgical contraindication.

LVOT obstruction risk. The possibility of LVOT obstruction is assessed by implanting a virtual valve in the mitral position and measuring neo-LVOT (Figure 4, B–D). An area <1.5 cm² is a surgical contraindication.¹³

LV access. The site of LV puncture must remain perpendicular to the valve for ideal positioning of the Intrepid device. A 10–15° deviation may be tolerated. Once the plane of the mitral annulus is determined, a perpendicular vector is drawn to determine the exact location of the LV puncture. LV wall thickness at the proposed site of the LV purse-string suture is assessed (Figure 4, E). A minimum 5 mm ventricular thickness is measured to ensure safe entry. As a precaution, the area of the access point is checked for any existing thrombus.

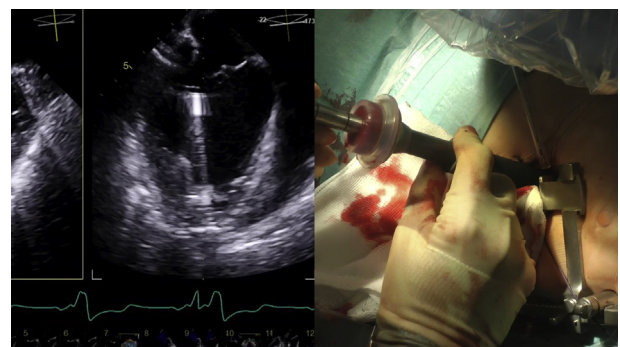
Chest wall incision site. Extending the same vector outside the chest wall provides the exact location of the chest wall incision with respect to the intercostal space and surface marking (Figure 4, F and G).

Device Implantation (Video 1)

Preparation and positioning. The procedure is performed under general anesthesia. The patient is placed supine, and the entire chest, abdomen and legs up to the knee are prepped and draped. The procedure is TEE-guided and fluoroscopy-assisted. TEE analysis is performed, and device suitability is confirmed. The target line for implantation is determined using the X-plane. The target line is approximately 4–5 mm above the mitral annulus and is

the line where the atrial brim is aligned during deployment to ensure optimal device positioning (Figure 5). Once the team is satisfied with landmarks and imaging, then they should proceed. The fluoroscopic coaxial view of the mitral valve annulus is checked. We recommend checking this view before draping the patient. This view is only used to confirm the brim expansion and is not used for positioning the device.

Incision. Using landmarks provided by the CT scan, the point of incision is identified. A transthoracic echocardiography (TTE) probe is placed on the point marked to visualize the left ventricle. If the site is immediately over a rib, the incision is made on the rib to allow entry through the space above or below through the same incision. We prefer to make a 5- to 6-cm incision with the point in the center. After entering the chest cavity, the pericardium is identified. Extra care should be taken in thin patients, those with large ventricles, and in redo situations, because the left ventricle may be extremely close to the chest wall. A soft



VIDEO 1. Step-by-step procedure for replacing the Intrepid transcatheter mitral valve via the transapical route. The transapical approach allows a safe and direct route for implantation of transcatheter mitral valve replacement devices. Early results have been encouraging. Modifications are on the way to facilitate less invasive transeptal implantations. Video available at: [https://www.jtcvs.org/article/S2666-2507\(20\)30178-4/fulltext](https://www.jtcvs.org/article/S2666-2507(20)30178-4/fulltext).

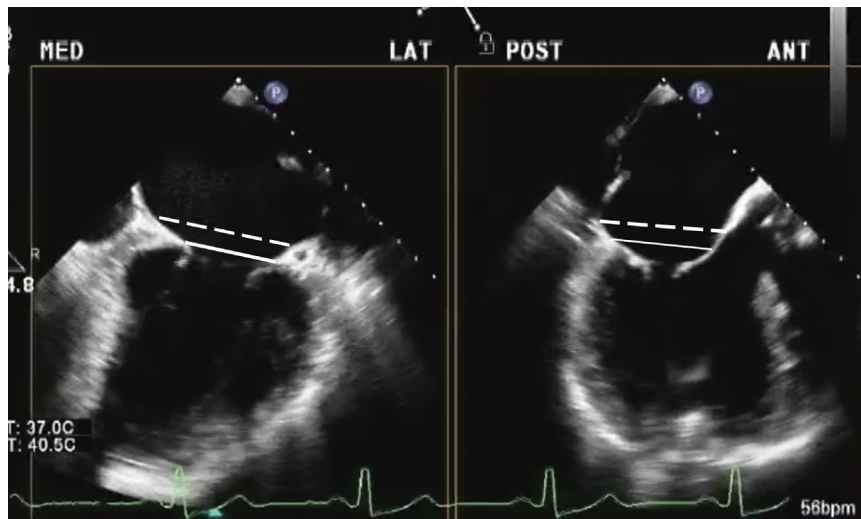


FIGURE 5. Reference plane for Intrepid implantation using transesophageal echocardiography. Images are obtained in X-plane and the reference line (dotted white line) is marked 5 mm above the mitral annular plane (solid white line).

tissue chest retractor can now be inserted at this point. Pericardial fat is dissected but not excised; this can be used later to cover the purse-string sutures.

Apical exposure. The pericardium can be opened parallel to the incision, because it provides better exposure. The pericardium is sutured to the skin. If necessary, a small chest spreader is used to provide better exposure (Figure 6, A). It is important to use a retractor with minimum metal components, because it can overlap with important fluoroscopic information. We usually take purse-strings and then remove the retractor when the procedure starts, and then reinsert it when the sheath is removed, allowing for apical control.

Purse-string sutures. The site of the purse-string sutures provided by the CT analysis is confirmed by the “finger poke” test (Figure 6, B). This is the most critical step. The finger poke test is performed in X-plane view and the trajectory of the delivery system in relation to the mitral annulus is assessed. Two purse-string sutures are placed with pledgets to ensure hemostasis during and after the procedure. The purse-strings are usually placed using 2-0 or 3-0 Polypropylene sutures. The size of the purse-strings must

accommodate the sheath. It is a good idea to place the sheath and draw a line with a marker, then place the purse-strings around it. The purse-string can be 2 horizontal mattress sutures, a triangle or a circle (Figure 6, C), depending on the assessment of LV quality after opening the pericardium. Teflon pledgets are usually preferred, but other materials, such as pericardium or Dacron, can also be used. In reoperations, if the pericardium is densely adhered, the purse-strings can be placed directly through the pericardium.

Insertion of the delivery system. Predetermined fluoroscopic projection is obtained, and the apex is punctured. A soft J-tip guidewire is placed into the left atrium through the apical puncture. If necessary, an 8 Fr sheath is introduced, and various catheters are used to help placement of the wire in the left atrium. The needle/sheath is then removed, and the Intrepid delivery sheath is introduced over the guidewire (Figure 6, D). Because the sheath is large, we prefer to make a linear incision with a knife on the ventricular wall immediately before inserting the sheath. This allows a predictable tear rather than an

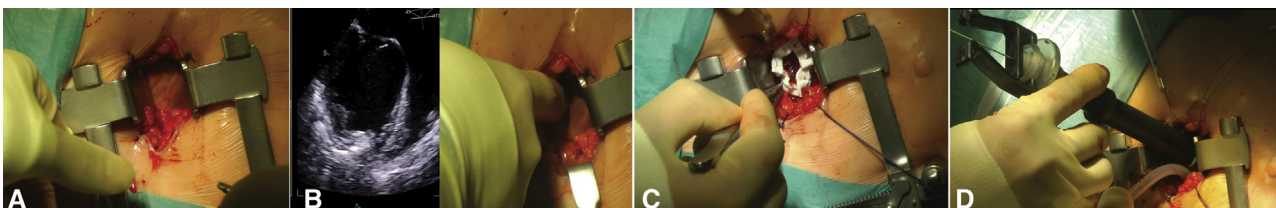


FIGURE 6. Intrepid implantation: transapical access. A, A 5- to 6-cm incision is placed in the left fifth to sixth intercostal space according to computed tomography planning. Once the pericardium is opened, the left ventricle is visualized. B, The finger-poke test is performed on the left ventricle under transesophageal echocardiography guidance to select the site of the purse-string suture (white arrow). C, Purse-string sutures are placed using Teflon pledgets. D, The sheath is inserted over the guide wire.

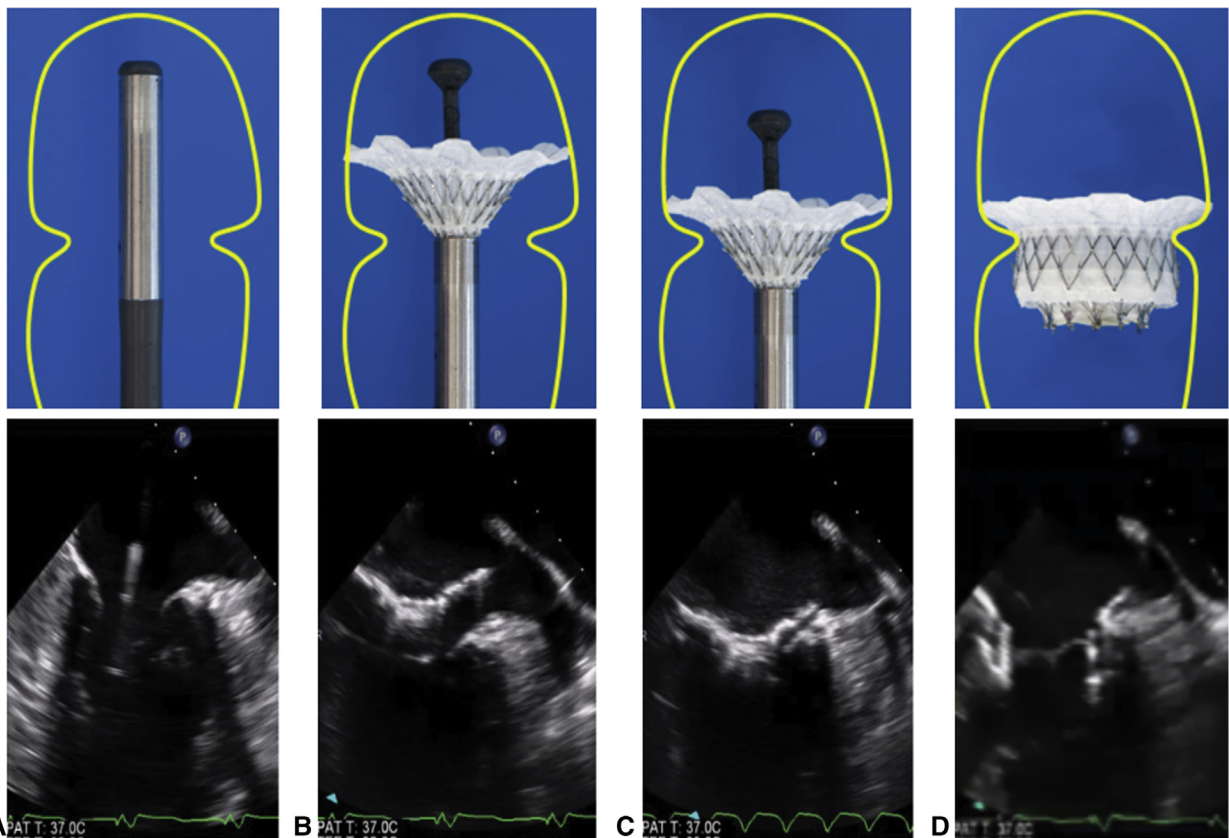


FIGURE 7. Steps of Intrepid implantation. A, Insertion of the delivery system into the left atrium. B, Expansion of the atrial brim. C, Retraction of the brim to the “reference plane” under rapid pacing. D, Deployment of the Intrepid device under rapid pacing.

unpredictable tear caused by the sheath. Furthermore, we have seen less hematoma in the LV wall with this technique. The tip of the sheath protrudes approximately 1-2 cm into the LV cavity. The sheath is secured and held by the first assistant, and the dilator is removed along with the guidewire. The Intrepid delivery system is inserted, and the sheath is deaired.

Valve implantation. Intrepid valve implantation is performed in 4 steps:

Step 1. The first step is to introduce the delivery system across the mitral valve into the left atrium (Figure 7, A). This is performed under echocardiographic guidance. Because this system is not over a wire, subtle manipulations under echocardiographic guidance allow for an easy introduction of the system into the left atrium. Care is taken to observe the progress of the delivery system and prevent entanglement within the chordae. If the puncture site is ideal, this step is remarkably easy.

Step 2. The atrial brim is fully expanded using the hydraulic mechanism within the left atrium (Figure 7, B). A complete brim expansion is confirmed under fluoroscopy by a 360° rotation of the delivery catheter within the sheath.

Step 3. The atrial brim is carefully pulled toward the target line and is aligned to it (Figure 7, C). The X-plane and 3D views are obtained to conform to this alignment all along the mitral valve annulus. It is important to ensure that no part of the brim is below the mitral valve annulus. Unlike other devices such as Tendyne, the brim does not provide anchoring.

Step 4. A short burst of rapid pacing is performed, alignment of the brim to the target line is optimized, and the valve is deployed using hydraulic mechanism (Figure 7, D). This step is performed under echocardiographic and fluoroscopic guidance. The device position and function are confirmed by echocardiography. Under fluoroscopic and echocardiographic guidance, the delivery system is withdrawn into the sheath.

Apical control. Hemodynamics are optimized. Then, under a short burst of rapid pacing, the sheath is removed, and purse-string sutures are tied. Additional sutures are placed if needed. The pericardium is partially closed, with care taken to cover the pledgets and sutures with fat. The chest is closed with a pleural drain. An intercostal block

is performed for postoperative pain control. The patient is extubated on the table.

Postprocedure anticoagulation is started on the next day with warfarin. The chest tube is removed on the following day. Anticoagulation is mandatory for 3 months (international normalized ratio, 2.5-3.0), along with a single antiplatelet agent, either aspirin (75 mg daily) or clopidogrel (75 mg daily). Regular follow-up with echocardiography is mandatory.

FUTURE DIRECTIONS

From the first-in-human use of the Intrepid TMVR device in 2014 to the current ongoing APOLLO trial, more than 300 implants have been performed successfully with the device, and early results are promising.¹² The major challenge is improving the safety profile of the procedure and device modification to accommodate the wide range of morphologies. Second-generation iterations of the device allow recapturability and better sealing in certain mitral annular calcification morphologies. Future iterations will also result in reduction in the device crimp profile, which may impact the morbidity associated with large-bore TA access. A minimized device crimp profile also may allow the device to be delivered through a less invasive TS approach.

TA access continues to be the dominant and reliable access route for TMVR implantation. Greater clinical experience, enhanced patient selection, and improved procedural planning will result in better outcomes.

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