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TAVI: TRANSCATHETER AORTIC VALVE IMPLANTATION

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Introduction

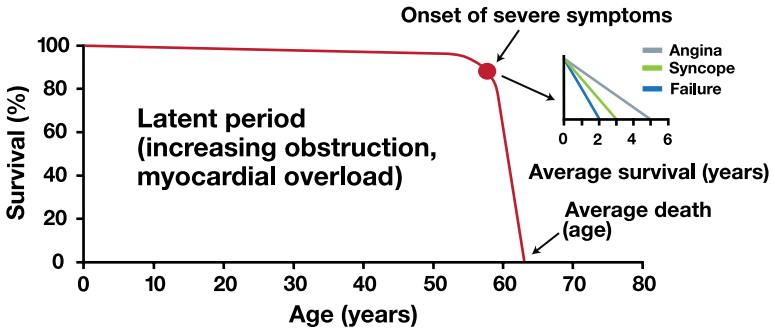

Figure 1. Survival in adults with aortic stenosis

Aortic valvular stenosis is a disease with a long latent period followed by rapid progression to death after the onset of symptoms. The classic series by Ross and Braunwald reports an average survival of 2 to 5 years after symptom onset (Figure 1).[1] There is no medical therapy proven to extend survival. Fortunately, surgical aortic valve replacement (AVR) is now done with an operative mortality of 3% to 4% for isolated AVR and 5.5% to 6.8% for AVR combined with coronary artery bypass (CAB)[2] and with a 10-year survival that averages a little over 60%. The success we have seen with surgical AVR is complicated by an increase in aortic stenosis with age combined with the aging of our population itself. It is estimated that by 85 years of age, 8% of the population will have aortic stenosis.[3] Surgical series have been reported with operative mortality of 2% for AVR in patients 80 years and older,[4] but increasing age is associated with increasing risk, and not all patients that meet guideline criteria for AVR are offered therapy.

It was recently reported in a survey of European centers that 31.8% of patients with severe, isolated, symptomatic aortic stenosis were not offered surgical therapy due to risk level, comorbidities, or patient refusal.[5] A large academic medical center in the United States reported a review of echocardiographic results from their institution that showed only 453 out of 740 patients (61%) with severe aortic stenosis — defined as aortic valve area (AVA) of 0.8 cm^2 or less — received surgery.[6] In the United States, it is estimated that about 749,000 patients have aortic stenosis and, of these, 125,000 have severe stenosis. This can be compared to the estimated number of AVR operations done in the United States annually of 70,000. It is clear that there is a substantial population with severe, life-threatening aortic stenosis that is underserved. This has led to the search for less morbid treatment options for aortic stenosis.

Treatment of Aortic Stenosis

Aortic stenosis is a mechanical obstruction to left ventricular outflow. As the impedance to outflow persists, left ventricular hypertrophy results from increased cardiac work and eventually leads to cardiac failure and decompensation. Effective treatment must incorporate relief of the mechanical obstruction. Surgical AVR provides complete excision of the stenotic native valve and replacement with a minimally obstructing prosthetic valve.

Temporary relief of obstruction may be obtained by percutaneous balloon aortic valvuloplasty (BAV). The technique was first used in the 1980s, but its use was diminished when the high rate of recurrent valvular stenosis (>50%) became evident. Modest reduction of gradient and increase in AVA are seen following BAV, and the procedure is very effective in relieving the symptoms of congestive heart failure (CHF). However, the increments in AVA are small (valve rarely exceeds 1.0 cm^2), recurrent symptoms usually occur within 6 months, and the long-term survival is not different from untreated aortic stenosis.[7] In the last several years, BAV has seen increased use as a bridge to surgery for patients with severe heart failure and as a temporizing therapy in patients with severe symptomatic disease who are not candidates for operative valve replacement. The increase in its use is due at least in part to improvements in balloon technology, allowing lower profiles that are less likely to damage the iliofemoral vessels, and to the adaptation of rapid ventricular pacing to eliminate cardiac ejection during balloon inflation, thus allowing the balloon's position to remain stable during inflation. As a result of the imperfect physiological and unsatisfactory clinical outcomes of BAV, the concept developed that a stent-mounted valve could be used to maintain its early success.

In a proof-of-concept experiment, Andersen reported in 1992 the placement of a stent-mounted valve inside of the native valve of pigs.[8] In 2002, Cribier reported the first-in-man transcatheter aortic valve implantation (TAVI).[9] Since this first success, there has been an explosion of interest in and technology for TAVI. Currently there are 2 catheter-based aortic valve systems available in Canada and Europe, where more than 12,000 implants have been performed. These are the SAPIEN Valve (Edwards Lifesciences, Inc.) and the CoreValve (Medtronic, Inc.). The SAPIEN valve is balloon-expandable while the CoreValve is self-expanding. Both valve delivery systems are large (18–24 Fr), and insertion of either prosthesis requires a fair amount of operator skill. The Edwards SAPIEN valve has been studied in the

Figure 2. SAPIEN Valve (Edwards, Inc.)

Placement of Aortic Transcatheter Valves (PARTNER) trial in the United States. The trial was a multicenter randomized clinical trial comparing TAVI with standard medical therapy (including BAV) in patients with severe aortic stenosis and high-risk surgical features. The first arm of the study compared TAVI to best medical therapy (including BAV) in patients thought not to be surgical candidates due to extreme risk. Mortality at the end of one year was 30.7% for TAVI and 50.7% for standard medical therapy, and heart failure symptoms of NYHA classes III or IV were 25.3% versus 58%.[10] The results of the second arm of the study, in which TAVI is compared to surgical AVR, are pending. A second trial with the Medtronic CoreValve is underway. Trial design is very similar to the PARTNER trial with two trial arms. The first arm will compare TAVI with the CoreValve versus best medical therapy with patients randomized 2:1. The second arm will be TAVI versus open surgical AVR randomized 1:1.

Several important design differences distinguish the CoreValve from the SAPIEN system. The SAPIEN valve consists of a trileaflet bovine pericardial valve that is mounted within a stainless steel stent (Figure 2). Prior to implantation, the valve is crimped by the operator onto a delivery balloon. The native valve is prepared for implantation by BAV. The prosthetic valve is then delivered through the femoral artery to the aortic annulus. Once satisfactory positioning is achieved, rapid atrial pacing is performed and the implantation balloon is inflated. In patients with severe iliac disease with vessels that are too small to allow transfemoral delivery of the valve, implantation can be performed via a small thoracotomy allowing transapical implantation through the left ventricle. Following implantation, the ventriculotomy is repaired by surgical closure with a purse-string suture.

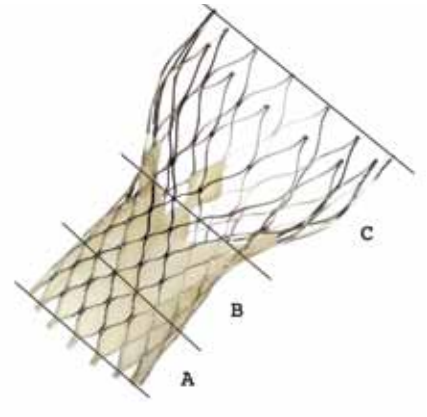

Figure 3. CoreValve (Medtronic, Inc.)

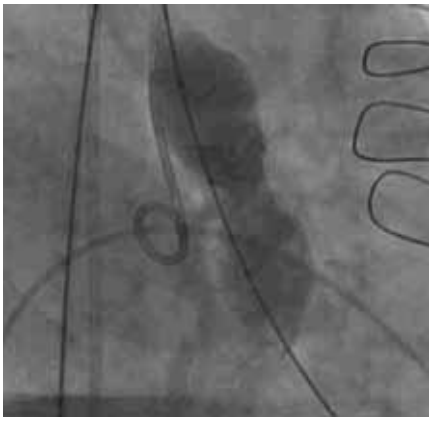

Figure 4. Balloon aortic valvuloplasty initial picture

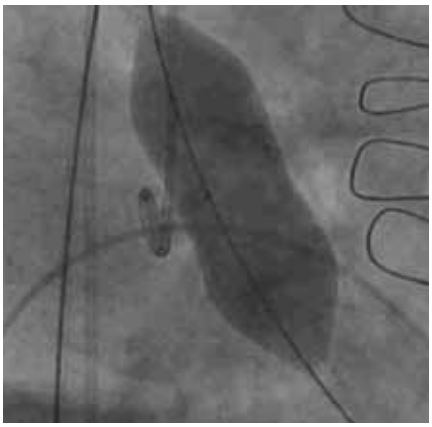

Figure 5. Balloon aortic valvuloplasty after inflation

Structure of Corevalve System

The CoreValve ReValving System consists of three separate components: the valve itself, which is a self-expanding Nitinol support frame with a trileaflet porcine pericardial tissue valve and anchoring skirt sutured to the frame; a catheter delivery system; and a disposable valve loading system. The valve forms the central component and is anchored to a self-expanding radiopaque Nitinol frame that holds the tissue valve in position. The Nitinol frame has three distinct levels of diameter with varying hoop and radial strength (Figure 3). The inflow portion of the frame exerts high radial force against the left ventricular outflow tract to allow secure fixation. This area exerts a constant centrifugal force that allows the valve to adjust to varying annular sizes during implantation and will help mitigate paravalvular leak over time. The skirt portion of the pericardial valve is sutured to this portion of the frame to achieve a seal to the annulus. The center section that contains the actual valve leaflets is constrained to allow coronary flow. It exhibits a high hoop strength to resist any deformation from the native valve leaflets. In this configuration, the valve actually sits in a supra-annular plane. The outflow portion has the largest diameter and a low radial force. This portion of the valve is not engaged in the anchoring process and serves to orient the valve to the aorta. This portion of the frame also contains the loading loops used to secure the valve to the delivery system (Figure 3).

There are two separate sizes available that will cover the majority of annular sizes. The proper size is chosen based on imaging studies of the aortic root. Access is gained via the femoral artery either by cut down or percutaneously. The proper sized valve is then prepared and hand-loaded onto the 18-Fr catheter delivery system using the dispos-

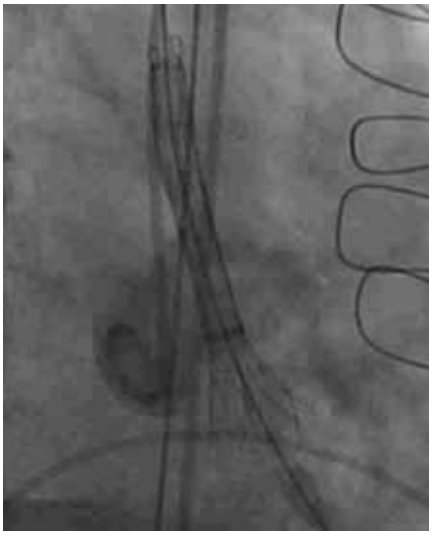

Figure 6. CoreValve initial deployment

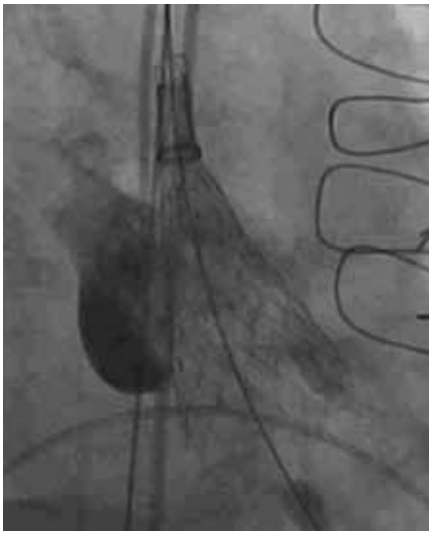

Figure 7. CoreValve two-thirds deployment

able loading tool from the CoreValve ReSizing System. The patient's native aortic valve is prepared for CoreValve insertion with BAV under rapid pacing (Figures 4 and 5). After BAV, the valve is positioned across the native aortic valve, which allows several mm of the inflow portion to sit below the annulus to allow anchoring (Figure 6). Once the inflow portion is seated properly, the valve is rapidly deployed to about two-thirds release. This allows flow to resume through the new CoreValve while maintaining attachment to the delivery system to allow outward adjustment if necessary (Figure 7). An aortogram is performed at this point to confirm positioning and, if correct, the rest of the valve is deployed and the delivery system removed. A final arteriogram is done to confirm final position, and an echocardiogram is done to check valve function, gradient, and paravalvular leak.

The Methodist DeBakey Heart & Vascular Center is excited to participate in this trial. Additional information about the trial or participation in the trial is available at our multidisciplinary valve clinic site, available at *www.debakeyheartcenter.com/valveclinic*.

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