PITFALLS IN THE SURGICAL CLOSURE OF ATRIAL SEPTAL DEFECT

Based on Experience with One Hundred and Fifteen Cases

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SURGICAL closure of atrial septal defects was attempted first by external technics wherein the redundant wall of the right atrium was imbricated against the septal rim of the defect.[1-4] The surgeon relied upon his index finger for orientation—that, and a preconceived mental picture of how a characteristic atrial defect should lie in relation to other structures. The imbrication technics reached their ultimate with the ingenious Sondergaard[5] approach wherein the dissection was carried on within the plane of the septum itself. In effect, this technic resulted in a purse-string closure of the centrally located ostium secundum defect.

The limitations of the imbrication methods for closing septal defects at the atrial level soon became apparent. Atrial defects even in their simplest form are not standard in size and location. There is considerable variation in related anatomic features, and the need for a direct open approach was soon realized. The well technic of Gross[4] was the first practical breakthrough in this direction.[6] With this technic a surgeon could not see within the depths of the operative field, but his range of "digital visualization" and his surgical maneuverability were greatly increased *(Fig. 1)*.

There is no doubt that by application of these earlier methods many patients were treated effectively and were relieved of their interatrial shunts. Unfortunately, some patients were not improved and others were made worse, as the surgeon could not cope with complex underlying problems that were beyond limitations imposed by these technics. In the light of present-day knowledge, the early methods briefly described above must be considered obsolete.

Direct Closure of Atrial Septal Defects

The surgical treatment of atrial septal defects today is accomplished under direct vision. The open approach is performed with hypothermia alone or with some form of extracorporeal circulation. It would appear that this former method is losing favor. Increasing experience with the unhurried approach that is provided by adequate extracorporeal circulation has taught the surgeon invaluable lessons. Most important of these are the multiplicity of facets associated with septal defects at the atrial level, and the wide range of potential surgical errors. Whereas accurate physiologic and anatomic appraisal of atrial septal defects can be accomplished in

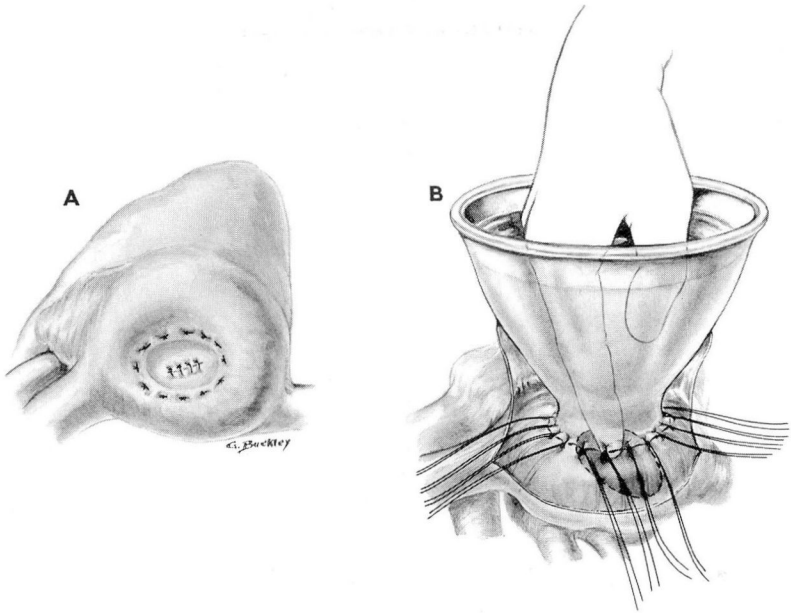

Fig. 1. A, Illustrates the principle of the external imbrication technic for closure of ostium secundum defects in the atrial septum. This is the basic method described by Bailey and associates,[1] modified by Lam,[3] and others. This method is accomplished by intraatrial digital palpation and external application of sutures. B, Illustrates the principle of the Gross[4] well technic. Although the surgeon was not able to visualize the surgical field, the basic approach must be considered a precursor of the "open-heart" methods.

the cardiovascular laboratory, the ultimate appraisal of anatomic details must take place within the operating room. Defects of the atrial septum provide the simplest and the most common of all intracardiac shunts. Hence, it is the responsibility of all interested surgeons to combine efforts that will make operations upon interatrial defects safe, simple, and relatively free of complication.

Surgical Pitfalls

Postoperative bleeding, inadequate pulmonary ventilation, infection, acidosis, air embolus, and cardiac arrhythmia are potential complications that may follow any type of cardiac surgery. It would serve little purpose to discuss management of these specific complications, as they are well understood by all cardiac surgeons. There is an increasing number of new surgical teams that are entering the expanding field of open-heart surgery. These teams consist of well-trained surgeons who have a clear concept of the physiologic and the anatomic problems that will be encountered. Dissemination of specific detailed information that would enable the less experienced surgical groups to avoid tragic accidents that have occurred

in the development of open-heart surgery is an obligation of the surgeons who are established in this field *(Fig. 2)*. A detailed description of potential pitfalls that may be encountered in a closure of a relatively simple atrial septal defect may be of value. The observations to be described are based upon experience and

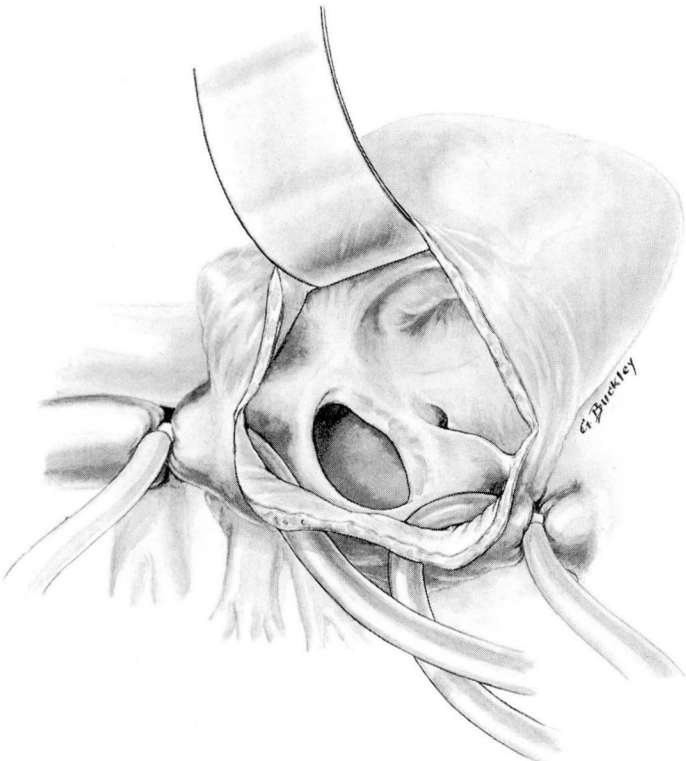

Fig. 2. Diagrammatic representation of the surgical field in the closure of an ostium secundum defect utilizing extracorporeal circulation. Surgical closure of this common form of atrial septal defect does not require elective cardiac arrest. The systemic venous return to the heart is diverted to the pump-oxygenator by two caval cannulae. The complete bypass is assured by the use of tourniquets that compress the venae cavae around the indwelling venous cannulae. With this technic the only blood return to the heart is that which enters from the coronary circulation and the bronchial vessels whose drainage enters the left atrium. With the patient in a supine position, right side slightly elevated, the left heart maintains a dependent position. A sterile sucker is used to keep the right atrium relatively dry. The blood level is never lowered below the plane of the atrial septum itself; in this way the hazard of air embolus is avoided. With this exposure and with the unlimited time afforded by good extracorporeal circulation, the surgeon may inspect his field with meticulous care and identify his landmarks with a certainty: the tricuspid valve, the coronary sinus, and unsuspected anomalous drainage of the pulmonary veins can be visualized. Although the majority of published illustrations suggest that the ostium secundum defect presents a standard appearance, this is by no means true. There may be considerable variation in size, location, and character of the membranous tissue that comprises the septal remnant.

on surgical lessons that have attended 115 open-heart operations for the treatment of ostium secundum defects. The complicated problems related to the ostium primum type of defect and atrioventricular communis will not be discussed in this paper.

1. *Inadequate closure.* Most ostium secundum defects visualized at surgery are related to faulty development of the foramen ovale. The surgeon usually finds a remnant of valve flap on the inferior aspect of the defect itself. This meniscus of tissue may be exceedingly thin and almost avascular in character; it, too, may contain fenestrations that are overlooked when the operation is performed in haste. A continuous suture that utilizes this thin partition as the inferior segment of the septum may not be of lasting support. Subsequent fenestration may result, and may produce a virtual reopening of the entire defect. It is worthy of emphasis that the surgeon must be permitted an unhurried appraisal of the atrial septum and its related structures. Although the initial surgical closure may easily be accomplished by a continuous suture, to insure complete interruption of the atrial shunt, meticulous reinforcement by carefully placed interrupted single or mattress stitches is necessary *(Fig. 3).*

It would seem self-evident that a meticulous, well-conceived closure of a simple atrial septal defect would be the only acceptable operation for this common lesion. It is unfortunate that this concept is not in general acceptance; perhaps the basic simplicity of the anatomic defect itself has encouraged operative technics that are almost slapdash in character.

2. *Prosthetic repair.* Direct efforts to close atrial septal defects by means of the Gross well technic frequently utilized a prosthetic patch. The vogue for patch closure of ostium secundum defects carried over into the period of open-heart surgery that utilized extracorporeal circulation. It is safe to say that many types of prosthetic devices were utilized in the reconstruction of the atrial septum before the ultimate fate of these foreign bodies had been ascertained. Subsequent experimental work as described by Kolff and his co-workers,[7] illustrates the encapsulation of prosthetic patches by various blood elements; this may begin by an initial clot that is subsequently replaced by heavy fibrous tissue, and occasionally by calcification. There is no question that the majority of prosthetic patches when properly positioned serve a useful and permanent purpose; however, results in a significant number of cases have demonstrated that the prosthetic patch on occasion may prove to be a poorly tolerated foreign body that becomes a liability to the host.

On the basis of our experience here, it would appear that prosthetic repair of an uncomplicated secundum defect is indicated rarely. The tissues of the atrial septum, which surround even the larger defects, are rather elastic and under little stress when compared to those at the ventricular septal level. Therefore, direct suture closure can be accomplished in the large majority of patients. It is not to be construed that prosthetic repairs of atrial septal defects are never indicated or

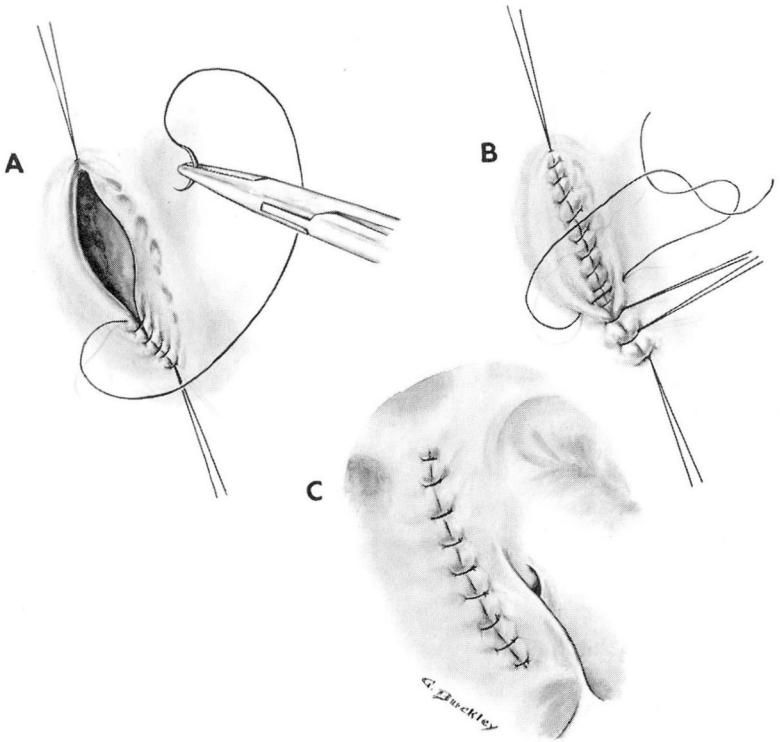

Fig. 3. Surgical closure of ostium secundum defect is accomplished by direct suture in the majority of operations. The routine use of a plastic prosthesis is to be condemned. Direct inspection of the defect permits the surgeon to select the plane of closure. A, Shows how this plane is further developed by the placement of interrupted sutures at each end of the plane of closure. Initial closure may then be accomplished by a direct continuous silk suture. As mentioned in the text, the ostium secundum defect presents in most instances a meniscus of thin fibrous tissue that may represent the valve flap of the foramen ovale. This tissue flap may be papyraceous in character and prone to subsequent fenestration when subjected to the stress of cardiac motion. For this reason it is good practice to utilize a series of interrupted sutures, B, to reinforce the original closure. This second line of closure will reinforce the original suture line when the needle bites are brought through selected areas in the septum where tissue substance is increased. This is not difficult to accomplish after initial closure of the shunt. Again, it must be emphasized that the surgeon must have the security of unlimited time as provided by extracorporeal circulation, if this method is to be employed. C, Shows the completed surgical closure of an ostium secundum defect.

that all are doomed to ultimate failure. There will always be instances where success cannot be achieved without the use of prosthetic material, particularly when the defects are extremely large and are associated with anomalous pulmonary venous return. The fact remains that the prostheses are foreign bodies, and their presence within the heart may constitute a serious liability, particularly in the presence of

infection. For this reason, the author believes that prosthetic devices should be used rarely in the surgical treatment of ostium secundum defects.

3. *Intracardiac conduction.* In our experience, permanent heart block has never occurred in the surgical closure of ostium secundum defect. Transient cardiac arrhythmias are common occurrences during the actual operative procedure, and it is likely that they are stimulated by the sterile aspirator and the surgical instruments.

In the experimental animal, complete heart block may be produced by placing sutures through large sections of the lower posterior aspect of the atrial septum close to the ventricular cushion; in the human, the utilization of massive suture bites is not indicated. In those defects that are low and close to the tricuspid valve it has been our practice to use simple interrupted sutures placed with meticulous care, and every effort is made to avoid the producing of necrosis of local tissue, which might reflect damage to the conductive tissue. In the ostium secundum defect there will always be some septal remnant above the level of the tricuspid valve which will be safe to use for supporting suture material.

4. *Anomalous venous drainage.* Atrial septal defects may be associated with anomalous pulmonary venous return. This situation usually is recognized after preoperative catheterization study. When the orifice of the pulmonary vein is close to the septal aspect of the defect and a large shunt volume is present, the diagnosis may not be obvious. When anomalous venous drainage of the right lung is present and not recognized, the surgeon may close the defect without regard for the misplaced venous orifice. This error is most likely to occur when the surgeon is distracted by the need for haste or by inadequate support from anesthesia.

This technical error is best avoided by inspection of the pulmonary veins of the right lung before the atrial incision is made. It is good practice to make a routine inspection of the superior vena cava above the level of the azygous vein, as unexpected communications between the vena cava and the venous drainage of the upper lobe may exist. Routine establishment of the presence or the absence of anomalous venous return to the right atrium should be done after the right atrium is entered and the initial surgical inspection has been made.

When the venous drainage of the right upper lobe enters the superior cava above the level of the azygous vein, it has been our practice to sacrifice the entire lobe rather than to attempt to transpose the vein itself. When the venous return from the right lung enters the right atrium in the region of the septal plane, the problem is best handled by extending the septal plane to the right of the venous orifices; under these circumstances the use of a prosthetic patch may be mandatory.[7]

5. *Diversion of inferior vena caval return.* Clinical experience has demonstrated an occasional variation in the internal topography of the inferior vena caval orifice. The junction of the right atrium and the orifice of the inferior vena cava may, on direct inspection, resemble the open end of a funnel. Sometimes, however, a

flap of thin fibrous tissue exists in the form of a peculiar valve flap that takes a circumferential origin from the vena caval orifice itself. This membranous structure seems to be variable as to its exact point of origin, its size, and even as to its presence or absence. Nevertheless, it can exist and, in the presence of a large low-lying atrial septal defect, may constitute a surgical booby trap.

An open-heart operation for atrial septal defect requires occlusion of the inferior vena cava by clamp or by tourniquet.[8] This alters greatly the appearance of the vena caval orifice as it is inspected from within the atrial chamber itself. Whereas the inferior vena cava normally is a large tubular structure, it now appears as a wrinkled or fluted orifice comprised of thin flaccid tissue. It is important that the surgeon keeps this morphologic point in mind, particularly when dealing with a low-lying septal defect whose lower margin lies close to the superior vena caval orifice *(Fig. 4)*.

The importance of the peculiar valve flap arising from the inferior vena caval orifice, and the fact that there is considerable anatomic distortion associated with vena caval occlusion were not appreciated by the authors until the combination of the two conditions led to an unfortunate surgical accident. While a large low-lying ostium secundum defect was being closed under direct vision, the inferior vena caval flap was erroneously identified as part of the inferior septal rim of the defect itself, and it was incorporated in the suture line when the major part of the defect was being closed. The fact that large vena caval cannulae had been used and were in proper position, only contributed to the false sense of security. It became apparent soon after the operation that a serious error had been made, and that a significant amount of systemic venous return to the heart was being diverted into the left atrium. It is indeed fortunate that the patient survived after a stormy period of convalescence, and that reoperation was possible. At the second operative procedure it was apparent that the entire inferior vena caval return was entering the left atrium. Apparently the development of healing fibrosis had compounded the original surgical error.

Accidental diversion of the inferior vena caval flow to the left atrium is by no means a rare accident. For understandable reasons, this error has not appeared prominently in surgical literature; however, by personal communications we have become aware of a number of instances in which this accident has occurred.[9] In every instance it has been the inferior vena cava that has been involved; diversion has been virtually total, and the patients have survived only after considerable postoperative difficulty.

It would seem that prevention of this surgical accident would depend first of all upon the surgeon's knowledge that the possibility for such an accident exists. It is the authors' policy when dealing with low-lying atrial septal defects to make a careful identification of related anatomic structures before making any effort to effect closure. The orifice of the coronary sinus, the vena caval orifice itself, the

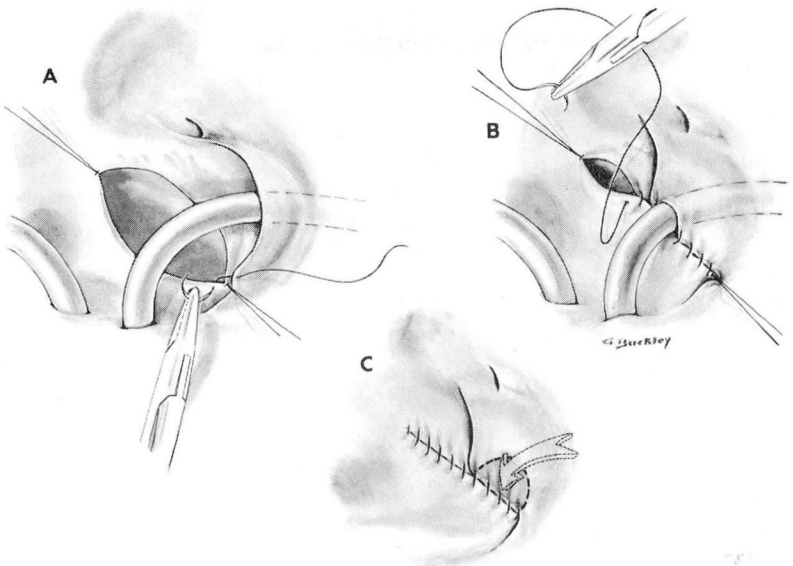

Fig. 4. Diversion of the inferior vena cava to the left atrium constitutes one of the most serious pitfalls in the surgical closure of atrial septal defect. As mentioned in the text, the authors assumed that the presence of vena caval cannulae would prevent this surgical mishap. Experience has shown that the only protection against this accident is the knowledge that it can occur and perfect orientation throughout the operative procedure. A, Illustrates how atrial defect of the ostium secundum type is usually closed on an oblique plane. In the presence of a well-developed thebesian valve that projects from the orifice of the inferior vena cava, the surgeon may erroneously identify it as the inferior aspect of the rim of the defect. This error has been made by experienced surgeons and is understandable when there is a large flow of blood across the defect from the left atrium and this is compounded by the motion of the heart plus the need for completion of the operation within a specified time. B, Illustrates one method in which the caval flap is incorporated in the surgical closure of a low-lying ostium secundum defect. This accident is prone to happen in operations performed under hypothermic technics where time is an essential factor and vena caval cannulations are not required. Partial or complete diversion of the inferior vena caval return to the left atrium will result when the inferior vena caval flap is incorporated by mistake into the surgical closure of the low-lying septal defect. C, Illustrates the completed erroneous repair after removal of the inferior vena caval cannula. The vena cava drains completely into the left atrium.

presence or absence of a vena caval flap, and the position of a septal rim in relation to the inferior pulmonary vein are all verified; additional protection is afforded by the utilization of interrupted silk sutures to initiate the defect closure at its posteroinferior aspect. In some instances it is our practice to initiate the sutures from outside the atrial wall immediately above the junction between the posterior aspect of the inferior vena cava and the right atrium. These sutures are tied externally. The most important safeguard, however, is the practice of releasing inferior vena caval occlusion immediately after septal closure has been accomplished. If the vena caval orifice is in normal relation to the atrial septum, there

will be a cascade of unsaturated blood into the right atrium—if this does not occur, complete revision of surgical closure is in order. It has been suggested by Scannell[9] that retrograde cannulation of the inferior vena cava by way of the femoral vein may be an additional safeguard to avoid the serious accident of inferior vena caval diversion to the left atrium.

Summary and Conclusions

Surgical closure of atrial septal defects is best accomplished under direct vision, and utilizing extracorporeal circulation. The ostium secundum type of atrial septal defect is the simplest intracardiac shunt to repair, but it is well for the surgeon to recall the certain pitfalls that may be encountered.

Any operation within the heart that utilizes extracorporeal circulation or hypothermia alone may be subject to complications associated with hemorrhage, infection, metabolic acidosis, air embolus, and cardiac arrhythmia. For the most part these complications are well understood and are avoidable.

Experience in 115 operations for simple atrial septal defects has convinced us that the overwhelming majority may be closed by a direct suture technic. In all probability, prosthetic closures should not be used unless loss of septal substance is of such magnitude that direct closure is impossible, or the surgeon is confronted with anomalous pulmonary venous return. Under these circumstances prosthetic closure is indicated.

Perhaps the most serious and least publicized surgical error associated with the closure of atrial septal defect is inadvertent diversion of the inferior vena caval return to the left atrium. This may be avoided if the surgeon is aware that the possibility exists and he utilizes routine simple precautions.

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