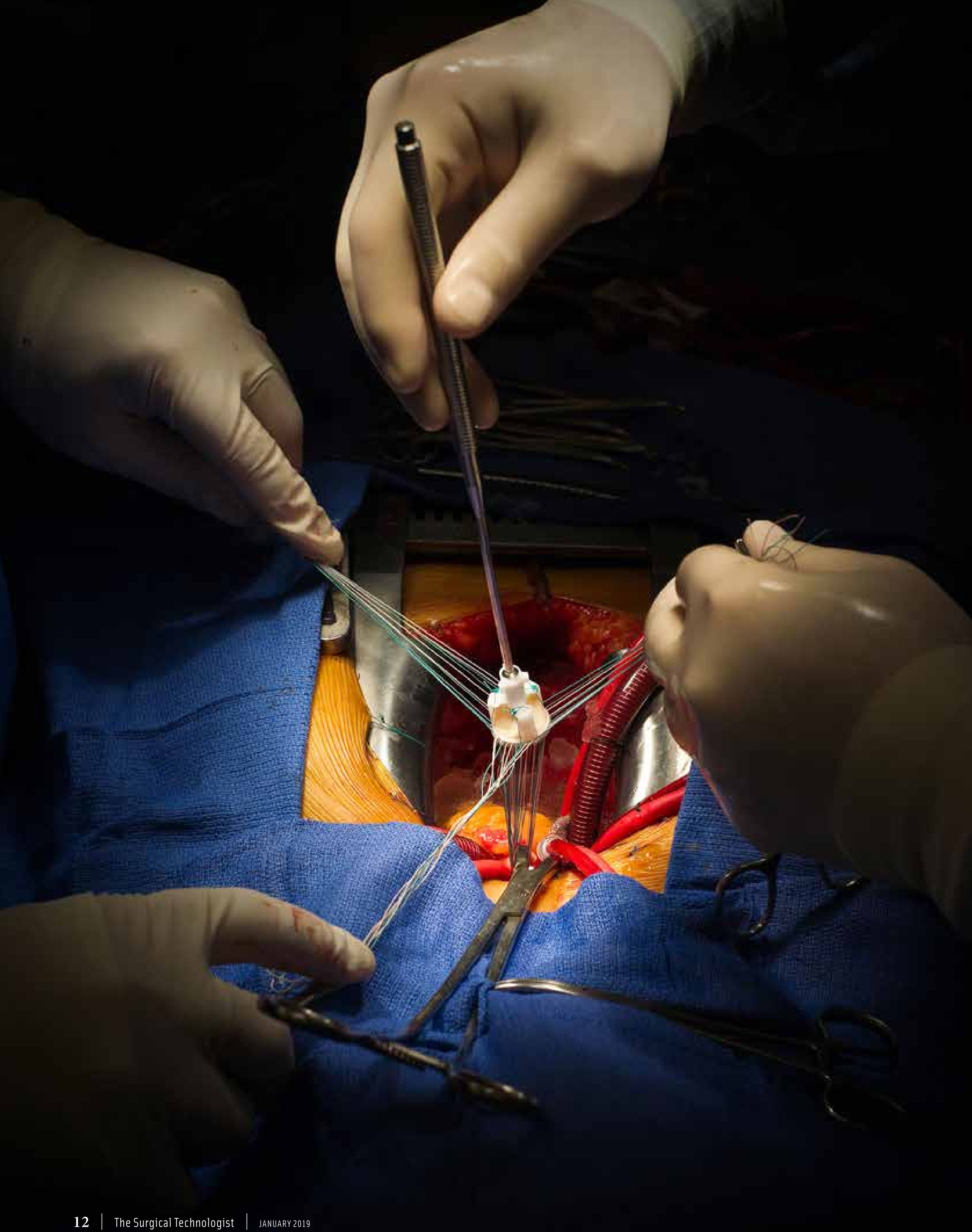

Aortic Valve Replacements

Alex Burke, CST

An aortic valve replacement (AVR) is a procedure in which the existing aortic valve tissue is removed and replaced with one of two types of valves: a tissue valve or a mechanical valve. Replacing the aortic valve will result in a decrease of aortic regurgitation and an increase of blood flow through the aorta.

In comparison with other procedures, this procedure is relatively new having only been around for about 68 years. However, for more than 60,000 people in the United States[3], an AVR is as important for them now as it was for the first few dozen people to undergo this procedure back in mid-1900s.

AORTIC VALVE: ANATOMY AND PATHOPHYSIOLOGY

The aortic valve is one of the four valves in the heart that consists of three leaflets. It is anatomically positioned in the aortic root which comes off of the left ventricle. During systole the aortic valve opens to allow blood to flow through the aorta to the rest of the body. During diastole the aortic valve closes to prevent blood from regurgitating into the left ventricle, referred to as aortic regurgitation or aortic insufficiency, that can lead to heart failure, heart rhythm abnormalities, infection or death.[7]

Aortic stenosis is a condition in which the aortic valve narrows forc-

LEARNING OBJECTIVES

- Recall the history of aortic valves
- Describe the anatomy and pathophysiology affected by these types of procedures
- Compare and contrast between a tissue valve and a mechanical valve
- Review the procedural steps for this operation
- List the equipment and instrumentation needed for an AVR

ing the heart to work harder. To compensate, the left ventricle increases in muscle mass leading to chest pain.[8] Valve stenosis can be congenital, but also can be caused by calcium buildup, rheumatic fever, endocarditis, trauma or rare conditions such as Marfan syndrome and lupus.[7,8]

THE HISTORY OF THE AVR AND THE TYPES OF VALVES

As early as the 1920s, valvular heart disease was corrected by valvuloplasty. Surgeons tried to decalcify the leaflets, while some attempted to attach artificial leaflets. Regardless of the method, results were less than ideal. The calcified leaflets still were stenosed, and the artificial leaflets ruptured.[2]

Dr. Hufnagel, a surgeon from Georgetown University, performed the first heart valve replacement on a human patient in 1952. The patient presented with aortic regurgitation. Dr. Hufnagel's solution was to place a prosthesis, which he created, in the patient's descending thoracic aorta.[1] This prosthesis, essentially a ball in a plexiglass cage, was implanted to decrease the patient's regurgitant flow by 75%. Patients who underwent this procedure ended up with improvements in their symptoms of congestive heart failure.[1] Dr. Hufnagel replaced more than 200 aortic valves with his design; some of the valves lasted around 30 years.[5] Since Dr. Hufnagel, more than 80 different types of mechanical metal or plastic valves have been created and surgically implanted. These include the ball-in-cage design, single-tilting-disk design and bileaflet-tilting-disk design.[3]

The Harkin-Soroff ball valve was first used in 1960. Dr. Dwight Harkin created a ball valve with a double cage made of stainless steel and a ball made of silicone. Two of the first seven patients Dr. Harkin operated on using this valve survived, however, they both needed a second valve replacement. One was redone after 22 years, with the ball showing no signs of deterioration.[5] Following Dr. Harkin's valve were several more types of ball-in-cage valves, essentially the same design with different materials.

Several types of disc valves were created throughout the 1960s, many of which were used on mitral valves. Toward the end of the 1960s, Dr. Viking Bjork and Donald Shiley created a single-tilting-disc valve.[5] This valve was immobile, allowing blood to flow through the aorta without falling back into the left ventricle. It was an exceptionally successful invention that was used around the world on about 300,000 patients between 1969 and 1986.[5]

Bileaflet disk valves were introduced in the early 1960s, starting with the Gott-Daggett bileaflet valve which was implanted in more than 500 patients.[2] The idea of a bileaflet design was to create a lower profile compared to the ball-in-cage valve. The Gott-Daggett valve had a heparin coating, but had an issue with stagnant blood flow which led to thrombosis and was discontinued in 1966.[5] In 1977, the St. Jude Medical bileaflet valve was invented as a result of collaboration between doctors and engineers. The leaflets rest on hinges that allow them to open and close with the flow of blood. The first one was implanted in October 1977, and they are still used today, with more than 1.3 million valves used since its inception making it the most popular mechanical valve in the world.[5]

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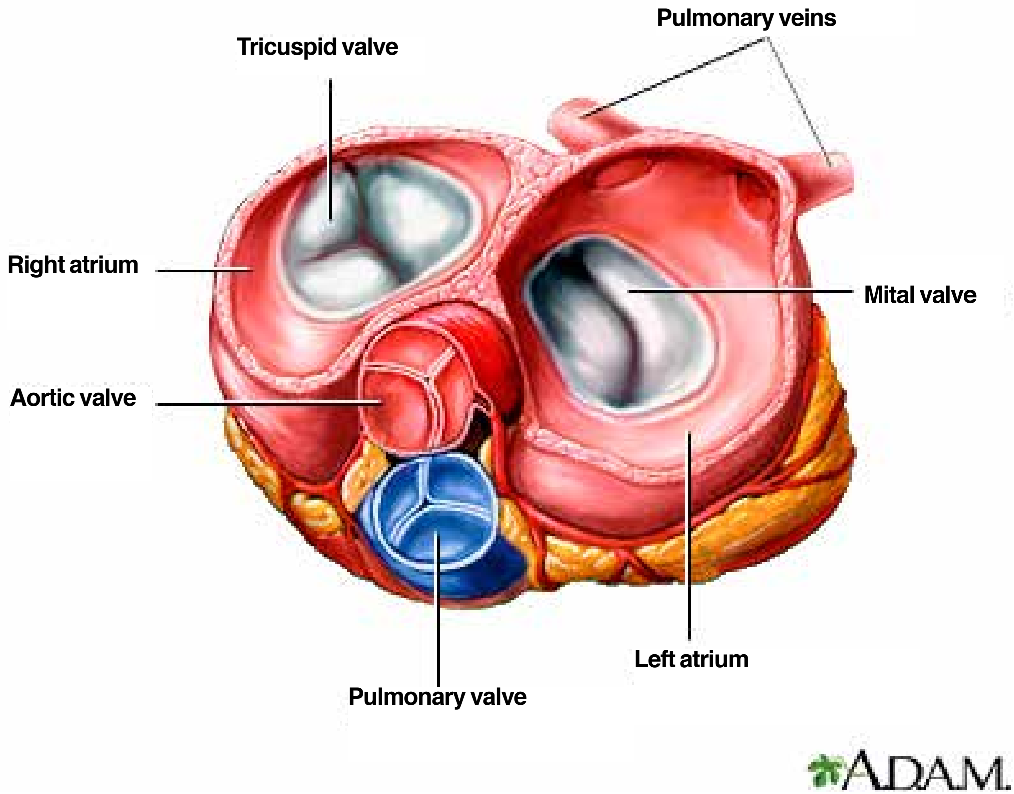
While the mechanical valve has a rich history, the history of the tissue valve is less extensive. The first source of tissue valves was from human cadavers, but this practice didn't last long due to logistical issues with the supply.[4] Currently, the most common type of tissue valves are xenografts, usually porcine or bovine origin.[13] The first xenograft aortic valve replacement was in 1965 performed by Dr. Carpentier in Paris. Two and a half years later, Dr. Carpentier had replaced 61 valves in 53 patients with a very poor success rate. While there were issues with the technical aspect of the valve replacements, most failures were due to an immune response to the xenografts.[13] Following these failures were studies to determine how to decrease the immune response. The studies revealed washing the valves in various chemicals decreased the immune response. The valves were washed in sodium periodate and ethylene glycol that denatured and neutralized the soluble proteins of the xenograft, respectively. The valves were then soaked in glutaraldehyde that reduced the antigenicity of the valves.[13] Washing the valves increased their functionality at one year to 82%, an increase of 37% from before the studies.[13] Today, when purchased and delivered, the tissue valves come soaked in a glutaraldehyde solution.

WHICH TYPE OF VALVE IS BETTER?

The indications for using a tissue valve over a mechanical valve ultimately depends on the patient. The American Heart Association and American College of Cardiology recommend tissue valves for patients 70 years of age or older and mechanical valves for patients younger than 60 years of age.[10] Based on randomized trials, patient survival is the same up to 15 years post-operation in both mechanical and tissue valves, based on randomized trials. There is also no significant difference in stroke occurrences between the two types of valves.[14] Mechanical valves, however, show more mid-term morbidity than tissue valves due to blood clots.[10] In a retrospective study of 4,253 patients aged 50 to 69 from the years 1997 to 2004, 58 major bleeding events were recorded in patients with tissue valves, and 101 major bleeding events in patients with mechanical valves.[14] Mechanical valves require patients to continuously take blood thinners; therefore, mechanical valves are recommended for patients who can take or are already taking blood thinners.[11] Patients who have tissue valves do not need to take blood thinners, so a tissue valve is ideal for patients who cannot or do not want to be on blood thinners.[11] This is a consideration for a middle-aged patient who has an active lifestyle as being on blood thinners during the prime of one's life can restrict or inhibit the patient's lifestyle, especially if they are particularly active. If a patient would need a reoperation at some point, it may be necessary with a tissue valve. The St. Jude Medical Trifecta Valve, made with bovine peridardium, can last 8 to 20 years.[12] In older patients this may not be an issue; however, in younger patients, it is something to consider. According to the retrospective study previously mentioned, in a follow-up time of 16.9 years, 79 patients with tissue valves required reoperation, while only 43 patients with mechanical valves required a second operation.[14]

An aortic valve replacement is a good option for people with aortic regurgitation and/or aortic stenosis. A tissue valve may be ideal for an older patient who will not outlive the valve, but it also may be ideal for a younger, active, healthy patient, due to their likelihood of not needing blood thinners. A mechanical valve also would be better suited for a younger patient who takes blood thinners and not at risk for falls. The type of valve used depends on the patient's age, health condition, lifestyle and surgeon recommendation.



THE PROCEDURE

The patient is positioned onto the operating room (OR) table with the help of the OR staff. The OR staff uses the appropriate padding on the patient's arms and uses a sheet to tuck the arms at the patient's side. The circulator places the appropriate monitors on the patient. The anesthesiologist inserts a radial arterial pressure line to monitor the patient's blood pressure in real time and administers general anesthesia. The circulator will insert a Foley catheter while the anesthesiologist places a central line. Prior to performing a scrub, the surgeon marks the incision site, and a time out is called to verify correct patient identity, correct surgical site and procedure to be performed. The anesthesiologist will perform a transesophageal echocardiogram (TEE) to look at the aortic valve before the operation starts. The circulator preps the patient with a chlorhexidine gluconate prep solution applying the prep chin to toes, and the legs circumferentially. The CST assists the surgeon draping the patient and passes off the sterile field to the circulator the cord to the electrosurgical pencil, suction tubing, cell-saver tubing, CO2 tubing, pump suction tubings, aortic root vent tube, left ventricle (LV) vent tube and cardioplegia lines. The CST will then arrange the arterial and venous lines on the field, given to him/her by the perfusionist.

The surgeon uses a #10 blade to make the incision over the sternum. After dissecting down to the sternum using the Bovie, the surgeon uses a sternal saw for the median sternotomy. Bleeding along the sternum is controlled, and a hemostatic agent is applied to the marrow. The surgeon then places the sternal retractor and divides the pericardium using electrosurgery and DeBakey forceps, and tacks the pericardium to the sternum using 0 silk sutures on CT-1 control-release needles.

The next steps of the procedure involves cannulation. The surgical assistant fills the area around the aorta with warm saline, while the surgeon uses an epi-aortic ultrasound probe to check the aorta for plaque. This helps the surgeon determine where to place the arterial and antegrade cannulas. The surgeon uses a 2-0 polyester suture, double-loaded on long DeBakey needle holders to place a purse-string suture into the aorta. The CST hands a Rumel tourniquet to the surgical assistant. The surgical assistant cuts the needles off, hands them to the CST and applies the tourniquet, and then the CST hands a small tubing clamp to the surgeon. This process is repeated after each cannulation stitch.

The next stitch is a 2-0 polyester pledgeted suture, double-loaded. When asked, the CST gives the surgeon a free pledget. For the implantation, pledget-armed sutures are commonly used to secure the valve in either an intra- or supra-annular position. The surgeon cannulates the aorta with the arterial cannula. The surgeon inspects the cannula, and then takes a #11 knife blade followed by the cannula. The surgeon connects the cannula to the arterial line and requests the perfusionist to check the flow to make sure there are no issues. The CST passes a #5 silk tie on a Stille clamp for the surgeon to tie the cannula to the tourniquets.

The next cannulation suture is the venous purse-string. This is a double-armed, 4-0 polypropylene suture on SH needles. After the surgical assistant applies the tourniquet, the surgeon uses Metzenbaum scissors and DeBakey forceps and opens the right atrium. The surgeon places the venous cannula through the right atrium and into the inferior vena cava. The surgeon ties the cannula to the tourniquet using a #5 silk tie. The surgeon asks the perfusionist to start the cardio-pulmonary bypass machine.

The final three cannulation stitches are accomplished using double-armed, 4-0 polypropylene sutures. The first is the retrograde cannula stitch. After the surgical assistant applies the tourniquet, the surgeon uses a #11 blade to open the coronary sinus and places the cannula. The second and third cannulation stitches for the left ventricular (LV) vent and antegrade cannulas, respectively, are pledgeted. A free pledget follows each stitch. The surgeon uses a #11 blade to enter the left ventricle, and places the LV vent. Finally, the CST hands the antegrade cannula to the surgeon, who uses the spike that comes with the cannula to insert it into the aorta. After the rest of the cannulas are placed, the surgeon connects the LV vent to the pump suction, the retrograde cannula to the cardioplegia line and the retrograde pressure line and the antegrade cannula to the cardioplegia line. The surgeon places the aortic cross clamp inferior to the arterial cannula but superior to the antegrade cannula. This ensures the cardioplegia solution goes to the heart while the incoming blood flow goes to the body. The perfusionist administers the cardioplegia solution to arrest the heart, and the surgeon pours cold saline and saline slush onto the heart to help with the arrest.

Using long Metzenbaum scissors, the surgeon opens the aorta. The surgeon uses three 2-0 silk sutures on control-release SH needles to retract the aorta, followed by small hemostats to tag the stitches. The surgical assistant uses an aortic retractor to provide exposure, and an open-ended suction tip to vacuum pieces of the calcified valve. Switching between long scissors, a #15 knife blade on a #7 knife handle and pituitary rongeurs, the surgeon removes the calcified leaflets of the valve. Based on the body surface area of the patient, the surgeon uses a specific valve sizer to determine which size valve to use. The surgeon then asks for three towels with a Gabby-Frater suture guide attached to each towel. The surgeon divides the annulus into three sections using three white 2-0 polyester pledgeted sutures on RB-1 needles on long needle holders. Next, the surgeon alternates between green and white 2-0 polyester pledgeted sutures on RB-1 needles placing the stitches around the annulus of the valve and organizes then into the suture guides.

At this time, a second CST preps the valve. Because the tissue valve is packaged in a glutaraldehyde solution, it must be rinsed. The CST has two basins of 500 mL IV

Equipment
Bed warmer
Suction machine
Cell-saver machine
Electrosurgery Unit (ESU)
Fluid warmer and slusher
Cardiopulmonary bypass machine

Supplies
Bone wax
Chest tubes
Sternal wires
Sterile water
Specimen cup
Sternal saw blade
Red rubber catheters
Open-ended suction tip
Gabby-frater suture guides
0.9% IV saline for warmer and slusher
Absorbable and non-absorbable sutures
Arterial, venous, retrograde and antegrade cannulas for cardio-pulmonary bypass
Open heart pack that includes: laparotomy sponges, Ray-tec sponges, towels, #10, #11, #15 knife blades, ventricular pacing wires, suture boots, cross-clamp inserts, various basins and dressings

Instruments
Hemostats
Sternal saw
Wire cutters
Freer elevator
Needle holders
Sternal retractor
Aortic retractors
Pituitary rongeur
Aortic valve sizers
Rumel tourniquets
Aortic cross clamp
Backhaus towel clamps
Small and large tube clamps
Nickel plate with tube holders
Metzenbaum scissors (short and long)
#3 (short and long) and #7 knife handles
Forceps (long and short Debakeys, Russians, Ferris-Smiths, Adsons)

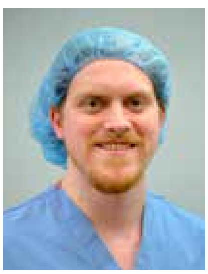
saline. The CST rinses the valve for 10 seconds, or per manufacturer's instructions, in one basin, and then rests the valve in the second basin until it is needed.

The surgical assistant holds the valve for the surgeon, who sews the polyester sutures into the replacement valve. With each third of the valve annulus, the surgeon takes one hemostat to wrap the suture around, and another hemostat to clamp the suture near the needles, which the CST will cut and place in the needle holder. When finished, the CST squirts the suture with cold saline so the valve slides down easily. The surgeon ties the sutures to secure the valve into place and cuts the sutures.

Using two 4-0 polypropylene pledgeted sutures on RB-1 needles, each followed by a free pledget, the surgeon closes the aorta. The surgeon removes the antegrade, retrograde and LV vent cannulas and closes each site with the stitches already in place. The surgeon asks the perfusionist to stop bypass. Next the surgeon removes the venous cannula and ties that site off. The CST submerges the venous cannula in saline for the perfusionist to refill the venous line, and the CST clamps it. Once all blood volume is returned to the patient, the surgeon removes the arterial cannula and closes the site. The surgeon removes the sternal retractor, checks for bleeding with the help of the surgical assistant and places 32 French angled and 36 French straight chest tubes in the right pleural and mediastinal spaces, respectively. The surgeon injects local anesthetic, and begins placing sternal wires for sternal closure. After the chest is closed, the surgeon and surgical assistant use a #1 polyglactin 910 suture on a CTX needle for the fascia, 2-0 polyglactin 910 sutures on CT-1 needles for the dermis, and finally, 3-0 poliglecaprone 25 sutures on PS-1 needles for the skin. The chest tubes are connected to an atrium, and the dressings are applied.

POST-OP RECOVERY

The patient is admitted to the Cardiovascular Recovery Unit, and is extubated after approximately 24 hours. The patient stays in the hospital for five to seven days, closely monitored to ensure there are no post-operative complications. During the patient's stay, a normal diet is resumed, and the nursing staff assists the patient with moving from the bed to a chair, and with walks in the hallway. Follow-up appointments with a cardiologist are very important in the first four to six weeks.



ABOUT THE AUTHOR

Alex Burke has been a CST for 3 years at Indiana University Health Bloomington Hospital. He specializes mainly in orthopedics and cardiovascular, while having experience in other specialties as well. Aortic valve replacements are his favorite cases, but he also enjoys total joint replacements and orthopedic trauma cases.

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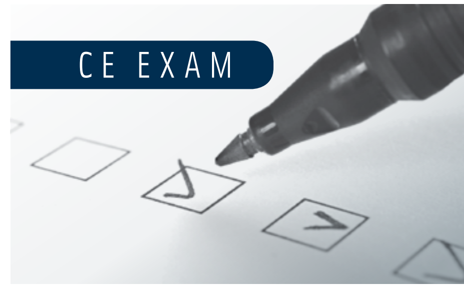

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Aortic Valve Replacements

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1. **The first heart valve replacement performed on a human was in:**
   a. 1946
   b. 1950
   c. 1952
   d. 1958

2. **Before the procedure begins, the anesthesiologist will perform which assessment?**
   a. CT scan
   b. Heart MRI
   c. EKG
   d. TEE

3. **Who created the first heart valve replacement used on humans?**
   a. Dr. Harkin
   b. Dr. Hufnagel
   c. Dr. Bjork
   d. Donald Shiley

4. **The first xenograft aortic valve replacement was in 1965 in _____.**
   a. New York
   b. London
   c. Washington, DC
   d. Paris

5. **The skin prep for this procedure will start from the ______.**
   a. Chin
   b. Legs
   c. Abdomen
   d. Toes

6. **Since Dr. Hufnagel, more than ___ different types of mechanical metal or plastic valves have been created and surgically implanted.**
   a. 80
   b. 100
   c. 150
   d. 180

7. **For the implantation, which sutures are commonly used to secure the valve?**
   a. Pledgeted
   b. Purse-string
   c. Pledgeted-armed
   d. Retrograde cannula

8. **After the tourniquet is applied, the surgeon will use a _____ to open the coronary sinus and place the cannula.**
   a. #7 blade
   b. #11 blade
   c. #15 blade
   d. Both b and c

9. **The surgeon will place the aortic cross clamp ______ to the arterial cannula but ______ to the antegrade cannula.**
   a. Inferior, distal
   b. Inferior, lateral
   c. Distal, superior
   d. Inferior, superior

10. **The American Heart Association and American College of Cardiology recommend tissue valves for patients who are at least what age?**
   a. 50
   b. 60
   c. 70
   d. 80

AORTIC VALVE REPLACEMENTS #421 January 2019 2 CE CREDITS $12

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