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Minimally Invasive Atrial Septal Defect Closure Using the Subxyphoid Approach

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ABSTRACT

Background: Atrial septal defects in adults are associated with paradoxical emboli, atrial tachyarrythmias, and congestive heart failure. Surgical closure is highly efficacious with low operative mortality and morbidity. However, in young women sternotomy scars are unsightly reminders of an otherwise curative procedure. Alternatives such as lateral thoracotomy or extended transverse incisions are more cosmetic but associated with breast maldevelopment, numbness and other side effects. The authors are proposing a new surgical approach based on their observation that the right atrium and septum actually lie only 1 inch superior to the xyphisternal junction.

Methods: A 4 inch transverse inframammary incision is used and the linea alba divided. The lower sternum is lifted forward with a commericial cable-pully retractor system (Rultract®). Using femoral bypass augmented by a balloon tipped cannula in the superior vena cava, the septal defect is easily visualized and closed with conventional techniques and equipment.

Results: Two young women have undergone closure of a patent foremen ovale (N=1) and a large ostium secundum (N=1) defect through this approach. One patient had minor fat necrosis in the incision which subsequently healed without incident.

Conclusions: Close anatomic proximity between the atrial septum and the lower sternum make it feasible to approach ostium secundum defects using a purely subxyphoid exposure. Visualization of the defect is excellent without the need for thoracotomy and sternotomy. The use of a small transverse incision in the inframammary crease makes the result cosmetically invisible.

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INTRODUCTION

Patent foremen ovale (PFO) and atrial septal defects (ASD) result from incomplete development of the superior aspect of the septum primum. The presence of an interatrial communication is a known risk factor for stroke. Webster et al. reported that the prevelance of PFO was 50% in patients under 40 years of age who presented with new non-hemorrhagic focal neurologic events as compared to 15% in the control population [Webster 1988]. Lechat, et al. reported a four fold increase in prevelance of PFO in stroke patients compared with the normal population controls [Lechat 1988]. Guffi, et al. reported no neurologic recurrences within the first year following prophylactic closure of PFO defects in a carefully studied cohort of 18 patients with preoperative paradoxical emboli [Guffi 1996].

Another indication for closure is prevention of late onset congestive heart failure (CHF). In natural history studies, the mean life expectancy of adults with unclosed ASDs is only 40 years. Konstantinides, et al. reported a significant incidence of late onset CHF in adults with open septal defects, presumably due to the added volume loading of the left-to-right shunt [Konstantinides 1995]. There is a small but discrete incidence of late pulmonary hyptertension (PHTN) as well.

Current surgical techniques for septal defect closure are both efficacious and safe. At present, ASD closure is considered a curative operation which can be recommended to patients with a negligible mortality rate. Despite uniformly successful technical results, there are still patient-driven concerns. One modern concern is the residual scar, especially in female patients. Since the majority of adult ASDs occur in women, there is a need to refine the surgical approach and try to eliminate the obvious cosmetic defect associated with classic sternotomy.

Willman, et al. [Willman 1960] and Brutel, et al. [Brutel 1981] independently described an extended transverse submammary incision accompanied by vertical split of the sternum. This technique has been successful in permitting unhindered closure of ASDs. However, it involves mobilization of a large triangular shaped subcutaneous prester-

nal flap with division of the inferomedial perforating neurovascular bundles to both breasts. There is a 15% incidence of abnormal breast development, sensation or lactation reported after this incision. The incision is also time consuming to create and close.

Another cosmetically acceptable approach is the right submammary anterolateral thoracotomy [Grinda 1996, Rosengart 1993]. Surgical exposure is satisfactory, including the potential to repair sinus venosus defects. Central cannulation can be performed, although sometimes aortic cannulation is uncomfortable. Many successful ASD closures have been accomplished through this approach. However, post-thoracotomy pain and breast maldevelopment are notable complications.

The era of minimally invasive cardiac surgery has already been ushered in with recent reports of single vessel coronary artery grafting and valve replacements through 3 or 4 inch alternative incisions. The authors of this report believe that the atrial septum is an ideal surgical target for a minimally invasive approach. A review of the normal anatomic relationships between the atrium and lower sternum has lead the authors to propose a subxyphoid approach for ASD repair. This technique is both cosmetically acceptable and significantly less traumatic as it does not require either a sternotomy or thoracotomy.

The fundamental principle for proposing the subxyphoid approach lies with the normal anatomy. When viewing a lateral chest roentgenogram, the right atrium is actually situated directly posterior to the xyphisternal junction. (see Figure 1, ◉) Measurements taken during median sternotomy revealed that the midatrial septum is only 1 inch superior to the xyphisternal junction. The radiographic stripe which locates the inferior vena caval (IVC) entrance to the right atrium (RA) is typically inferior to the xyphoid tip. In addition, the right atrium (despite its name) is actually a midline structure. In the supine patient, the plane of the septum is nearly horizontal. Thus the angle of view obtained by looking into the mediastinum from the subxyphoid region is directly "en face" with the plane of the fossa ovalis.

These anatomic relationships make it possible to approach the atrial septum without musculoskeletal invasion other than division of the linea alba. Successful use of this exposure for minimally invasive direct coronary artery bypass (MIDCAB) to the right coronary has been reported by Fonger, et al. [Fonger 1996]. This current report describes the first successful closures of intracardiac defects in adults under direct vision without opening the chest or sternum in any way. Successful outcomes in the first two patients indicates the potential for the subxyphoid approach in other cardiac procedures as well.

MATERIALS AND METHODS

Patients were positioned supine with a transverse interscapular roll to help deflect the xyphoid anteriorly. The submammary crease was marked with an indellible pen and a 4 inch transverse incision made. Detachment of the deep subcutaneous from the anterior rectus fascia permitted increased mobility of the recti. The linea alba was divided and the preperitoneal attachments to the posterior rectus sheath were liberated to further increase mobility of the recti. The xyphoid was removed and bilateral Rultracts® were used to slowly hoist the lower sternum and costal margins away from the operating table (see Figure 2, ◉). The diaphragmatic muscle attachments to the posterior sternum and costal margins were divided.

The anterior mediastinal fat was widely cleared from the parietal pericardium. The pericardium was incised transversely at the level of the diaphragm and then vertically up to the pericardial reflection over the aorta. The right edge of the pericardium was tacked to the periosteum of the inner table of the sternum. Optical magnifiers and an illuminating headlamp were vital aids for visualizing the higher structures. However, with careful mobilization of the anterior mediastinal structures, a clear view up to the innominate artery was possible.

The anterior surfaces of the femoral artery and vein were exposed through a small, oblique groin incision. After heparinzation, high flow, thin-walled perfusion cannulas (Fem Flex II; Research Medical Inc., Midvale, Utah) were introduced over guidewires through the center of small pursestrings in the anterior vessel wall. Partial bypass was begun. As the heart decompressed, cardiac exposure improved dramatically. The inferior vena cava was isolated with a tape and tourniquet. Isolation and drainage of the superior vena cava (SVC) was accomplished with a 37Fr balloon tipped uptake cannula (Model # 91037; Medtronics-DLP, Minneapolis, Minn) introduced through a pursestring in the RA appendage. A vascular clamp or tape/tourniquet was used to occlude the IVC. After inflation of the SVC balloon and electrical fibrillation of the heart, the right atrium was incised horizontally and a right angled retractor blade placed into the opening to lift both the atrial wall and the SVC cannula anteriorly. Coronary sinus flow was easily managed with a single hand-held cardiotomy suction which also served as a gentle retractor. Excellent visualization of the atrial septum and fossa ovalis was obtained (see Figure 3, ◉). Standard suture closure was used for the two cases reported here, but there is ample exposure for patch repair if needed.

After closure of the defect and the atriotomy, standard decannulation is performed, a soft silicone pericardial drain is placed and the linea alba is approximated with interrupted sutures. The subcutaneous is reapproximated to the rectus fascia to eliminate dead space. Early extubation and abbreviated intensive care monitoring was achieved.

RESULTS

The first patient was a 37-year-old female with transient neurologic symptoms (aphasia, right-sided numbness and clumsiness) and a PFO detected by bubble study during Valvsalva. She underwent subxyphoid closure and was discharged on postoperative day 3. The second patient was a 35-year-old female with a large ostium secundum defect

repaired by double layered running suture. She was also discharged on postoperative day 3. The midpoint of her transverse skin incision developed mild fat necrosis easily treated by minor debridement with subsequent full healing.

DISCUSSION

The first successful ASD repair was performed by Gross in 1953 using the atrial well technique [Gross 1953]. The heart-lung machine was introduced the following year by Gibbons. This major milestone opened the door to many technical advancements in cardiac surgery by permitting safe access to the intracardiac anatomy. As experience progressed, the operative mortality for ASD closure fell dramatically and is now below 0.5% in most centers.

The median sternotomy incision has become the universal method of exposure for most cardiac procedures. Sternotomy was originally described by Milton in 1897 [Milton 1897], but it was Julian who ressurected and popularized this incision [Julian 1957]. Practicing surgeons quickly learned that median sternotomy provided ideal exposure to every region of the heart, great vessels, and mediastinum. As a result of frequent usage, surgeons are universally comfortable with the angle of view and exposure to cardiac structures obtained via sternotomy. Furthermore, concerns about wound trauma and the final appearance of the surgical scar were a low priority for the pioneering surgeons facing congenital lesions for the first time. However, now that the technical challenges of repairing less complicated congenital lesions have been met, other considerations are surfacing.

For young women with simple congenital defects, a prominent midline scar remains an unsightly and lifelong reminder of an otherwise low-risk and successful procedure. Now that such defects can be safely closed, the challenge remains to reduce the impact of the cosmetic blemish characteristic of median sternotomy.

Willman was the first to describe the use of an alternative incision to reduce the visible scar characteristic of sternotomy [Willman 1960]. He demonstrated that the sternum could be exposed and divided vertically through an extended transverse submammary incision. Several reports in the last two decades have confirmed that uncomplicated atrial septal defects can be successfully repaired using the Willman incision without additional operative risk [Bedard 1986, Brutel 1981, Laks 1980]. The residual scar is hidden in the submammary skin fold. However, a large triangular shaped subcutaneous flap must be created to expose the entire sternum and suprasternal notch [Bedard 1986]. The lateral aspect of this incision must extend from one anterior axillary line to the other. If the prepectoral flap is not meticuously reanchored to the deep fascia during wound closure, seromas and/or secondary infection can occur with troublesome drainage. In addition, extensive dissection and undermining of the breast tissue causes residual hypesthesia of the nipple in as many as 10% to 15% of patients. Abnormal breast shape, size or alignmnent and altered lactation have all been reported when this incision is utilized in prepubescent females. The total operative time for opening and closing this incision is certainly lengthened when compared to a vertical midline approach.

Another cosmetically acceptable alternative is right anterior thoracotomy [Grinda 1996]. The exposure of the right heart is adequate for bicaval as well as aortic cannulation. In women, the unilateral submammary incision used in this approach remains cosmetically hidden. However, the breast tissue must be partially mobilized and this is associated with physical size defects in the ipsilateral breast in 7.4% and periareolar numbness or hypesthesia in 38.8% of patients [Dietl 1992]. Mobilization of the pectoral muscles and breast tissue en bloc with a muscle sparing thoracotomy can reduce the incidence of nipple hypesthesia to 12.5%, but does not eliminate this complaint altogether. Pain and post-thoracotomy skeletal muscle dysfunction is also common. In addition, post-thoracotomy pain and other complications (atelectasis, right phrenic palsy, rib fractures) are destined to occur [Dietl 1992]. Grinda recently reported his results with ASD closure via thoracotomy in 80 female patients. Mean hospital stay was 9 days [Grinda 1996]. Rosengart reported a mean hospital stay of 6 days [Rosengart 1993]. Sequelae of thoracotomy pain (splinting, respiratory compromise, inactivity, extremity dysfunction) certainly affected the timing of discharge in these otherwise healthy patients.

Transcatheter closure devices have been tried as a non-surgical method of ASD closure. However, these devices are still imperfect with Rosenfeld reporting a 41% failure rate when used to close ASDs larger than 13 millimeters [Rosenfeld 1995]. Late failure from unbuttoning and wire fracture [Lloyd 1994], device related thromboembolism [Prewitt 1992] and device infections have also been reported.

It is an axiom that surgical closure still provides the safest and most certain means of ASD/PFO closure. However, the musculoskeletal trauma typical of surgical repair (through either extended transverse or right thoracotomy) is not without adverse consequences (pain, healing, wound complications, extremity dysfunction, breast development or sensory changes, lost employment time, etc.). A less invasive surgical technique that utilizes a cosmetically hidden approach would be welcome.

The current authors are proposing a subxyphoid approach based on several key anatomic relationships between the cardiac structures and the thoracic cage. First, the submammary crease nearly always traverses the midline at the xyphisternal junction. Second, the right atrium is a midline structure and is much lower in the chest than initially appreciated. The mid RA is located at the same level as the xyphisternal junction. Thirdly, in the supine patient, the septum is horizontal and the subxyphoid view of the fossa ovalis is directly "en face".

To create this exposure, several important points should be emphasized. In our adult patients, bilateral Rultracts® (Rultract Inc., Cincinatti, Ohio) are used to provide the needed vertical lift of the lower sternal bone. This vertical force rotates the ribs forward and cephalad mimicking normal respiratory movement. Additionally, the retractors pull the costal margins outward somewhat ("flare"), increasing

the exposure. In children, excellent transxyphoid exposure of the cardiac anatomy is obtained with a custom retractor designed by Wilson Pereira da Silva and his colleagues at the Instituto do Coração in São Paulo, Brazil [Barbero-Marcial 1998]. By fully mobilizing the recti on each side, the soft tissues can be retracted creating a wide opening for instruments and suturing. And finally, the diaphragmatic edge of pericardium and central tendon of the diaphragm are very firm tissues which can be pulled caudaully with stout sutures to further augment the exposure. All this is achieved without debilitating musculoskeletal trauma. In addition, conversion to either an extended transverse incision, mini lower sternotomy, right thoracotomy or a even a standard median sternotomy can be done at any time should the need arise.

At this time, closure of sinus venosus defects through this incision is not recommended. If a cosmetically hidden incision is needed to repair a sinus venosus defect, right anterolateral thoracotomy is recommended [Dietl 1992, Grinda 1996]. Additionally, the frequent presence of clefts in the anterior mitral leaflet in association with ostium primum septal defects makes it preferable to approach these anomalies through sternotomy or thoracotomy.

One potential drawback of the subxyphoid technique is the need for peripheral cannulation. In children, this can be difficult and cause local vascular complications. In addition, the currently available balloon tipped SVC cannula is only marketed in one size, 37Fr. This is too large for some smaller patients. Until commercial cannulas are available in multiple sizes, an endotracheal tube could be considered an option for the SVC.

The potential of this technique is reinforced by recent reports from Professor Miguel Barbero-Marcial at the Instituto do Coração who has performed closure of atrial septal and other congenital defects in young children using the subxyphoid approach with a custom retractor [Barbero-Marical 1998]. In the near future, specially designed cannulas and instruments will likely make this approach more versatile and eliminate the need for peripheral cannulation.

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REVIEW AND COMMENTARY

1. Editorial Board Reviewer DK3X comments:

This is a well conceived and written analysis of the options for ASD (PFO) closure and presents an alternative, untested approach. I see no intrinsic flaw with the approach used, in properly selected patients. It does reduce the number of options available to the surgeon should adverse events develop, eg. air embolus, defibrillation (more likely while warm) during defect closure, etc. However, this is also true of other nonsternotomy approaches. Perhaps this could be commented upon.

Noteworthy, we currently use the sternotomy approach and discharge patients (pediatric) on the day after operation (hospital day # 2). Older pediatric patients seem to have a different reaction to the trauma of operation when uncomplicated and bounce back more quickly.

Authors' Response by Mark M. Levinson, MD

With other non-sternotomy closures, the morbidity and mortality rates from all causes, including air, are next to nil. Nonetheless, air embolism prevention is absolutely crucial for all ASD surgery. Air in the coronaries could make it impossible to defibrillate the heart. Air in the cerebral circulation is dangerous for obvious reasons.

In warm fibrillatory closure of ASDs on bypass, the essential precaution is to avoid evacuation of the left atrium. The septum is coronal in position, with a slight angulation. The upper limbus is slightly higher (anti-gravity) than the inferior limbus. A pool of left atrial blood will leave very little air space at the top of the septum or dome of LA. If left undisturbed, pulmonary venous return washes through the defect during fibrillation, and very little air crosses leftward.

If the heart should spontaneously defibrillate, it is possible that air could be ejected, but this depends on how careful the surgeon is in preventing air from crossing in the first place. In this operation, temporary pacer wires are left on the RV, and fibrillation can be reintroduced by electrical AC current at any time if spontaneous defib occurs. As long as the LA remains full, air should not be ejected in the brief time it takes to refibrillate.

The final proof of these theories lies with additional case experience. It is my plan to peform intraoperative bilateral transcranial doppler on all subsequent patients to demonstrate what the air embolic pattern is for this surgery...of course knowing that TCD has not been used in ASDs before and there may always be some air in such cases regardless of the surgical technique.

In regard to the second point, it is certainly common for patients to be discharged earlier and earlier from all manner of adult and pediatric surgery. Better intraoperative, anesthetic, and nursing management have made it possible for surgeons to improve results with operations many decades old, like ASD closure. The subxyphoid approach offers some advantages as described, but hospital length of stay may now be so short with conventional closure techniques that a statistical difference may never be obtained. However, only a series of patients with subxyphoid closure will determine this.

2. Editorial Board Reviewer AR4 comments:

As a small note, I would suggest indicating that normothermic ventricular fibrillation is 'safe' for the non-hypertrophied, VENTED heart. As Buckberg clearly demonstrated years ago, any LV distention during fibrillation diminishes subendocardial blood flow and can lead to ischemia.

Authors' Response by Mark M. Levinson, MD

Technically you are correct. Fortunately, it took longer to take the photographs of this case than it did to perform the suture closure of the PFO. The subxyphoid exposure proved quite ideal, so closure time for a routine case of this type should on the order of a few minutes, after which the heart can be defibrillated.

Pulmonary venous return coming into the fibrillating closed heart can cause distension. During repair of a secundum defect, the heart is not closed. The pulmonary venous return is decompressed by spillage across the ASD until the defect is closed (afterwhich it is safe to defibrillate). The heart is thus passively vented and the risk of distension is small.

3. Editorial Board Reviewer JZ39 comments:

This case report is excellent data that deserves mention in the literature on a fast track because further evolution of this data and refinement may well be the technique of choice for atrial septal defect closure in the future.

Concerns are that exposure through this technique limits ones' ability to place a patch, as in a primum defect, which in this day and age with transesophageal echo should not be missed.

Authors' Response by Mark M. Levinson, MD

This procedure at its current stage is not recommended for primum defects, primarly because of the frequent association with anterior mitral cleft. It is possible to cannulate the SVC peripherally and repair the septal defect with a patch through the subxyphoid approach, but I would not recommend this until further experience with uncomplicated ASD closure has verified the safety of this approach.

Echo should be able to rule out primum preoperatively. However, if the surgeon opens such a case and finds an unexpected primum, it would be a simple and uninvolved maneuver to split the sternum vertically and repair the defect with standard exposure. With all minimally invasive techniques, conversion to a standard sternotomy must be part of the surgical design.

4. Editorial Board Reviewer TL41 comments:

If natural scientists can be categorized as Lumpers vs. Splitters, surgeons can be categorized as Simplifiers vs. Complicators. This report exemplifies the latter.

Authors' Response by Mark M. Levinson, MD

Part of the complexities involve the retraction system, adapted from 2 commercially available devices designed for other uses. The authors are working now with the Rultract engineers to refashion the retractor system just for subxyphoid exposure. It is hoped that a single, easy device will eventually provide all of this exposure. In addition, the exposure is certainly good enough already to move the femoral venous cannula up to the chest. With additional experience and refinements, the groin cannulation may be eliminated altogether.

If so, the "complexities" (or should I say "tedium") of opening and closing a sternotomy would be obviated without much change in the remaining surgery. Compared with ASD closure under cardioplegic arrest (as some surgeons do), this procedure is already simpler.