Closure of Ventricular Septal Defect

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For more than 25 years, primary early repair of ventricular septal defect (VSD) has been the accepted standard of practice in the United States, as opposed to staged pulmonary artery band placement and subsequent VSD repair. Elements of the surgical technique for VSD closure have remained subject to debate. Some surgeons espouse the running suture technique for VSD closure; others, the use of interrupted suture. Site, depth, and order of suture placement; use of pledgets; cavitary or vessel approach to the defect; tricuspid valve takedown for exposure have all been debated as well.

In general, there are five operative approaches for VSD closure: right atrial, transpulmonary, transaortic, right ventricular, and left ventricular. Mixed and multiple VSDs and defects with extensive involvement of more than one region of the septum may require a combined approach. Along with general tenets regarding appropriate cavitary incision and conduct of extracorporeal circulation, many established techniques may help facilitate exposure during VSD closure using these different approaches. Aortic cross-clamping, cardioplegia, hypothermia, and a left ventricular vent are important not only to provide myocardial protection and a relatively bloodless intracardiac surgical field, but also to relax the heart muscle to optimize exposure.
SURGICAL TECHNIQUE

Right atrial approach. This is the most frequently used approach and is usually applicable to the paramembranous, inlet, muscular, and the left ventricle-to-right atrium types of VSDs. Closure of trabecular VSDs is usually first attempted through the right atrium, but sometimes the apical and the "Swiss cheese" subtypes require a limited right or left apical ventricular incision.

This illustration shows the right atrial approach for VSD closure after aortobicaval cannulation and aortic cross-clamp with cardioplegia. The tricuspid valve leaflets are retracted to expose the VSD and the important surrounding structures. Double-armed sutures (5-0 or 6-0) with buttressing pledgets are placed 2–3 mm away from the edge of the defect on the right ventricular side. This provides a wider contact area between the patch and the myocardium, helping avoid injury to the conduction bundle that often runs near the crest of the defect. The pledgets tender to bolster the attachment to the often-friable endomyocardium that surrounds the VSD. In addition, the surgeon can use gentle traction on the previously placed pledgetted suture to retract the adjacent proposed suture site into the field for accurate placement; this is particularly helpful when the VSD extends to the aortic annulus. When the VSD is large, the sutures can be placed without having the patch material in the field, allowing more accurate placement and sizing of the VSD patch. The interrupted suture technique allows the surgeon to visually assess each suture during tying. The surgeon can use visual and tactile cues to assess the amount of gentle tension required between the pledget, the muscle, and the patch. Each interrupted suture can be visualized in this manner to prevent poorly tied or tangled sutures. At the end of the tying phase, the patch is inspected to assess closure. Ao, aorta; AV, atrioventricular; VSD, ventricular septal defect.
The view through the orifice of the tricuspid valve may not be sufficient to effect complete and simultaneous exposure of all areas and the extent of the defect. In the relaxed heart, however, changing the direction and tension of retractors permits viewing the lesion one sector at a time. Radial tricuspid incision for VSD exposure and its long-term effect on tricuspid valve function have been reviewed with excellent results, establishing support for this technique. Some authors prefer circumferential incision of the tricuspid valve for exposure; we have used this technique for large paramembranous VSDs with an inlet extension.
(continued) Often, defects in the membranous area are covered by the tricuspid valve septal leaflet and may not be visualized. When the chordal attachments of the tricuspid valve to the edge of the defect are short and tight or a pouch is formed by redundant or accessory tricuspid valve tissue, a clue to the VSD location may be a depression in the tricuspid valve caused by valve tissue being sucked into the defect by the action of the left ventricular vent. The surgeon may believe that a small opening in the tricuspid valve tissue represents the total extent of the VSD and use a simple direct suture closure, leaving the actual defect open behind the leaflet. To avoid this pitfall, the tricuspid valve can be opened in a radial fashion to expose the true perimeter of the defect, which should always be closed with a patch. (A) Tricuspid valve pouch exposed through a right atrial incision and retracted with sutures. The dotted line outlines the proposed incision site. When incising the tricuspid valve, the surgeon must proceed carefully from the free edge toward an area 3–4 mm from the annulus, gradually increasing the size of the opening in the tricuspid leaflet depending on the needed exposure. This incision should be made meticulously, keeping the aortic leaflet constantly in view, because of the aortic-tricuspid valve proximity on the upper rim and because the aortic valve leaflet may have been prolapsing to varying degrees in this area. (B) The tricuspid valve pouch has been incised toward the annulus and retracted exposing the actual extent of the VSD.
(continued) To avoid injury to the conduction system, sutures are placed superficially and carefully along the inferior and posterior margins of the defect, starting at the area of insertion of the muscle of Lancisi to the annulus of the tricuspid valve near the region of the triangle of Koch apex. At this junction, buttressed sutures are placed from the right atrium inward through the septal leaflet of the tricuspid valve about 1–2 mm away from the annulus. This suturing technique is continued superiorly until the transitional area, where the superior edge of the VSD begins to be formed by muscle of the infundibular septum; here the risk of injuring the conduction system is minimal, but the risk of damaging the aortic valve is increased. It may be tempting to place the sutures through remnants of the membranous septum in the posteroinferior angle of the defect; however, we do not recommend this technique because of the risk of injuring the conduction system. Furthermore, placing the sutures through a fibrous-appearing rim on the crest of the defect is not advisable, because this tissue lacks holding qualities. (C) Pledget placed through the incised tricuspid valve. (D) Completed VSD closure showing repair of the incised tricuspid valve. Ao, aorta; SVC, superior vena cava; IVC, inferior vena cava.
Transpulmonary artery approach. Usually used for repair of conal (supracristal) defects, the transpulmonary artery approach exposes the defect through a vertical incision in the pulmonary artery (A). The bypass and myocardial preservation techniques are the same as for the right atrial approach. Interrupted pledget-supported sutures are placed circumferentially around the defect and then through an elastic Dacron or Gore-Tex patch. Using a patch is particularly important in conal VSD closure because the patch helps support the prolapsing aortic valve and prevents continued downward pressure on the leaflets. Complete closure of the shunt through the VSD eliminates the Venturi effect that pulls the aortic valve cusp into the defect. The prolapsing aortic valve leaflet may partially occlude the defect so that the VSD orifice appears small and amenable to direct suture. It is important to recognize this pitfall and avoid injury to the aortic valve leaflet by using an appropriate-sized patch and by placing the sutures around the actual perimeter of the ventricular septal defect, rather than around the small false opening (B).
(continued) On the superior aspect of the VSD, where the aortic-pulmonary valve junction does not allow a suturing rim, a few sutures must be anchored through the base of the pulmonic valve cusps at the junction with the valvar sinuses. At this point, the small pledgets rest against the arterial wall, decreasing the chance of the sutures tearing the thin tissue (C). A combined transaortic-transpulmonary artery approach for concomitant surgical repair of aortic insufficiency also has been advocated. The patch should not interfere with pulmonic valve function and should provide support to the previously prolapsed aortic valve (D). The pulmonary artery is closed primarily. Ao, aorta; PA, pulmonary artery.
Transaortic approach. When there is need for concomitant correction of associated lesions, such as aortic valvuloplasty for prolapsed valve, or for relief of valvar or subvalvar stenosis, closure of a VSD via an aortic incision is usually performed. This exposure has also been used for double-outlet right ventricle with a subaortic VSD. Because of the increased risk of heart block, most surgeons prefer the other approaches for VSD closure.

An obliquely curved incision is made beginning on the anterior aspect of the ascending aorta above the aortic valve commissure at a level above the center of the right coronary sinus. The coronary ostia occasionally arise high in the aortic sinuses and can be injured by the aortic incision. The incision is carried inferiorly and to the right under direct vision toward the center of the noncoronary sinus. The incision may be extended as needed transversely toward the left. Alternatively, the aorta can be transected 1–2 mm above the aortic commissures. This maneuver can mobilize the proximal aorta anteriorly and maximize the transaortic view. The aortic valve leaflets are retracted carefully to expose the defect. Often there is absence of a superior muscular or fibrous rim of the defect, hindering suture placement. In this situation, mattress sutures buttressed with pledgets may be taken through the aortic wall from the inside of the aortic valve sinuses.
Right ventricular approach. Because most isolated VSDs may be approached through the right atrial, transpulmonary, or transaortic routes, the right ventricular approach is infrequently used for closure. Indications for its use include (1) inaccessibility from the right atrium or pulmonary artery approaches, (2) superior extension of the defect into the infundibular septum, (3) optimization of exposure in the presence of obstructive infundibular muscle bundles, and (4) difficulty exposing the inferior margin of a conal defect. A ventricular incision may optimize exposure in the presence of abnormal and obstructive infundibular muscle bundles that cannot be excised adequately from a right atrial incision, especially when enlargement of the infundibulum with a patch is deemed necessary. When repairing a conal subarterial defect through the pulmonary artery, if exposing the inferior margin is difficult due to extensive absence of the conal septal muscle, then a small infundibular incision will help secure the patch to the inferior border of the VSD. At times this may be accomplished through the right atrium without a ventriculotomy. When sutures in the tricuspid annulus are required, care must be taken to attach the sutures from the ventricular side, because the atrial side is inaccessible from the right ventricular exposure.

Right ventriculotomy incisions are either transverse or vertical. A transverse incision may limit injury to the circular muscle fibers but may restrict exposure and is inadequate when patch enlargement of the infundibulum is needed. The vertical incision should be limited to the infundibular area. Under direct vision, it is usually started in the middle of the anterior infundibular wall between traction sutures and extended upward in the direction of the pulmonary artery or downward toward the sinus portion of the right ventricle.

Before the ventriculotomy is begun, the epicardial coronary artery distribution must be examined. The origin of the left anterior descending coronary artery (LAD) from the left main coronary artery is ascertained. Occasionally the LAD arises as a branch of the right coronary artery crossing the infundibular wall. At times the LAD supply is dual, with one branch originating from the left coronary artery and the other an extension of a large conal artery arising from the right coronary artery. In these situations a ventriculotomy is dangerous and should be avoided because of the risk of injuring the coronary arteries and myocardium. Infrequently, these arteries crossing the infundibulum are intramyocardial and may not be clearly seen, or the coronary artery distribution may be obscured by adhesions from previous surgery.
Left ventricular approach. This rarely used approach is limited to certain types of trabecular ventricular septal defects, particularly those with multiple apical, sieve-like perforations (i.e., Swiss cheese). These defects may be easier to patch from the left ventricular side because of the relatively smooth septum, in contrast to the right ventricle with its trabeculation and papillary muscle attachments. Also, trabecular muscular defects may be hidden or divided by heavy right ventricular trabeculae or by the septal band, thus appearing as multiple openings on the right side and a single opening on the left side of the septum.

There are two types of left ventricular incisions, the more frequently used vertical incision, starting in the relatively avascular left ventricular apical area with limited extension superiorly, and the transverse incision. Whichever type is used, attention to the coronary artery distribution is essential to minimize injury. Except for the small apical incisions that are well tolerated, left ventricular incisions should be avoided whenever possible to minimize the risk of associated significant long-term ventricular dysfunction.
REFERENCES


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