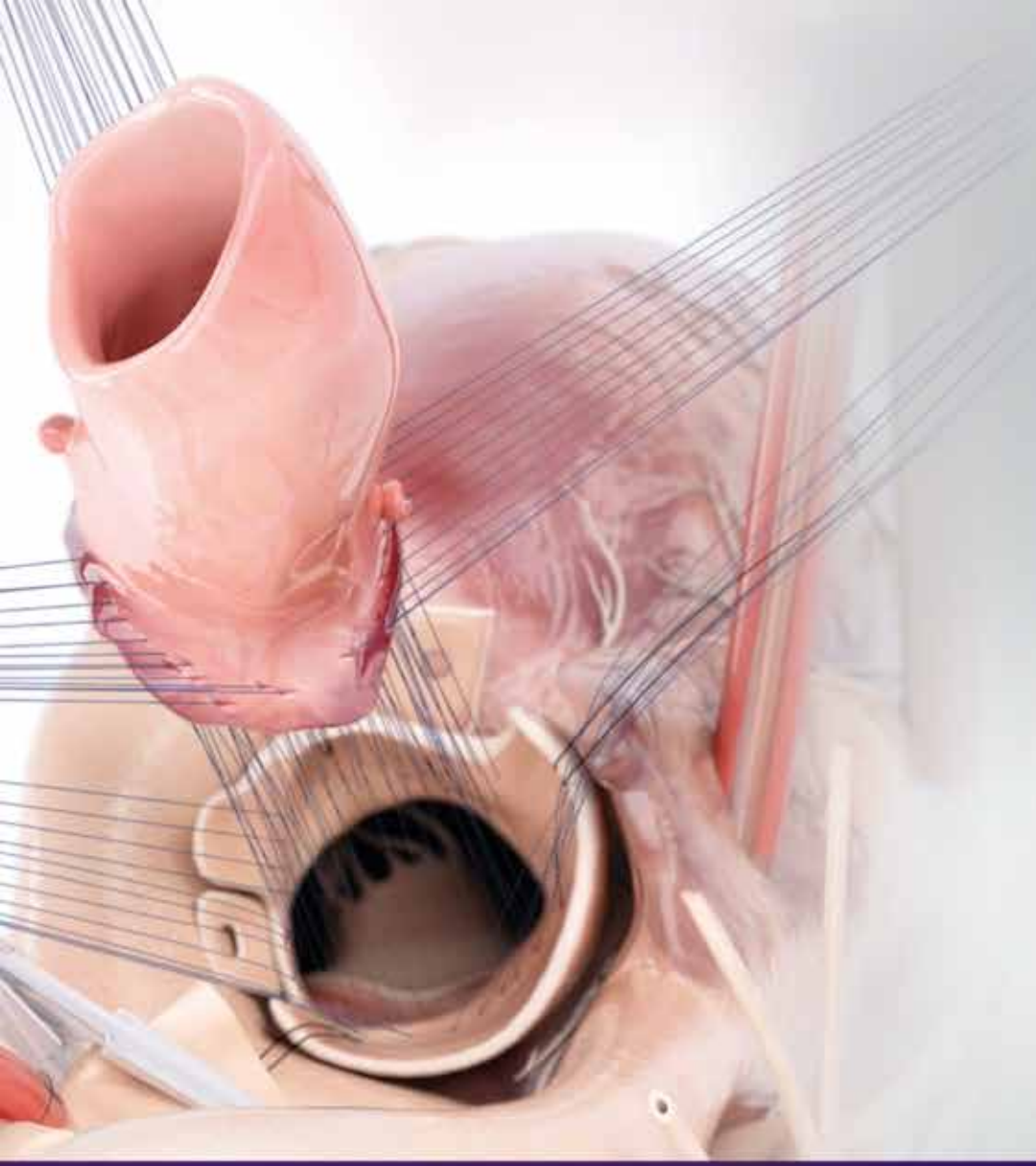

AORTIC ALLOGRAFT IMPLANTATION

Full Root Procedure

William F. Northrup III, M.D.

CryoLife's ***ELITE*** Educational Experience

ELITE
EDUCATIONAL EXPERIENCE

The content provided in this presentation is strictly for educational purposes and should not be considered medical advice. Specific decisions regarding allograft selection, patient populations, surgical judgment, and techniques belong to the discretion of the prescribing physician or surgeon. Unattributed data, allograft selection, and procedural guidance is a matter of physician preference are presented on the basis of the individual speaker's observations and experiences and should be treated accordingly.

The content provided in this presentation relates to aortic allografts processed and marketed by CryoLife. Federal law restricts the allografts discussed herein to sale by or on the order of a physician. Refer to the Instructions for Use and other product insert documentation that accompanies each of these allografts for indications, contraindications, warnings, precautions, possible complications, and instructions for use.

ELITE

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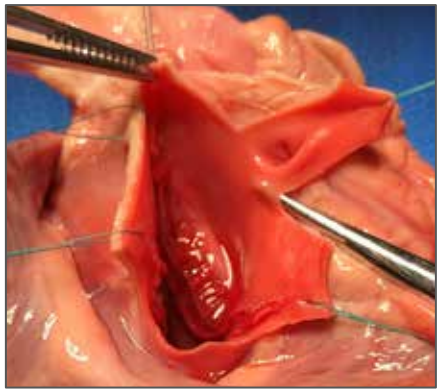
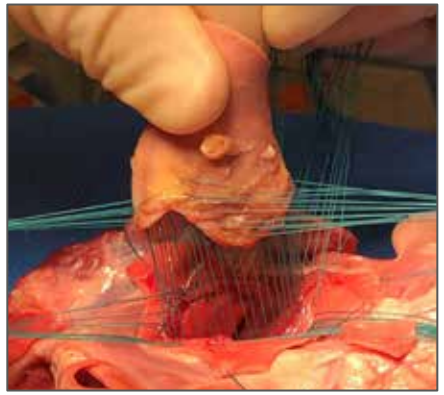
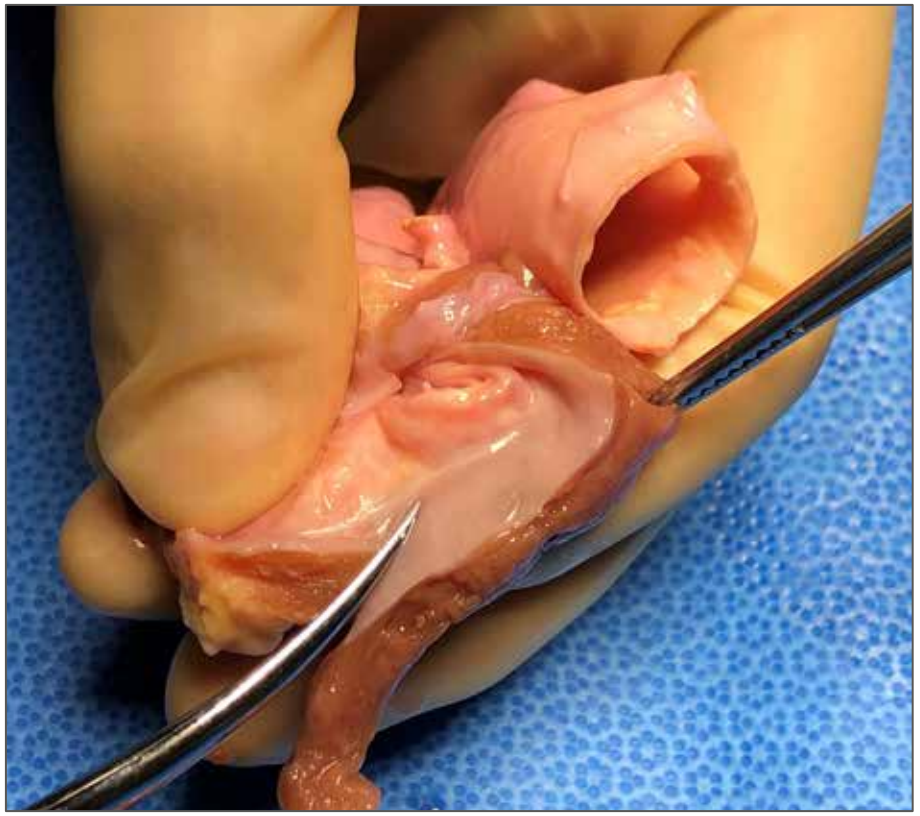




Allograft Preparation and Measurements

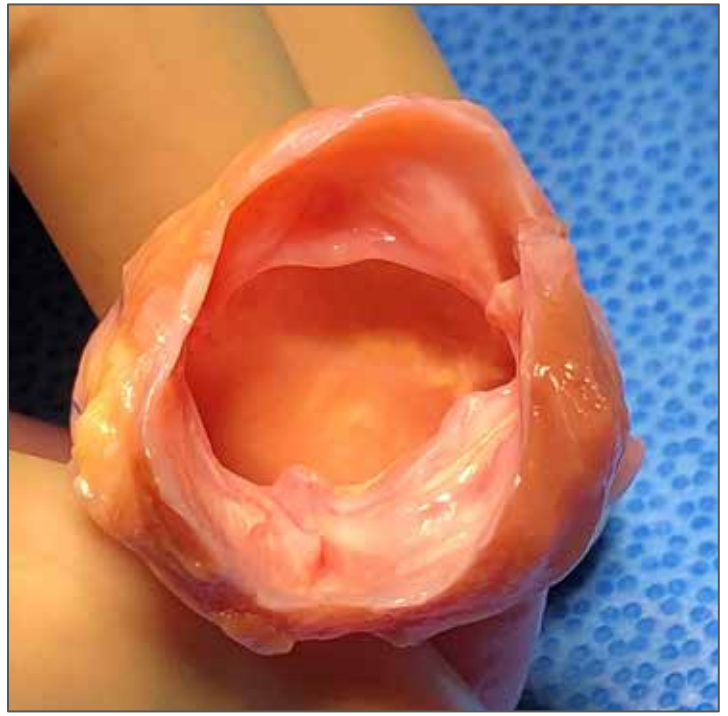
Allograft Preparation and Measurements

1. The aortic allograft is thawed according to protocol.
2. The proximal cuff of the aortic allograft is then trimmed in a scalloped fashion 3 mm from the valve cusp attachments at 90 degrees, full thickness, following the curvature of the individual cusps up into each interleaflet triangle. Remember to avoid saw teeth on the cuff by staying in the crotch of your previous cut. Many little cuts with the tips of the scissors are more precise than big cuts. The priority is a **smooth cuff** with a uniform width of 3 mm from the cusp attachments.
    - This scalloped trimming leaves the minimum of non-annular tissue which:
        1. Minimizes the risk of suture line disruption.
        2. Facilitates visibility and access to the cusp attachment.
        3. Facilitates uniform suture spacing.
        4. Facilitates a steady rhythm of suture placement.
        5. Facilitates allograft seating and coronary button anastomoses.
        6. Minimizes resistance along each suture loop, by reducing bulk and making it easier to tell when the suture is tight, avoiding over- or under-tightening.



Allograft Preparation and Measurements

3. The aortic allograft is then debulked to a thickness of 2–3 mm, leaving a uniform scalloped cuff (“skirt”).
   - This debulking is done as a separate maneuver from scalloping in the same plane as the conduit (90 degrees from the scalloping plane). Use the back end of the scissors, gently “sawing” through the cuff. If any resistance occurs, you are likely to “button-hole” the conduit. Stay shallow in the soft muscle.
   - Do not combine scalloping and debulking. Do them separately.

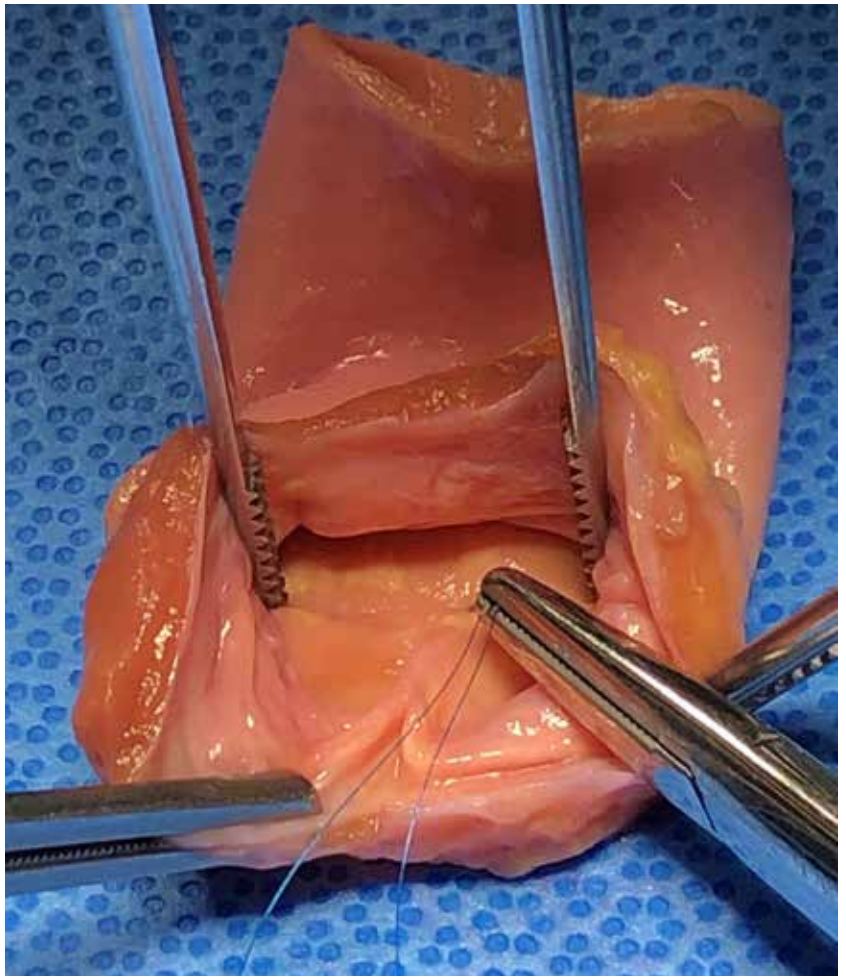


Allograft Preparation and Measurements

4. The allograft is placed on the table and held by the surgeon with forceps, while the assistant uses an open forceps as a retractor. A double-armed 6-0 or 7-0 monofilament suture is then placed “inside-out” just above the top of each commissure and tied outside.

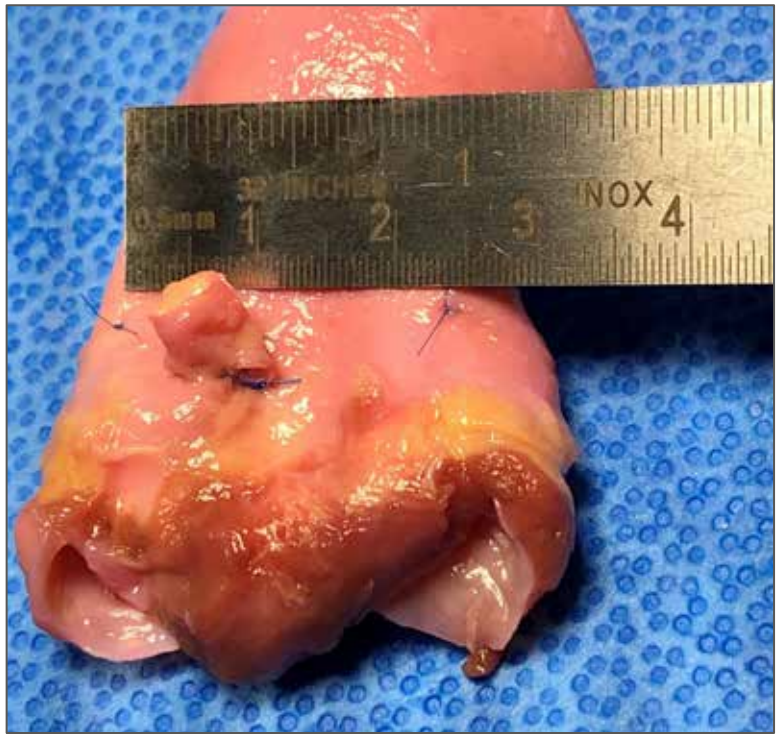
    * In the photo, notice both needles of the double-armed suture are in the needle-holder to save time.

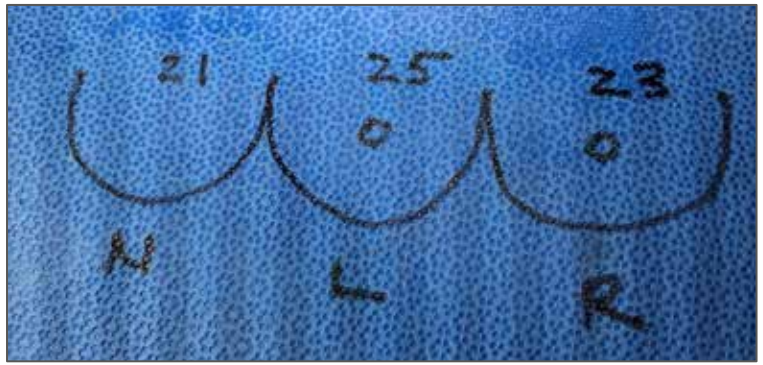
    – This step (1) allows an external measurement of the allograft sinus widths from the outside of the allograft (which are almost always asymmetric) and (2) provides a constant reminder of the location of the commissures from the outside of the allograft.



Allograft Preparation and Measurements

5. The distance between each commissural marking suture is then measured to assure proper placement of the aortic allograft within the patient's respective aortic annulus. These are the dimensions of the new aortic root, which replace the dimensions of the old aortic root. Because these sinus dimensions are almost always asymmetric (sometimes very asymmetric), it is important to know the dimensions for correct placement of the coronary buttons in the sinus, avoiding the commissures. For example, a very small left sinus (which is common) and a large left coronary button (a "sombrero" vs. a "bowler") might not fit without impinging on one of the commissures.





Aortic Root Set Up

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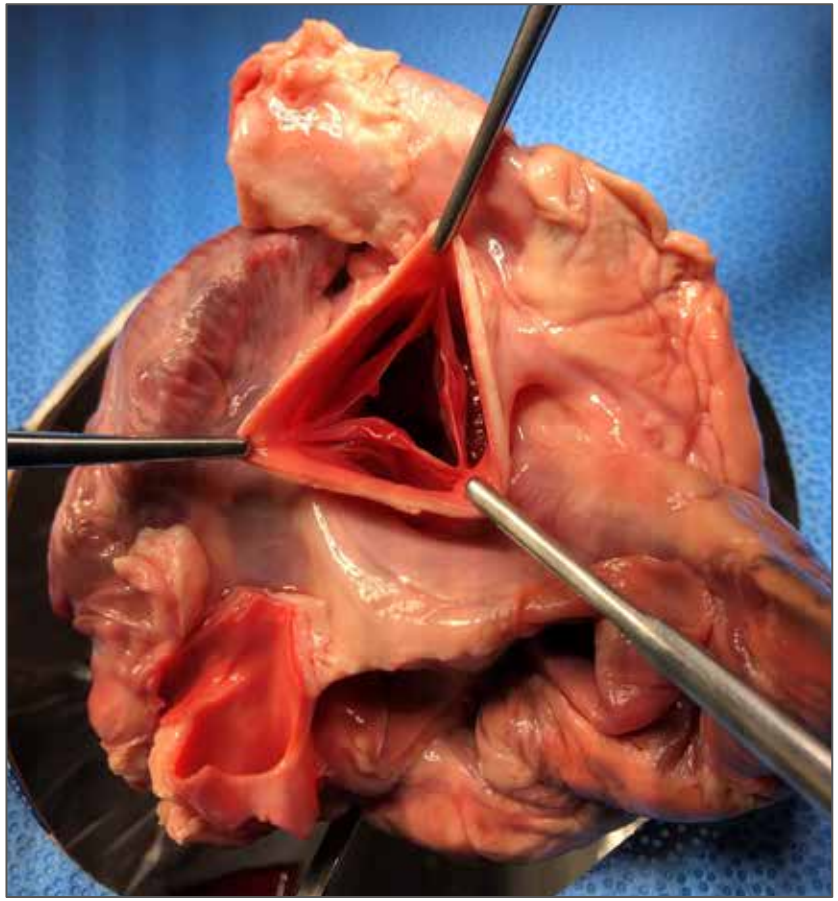
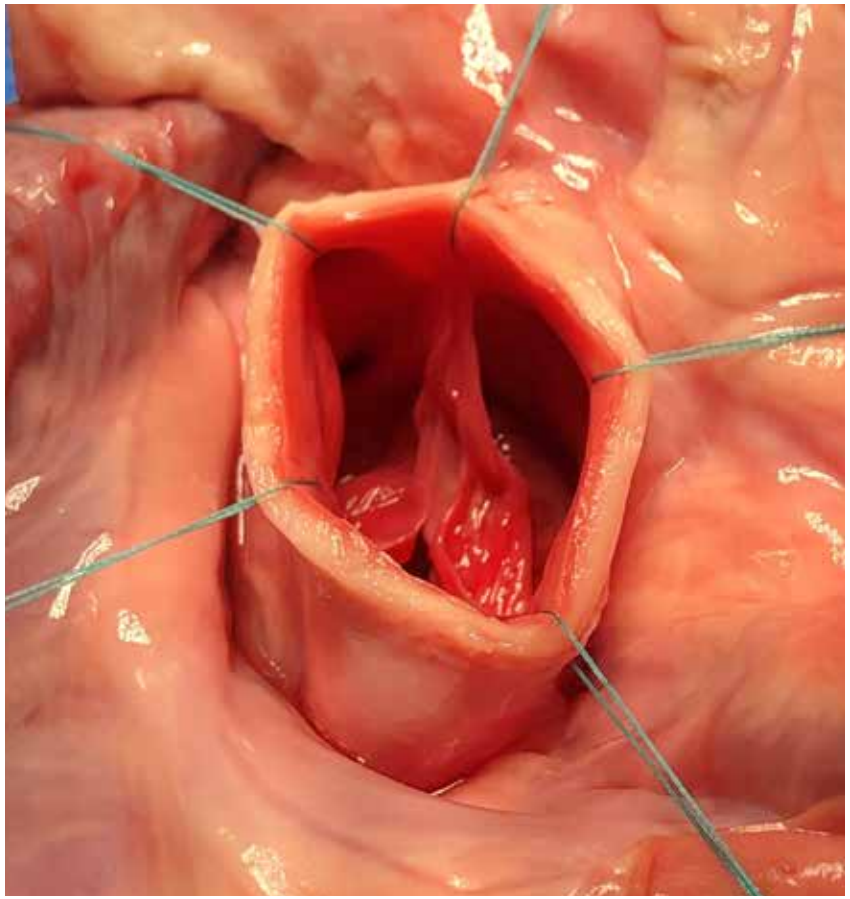
Aortic Root Set Up

1. The aorta is transected 5 mm above the sinotubular junction (STJ). Since the root is being replaced, it is an advantage for the surgeon to be as close to it as possible.



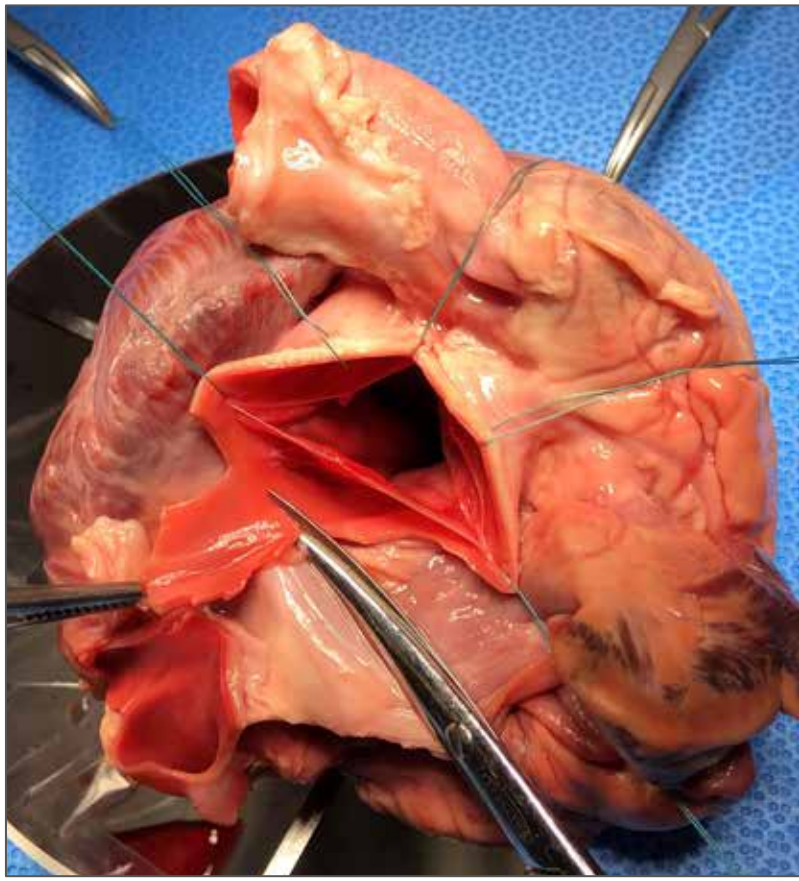
Aortic Root Set Up

2. Five simple traction sutures are then placed: one above the top of each commissure and one above the top of each coronary artery ostium at 12 o’clock.



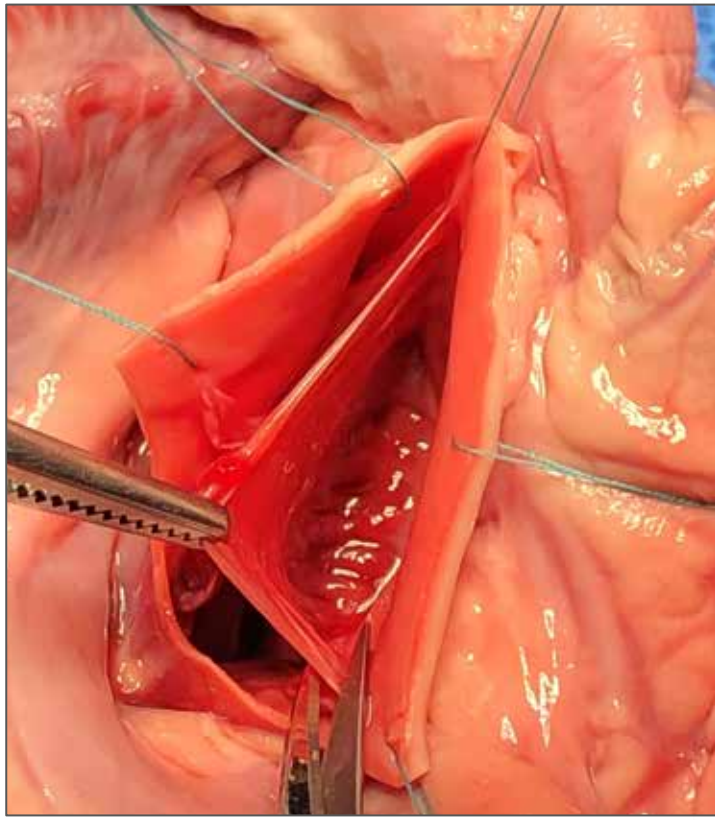
Aortic Root Set Up

3. The non-coronary sinus is then removed.
   - Removing the non-coronary sinus allows for better visualization of the aortic annulus, especially in small aortic roots.
   - This maneuver is also good practice for a valve-sparing aortic root replacement.



Aortic Root Set Up

4. The aortic valve cusps are then excised.
    * This is facilitated by lateral traction on the sutures in the right-left and right-non commissures by the assistant as illustrated.
    – This technical advantage of operating with **straight lines** will be a recurring theme in this implant manual.



Coronary Button Development

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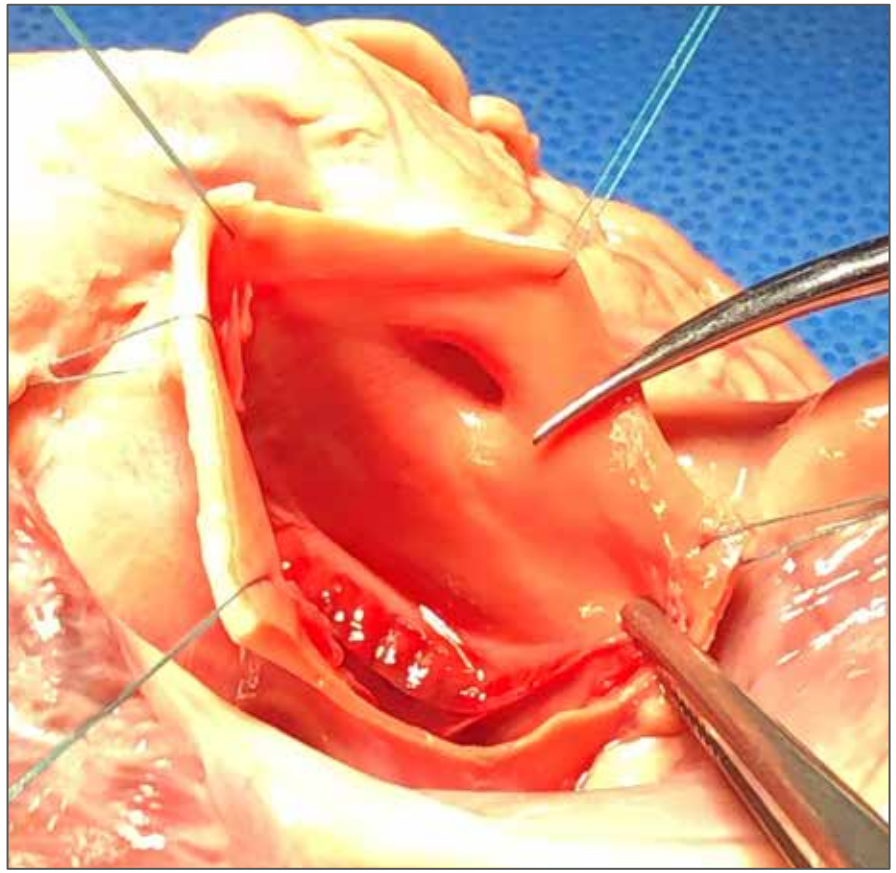
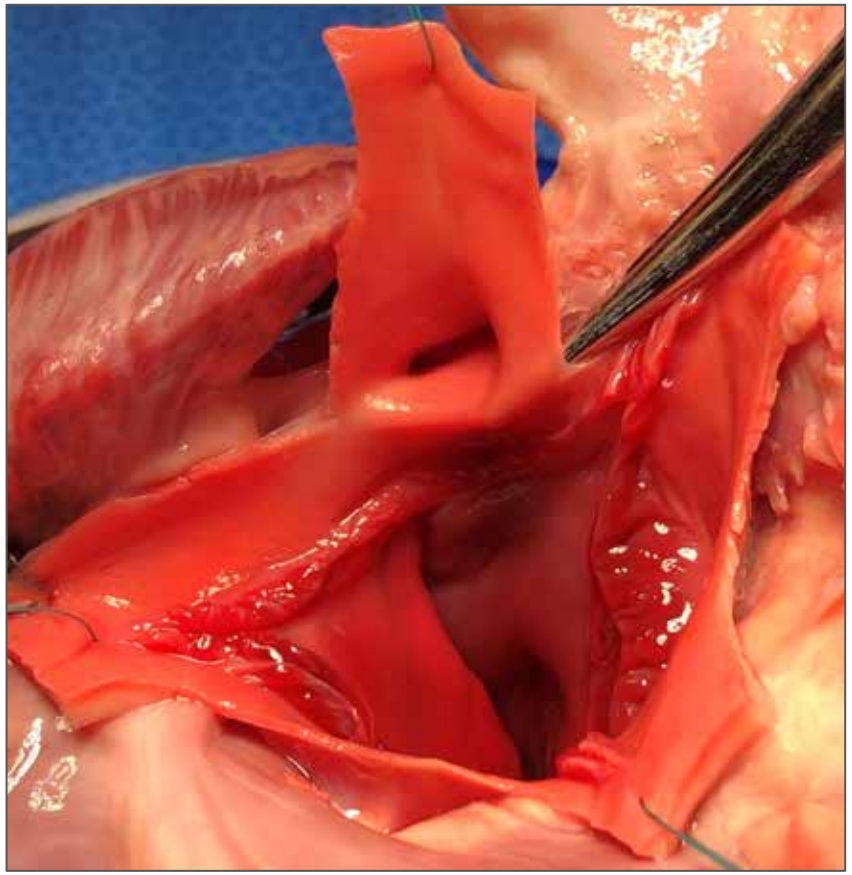
“Mobilization” of Coronary Buttons

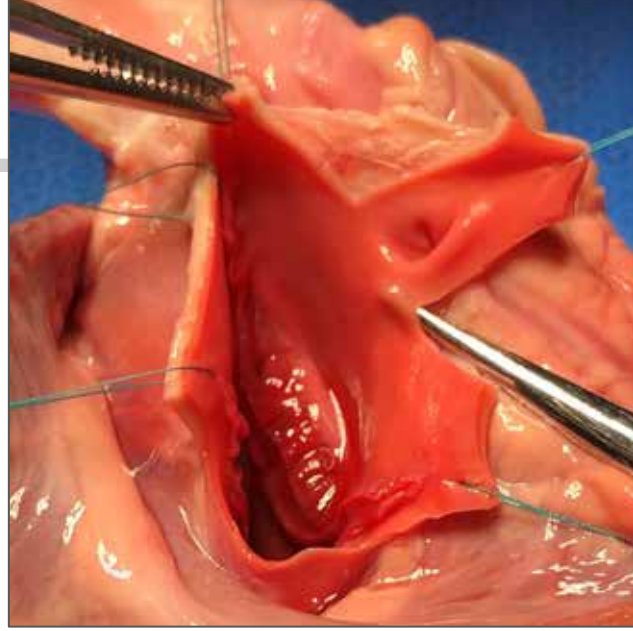
1. The surgeon should view the coronary ostium as a clock-face. The traction stitch is at 12 o’clock. The coronary buttons are developed first by cutting straight down from the upper cut edge of the aorta on both sides of the coronary ostium to the imaginary “equator” (9 o’clock and 3 o’clock), creating a smooth 2–3 mm flange (cuff) of sinus wall.

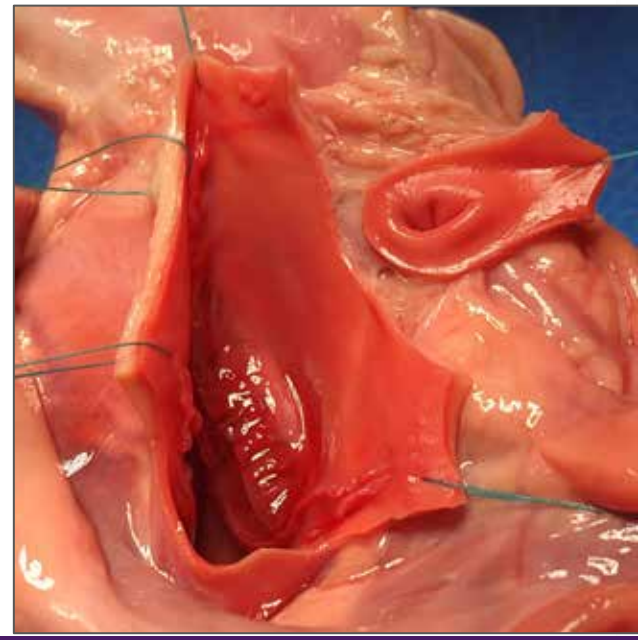




“Mobilization” of Coronary Buttons

2. The lower half of the flange is carefully developed by blunt and sharp dissection, with a smooth curve matching the curvature of the coronary ostium.
    - Use sharp pointed tenotomy scissors, with the jaws closed, using a gentle “push and lift” technique, hugging the back wall of the aorta and lifting toward the aortic lumen. As far as you can gently slide forward with this maneuver, you can cut. As with the cuff development of the allograft, the priority is a **smooth cuff** with a uniform width of 2–3 mm from the coronary ostium.
    - Remember to avoid saw teeth on the cuff of the button by staying in the crotch of your previous cut. Many little cuts are more precise than big cuts. Do not spread the jaws of the scissors in order to avoid getting into the coronary artery, the right ventricle or the left atrium. It is only necessary to bluntly create a narrow trail with the gentle “push and lift” technique rather than a wide highway behind the aortic sinus in order to complete the sharp dissection of the flange at the lower half of the coronary button.
3. The other coronary button is created in the same manner as the first coronary button.





“Mobilization” of Coronary Buttons

4. “Mobilization” of the coronary arteries is necessary to replace the old root with a new root and maintain blood supply to the heart. However, it is imperative to place the coronaries back on the new root in their **original axis** (original longitude and latitude) to avoid kinking and obstruction to flow. After the flange (cuff) is developed, the tethering bands are divided by ***dissecting the aorta away from the coronary*** rather than the coronary away from the aorta.
    - Stay just on the backside of the aorta. The goal is to free up the coronary artery from the old root, not from the heart. Do not chase down the length of the coronary artery. It is attached to the heart, where it belongs.
    - Cutting along the backside of the aorta rather than on the coronary button prevents accidental injury to the coronary. Keep the scissors away from the coronary arteries. Elimination of the tethering bands allows the coronary ostium to move inward toward the allograft and become part of the new root.

Suturing 101

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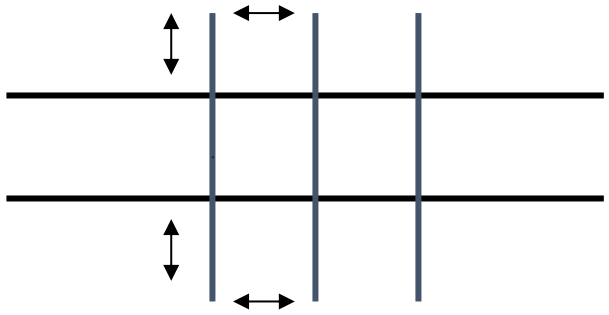
Suturing 101

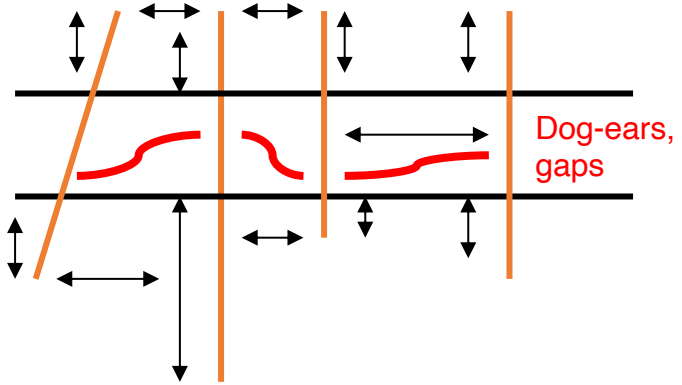
“Machine-Made By Hand”

- Match: Equal Spacing From Edges and Each Other

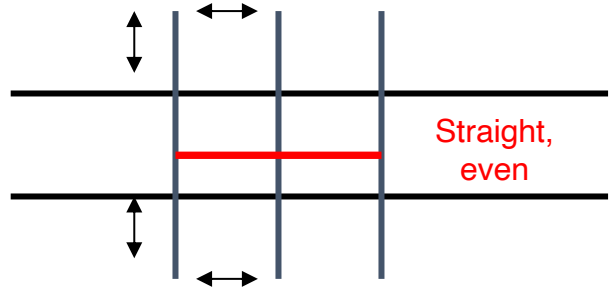
Facilitated by Straight Lines and Smooth Surfaces



Yes



No



Yes

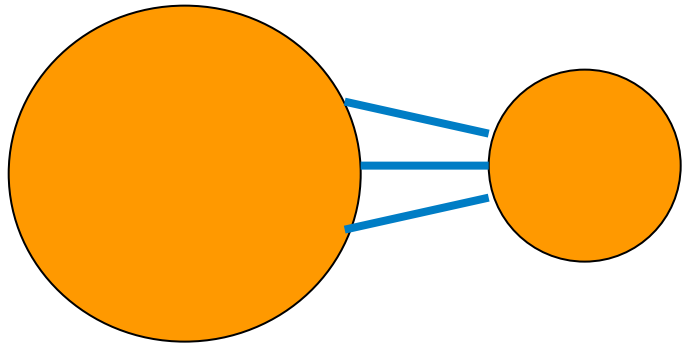
Annuloplasty

Annuloplasty

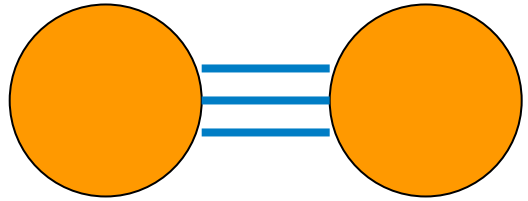
“Two Equal Circles” Principle

In “Suturing 101,” equal spacing of sutures on both sides of smooth surfaces of an anastomosis oriented in **straight lines** is a success factor for a perfect anastomosis. This principle is equally applicable to circular surfaces, since a circle opened up becomes a straight line. Anastomosing 2 equal straight lines together is identical to anastomosing 2 equal circles together. “Matching” the sizes of the recipient and allograft annuli by performing the annuloplasty first makes it possible to “match” the spacing of the sutures, rather than trying to calculate differential suture spacing and risking gaps, dog-ears and bleeding. Matching the suture-spacing of 2 equal circles is essentially an “aortotomy principle”. As with an aortotomy closure, when two circles are the same size and suture travel-distances are equal on both sides, the 2 circles always come together perfectly.

It is possible to “match” 2 unequal circles if the travel-distance of the sutures on the larger circle is farther than on the smaller circle, creating mini-plications in the larger circle to gradually reduce its circumference. But this is a very difficult math problem to come out with equal circles after placing over 30 sutures. Moreover, each of the suture travel-distances on the larger circle is at risk for dog-ears and leaks. Why bother? Life is simple if you make it simple. Do the annuloplasty first to create 2 equal circles.



Without annuloplasty

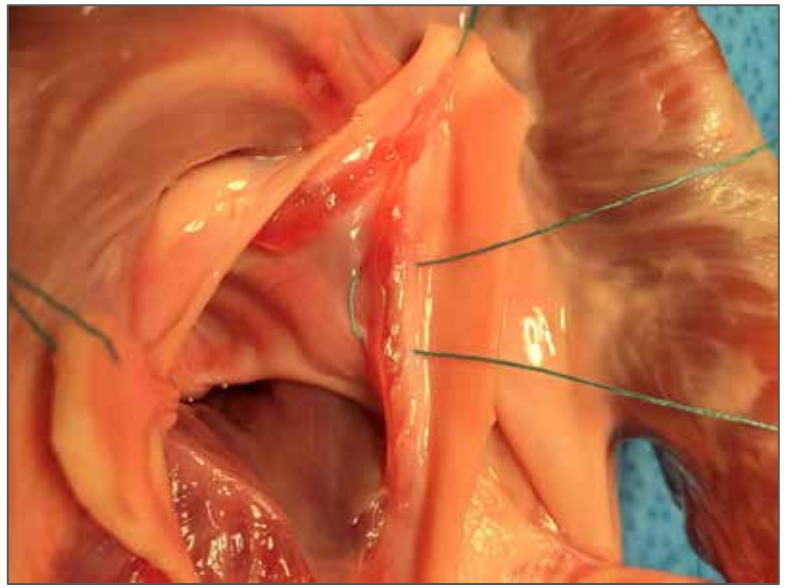


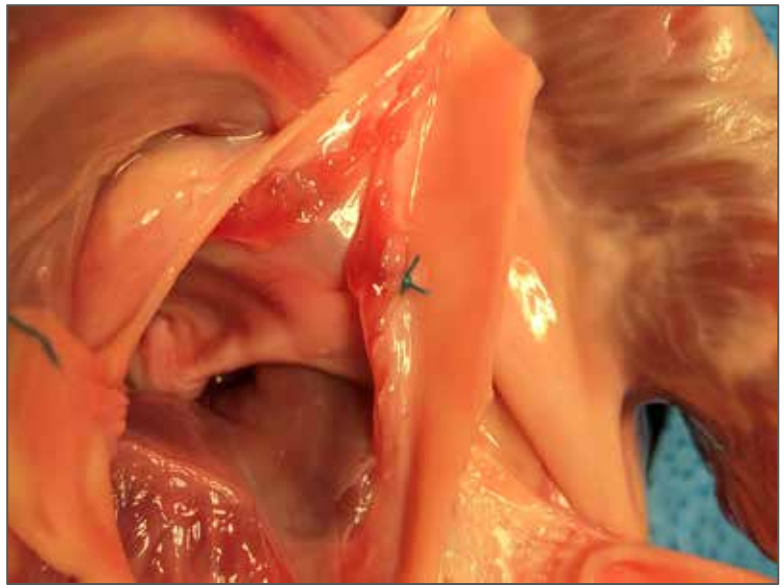
With annuloplasty

Annuloplasty

Principles

1. The relationship between annulus circumference and diameter is 3:1 ($C = \pi D$). For every 3 mm of circumferential plication, the diameter is reduced by 1 mm ($D = C/\pi$).
2. The most secure annuloplasty and the simplest is a 4-0 braided mattress suture (the same suture used in the anastomosis of the aortic allograft to the patient's annulus) in the fibrous annulus.
3. In the area of the aortic-mitral curtain a simple mattress suture is adequate, with short travel-distances of no more than 8–9 mm in order to avoid ugly "cobblestones" along an otherwise smooth annulus surface.

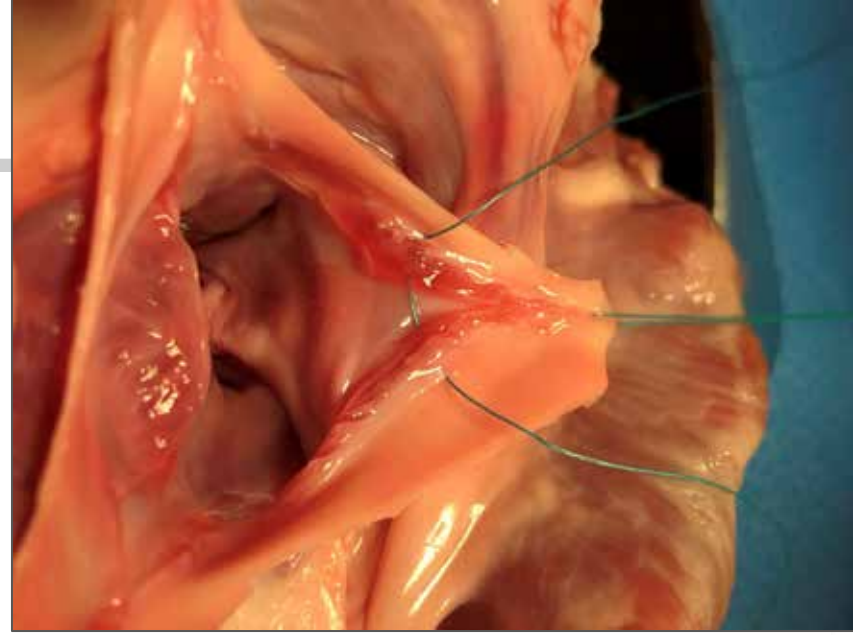


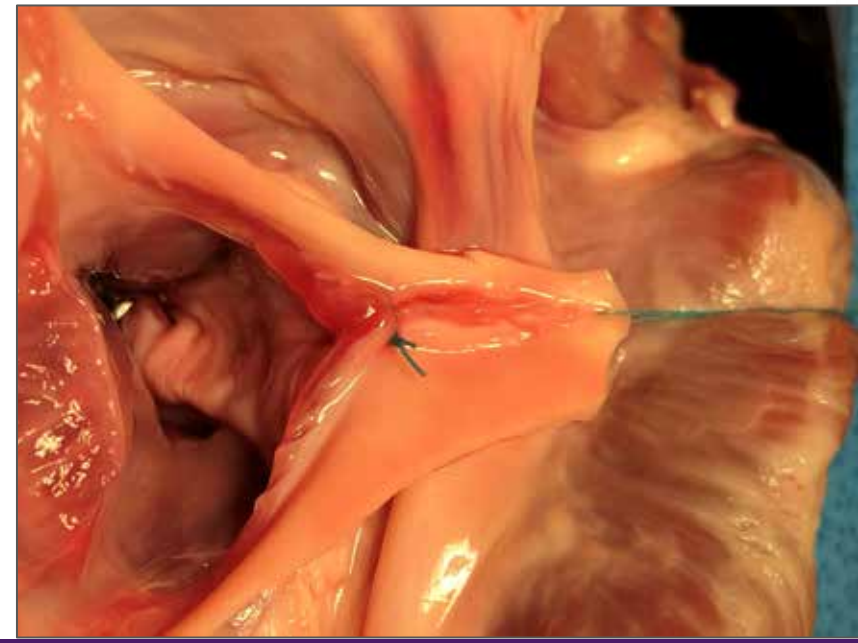


Annuloplasty

Principles

4. In the interleaflet triangles, closing the triangle with a simple mattress stitch is ideal.
    - Avoid circumferential suture travel-distances more than 8–9 mm. Small plications maintain a smooth annulus and avoid “cobblestones” in the area of the annuloplasty.
    - **Smooth suture lines** are the priority, and they don’t bleed.
5. All annuloplasties must be “excluded” from the proximal allograft suture-line by placing the allograft sutures just 1 mm below the annuloplasty sutures. The left ventricle should not “see” any annuloplasty sutures.





Proximal Suture Line

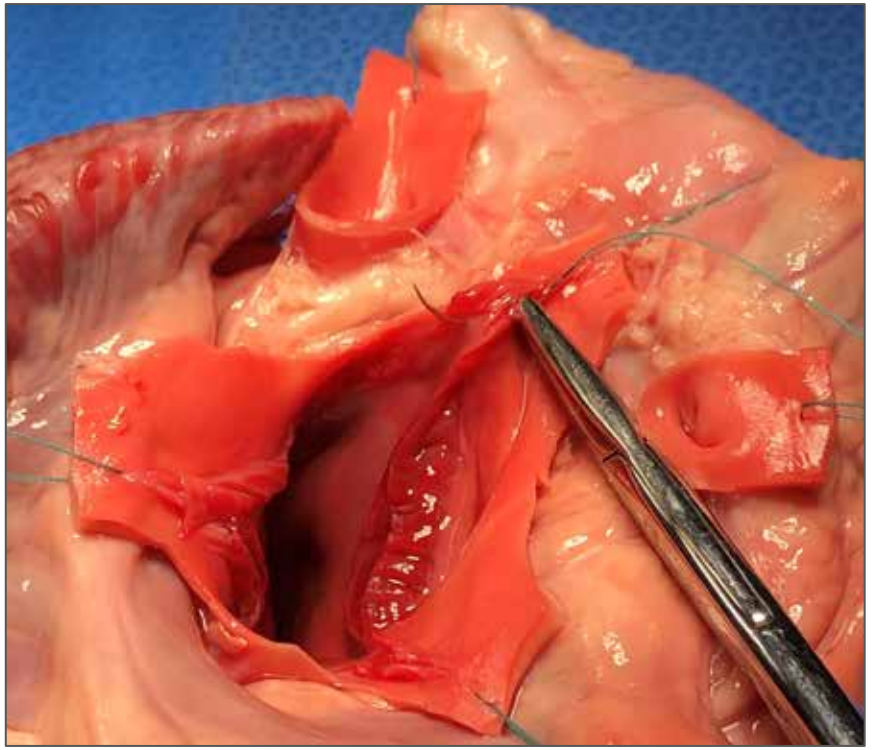
Proximal Suture Line

The “Pilot” Suture

1. The suturing begins with a reference, or a “pilot” suture, in the patient’s interleaflet triangle below the left-right commissure, “top down”. All suturing goes from patient to allograft, “top down” in the patient, “inside out” in the allograft.

    – Braided and coated 4-0 polyester (e.g., Ethibond®, Tevdek®, Ti-cron™, Cardioflon®) is preferred because it has no memory, is not bulky and only requires 3–4 knots. Because it is coated, it can be used in endocarditis cases. 4-0 monofilament polypropylene can also be used, but has memory and requires more knots. The usual 2-0 braided polyester suture typically used in prosthetic valve implantation is not necessary, adds bulk and requires more knots.

    Note: If one of the recipient’s coronaries is close to the commissure, a “mini-rotation” of the “pilot” suture can be made to allow the coronary to better fit within the sinus without crowding the commissure. Avoid placing the coronary too close to the commissure.

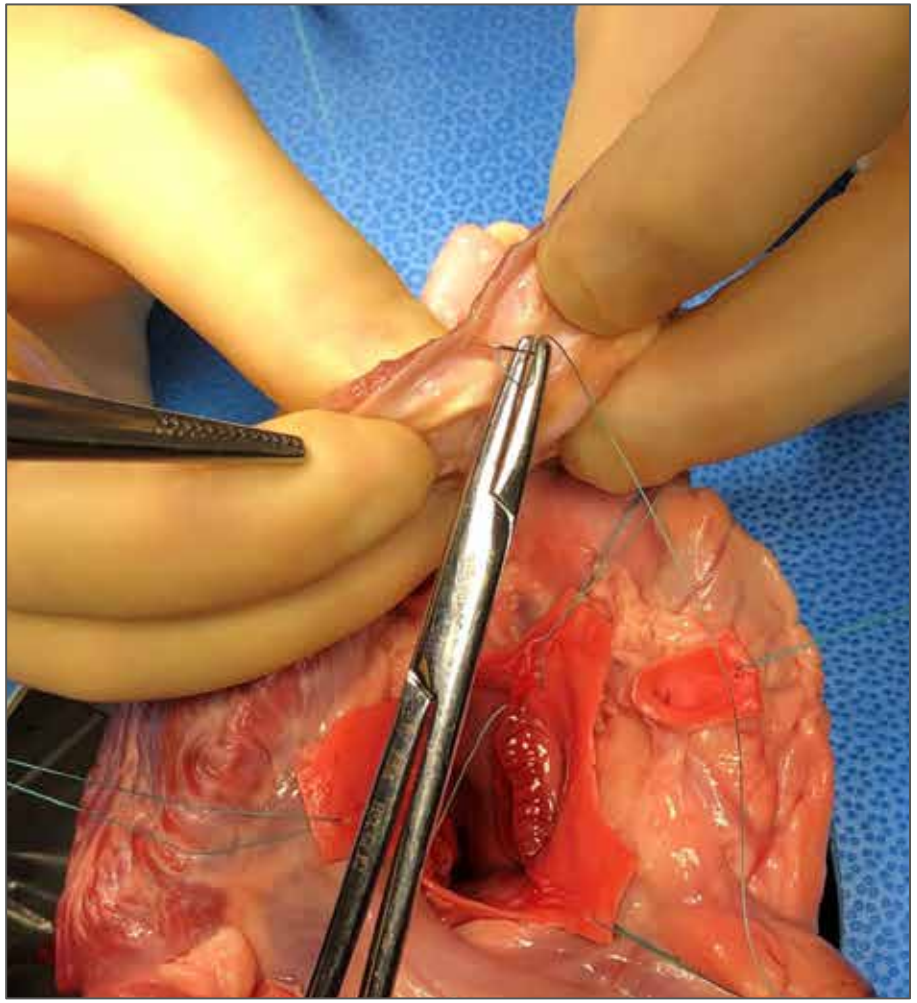


*In this photo, note the suture exiting the base of the patient’s interleaflet triangle.

Proximal Suture Line

The “Pilot” Suture

2. Suturing continues “inside-out” in the base of the left-right interleaflet triangle of the allograft. The assistant holds the allograft with the hands and fingers in such a way as to flatten and invert the interleaflet triangle, as illustrated in this image. As suturing continues, inverting the other 2 interleaflet triangles with a thumb or finger will result in the same excellent visibility of this important crowded area between the 2 adjacent valve cusps.

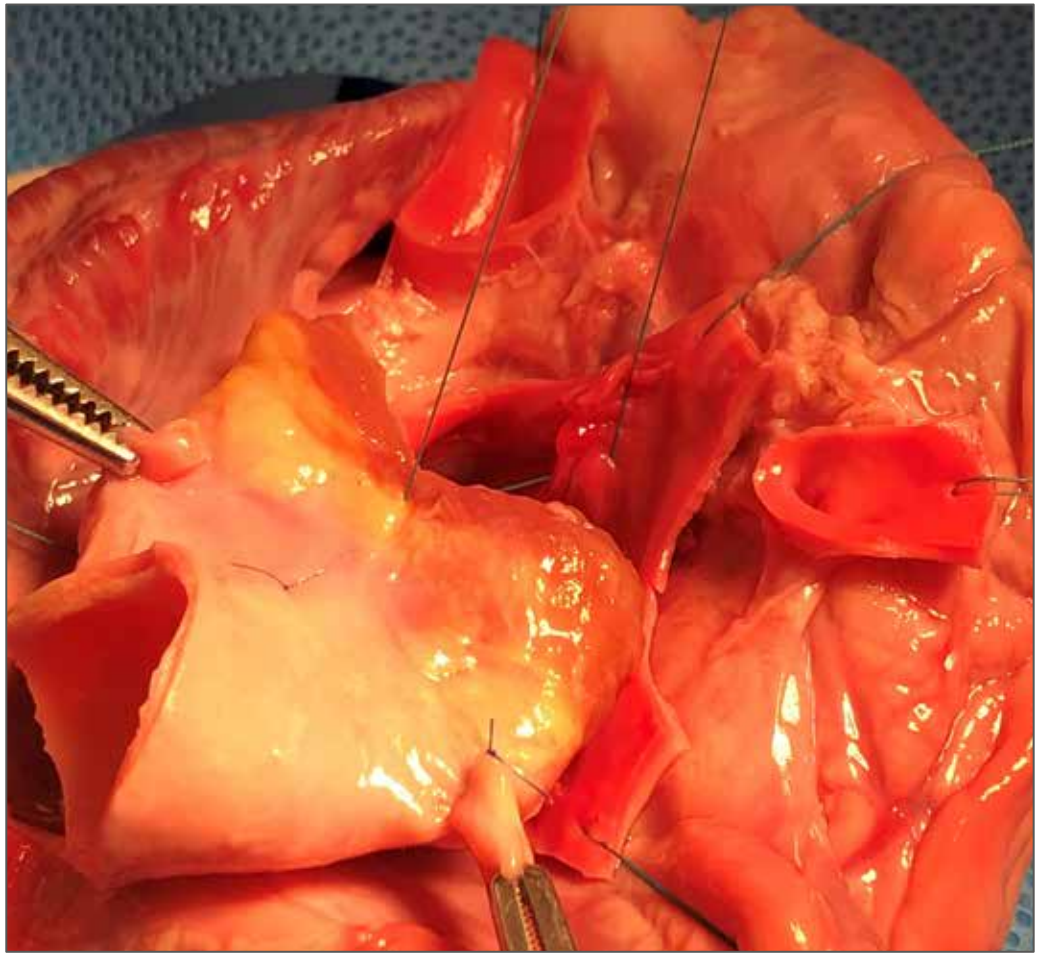


Proximal Suture Line

“Pilot” Suture Verification

3. To verify that the “pilot” suture was placed in the correct interleaflet triangle, it is suggested that the aortic allograft be lowered onto the heart to verify correct positioning of the allograft.

    * In this photo you can see the coronary stumps of the allograft (held by the forceps) are clearly opposite the native coronary buttons. The suturing sequence “top down” in the patient and “inside out” in the allograft is clearly visible here.

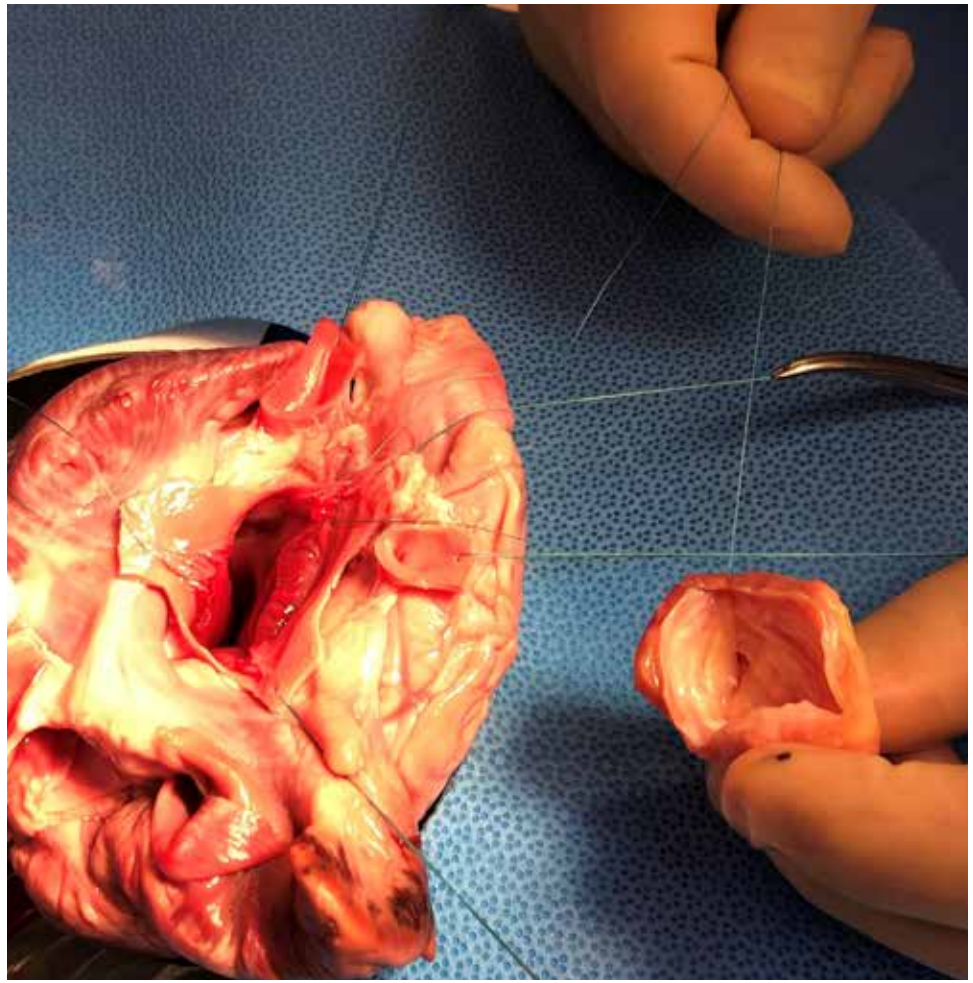


Proximal Suture Line

Left Coronary Sinus Sutures

4. The aortic allograft is placed opposite of the sinus that is being sutured. Therefore, for placing the left coronary sinus sutures, the aortic allograft is placed at the 1 o'clock position in relation to the surgeon.

    * In this photo, notice the assistant holding both ends of each suture loop in one hand and the allograft in the other hand. The assistant's "instruments" are hands and fingers.

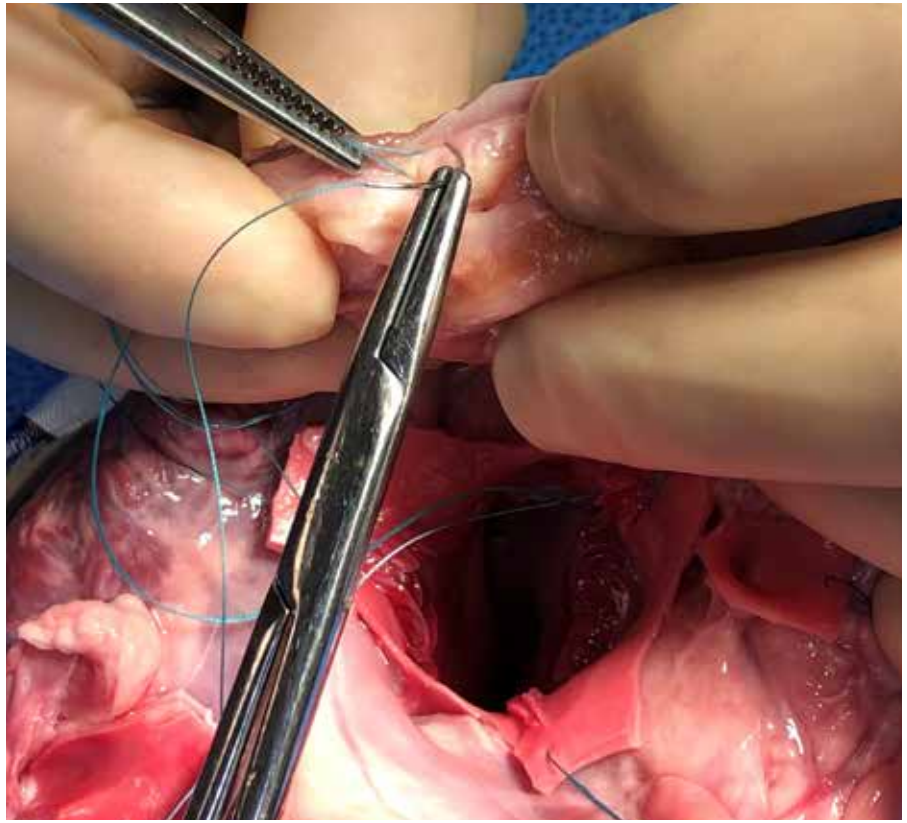


Proximal Suture Line

Left Coronary Sinus Sutures

5. Suturing is always *forehand-forehand* from annulus to aortic allograft, “top-down” in the annulus of the patient and then “inside-out” on the aortic allograft at 90 degrees, just below the cusp attachment—*in* the aortic valve annulus. This annulus is only ≈1 mm wide in the muscular portion of the aortic root. In the inter-trigonal portion of the aortic root, which is occupied by the aortic-mitral continuity, good fibrous tissue extends well below the cusp attachments of the non-coronary cusp (except in the area immediately adjacent to the membranous septum) and half of the left coronary cusp. Placing all sutures immediately below all cusp attachments simplifies suture placement location and guarantees the most robust fibrous tissue engagement.

6. Suturing proceeds *forehand-forehand: forehand* and *counter-clockwise* in the left sinus of the patient sewing towards yourself, while sewing *forehand* and *clockwise* in the allograft. Sewing *forehand-forehand* saves time by eliminating the extra move of re-orienting the needle back-hand in the needle-holder for the allograft portion of the anastomosis.

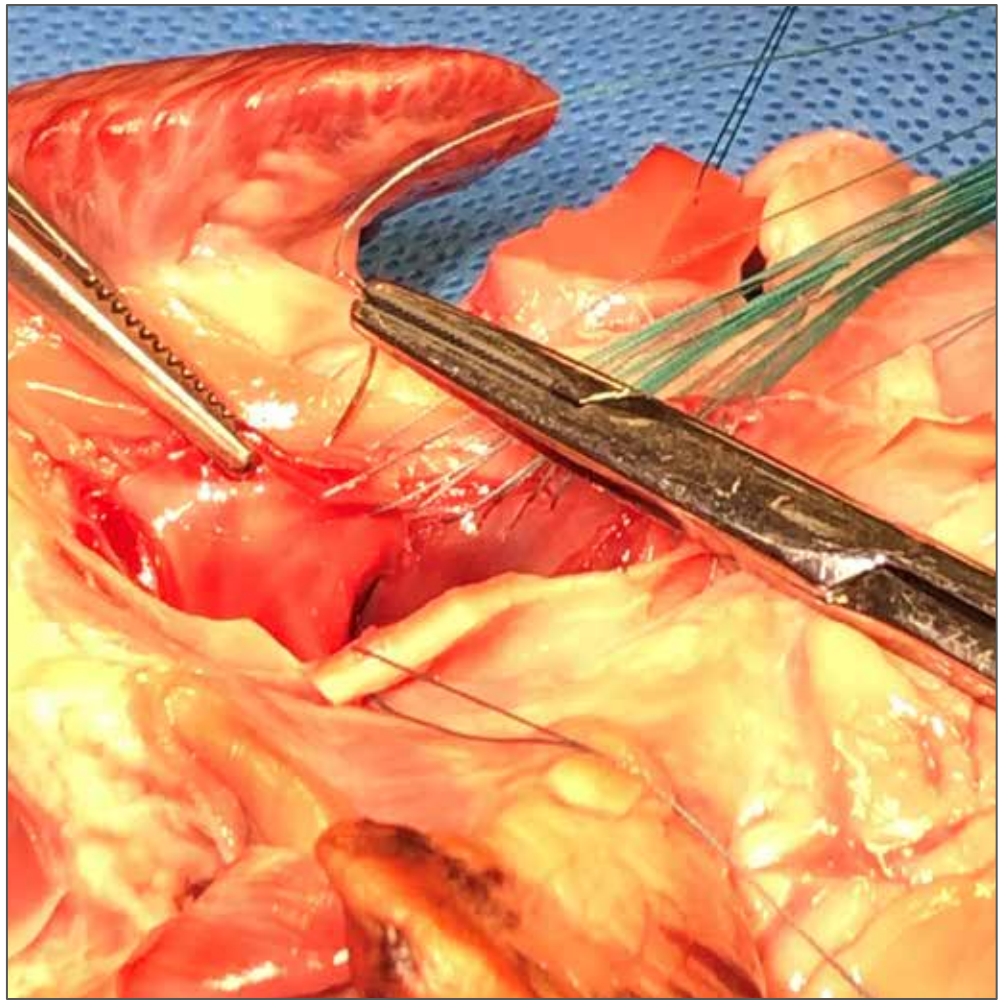


* Note the needle is placed in the allograft annulus immediately below the cusp attachment.

Proximal Suture Line

Left Coronary Sinus Sutures

7. It is important to *evert* the patient's annulus with a forceps in order to facilitate precise suture spacing on the *underside* of the annulus, just in the annulus. Because the allograft will seat on the *underside* of the patient's annulus, the suture travel-distance must be determined here, not on the top-side of the annulus. It is important to avoid excess bulk in the suture loop by only engaging the fibrous annulus.
8. In the left sinus, sew toward yourself, just in the annulus, with precise 2.5 mm travel-distances.



Proximal Suture Line

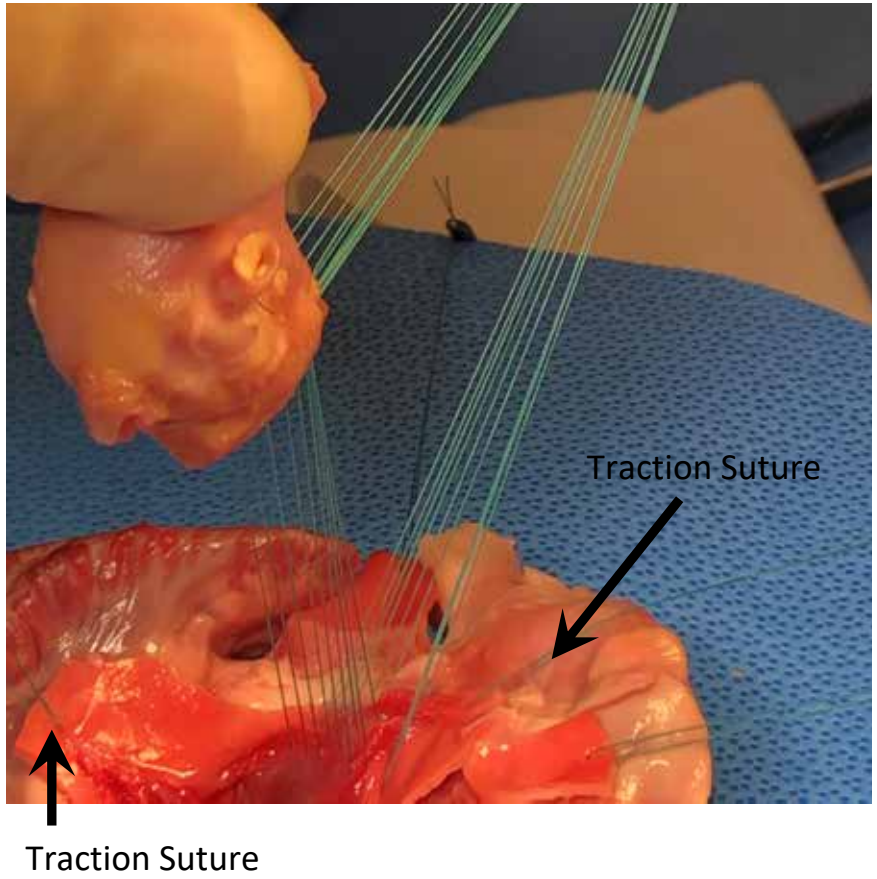
Suture Management

9. Surgery should be like ballet. To facilitate a steady rhythm and flow, organized suture management is a critical success factor for an expeditious operation without any wasted extra moves. We prefer the concept of “single-use”. Use the needle and handle the suture *only once*. Accordingly, we do not use suture guards, which require handling suture more than once. Nor is a second needle necessary since the same needle can be passed sequentially through the patient’s annulus and the allograft annulus in the same direction. The assistant simply holds both ends of each of the single-armed sutures for each sinus. After the completion of each sinus, the sutures are clamped together in one group and all the needles are discarded together with a single cut (see slide 32). Leaving needles attached to sutures after their task is completed leads to a tangled mess. Life is simple if you make it simple.

   It is important that the assistant hold the back end of both arms of the suture *outside* the allograft to avoid crossing of the suture. It is also important that the assistant use the traction sutures to create a straight line along each of the sinuses. For example, in the left sinus the assistant uses the traction sutures in the left-non and left-right commissure, using lateral traction to create a **straight line**.

   Note: Any annuloplasty sutures must be incorporated in the proximal suture-line, such that the proximal suture comes 1 mm *below* the annuloplasty stitch in order to exteriorize it.

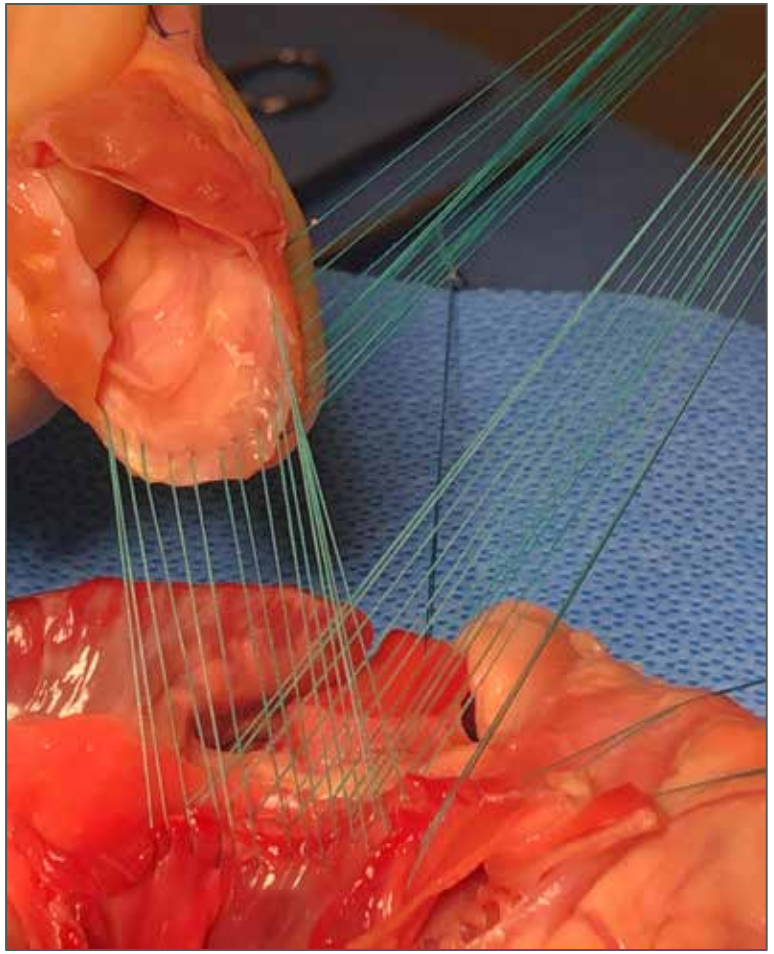
   * The repetitive suture travel-distances of 2.5 mm on the underside of the patient’s annulus are illustrated here.



Proximal Suture Line

Left Coronary Sinus Sutures

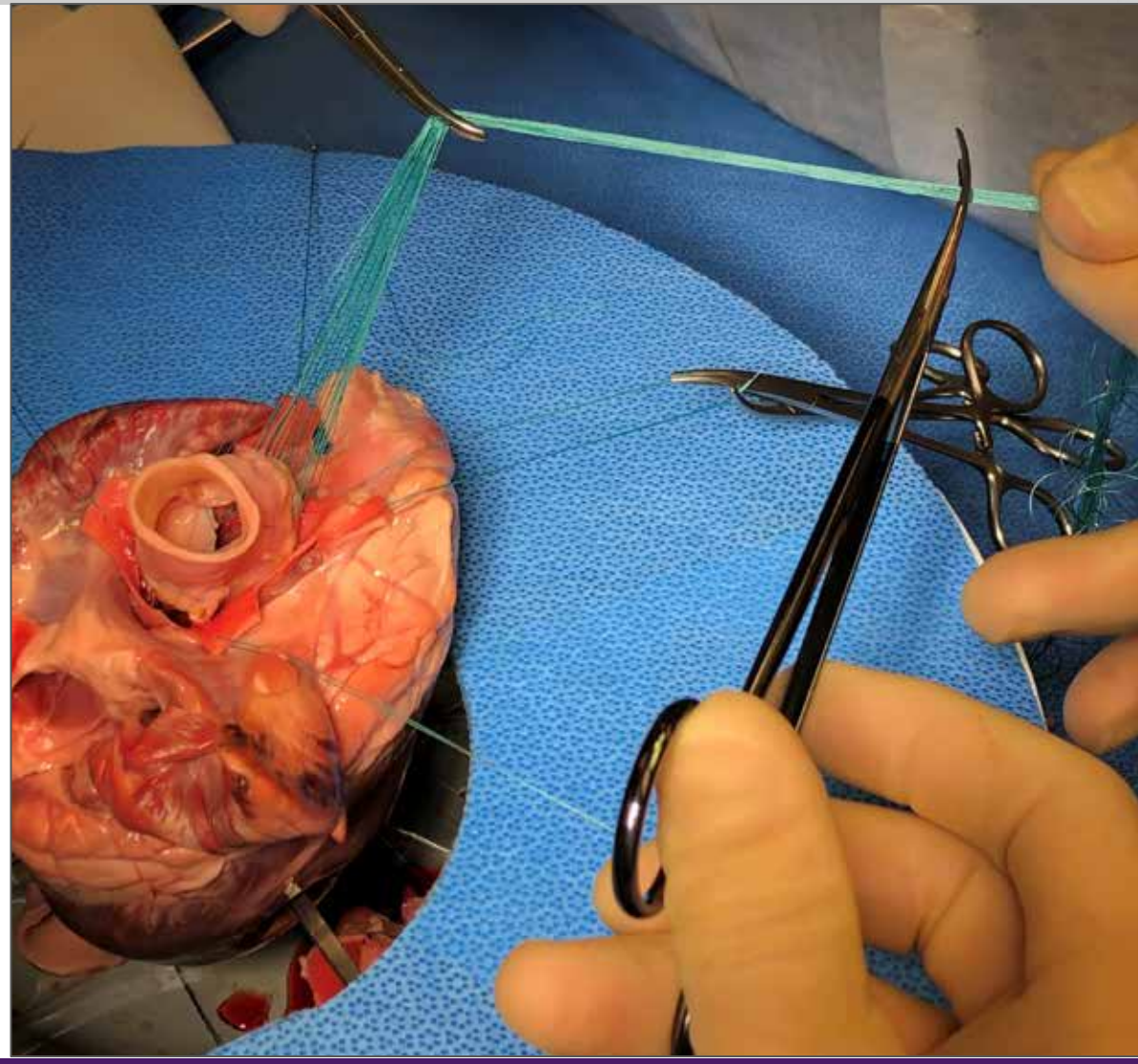
10. Suturing continues in the left sinus until the last suture is placed at the base of the non-left interleaflet triangle.
    - ***Do not try to match commissures.*** Just sew 2 equal circles together ("aortotomy principle"). ***Ignore the commissures.*** The commissures will be important to avoid when it is time to reimplant the coronary arteries into the conduit.
11. Parachute the sutures in each sinus to be sure the suture travel-distances are equal on both sides of the anastomosis and sutures are not crossed. If the travel-distances are not equal along the way, the "aortotomy principle" will not be guaranteed.



Proximal Suture Line

Left Coronary Sinus Sutures

12. All of the left sinus sutures are placed in one clamp and the needles cut. Sutures should be clamped short (keeping the clamps in the same radius) and cut long (providing enough suture length for easy knot tying).

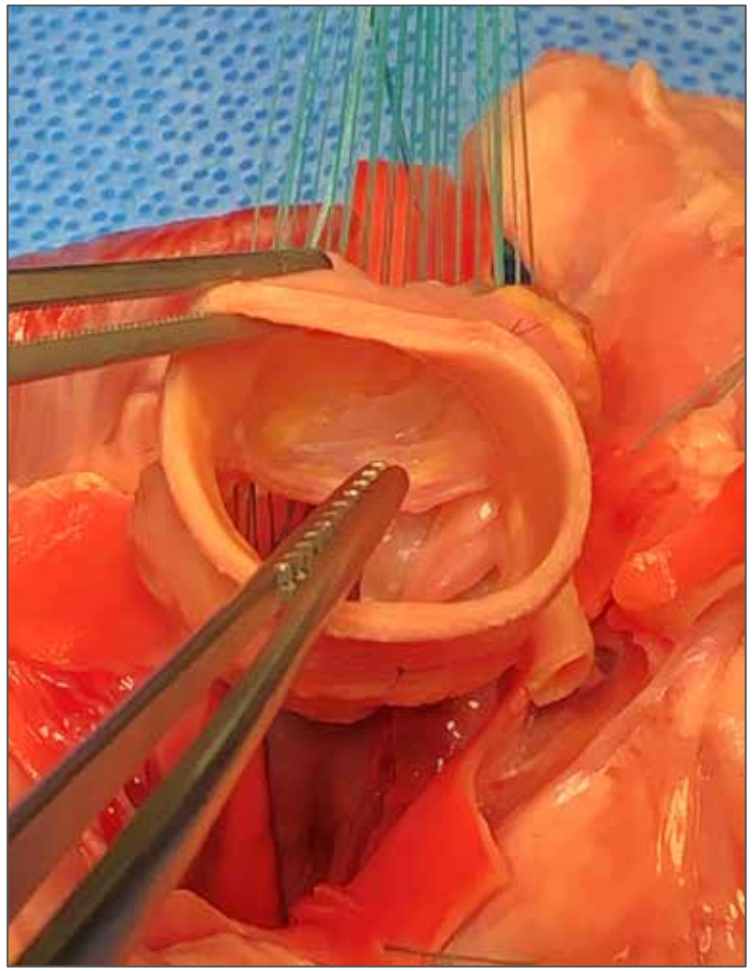


Proximal Suture Line

Aortic Cusp Integrity Verification

13. In order to confirm there is no cusp impalement by any of the sutures, the aortic allograft should be lowered onto the heart and a visual inspection of the base of the aortic side of the cusp should be made to verify that the cusp is free of any suture which could potentially restrict the cusp function.

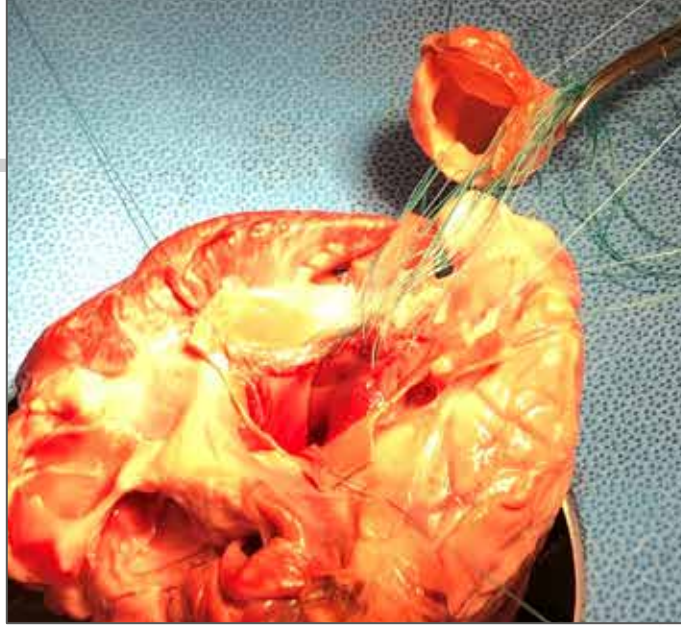
14. If a suture is visible, that suture should be removed with a nerve hook or fine forceps and another suture placed in that position, paying particular attention to avoid cusp impalement. Using the interrupted suture technique makes replacement of sutures easier than with a running technique.

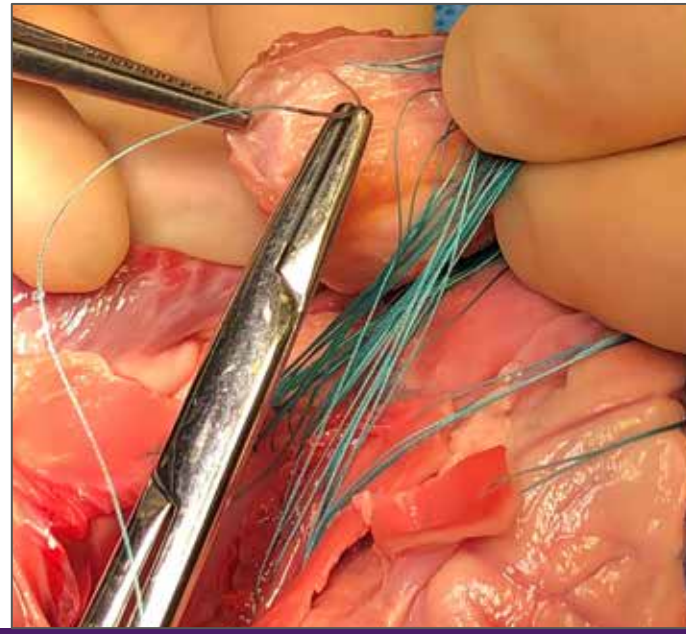


Proximal Suture Line

Right Coronary Sinus Sutures

15. The aortic allograft is placed at the 11 o'clock position in relation to the surgeon.
16. Suturing in the right coronary sinus continues *forehand-forehand: forehand* and *clockwise* in the patient, *counter-clockwise* in the allograft. Sewing *forehand-forehand* saves time by eliminating the extra move of re-orienting the needle back-hand in the needle-holder for the allograft portion of the anastomosis.
    - The assistant holds all the sutures with the "outside" hand and the allograft with "inside" hand, placing the proximal end of the allograft toward the surgeon, inverting the interleaflet triangles toward the surgeon with a thumb or finger to improve visibility of the cusp attachments in this crowded transition from one sinus to the other. The surgeon is able to continue sewing toward himself *counter-clockwise* in the allograft annulus. The assistant only holds the allograft with his hands, no instruments.
    - * Note again: the needle is placed in the allograft annulus immediately below the cusp attachment.





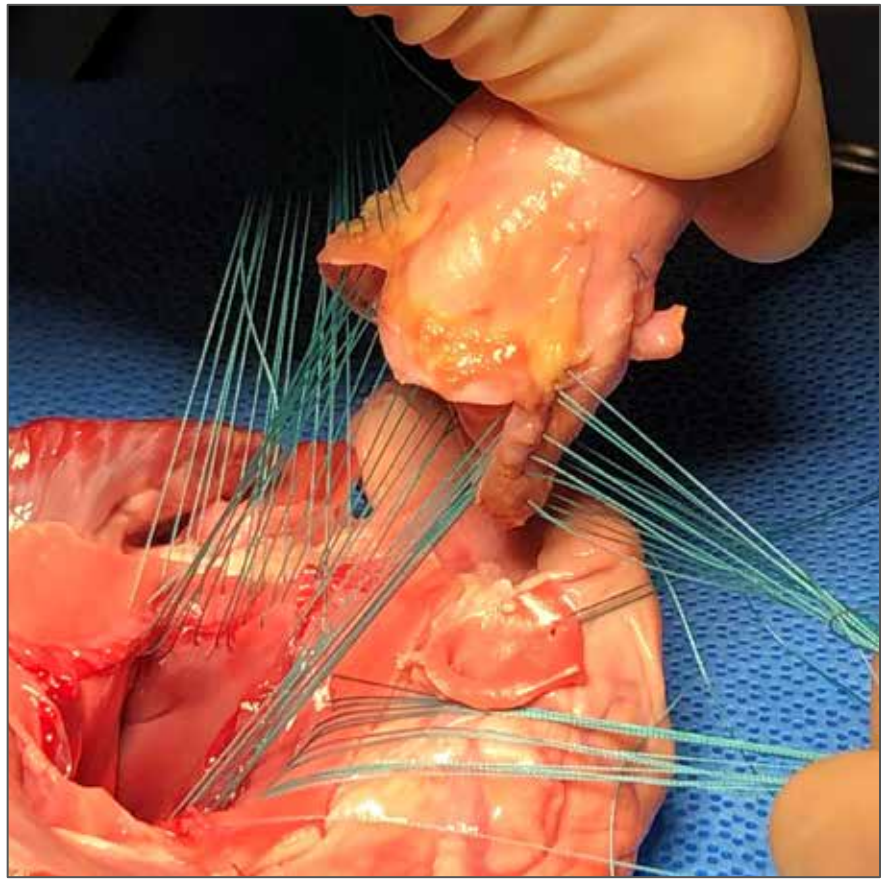
Proximal Suture Line

Right Coronary Sinus Sutures

17. Suturing continues in the right sinus until the last suture is placed in the base of the non-right interleaflet triangle of the allograft. It is especially important just below this interleaflet triangle to avoid placing sutures in any remnant of the membranous septum on either side of the interleaflet triangle. This is the most vulnerable area of the allograft anastomosis. The membranous septum does not have the same reliable integrity as the thin fibrous annulus immediately below the right coronary and non-coronary cusp attachments in this vulnerable transition zone. It is especially critical here to place the sutures *in* the annulus immediately below both cusp attachments to avoid dehiscence of the anastomosis.

18. The surgeon sews in the right sinus toward himself. Sutures are parachuted to check for spacing and any crossed sutures.

    * In the photo, notice that the last suture in the patient's annulus of the left sinus is well short of the left-non commissure. As can also be seen in this photo, this last suture ends in the non-left interleaflet triangle of the allograft, not the patient (unless the 2 sinuses happen to match). Because of the double asymmetry of the aortic sinuses of the patient and the allograft, sinuses typically won't match. Respect the usual asymmetry of the aortic root. **Do not force commissures to match.**

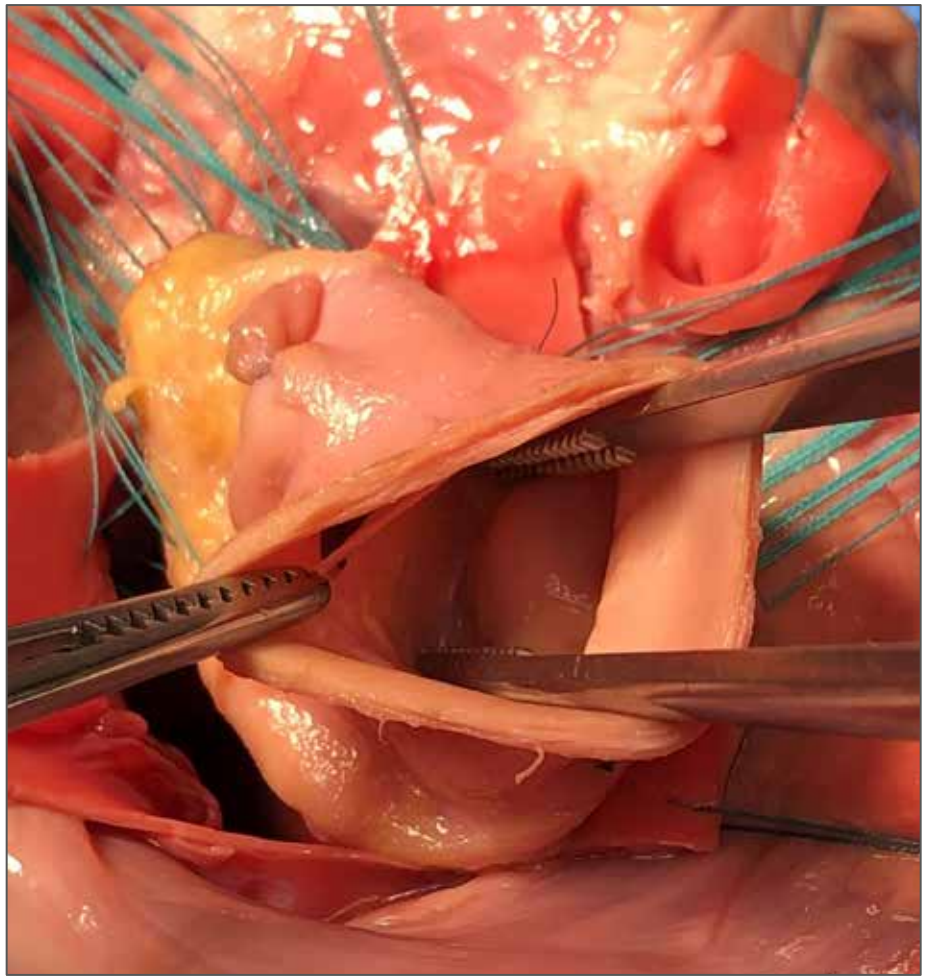


Proximal Suture Line

Right Coronary Sinus Sutures

19. All of the right sinus sutures are placed in one clamp and the needles cut. Sutures should be clamped short and cut long.

20. In order to verify that no sutures were put through the aortic cusp, a similar verification should be performed as was performed for the base of the aortic side of the left aortic cusp. Any misplaced sutures can be easily removed with a nerve hook or fine forceps and replaced.

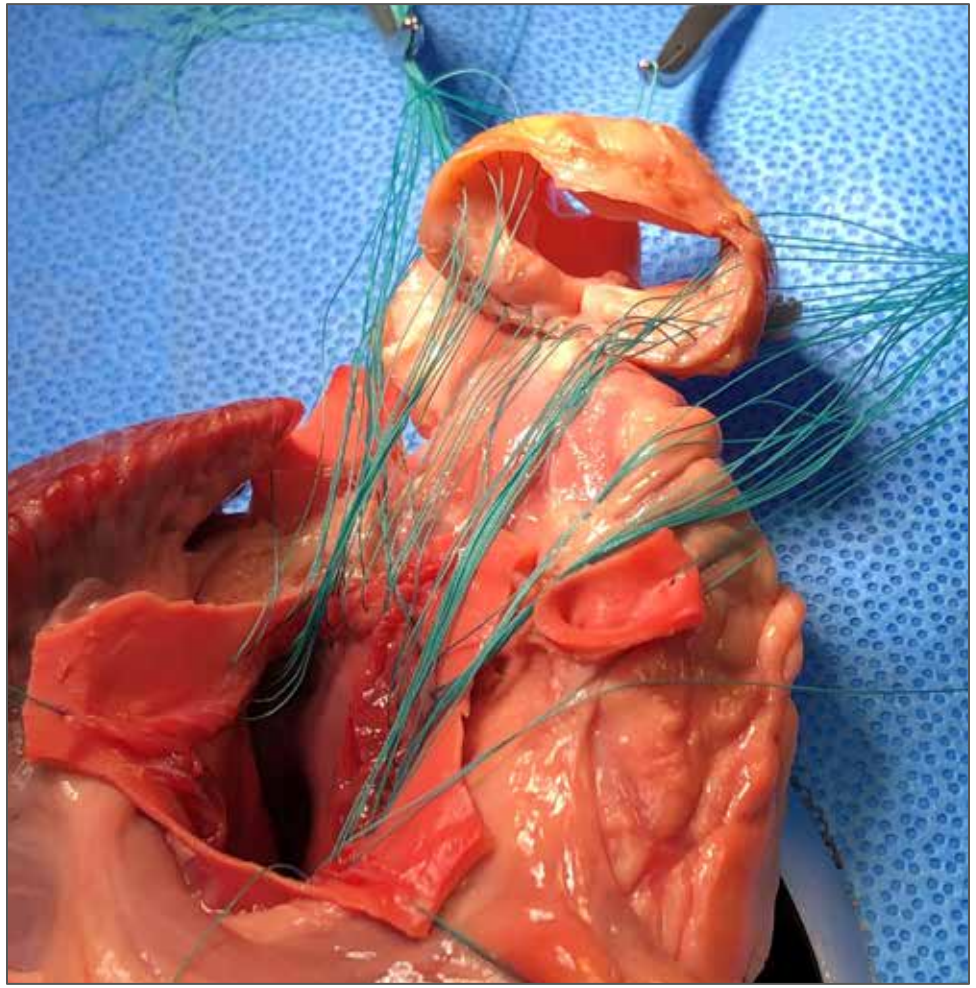


Proximal Suture Line

Non-Coronary Sinus Sutures

21. The aortic allograft is placed at the 12 o'clock position in relation to the surgeon.

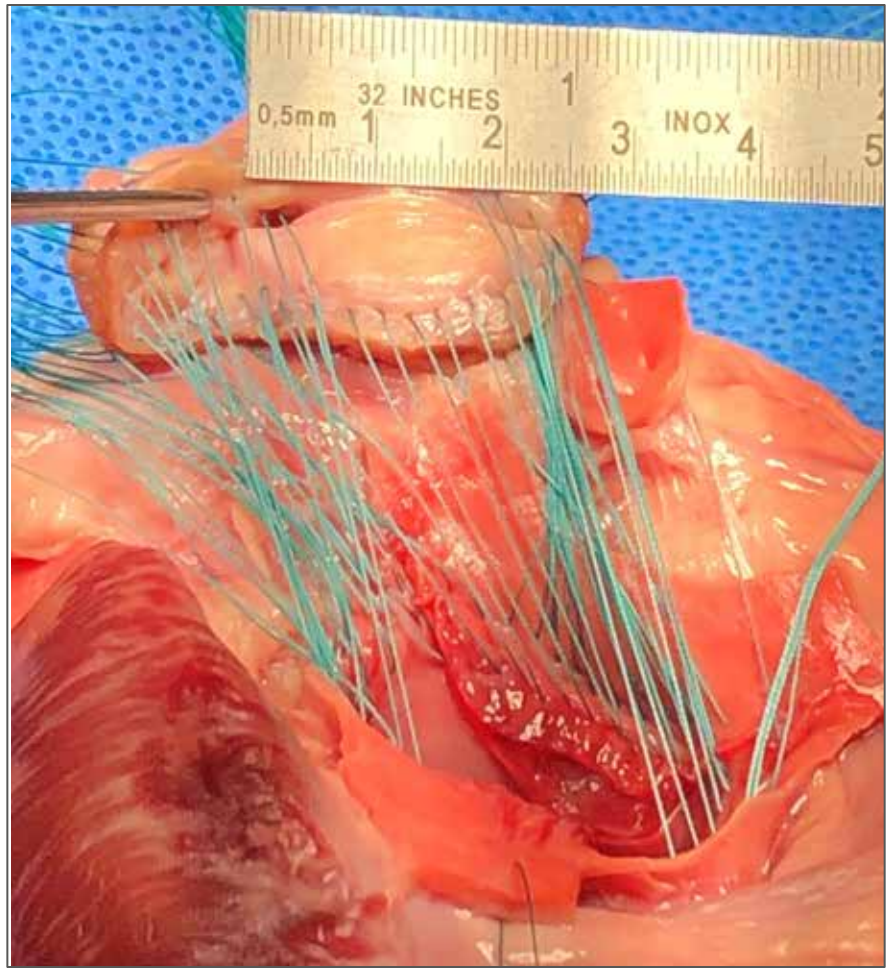
22. Begin with the right-non commissural suture proceeding *clockwise* in the patient, *counter-clockwise* in the allograft, both from right to left. *Backhand-backhand* suturing is often easier in the non-coronary sinus. The assistant *inverts* the interleaflet triangle of the allograft with a thumb or finger to facilitate suture placement.



Proximal Suture Line

Non-Coronary Sinus Sutures

23. When the nadir stitch is reached in the non-coronary sinus, an assessment of the spacing remaining in the allograft and the patient's annulus is made. The requirement for more suture travel-distance in the allograft requires an annuloplasty in the patient's annulus, to match the travel-distances in both annuli. The requirement for more suture travel-distance in the patient's annulus means any annuloplasty suture that may have been placed in the non-coronary sinus must be removed. Unfortunately, if there is no annuloplasty suture to be removed, it means that suture-travel distances have not been equal on both sides of the anastomosis. This is a major problem to be avoided by carefully matching the suture travel-distances in both annuli with each suture placement along the way. If the circles are the same size and the suture travel-distances are equal in each circle, the 2 circles will always precisely come together as they always do when closing an aorta (the "aortotomy principle").



Proximal Suture Line

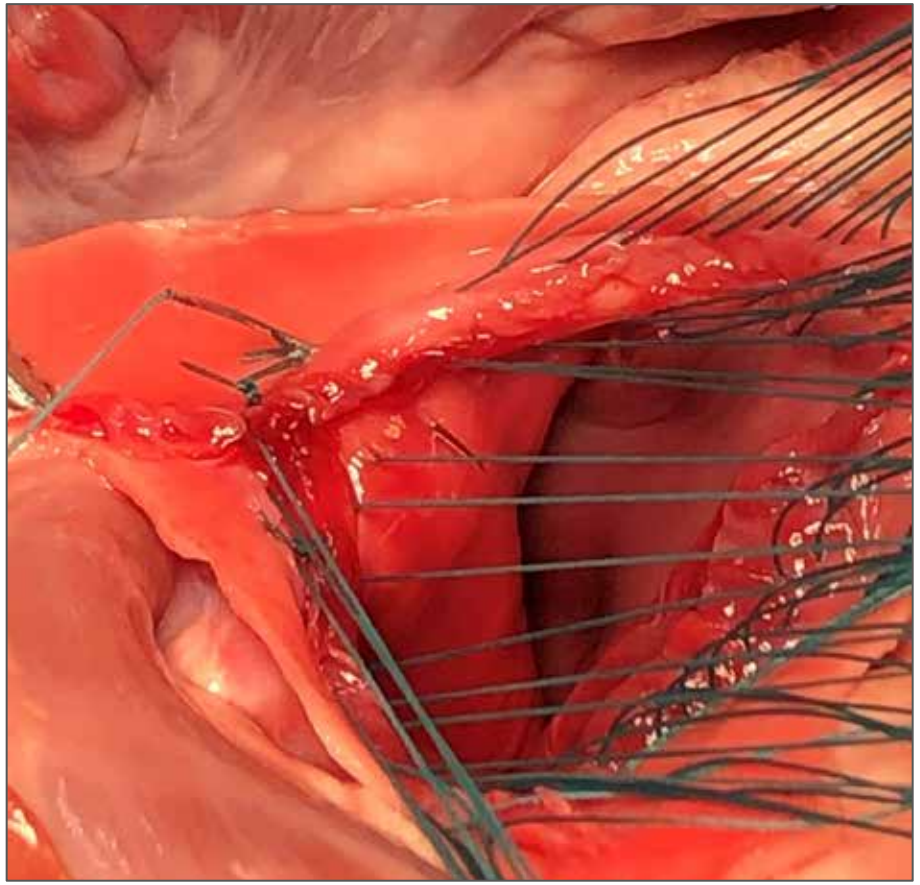
Non-Coronary Sinus Sutures

24. Suturing ends at the non-left interleaflet triangle in the allograft, not the patient. The assistant *inverts* the non-left interleaflet triangle with a finger or thumb to facilitate suture placement.

    * In the photo, notice that the last stitch in the patient's annulus is beyond the left-non interleaflet triangle and actually in the annulus of the left sinus. The arrow points to the tip of the needle of the last stitch in the patient's annulus. Remember to **ignore trying to match commissures**. Aortic roots almost always have asymmetric sinuses. The possibility that the surgeon can match 2 asymmetric sinuses is highly unlikely since an allograft aortic root implant is dealing with a double asymmetry (patient and allograft).

25. All of the non-coronary sinus sutures are placed in one clamp and the needles cut. Sutures should be clamped short and cut long.

26. In order to verify that no sutures were put through the aortic cusp, a similar verification should be performed as was performed for the other two aortic cusps by carefully visualizing the base of the aortic side of the non-coronary cusp.

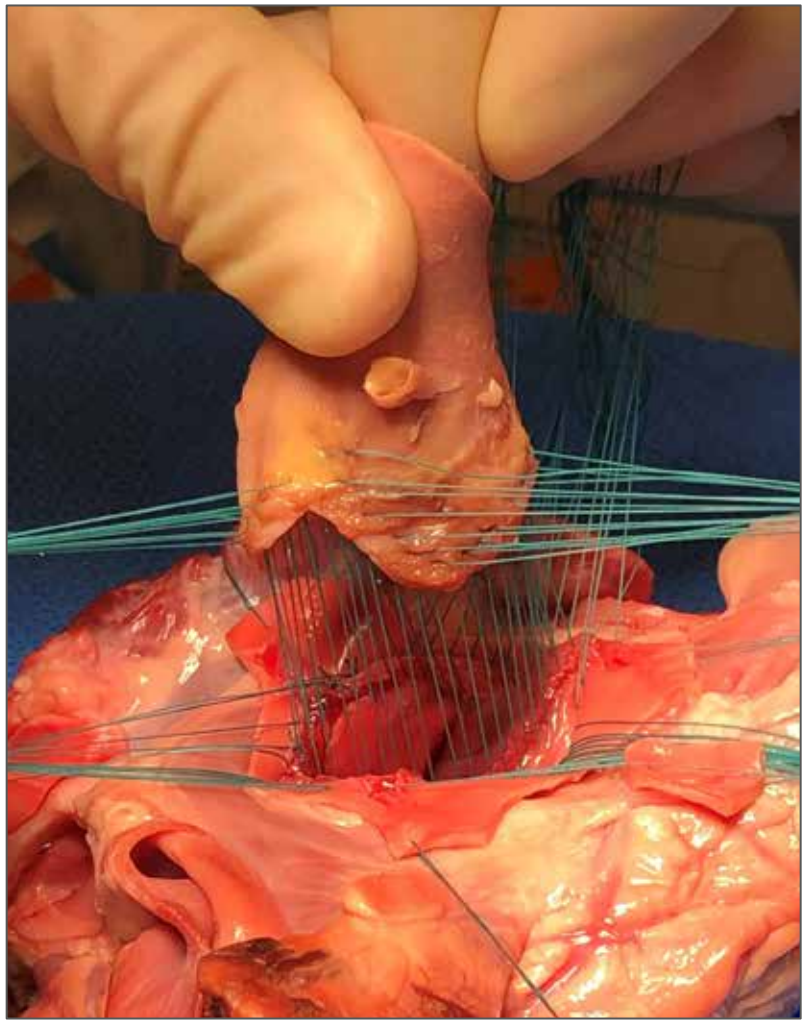


Proximal Suture Line

Parachuting Proximal Sutures and Tying

27. All three groups of sinus sutures are parachuted again to check for spacing and to make sure no sutures are crossed. Suture adjustments can be made again at this time.

    – If you wish to buttress, a buttress can be placed between the suture loops before tying down.

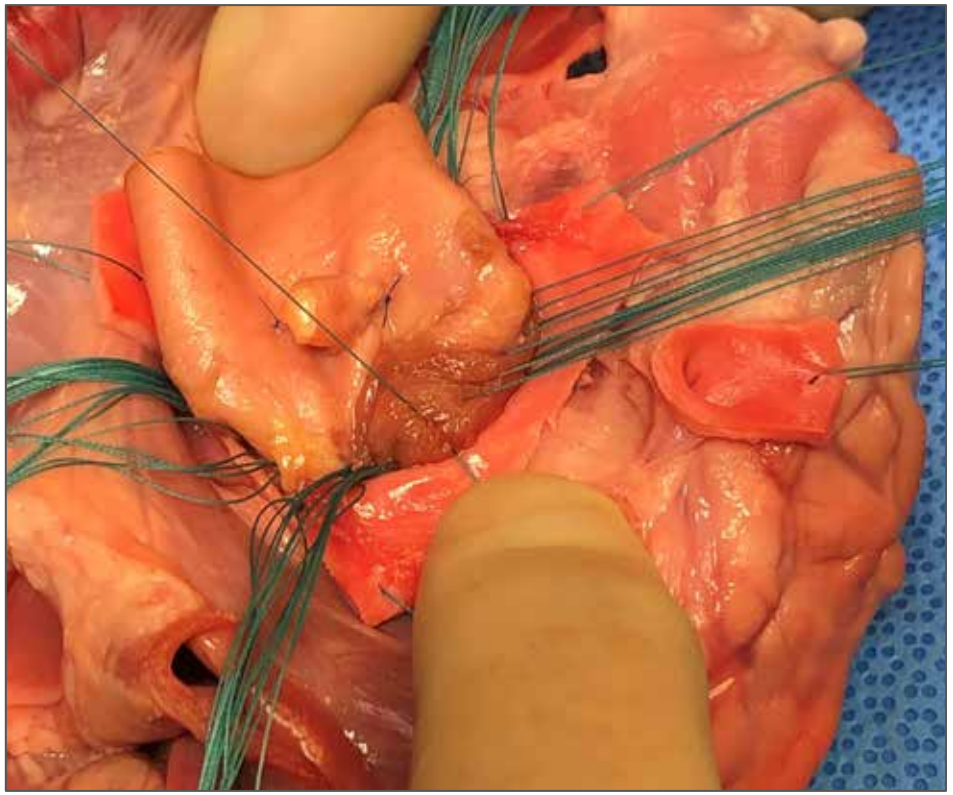


Proximal Suture Line

Parachuting Proximal Sutures and Tying

28. Seat the allograft.
29. After the allograft is seated, tying may begin anywhere.
    - Each knot should be tied down with the finger past the knot with each throw.
    - Four knots is enough: granny, granny, square, square.
    - No Air Knots. Air knots are more likely to break the suture or to be loose.

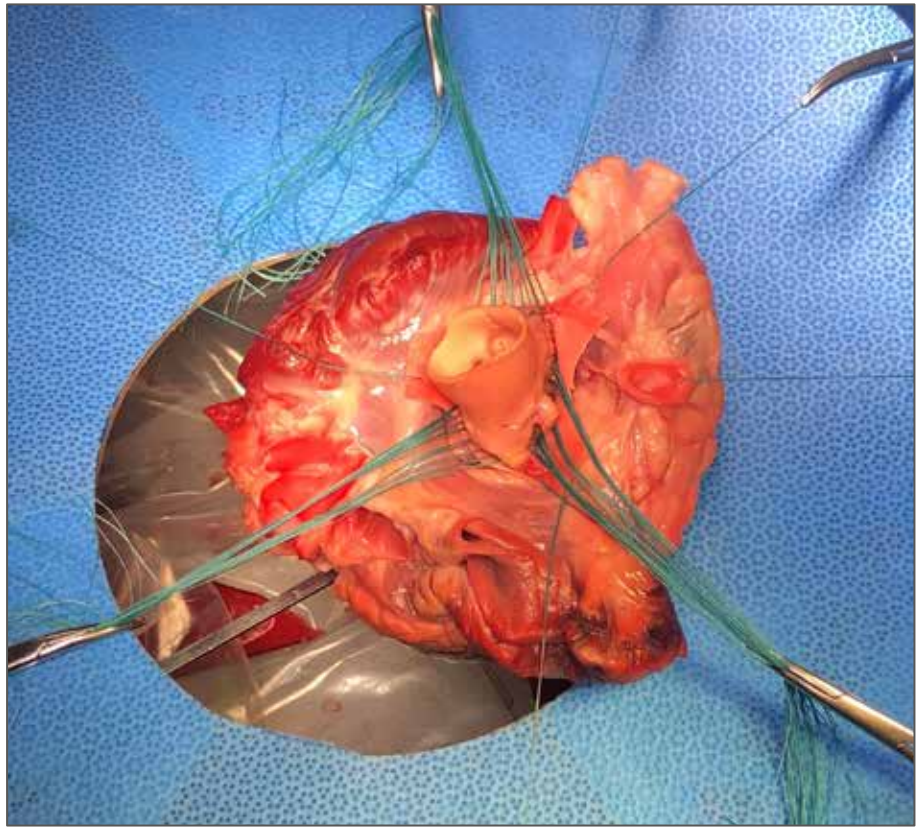
* Note in this photo that the knots are being tied *in* the muscle of the right coronary sinus. This is because the ventricular-aortic junction (VAJ), in that half-circumference portion of the aortic root which is attached to the left ventricle (the right sinus and half of the left sinus), is more cephalad than the aortic annulus. Remember that the other half-circumference of the aortic root between the 2 fibrous trigones represents the aortic-mitral fibrous continuity where only the fibrous trigones themselves are actually attached to the left ventricle.

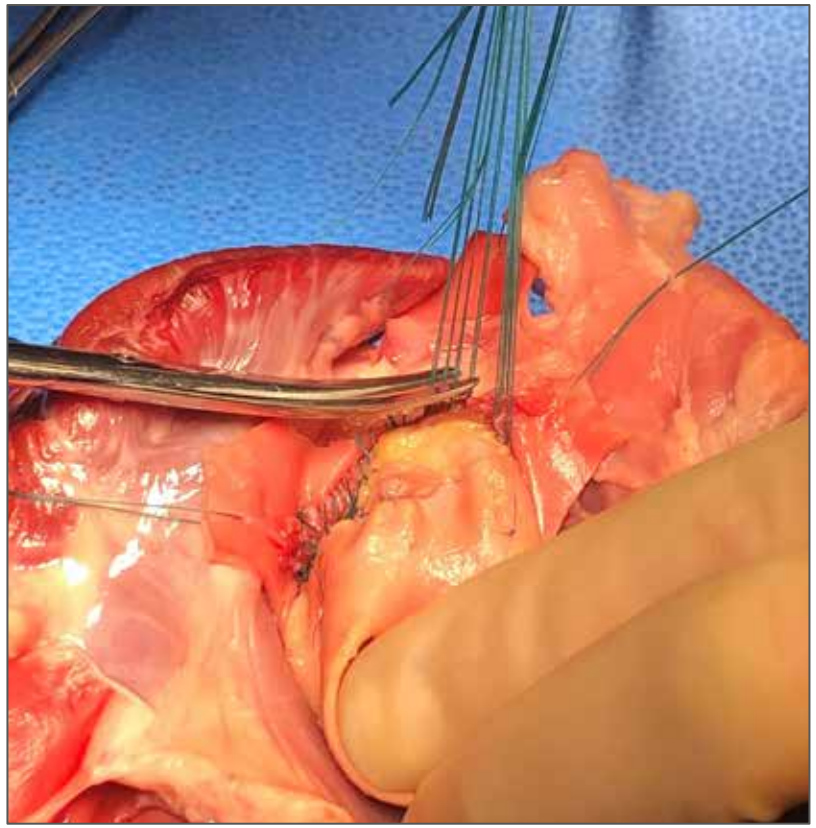


Proximal Suture Line

Parachuting Proximal Sutures and Tying

30. Tie all sutures before cutting. Cut the knotted sutures at the end to avoid cutting a suture that has not been tied and to save time.





Reimplantation of Coronary Arteries

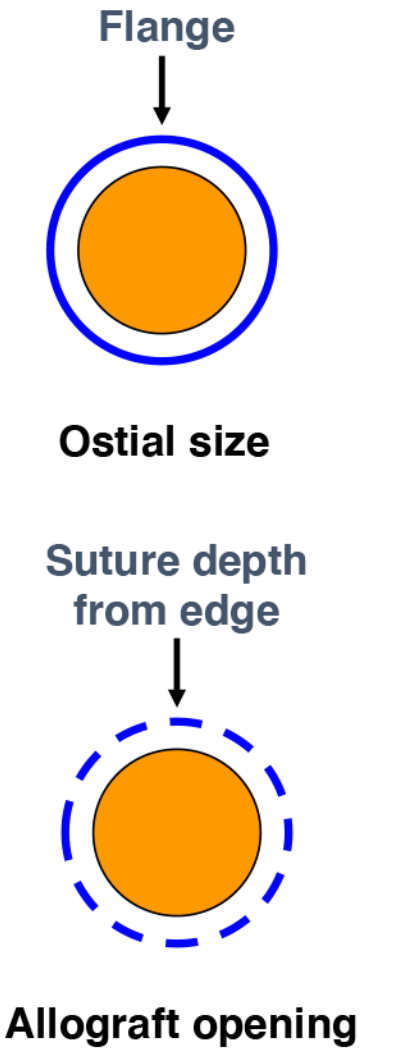
ELITE

Reimplantation of Coronary Arteries

“Two Equal Circles” Principle

1. The dimensions of the allograft button-holes must precisely match those of the patient's coronary buttons, whether they are at the original allograft coronary sites or are neo-ostia. They must also be made in the “distended” allograft by stretching it with a finger inside and noting the inside and outside edge of the coronary ostium width and the upper and lower edge of the coronary ostium height. Be sure to account for the cuff width of the coronary button at the inside and bottom edge when determining the matching position of the coronary ostial width and height in the allograft. The marking pen can match this dimension on the “distended” allograft. Be careful to also note the correct latitude of the coronary ostium by putting the “puzzle” back together first.

    * The following illustration assumes that the suture-line will engage a depth of 2–3 mm in both the button cuff and the allograft button-hole by an overlap of 2–3 mm of the button over the entire circumference of the allograft button-hole. A small (“bowler”) cuff is generally preferred as illustrated and brings the coronary ostium flush with the allograft. Looking from inside, very little cuff is visible with a small button. If a large (“sombrero”) button is fashioned, the button-hole in the allograft will be larger but should still “match” the button cuff, allowing for the same 2–3 mm depth of suture bites on both sides of the anastomosis. The button-hole in the allograft for the larger coronary button will therefore be approximately 4–6 mm smaller in diameter to allow the 2–3 mm overlap of the button cuff over the entire circumference of the allograft button-hole for the suture-line. Looking from inside, the cuff will be visible beyond the limits of the ostium. The larger the cuff, the more cuff will be visible. Large cuffs are to be avoided with syndromic aortic diseases, such as Marfan’s, because they originate from the diseased aortic sinuses. Large “sombero” cuffs are also more likely to buckle at the lower edge, possibly obstructing the ostium.



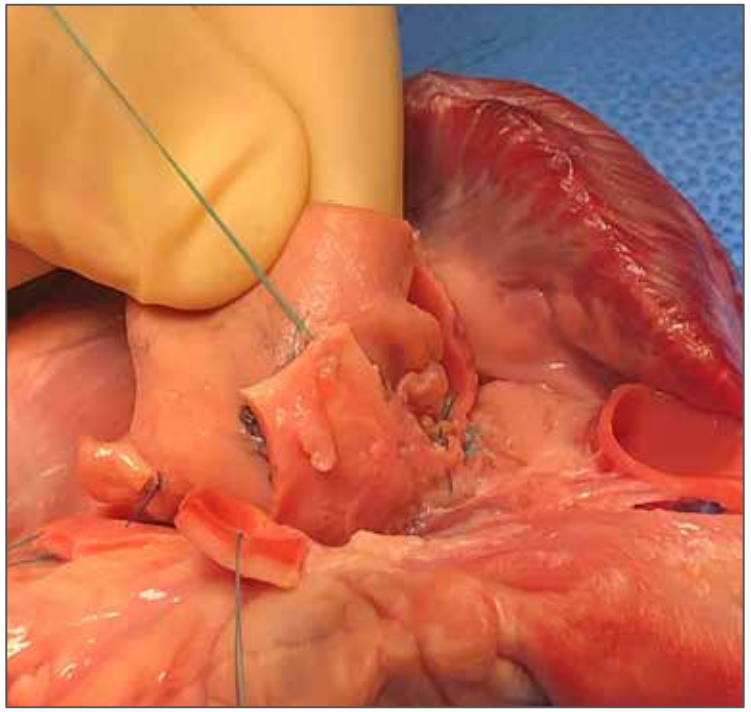
Reimplantation of Coronary Arteries

“Puzzle Maneuver”

2. The coronary arteries must be placed back in their **original axis** (longitude and latitude).

3. The *original* longitude and latitude of the coronary ostia relative to the left-right commissure can either be measured prior to developing the buttons or determined by the “puzzle maneuver”. This consists of simply placing the 3 pieces of the “puzzle” back together—the left-right commissural post and the left and right coronary buttons—to determine the *original* location of the coronary ostia. It is important to remember that early button development with traction sutures at the 12 o’clock position results in upward and lateral displacement of the coronary arteries. The coronaries must be placed back in their original axis by putting the “puzzle” back together again.

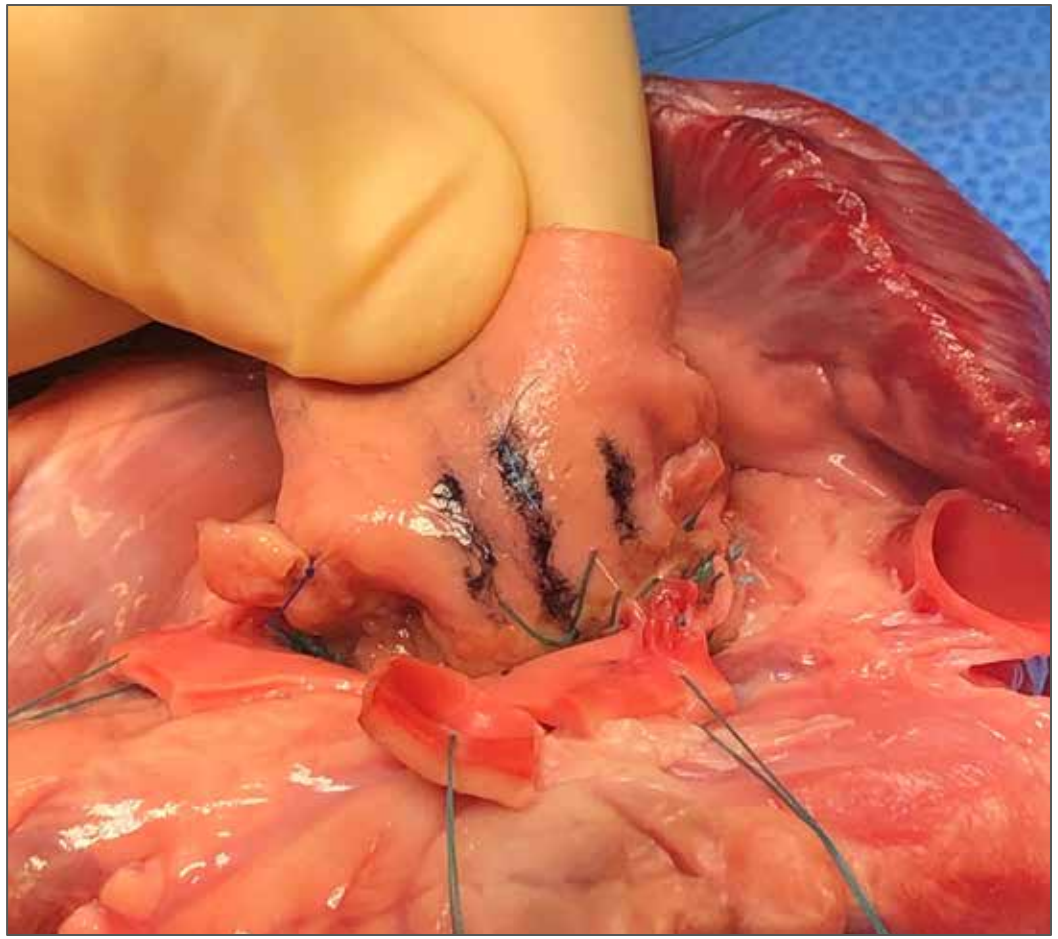
    * In the photo the allograft is “distended” by stretching it with a finger in the allograft to simulate distension at systemic pressures with the post placed against the allograft to simulate the original position of the post. Each of the lateral sides of the post are precisely where the buttons were cut. Accordingly, each lateral side of the post also represents the lateral side of each button facing the left-right commissural post.



Reimplantation of Coronary Arteries

“Puzzle” Maneuver

4. Using either the actual dimensions of longitude and latitude relative to the left-right commissure or the “puzzle maneuver”, the anastomotic sites for both coronaries are precisely determined by placing the index finger in the allograft to simulate distention by stretching it longitudinally and laterally, the same way you would “unkink” a Dacron graft.
    - If a marking pen is used on the conduit, it is important to be certain that the measurements of the lateral edges of the post are *parallel* to the vertical plane of the left-right commissure. The lateral measurements can be confirmed by simply applying the post to the distended allograft, as seen on the previous page.

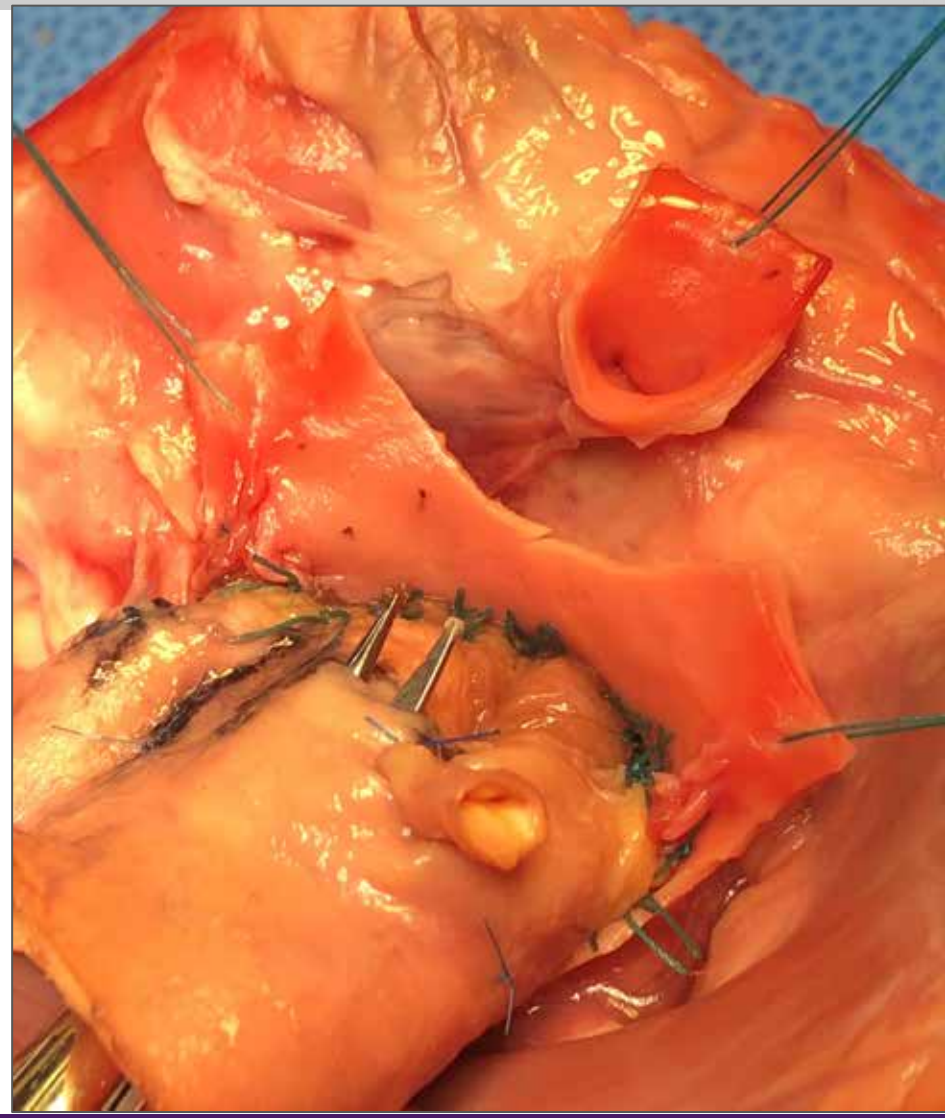


Reimplantation of Coronary Arteries

Left Coronary Button

5. A free-hand button-hole is then made in the “distended” allograft by stretching it with a finger inside. This is done precisely at the original longitude and latitude of the patient's coronary artery, respecting the exact dimensions of the recipient coronary ostium (“two equal circles” principle) in the “distended” allograft.
6. A neo-ostium, if necessary, can easily be made with a sharp tenotomy scissors passed inside-out (avoiding the leaflet) at the original latitude of the upper edge of the coronary ostium. A “trap door” is then trimmed free-hand around and down both sides with a width and height identical to the width and height of the coronary ostium as determined in a “distended” allograft. The bottom edge of the button-hole is at the same latitude as the bottom edge of the coronary ostium.

   Note: Saw teeth should be avoided while creating the button-hole in the conduit by taking very small bites and staying diligently in the crotch of the previous cut. **Smooth suture lines** are the priority here, to match the smooth suture lines of the coronary buttons.



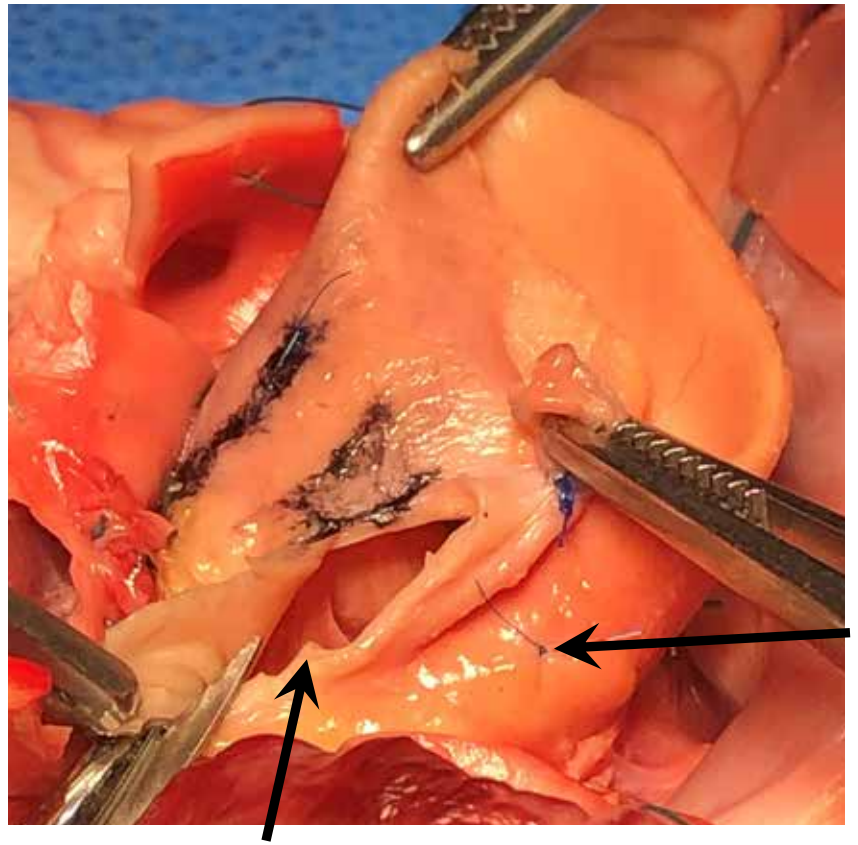
Reimplantation of Coronary Arteries

Left Coronary Button

7. If neo-ostia are made, the original allograft coronary sites should be reinforced with an additional suture.

    * In this photo, note that the hole in the conduit is safely separated from the right-non commissure. This commissure is represented by the suture indicated by the arrow.

    * In addition, notice a sawtooth was created when developing the button-hole. This will need to be corrected before the coronary ostium is sewn in place. It is easier, more efficient and quicker to create this free-hand ostium with the correct dimensions and a smooth surface in the first place, rather then coming back later to remove a saw tooth or enlarge the button-hole. Simplify, by eliminating all extra moves. Do everything deliberately and precisely in one motion. Make it flow, like ballet.



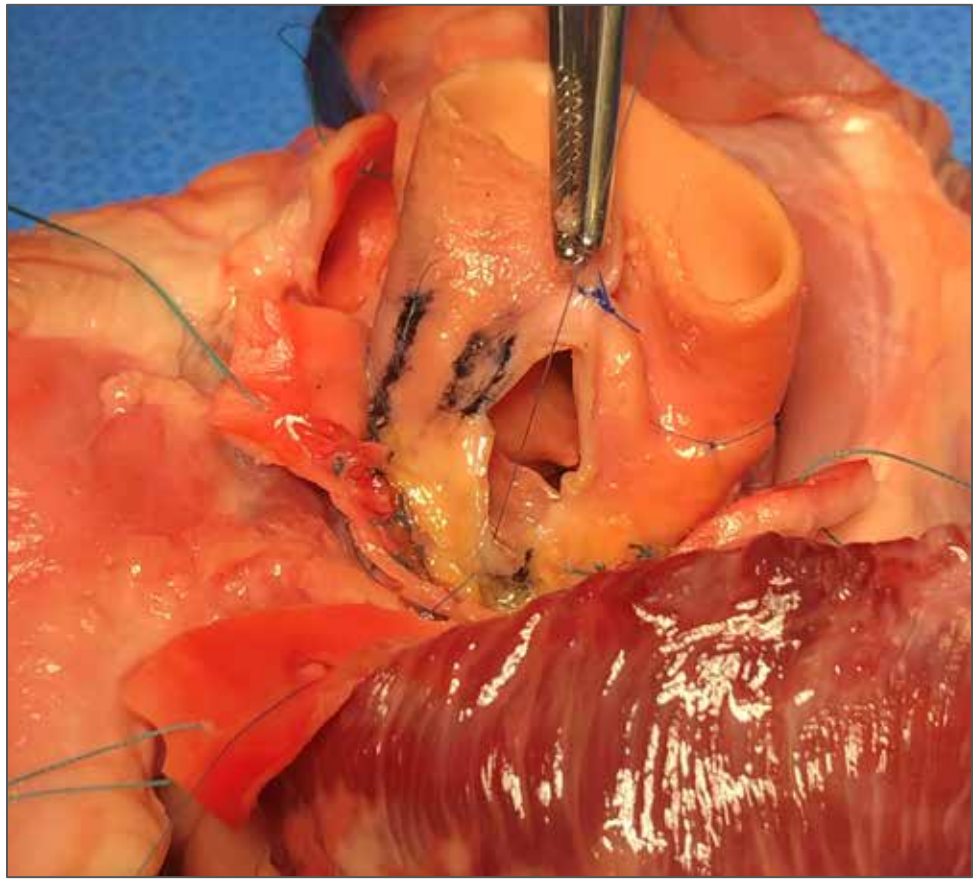
Reimplantation of Coronary Arteries

Left Coronary Button

8. Suturing begins at 6 o'clock with 5-0 Cardionyl®, 2–3 mm from the edge on both sides. Be careful not to get too shallow on the button and risk sutures tearing out.

   Note: I prefer the polyamide Cardionyl (Peters suture) because it is a bit elastic, has no memory and doesn't purse-string. However, it cannot be parachuted because it is "sticky", which requires each loop to be pulled up tight. Prolene® can also be used.

   * Notice in the photo that the sawtooth that was created making the button-hole has been removed and the button-hole is now smooth. This will allow for a **smooth suture line** that will not leak. It is always easier to do it right the first time.



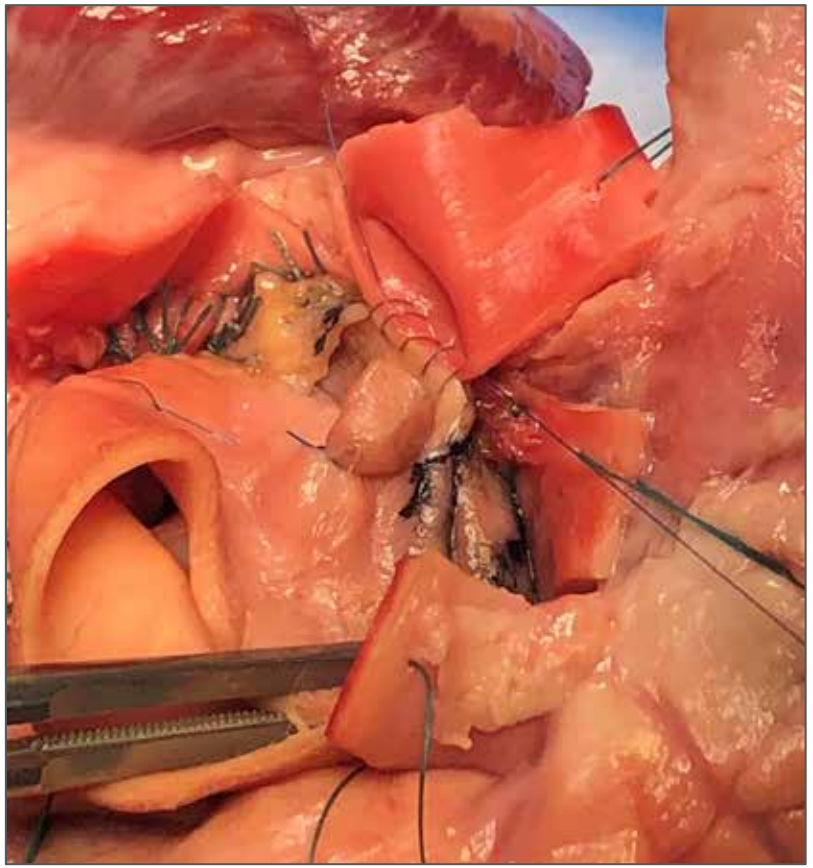
Reimplantation of Coronary Arteries

Left Coronary Button

9. Suturing continues first toward 3 o'clock and then toward 9 o'clock with separate bites in the button and the allograft until the 9 o'clock–3 o'clock plane at the imaginary equator is reached. The assistant uses the suture as a retractor with each half-throw, enabling the surgeon to easily see where to place the next "matching" suture in either the allograft or the button, ensuring equal travel-distances on both sides of the anastomosis. Because there is so much elastic tissue in the aortic root, it is important to "stretch" the button cuff and the allograft button-hole by creating parallel **straight lines** as much as possible. Be careful to avoid using forceps in any portion of the button cuff where sutures will be placed to avoid inadvertent crush damage. Traction with forceps must be in a remote portion of the button-cuff which will eventually be discarded.

   Note: If Cardionyl is used, each throw must be tightened. The advantage of Cardionyl is its elasticity, lack of memory and "stickiness", which is gentle on the tissue and prevents purse-stringing. However, because of these properties, it cannot be parachuted and must be pulled tight after each throw.

   – Since the "2 circles" are the same size, the "aortotomy principle" will be guaranteed if the intervals of suture travel-distance are equal on both sides of the circles.

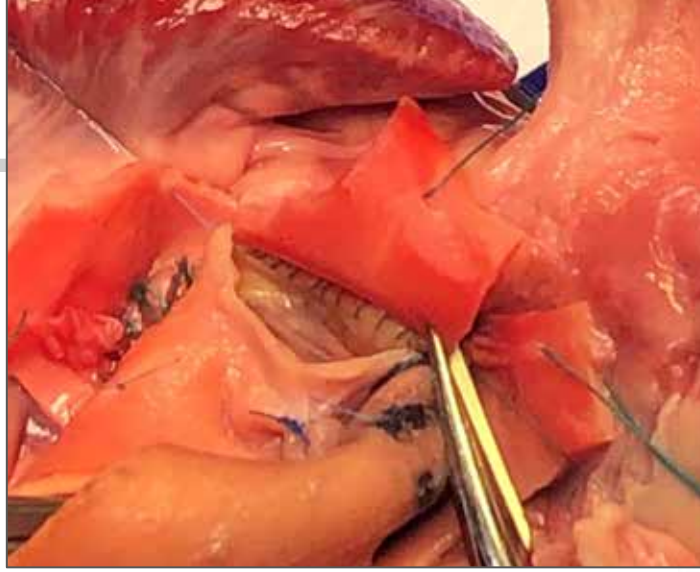


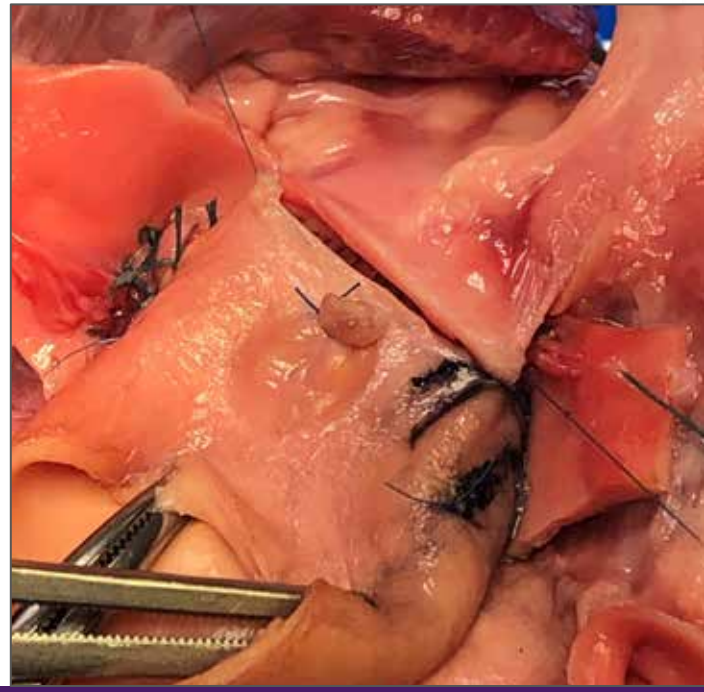
Reimplantation of Coronary Arteries

Left Coronary Button

10. With lateral traction on the equator stitches by the assistant, the upper half of the flange is cut to within 2–3 mm of the ostium, rounding the corners to prevent dog-ears.

    Note: Lateral traction of the sutures on either side of the “equator” converts 2 half circles to 2 **straight lines**. If the 2 straight lines are the same length, the circles are the same size. The use of lateral traction of the two sutures at the equator by the assistant facilitates suture placement.





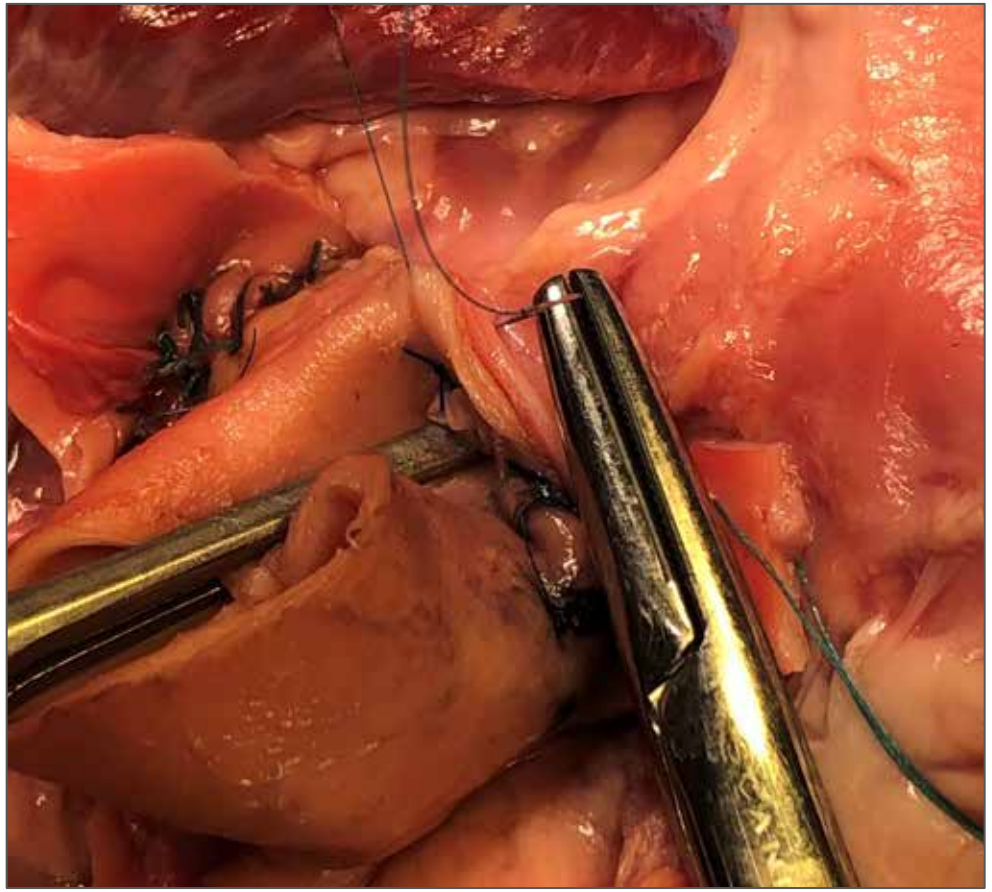
Reimplantation of Coronary Arteries

Left Coronary Button

11. With continuing lateral traction on the two ends of the running Cardionyl suture by the assistant, the upper half of the coronary anastomosis to the allograft is done, engaging both the button and allograft in *one bite*.

    Note: Lateral traction of the sutures at the “equator” by the assistant creates a **straight line**. Sewing in a straight line is always easier than trying to match 2 ruffles (or potato chips).

    * Notice in the photo the forceps is ducking the conduit to create an everted suture line where the suture enters and exits both sides of the anastomosis at 90 degrees in one throw.



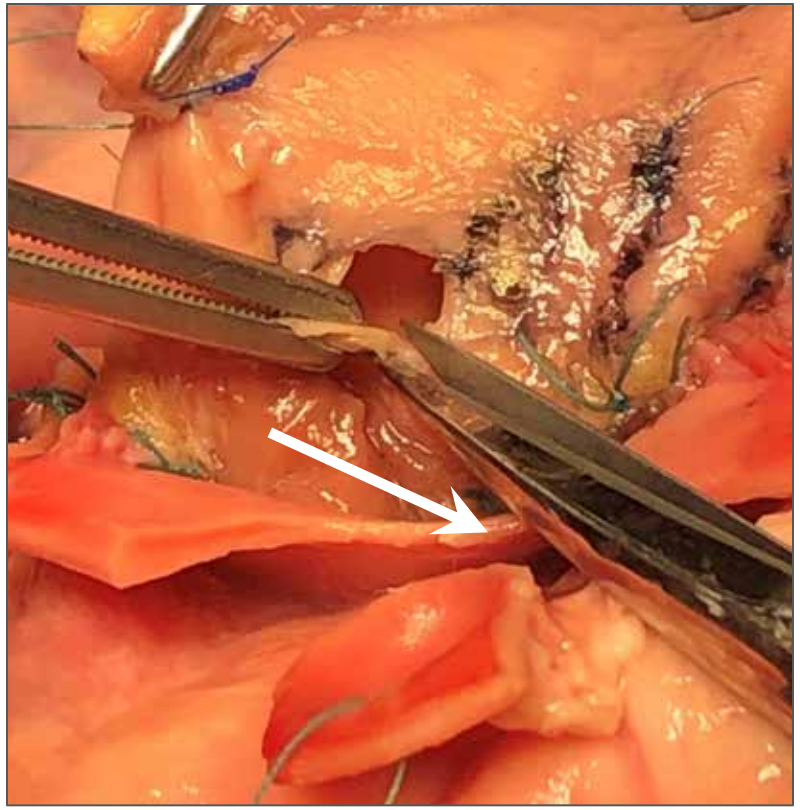
Reimplantation of Coronary Arteries

Right Coronary Button

12. The button-hole in the allograft for the right coronary ostium is fashioned precisely as for the left.

    – If a neo-ostium is required, the sharp tenotomy scissors begin the development of the opening by gently pushing the scissors from inside-out with the jaws closed and gently spreading the jaws to begin the cut. Be careful to avoid the leaflet. A button-hole is cut free-hand to precisely match the size and shape of the coronary ostium. These dimensions are determined in the “distended” allograft by stretching it with a finger inside. This free-hand cut is facilitated by holding the “trap door” of the divot to be removed with the forceps. For a smaller “bowler” button, this divot should precisely match the size and shape of the coronary ostium. If it does, the “aortotomy principle” will be guaranteed and the coronary ostium will perfectly match the button-hole in the allograft.

    * In this photo the arrow indicates the cut edge of the aortic root, which is also the bottom edge (the latitude) of the coronary button cuff when the “puzzle” is put back together. Remember that this latitude must be determined in a “distended” allograft by stretching it with a finger inside. Otherwise, the allograft will “unkink” with systemic pressure pulling the coronary artery more cephalad, with a risk of coronary artery kinking and compromised flow.

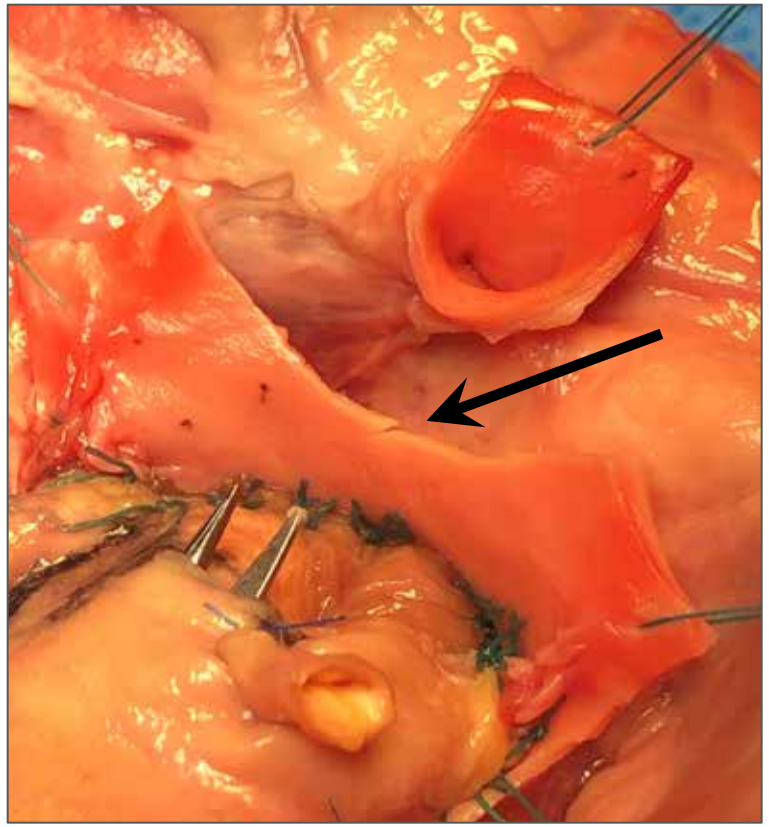


Reimplantation of Coronary Arteries

Right Coronary Button

* Note in the photo that the cut edge of the aortic root is also the bottom edge of the coronary button and represents the lower border of the latitude of the coronary axis at the bottom edge of the cuff of the button. Note that the actual lower border of the latitude of the coronary axis is at the ostium, not the bottom edge of the cuff. A large cuff (a “sombrero”) will require the lower border of the allograft button-hole to be appropriately lower and will, therefore, require a larger hole in the allograft. A small cuff (a “bowler”) will have the lower border of the allograft button-hole closer to the actual lower border of the latitude of the coronary axis and will, therefore, require a smaller hole in the allograft.

13. The “two equal circles” principle is respected.



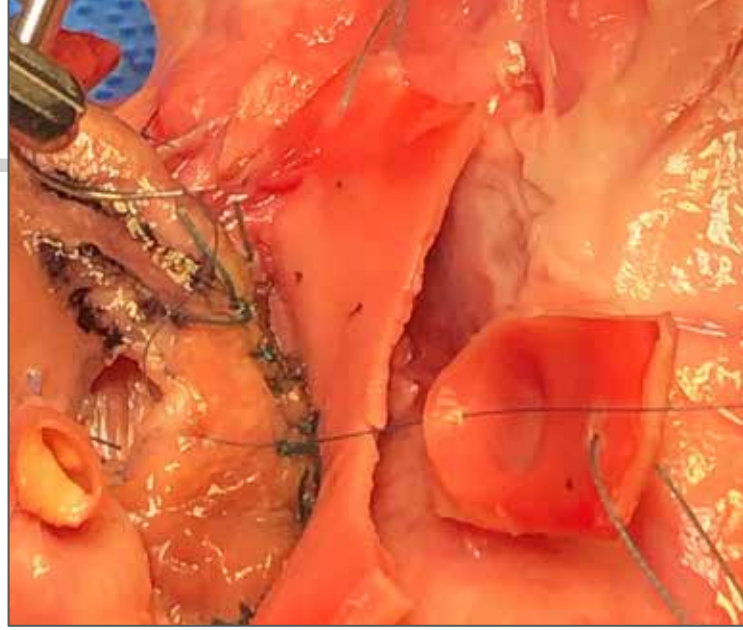
Reimplantation of Coronary Arteries

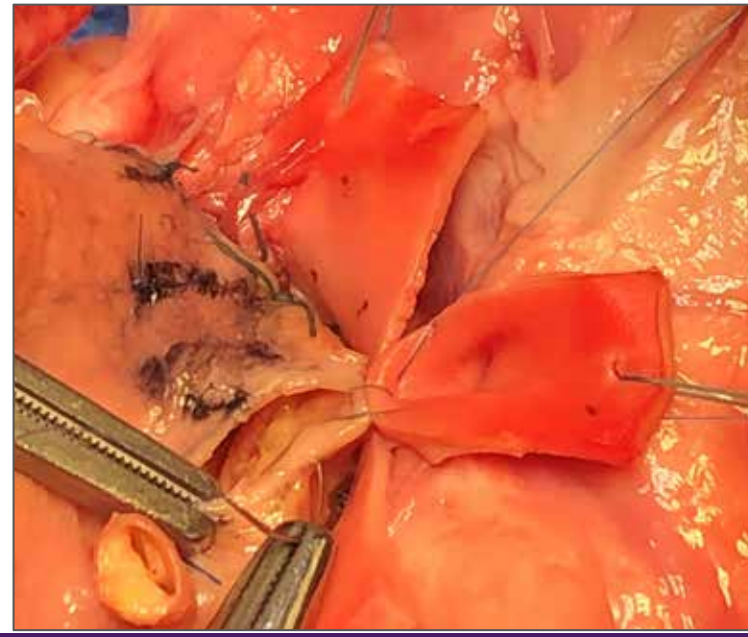
Right Coronary Button

14. Suturing begins at 6 o'clock.

15. Suturing is done exactly as for the left button, beginning counter-clockwise to the surgeon's right and ending at 3 o'clock. All “inside loops” of the Cardionyl are placed along the back row and pulled tight with even spacing. The entire back row is done with half-throws using the suture as a retractor to see the correct spacing. Note that the forceps on the allograft is “stretching” (“unkinking”) the elastic tissue of the aortic root surrounding the button-hole to create a **straight line** and a matching suture travel-distance on both sides of the anastomosis.

    Note: Be sure to pull each loop tight if using Cardionyl. The advantage of Cardionyl is its elasticity, lack of memory and “stickiness”, which is gentle on the tissue and prevents purse-stringing. However, because of these properties, it cannot be parachuted and must be pulled tight after each throw.





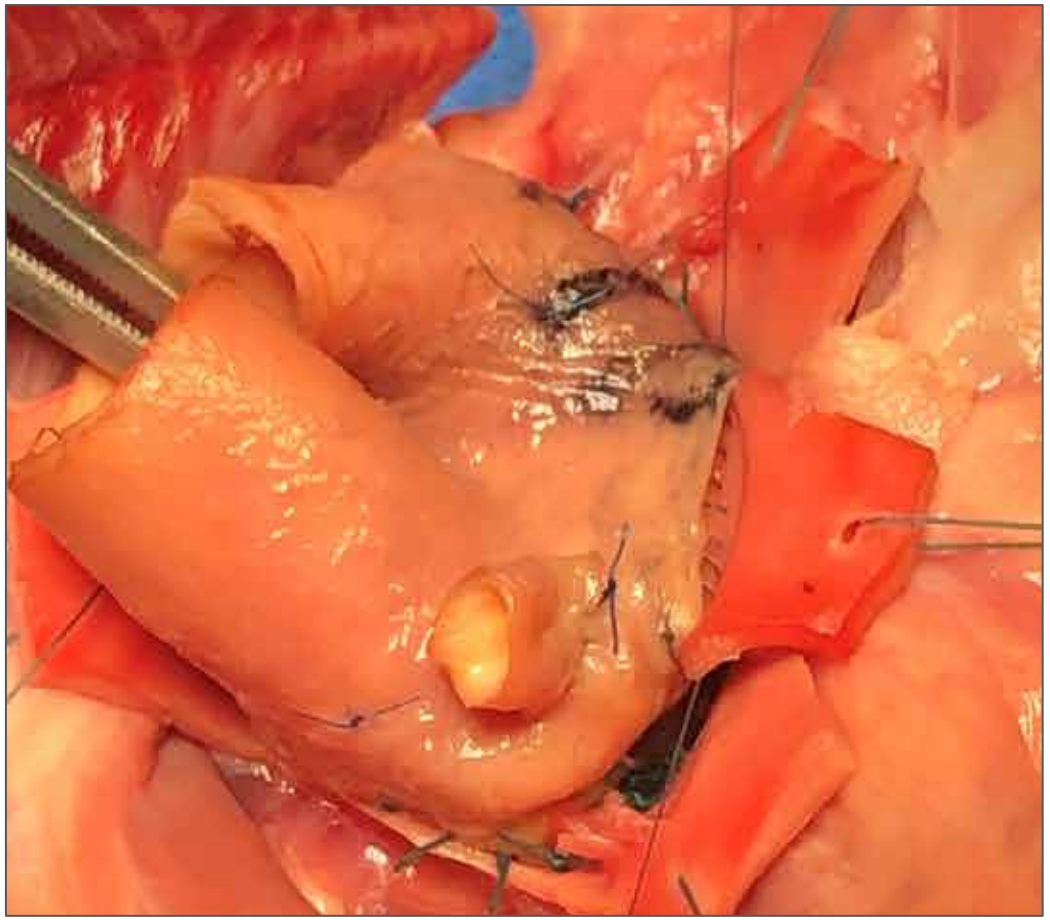
Reimplantation of Coronary Arteries

Right Coronary Button

16. Suturing continues along the back row clockwise to the left to 9 o'clock.

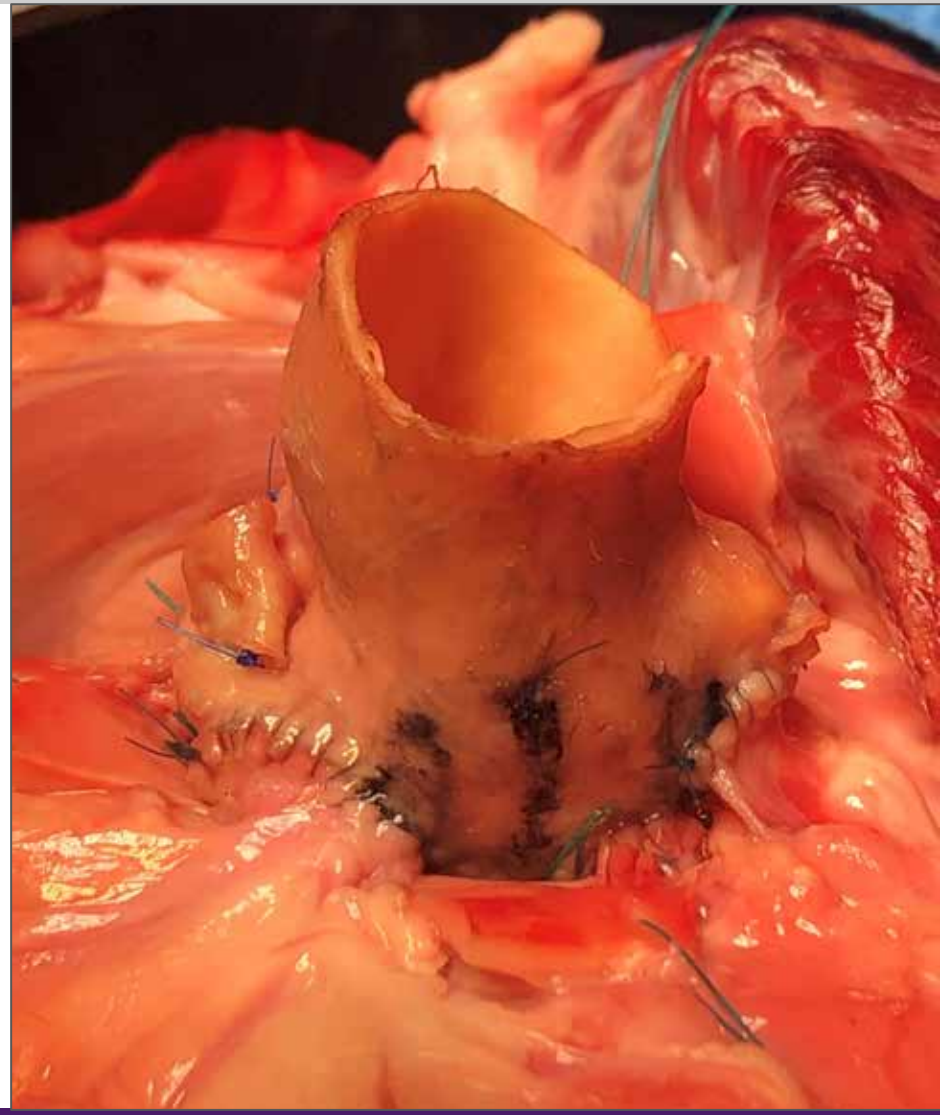
17. The assistant places lateral traction on the two ends of the Cardionyl suture at the plane of the “equator”. A 2–3 mm flange is cut, rounding the corners to prevent dog-ears.

18. With continuing lateral traction by the assistant, the upper half of the suture-line is accomplished in a straight line with single bites through button and allograft simultaneously.



Completed Aortic Root Procedure

The “Puzzle” Fits

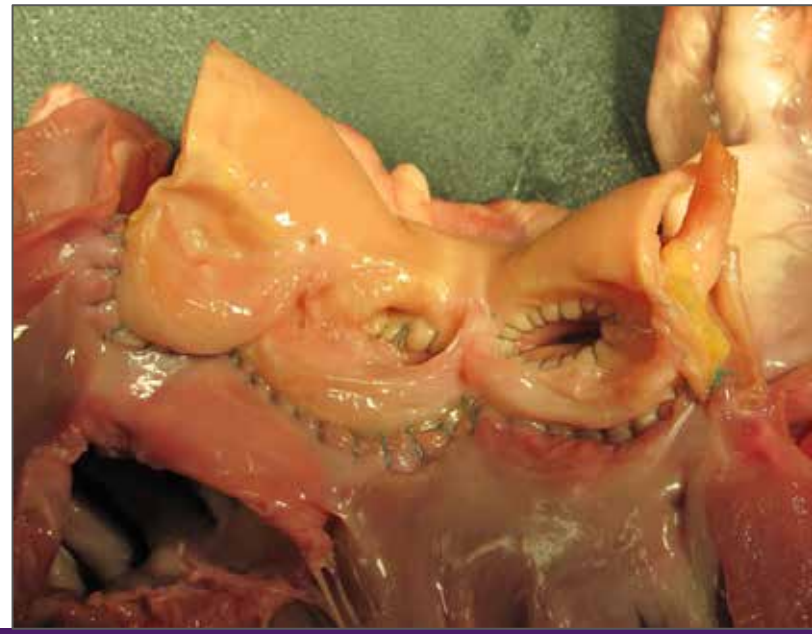


Assessment Tool

ELITE

Assessment Tool

1. To evaluate the aortic allograft implant procedure, the heart is opened by cutting across the ventricles a few inches above the apex of the heart. The heart is then opened by using a long knife inserted into the ventricle and out the aorta and cutting through the heart at the point of the right-non commissure.
2. Opening the aorta gives a clear view of all sutures and the coronary buttons. This allows for an immediate evaluation of suture spacing, tightness and placement in reference to the cusp attachments and the coronary ostia. The integrity of the valve cusps and the size match between the coronary ostia and the holes in the allograft are immediately obvious. Finally, it can easily be determined if the coronaries were reimplanted in their original axis—if so, the puzzle fits. This assessment tool is never punitive. It is only intended to facilitate quality improvement. It works best if mistakes made on the first implant (which virtually always occur) can be corrected on a subsequent implant (which virtually always happens).



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