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Subxiphoid Multi-Arterial OPCAB: Surgical Technique and Initial Case Report

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ABSTRACT

Background: The surgical technique of transsternal coronary artery bypass grafting (CABG) has remained relatively stagnant for the past three decades. Unlike general and orthopedic surgery, cardiac surgery has made very little progress in converting our most common procedure into a minimally invasive alternative. Minithoracotomy techniques introduced in 1995 enjoyed a brief period of popularity but were inherently single vessel (LIMA-LAD) procedures and thus not an answer to the need for a less invasive multivessel operation. Totally endoscopic CABG has been performed in a small number of cases but the learning curve is very steep and the rate of conversion to open surgery remains high with only a few successful multivessel cases. There remains a great need for a less invasive approach that has the potential to graft all coronary targets without disturbing the chest wall and which can be performed by all current and future surgeons with acceptable hospital costs. A small subxiphoid incision has been used for single vessel grafting to anterior or inferior targets, but until now lateral wall grafting has not been considered possible. Development of a successful multivessel subxiphoid technique on the beating heart, including lateral wall grafting, is now reported in this article.

Methods: Subxiphoid multi-arterial bypass grafting was performed on a 79-year-old male using commercially available equipment but modified surgical techniques. Instead of midline sternotomy, full exposure to the heart was obtained by four essential steps: (1) removal of the xiphoid process, (2) vertical lifting of the lower sternum, (3) caudal retraction of the diaphragm, and (4) spreading of the wound using a specific retractor to create an adequate working portal. Both internal mammary arteries were harvested for their full length as skeletonized conduits using only direct vision (headlight and loupes). Off-pump distal anastomoses to the left anterior descending (LAD) and first obtuse marginal branch of the circumflex (OMB-1) were performed using available stabilizer systems. The obtuse marginal was exposed using the Medtronic Starfish® suction-positioner without any hemodynamic compromise. The wound was closed with a simple running fascial suture and the patient discharged on postoperative day 4 with no complications and no angina.

Conclusions: Most practicing surgeons are reluctant to perform multiple distal grafts through small incisions because of the difficulty in simultaneously mastering a host of new skills at the same time (robotics, endoscopics, beating heart techniques). The subxiphoid approach offers the potential to perform distal anastomoses to all regions of the beating heart with excellent exposure while utilizing the same skill sets that surgeons now possess. There is potential that further evolution of this technique will permit outpatient CABG while providing long-term clinical outcomes superior to coronary stenting.

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INTRODUCTION

From the inception of coronary artery bypass grafting (CABG) in the late 1960s until the widespread use of coronary angioplasty in the mid-1980s, surgical bypass was the mainstay of treatment for symptomatic coronary ischemia. Surgical programs in that era grew rapidly as cardiac catheterization laboratories flourished. However, once percutaneous coronary interventions (PCI) became disseminated into all modern medical centers, surgery was quickly displaced as the primary mode of treatment.

In comparison to the incredible progress of PCI technology over the past 25 years, CABG has not evolved nearly as much. It is true that surgical outcomes have improved despite greater comorbidities in the surgical population. This is no small accomplishment, but does not eliminate the fear of open surgery in the minds of patients and referring physicians. The introduction of drug-eluting stents (DES) has further impacted the viability of surgery as a treatment for coronary artery disease (CAD).

The success of minimally invasive alternatives in other surgical specialties has been profound. Cholecystecomy has gone from an average 7 to 10 days hospital stay with significant lost employment time to an outpatient procedure with only a few days pause in employment. Open knee surgery with prolonged rehabilitation has almost disappeared since the development of arthroscopic surgery. None of us would volunteer to have an open cholecystecomy or knee reconstruction unless the endoscopic option was not possible. This observation demonstrates how profound the appeal of minimally invasive surgery has on the human mind.

Beginning in 1995, initial attempts at minimally invasive coronary bypass appeared in brief reports from various centers around the world [Benetti 1995, Robinson 1995, Subramanian 1997, Douville 1998]. However, the difficulty of performing microvascular surgery on the heart through a small incision proved to be a major challenge. Unlike our orthopedic and general surgery colleagues, currently practicing cardiac surgeons have not adopted any minimally invasive techniques in their practices. Thus, our specialty still does not provide a realistic alternative to the endoluminal procedures performed in the catheterization laboratory.

This article reports an incremental step toward a truly minimally invasive, multivessel CABG. It is the authors contention that a small subxiphoid incision can be used to perform CABG to all the regions of the heart using arterial conduits. The techniques reported here are within the current skill set of most practicing cardiac surgeons and do not require new training or elaborate equipment such as endoscopics or robotics. A successful multivessel case was recently performed and the technique is documented in this report.

ANATOMY

Traditional CABG creates a surgical fracture of the sternum and division of the fascial fibers between both rectus muscles (i.e., linea alba). Spreading of the sternum causes pain in the back, shoulders, and thoracic cage, often requiring narcotics for a period of weeks following surgery. Internal fixation of the bone with encircling wires leads to fracture healing within 6 to 8 weeks. However, patients must refrain from upper extremity work until that time, which means loss of employment for manual laborers.

The internal mammary arteries (IMA) are the most durable and reliable bypass conduits available. The left internal mammary artery (LIMA) has a documented 10 year patency of 96% to the left anterior descending (LAD) [Loop 1986]. The right internal mammary artery (RIMA) has similar patency rates when placed to the same target vessel, confirming that both IMAs have identical resistance to atherosclerotic plaque formation regardless of the patients serum lipids or other risk factors. Studies have confirmed that complete revascularization of all left ventricular branches with IMA conduits provides superior long-term freedom from death, angina, and coronary events when compared to all other therapies, including CABG using saphenous vein [Pick 1997, Schmidt 1997].

Both IMAs traverse the parasternal region and terminate in the epigastrium (as the superior epigastric artery) just lateral to the xiphoid process. The right gastroepiploic artery (RGEA) lays along the greater curvature of the stomach, just deep to the xiphoid process. The mutual proximity of these important arterial conduits to the xiphoid process suggests the potential for complete revascularization with arterial conduits through a subxiphoid approach if these vessels can be safely harvested and the coronary targets fully exposed.

Since CAD usually affects the proximal portions of the coronary tree while sparing the distal branches, the anastomotic targets are typically located more toward the apex than the base of the heart. The LAD, diagonal, marginal branches of the circumflex, and posterior descending/lateral branches of the right coronary all point to (and converge at) the left ventricular apex. The graftable portions of these vessels are all reachable within a 5 cm conical region represented by the left ventricular apex. If the apex can be safely delivered into the subxiphoid area without hemodynamic compromise, then multivessel (and particularly multi-arterial) bypass would be possible.

The diaphragm attaches to the back of the xiphoid process and to the costal margins on both sides of the midline at roughly the level of the xiphoid. Excision of the xiphoid process and liberation of the anterior diaphragmatic attachments to the costal margin allows the sternum to be retracted vertically and away from the heart. The ribs migrate forward in concert with the lifted sternum in the same manner as they would during normal respirations. Caudal traction of the diaphragm in combination with sternal lifting and lateral wound spreading creates a significant working window large enough for CABG.

SURGICAL FUNDAMENTALS

The patient is positioned in the same manner as for conventional CABG, but with a supporting roll under the mid-thorax at the level of the xiphoid. We have used a roll created from two or three bath towels. Bilateral external defibrillating patches are placed along the lateral surfaces of each hemithorax to provide for emergency defibrillation. The groins are exposed and draped sterile in case femoral-femoral bypass is needed.

A midline incision is made from the top of the xiphi-sternal junction for a distance equal to the width of the surgeon's hand (about 5 to 7 cm). The linea alba is incised directly along the decussation of fibers in order to avoid injury to the superior epigastric branches of the IMA on either side (which are surprisingly close to the midline). The pre-peritoneal space is generously liberated from the posterior rectus sheath in all directions, allowing the recti to retract laterally as needed. The xiphoid process is resected and the lower end of the sternum lifted vertically using bilateral Rultract SkyHook® IMA retractor frames [Beg 1985] attached together with a coupler tube (Rultract Inc, Cleveland, OH (Figure 7)). As the sternum is lifted, the diaphragmatic attachments to the back of the costal margin are taken down in both directions.

The anterior mediastinal fat is cleaned away up to the innominate vein using a long cautery attachment to the electrosurgical handle. The pericardium is incised in a traditional "inverted T" and the position and quality of the coronary targets assessed. The superior epigastric branch of the LIMA is located in the posterior rectus sheath using a 10 MHz doppler probe (Koven Technologies, St. Louis, MO). Incision of the posterior rectus sheath at this site locates the terminal aspect of the LIMA, which is then dissected in a retrograde manner as a skeletonized conduit up to the thoracic inlet. Optical magnifiers (loupes), long tissue forceps, and a headlight are essential. The same procedure is used to harvest the RIMA. Then the wound is spread open into a working portal using a Medtronic Octobase® retractor outfitted with 4 swivel blades (Medtronic, Minneapolis, MN). The upper blades achieve stability by anchoring the Octobase® to the costal margin while the whole device is prevented from slip-

Figure 1. Preoperative chest x-ray.

Figure 2. Chest x-ray on the first day following surgery.

ping downward by the lower set of blades. If the RGEA is to be harvested, a transverse incision in the peritoneum gives excellent access to the greater curve of the stomach.

Caudal retraction of the diaphragm is performed with a blade attachment to the retractor, or with retention sutures. Left-sided pericardial traction sutures are placed using a long needle holder and held under tension by suture guides on the retractor arms. This maneuver delivers the apex more toward the midline and more caudally toward the opening of the wound. A Medtronic Starfish® suction-positioner is used to tilt the apex into the subxiphoid wound for exposure to the lateral wall vessels.Conventional OPCAB techniques are used to construct the distal anastomoses.

CASE REPORT

A 79-year-old man presented to his physician with several months of progressing chest pain and pressure with exertion and relieved by rest. At the time of heart catheterization, NYHA Class III angina was occurring and the episodes were lasting longer. Pertinent past medical history included smoking for 50 years (stopped in 1976), hypertension, and asthma requiring 4 bronchodilators including theophylline. Sestamibi nuclear stress testing revealed inferior ST depression considered positive for ischemia. FEV1 was 2.21 (75% of predicted), FVC was 4.45 (121%) of predicted, and diffusion capacity (DLCO) was impaired at 45% of predicted. Chest radiographs demonstrated chronic interstitial markings at both bases consistent with mild pulmonary fibrosis (Figure 1).

Diagnostic cardiac catheterization revealed total occlusion of the proximal right coronary artery (RCA) and LAD with 90% stenosis of the first obtuse marginal branch of the circumflex (Figures 3, 4, and 5). The coronary system was left dominant and the only visible distal branch of the RCA seen by left-to-right collaterals appeared to be small and ungraftable. Right anterior oblique (RAO) ventriculogram confirmed normal LV function and wall motion with no evidence of mitral regurgitation. Electrocardiogram was normal with sinus rhythm. Multiple attempts at reopening the chronic RCA occlusion were unsuccessful and the patient was referred for surgical revascularization. His body habitus was average, with slightly increased AP diameter of the thorax and a wide costal margin. Body weight was 86.7 kg, height 175 cm, and body surface area (BSA) 2.02 m^2.

On March 18, 2005, the patient underwent bilateral IMA grafting to the LAD and first obtuse marginal branch (OMB). The surgical technique described above was utilized to create a

Figure 3. Diagnostic angiography showing total ostial occlusion of the right coronary artery (RCA).

Figure 4. Right anterior oblique (RAO) view of left coronary angiogram showing a left dominant circulation and a large first obtuse marginal branch with a 90% ostial stenosis. The left anterior descending (LAD) is totally occluded and non-visualized.

working window through a subxiphoid midline incision without division of the sternum, costal cartilages, or rectus abdomini. After opening the pericardium, the coronary anatomy and feasibility of OPCAB were confirmed visually before proceeding. The posterior descending branch of the RCA was tiny (less than 1 mm diameter) and no other graftable RCA branches were found. Manual palpation of the distal LAD and OMB targets was possible and revealed no significant plaque which would prohibit beating heart grafting techniques.

Both internal mammary arteries were harvested as skeletonized conduits (Figures 6 and 7). A long cautery tip was used for the lower two thirds of the dissection. As the exposure reached the first rib area, dissection was switched to the Harmonic Scalpel (Ethicon) to prevent injury to the phrenic nerves from stray electrical current. After the LIMA dissection was completed, the distal conduit was clipped and transected. The lumen of the mammary artery was gently injected with a vasodilating solution composed of verapamil, nitroglycerin, and regitine (phentolamine mesylate) [He 1996]. After meticulous branch hemostasis was confirmed, the lumen was then filled with tissue culture medium (Hank's Balanced Salt Solution; Cambrex Bio Science, Walkersville, Maryland, USA) to preserve the intima while the opposite IMA was harvested.

The surgeon then changed position to the patients left side and the RIMA was mobilized using the same technique. After both mammaries were harvested and dilated, heparin was administered at 3 mg/kg. Palpable pulsations and visual observation of both systolic and diastolic pressurized bleeding from the open mammary arteries confirmed the quality of the conduits.

The LAD was grafted first. Caudal retraction of the diaphragmatic pericardium along with left-sided pericardial traction sutures and a sponge behind the left ventricle

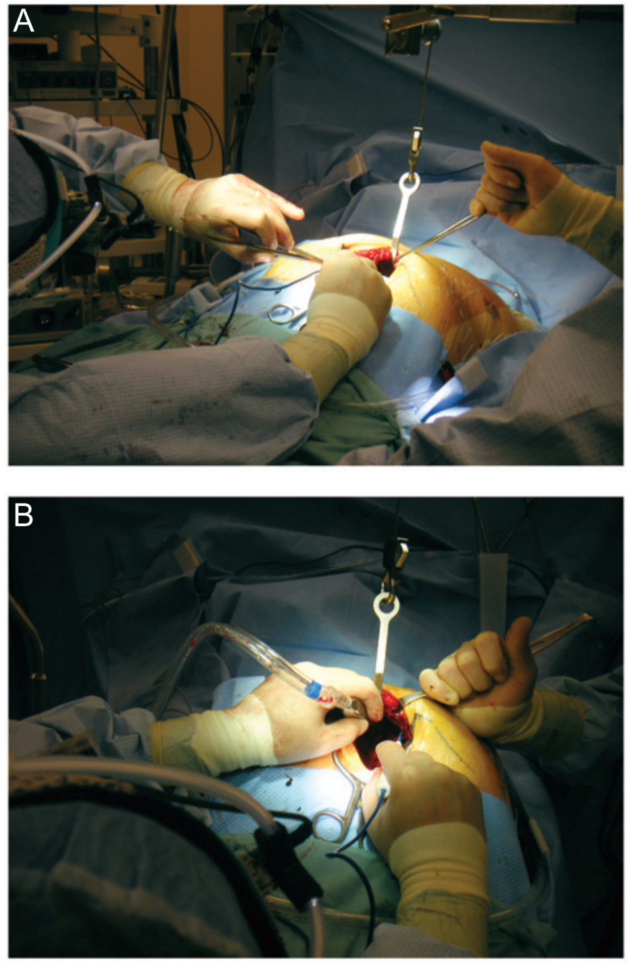

Figure 6. a, b. Midline vertical subxiphoid incision with sternal lifting. The left internal mammary artery (LIMA) is being dissected in a skeletonized fashion using a long cautery extension.

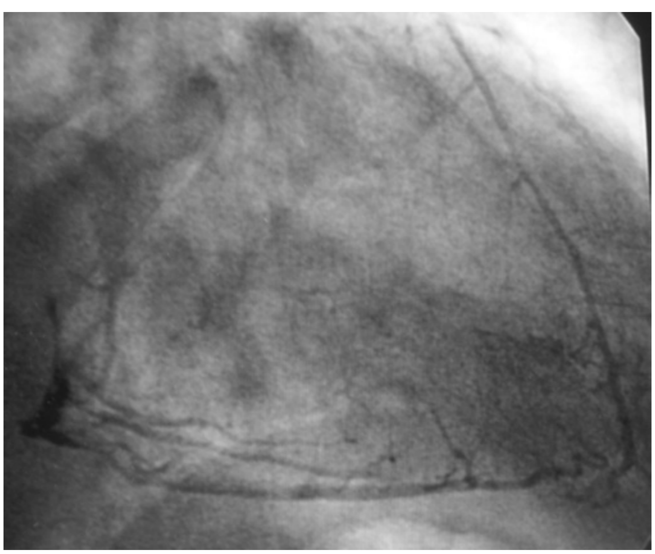

Figure 5. Delayed view of RAO left coronary angiogram showing late filling of the distal LAD via left-to-left collaterals.

Figure 7. Bilateral Rultract SkyHook® IMA retractors connected with a coupler tube assembly to distribute the lifting forces symmetrically onto both bed rails.

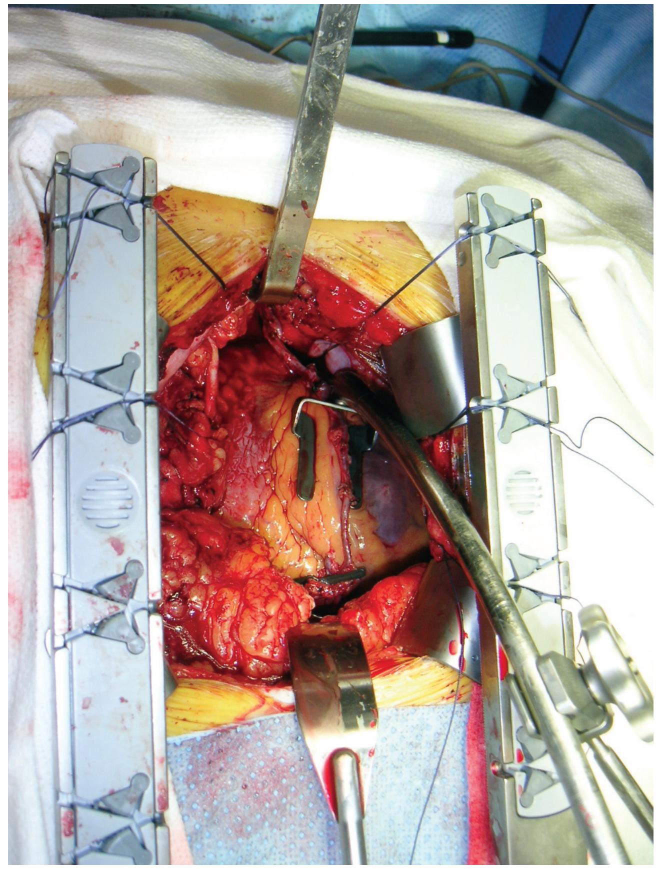

Figure 8. Surgeons view of subxiphoid working portal developed by vertical lifting of the lower sternum, caudal retraction of the diaphragm and lateral spreading with the Octobase® using swivel blades. Stabilizer is positioned over the distal LAD and the RIMA is positioned next to the LAD target site prior to beginning the anastomosis (Patient head at top of photo).

brought the LAD into view (Figure 8). A commercially available pressure stabilizer was attached to the Octobase® retractor, reducing motion of the LAD target. An incision in the LAD was made with a fine knife and a custom-made intracoronary shunt inserted to reduce back bleeding and facilitate safe suturing [Rivetti 1998, Ross 2003]. The RIMA was incised longitudinally and a side-to-side 7-0 Prolene® anastomosis performed with traditional running suture technique. A 1 mm probe confirmed patency of the heal of the conduit while removal of the shunt confirmed patency of the anastomotic suture line. The RIMA distal to the anastomosis was clipped and the unused portion excised. Transit time flow measurement (Transonic Systems Inc., Ithaca, NY) revealed 60 cc/min of blood flow in the completed graft. Tacking sutures were applied to hold the RIMA to the epicardium and prevent accidental disruption during the remainder of the operation.

Next, the apex was delivered into the subxiphoid space using a Medtronic Starfish® positioner, which also provided elongation of the LV chamber (Figure 9). Systolic blood pressures remained between 90 and 100 mm Hg with only slight Trendelenburg and dopamine (less than 5 μg/kg/min) for support. Exposure to the first OMB was excellent (Figure 8). Since the distal OMB in this case was very tortuous, insertion of the coronary shunt was difficult and time consuming. A temporary silastic tape (Quest Medical, Allen, TX) was used for hemostatic control on the proximal OMB during shunt insertion but no distal tape was used. The LIMA was draped over the stabilizer while a beating heart distal anastomosis was performed. After completion of the graft and replacement of the heart into the pericardial cavity, transit time flow measurement confirmed 33 cc/min of flow in this graft. There were no ischemic ST changes or arrythmias. After protamine administration, two mediastinal chest drains and bilateral pleural drains were inserted. The intercostal spaces were injected bilaterally with a 50:50 mixture of bupivicaine/lidocaine using an 18 guage spinal needle introduced through the subxiphoid wound. The anterior mediastinal pleura on both sides were used to cover the conduits and keep them away from the inner table of the sternum. The fascia of the linea alba was infused with the same local anesthetic mixture and then closed with running #1 Vicryl® while the remaining wound was closed with subcutaneous and subcuticular Vicryl®. The final closed incision is shown in Figure 10.

The patient was extubated 8 hours after surgery. Hemodynamics revealed a low systemic vascular resistance (400-500 dynes/cm/sec) responding to a few hours of arginine vasopressin. Chest x-ray remained similar to preoperative radiographs (Figure 2). Chest tube drainage rapidly tapered off and the mediastinal tubes were removed the following morning. At 24 hours from surgery, the patient walked unassisted in the ICU corridor without angina or other complaint. At 48 hours, he appeared ready for discharge, but was kept in the hospital until the 4th postoperative day for management of atrial fibrillation. During these 4 days, only 12 tablets of a non-narcotic analgesic (propoxyphene/acetaminophen) were taken for pain control.

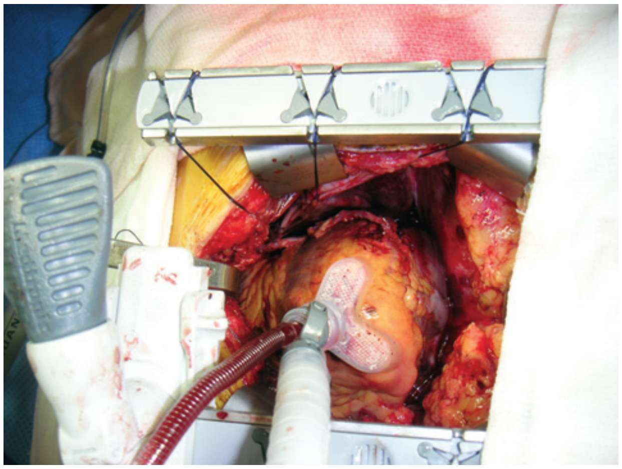

Figure 9. Surgeons view of the completed LIMA to OM-1 distal anastomosis (Patients head to the left). The LV apex is delivered into the subxiphoid portal using a Medtronic Starfish® suction-positioner. Hemodynamic stability was normal throughout construction of the anastomosis.

Figure 10. Final incision.

DISCUSSION

Although other surgical specialties have made huge strides in minimally invasive techniques, coronary surgery has remained essentially unchanged for decades. A few progressive centers have recently reported success with mini-thoracotomy CABG with or without endoscopic visualization [Subramanian 1997, Douville 1999, Vasilliades 2001, 2004, Hirose 2003]. Some programs have achieved limited success with LIMA-LAD grafting using robotically assisted anastomotic techniques [Menkis 2003]. However, the vast majority of practicing surgeons find these techniques very difficult to learn and master. Robotic equipment remains expensive and out of reach for most hospitals. Totally endoscopic CABG (or TECAB) is an admirable goal for the future, but it is not possible to predict when this will be achievable in the majority of centers [Menkis 2003]. Cardiac surgeons have not adapted to 2-dimensional endoscopic vision for the performance of microsurgical suturing. Most of the surgeons practicing today in busy heart programs were trained before laparscopic cholecystecomy and thus are unfamiliar (and suspicious) of endoscopically based CABG techniques. Even the experts who train to perform robotic suturing in research laboratories and animal models cannot complete TECABs in most of the clinical cases they attempt [Menkis 2003].

If cardiac surgery is to compete for patients in the modern era of drug-eluting stents, a different alternative must be developed that can be performed by all currently practicing surgeons. The profession cannot wait until a new generation of graduates skilled in endoscopics and robotics is trained and out in practice. In addition, any CABG technique that is designed (or achievable) only for single vessel LAD cases will never answer the problem. Modern cardiology has already stopped referring those patients for surgical treatment and thus any true minimally invasive CABG solution must be a multivessel operation.

In addition, our cardiology colleagues are no longer impressed with vein grafts. The saphenous vein is more accurately described as the "Fools Gold" of cardiac surgery since it makes the operation easier but suffers from a critical lack of durability (only 6 or 7 years). In today's marketplace, cardiologists know that saphenous veins are inferior when compared against multiple drug-eluting stents. Unless a multi-arterial, minimally invasive operation is developed, surgeons can count on relentless multivessel stenting and fewer referrals.

Some surgeons still doubt that double IMA grafting is superior to the more common LIMA-vein operation but there is no doubt when properly controlled studies are performed [Lytle 1983, 1989, Pick 1997, Schmidt 1997, Bergsma 1998, Calafiore 2000]. RIMA grafting to the RCA territory appears to have little value. Studies of bilateral IMA grafting where the RIMA was used for the RCA typically show no benefit over a LIMA-vein operation. In contrast, studies utilizing the second IMA for the circumflex territory consistently show better long-term outcomes than any other therapy for CAD [Pick 1997, Schmidt 1997].

Our cardiology colleagues know the superiority of arterial grafts very well since they are called upon to perform angiograms on our late failures. These studies typically show a widely patent IMA with closed vein grafts. The future of cardiac surgery cannot be based on the archaic saphenous vein and full sternotomy procedures of the 1980s or we will have few patients to operate upon.

All minimally invasive cardiac surgical options proposed until now have involved one or more intercostal incisions (or ports) which may disturb the segmental nerves and cause radicular pain. Spreading of the intercostal space increases surgical exposure to some degree, but as a downside further compresses the nerve risking post-thoracotomy pain.

The advantage of the subxiphoid incision is directly related to the thoracic anatomy. The incision is vertical through an avascular plane (the linea alba). No bone, cartilage, ligament, tendon, joint, or muscle is injured in any way, which makes this incision truly less traumatic than others. Since the segmental nerves terminate before they reach the midline, no neural structures are divided. The pre-peritoneal space is undermined, but there are no nerve trunks or branches in this plane. Separating the diaphragm fibers from the back of the thoracic cage does not cause any appreciable pain, nor does vertical lifting of the rib cage. Closure of the incision is quick and easy, requiring only a short running fascial approximation followed by subcutaneous and skin closure. Since the sternum is not divided, bone bleeding is absent and chest tube drainage is less, allowing early removal of the drains. If hemodynamic or other indications for conversion occur, a sternal saw can be quickly passed since everything deep to the sternum is already dissected free. The Octobase® retractor is simply repositioned into the divided sternum and a traditional transsternal operation performed as a bail-out.

Subxiphoid cardiac surgery is not entirely new, but has been relatively unexplored. Akhter et al described a subxiphoid approach with partial sternal splitting for selective reoperation candidates using the right gastroepipolic artery for grafting the distal right coronary branches [Akhter 1997]. Two double vessel cases (LIMA-LAD and RGEA-RCA) were performed but no lateral wall grafts were attempted [Akhter 1997]. Fonger et al demonstrated that sternal lifting alone can give enough exposure to the RCA branches for beating heart RGEA grafting to the RCA territory but no multivessel cases were reported [Fonger 1999]. Levinson et al reported two cases of atrial septal defect closure through a subxiphoid approach without sternal division using normothermic cardiopulmonary bypass [Levinson 1998]. Barbero-Marcial and colleagues reported a series of simple congenital heart defects repaired through a subxiphoid approach using a custom-built lifting device [Barbero-Marcial 1998]. Since the costal cartilages in children are more flexible, exposure suitable for intracardiac surgery was possible in these patients. Earlier hospital discharge was achieved compared with those operated through sternotomy.

Dullum et al reported single vessel LIMA-LAD beating heart cases performed through a subxiphoid incision [Dullum 1999]. In some cases, the left costal margin was detached or the lower sternum split to facilitate exposure. Benetti et al reported a larger series (55 patients) undergoing division of the xiphoid process as well as the lower 1 to 2 centimeters of the sternal bone [Benetti 2000]. Thoracoscopic assistance for IMA takedown was used in 60% of the patients, but the average length of mammary artery obtained was still only 7 centimeters. Only one bilateral IMA case was reported (LIMA-LAD and RIMA-RCA) and the authors concluded that their procedure could not be recommended for multivessel surgery [Benetti 2000].

Karagoz et al reported a "rib cage-lifting" technique using a subcostal incision, but in each case, the rectus abdominus muscle was detached from the costal margin and a lower mini-sternotomy used [Karagoz 1998]. Subramanian et al recently reported a multivessel technique using a "transabdominal" approach similar to that described by Karagoz but without the lower mini-sternotomy [Subramanian 2000]. However, one or both of the rectus abdominal muscles were divided to allow the rib cage to be lifted. Since the recti are innervated by segmental nerves, these structures must also be divided when the recti are detached or transected, causing pain and paresthesias similar to the now abandoned subcostal cholecystectomy incision. The subxiphoid technique proposed in this article does not divide any of the abdominal or thoracic musculature or segmental nerves and yet provides adequate exposure and hemodynamics for bypassing all regions of the heart.

The successful two vessel case reported here answered several important questions. The main question was access to the lateral wall of the heart. Although it is counter-intuitive to expect that exposure of the lateral wall would be adequate using a midline subxiphoid incision, exposure proved to be straightforward if certain concepts were adhered to. The diaphragm must be forcibly retracted caudally to bring the heart into a more vertical alignment. Lateral pericardial traction sutures and posterior packing in the pericardium further rotates the ventricle toward the surgeon. Finally, a suction positioner can deflect the apex with minimal hemodynamic consequence. With the surgeon standing more toward the patient's feet than with traditional sternotomy, an excellent view of the lateral wall is now obtained. It is anticipated that exposure can be further improved if normothermic femoral-femoral bypass is used. Cross-clamping would be unnecessary as the heart could continue to beat while the distals are being performed using OPCAB technique [Edgerton 2004]. Diverting the blood volume from the chambers will allow the heart to shrink, providing much more working room for the surgeon. To date, this maneuver has not been needed but will probably be necessary in future patients with large hearts or decreased left ventricular function.

Currently, the chief disadvantages of the technique relate to the conduits. When the heart is brought more caudally, a greater length of IMA is needed to reach the coronary targets. Thus, it is essential to take down an extended length of IMA in a skeletonized manner which is something not many surgeons are familiar with. The conduits are very difficult to skeletonize after harvesting because of the limited working space in the upper thorax and interference from cardiac motion. Finally, some cardiologists are opposed to the use of the RGEA because it is so difficult to cannulate during subsequent cardiac catheterization. It is likely that radial artery T-grafts will answer most of these drawbacks in the future.

In conclusion, efforts to develop a minimally invasive CABG technique that can be widely applied to the majority of patients by the majority of surgeons have failed so far. In the immediate future, widespread application of endoscopic or robotically assisted CABG is not likely to occur. An operation needs to be developed that restores the faith of our patients and cardiologists that surgery is an equivalent choice to angioplasty, but will last much longer. The solution must rival the non-invasive nature of angioplasty, be cost effective, and "teachable" to any currently practicing surgeon. An operation based on revascularizing the left ventricle with mostly saphenous veins will not be accepted as a viable alternative by our referring cardiologists.

Using refinements in current equipment and surgical techniques that are within the grasp of any practicing surgeon, the subxiphoid window can be adapted to create an excellent portal for beating heart surgery, with or without the pump. As the sternum is not divided, sternal wound infections and dehiscence cannot occur. This permits expanded use of double IMA operations in patients at risk for sternal complications, including diabetics. Since the subxiphoid incision does not violate any muscle, ligament, bone, cartilage, nerve, or nerve branch, pain is minimal and return to full activities/employment (including manual labor) will rival that of angioplasty. The threat of perioperative stroke is also eliminated if the ascending aorta and cardiopulmonary bypass are avoided.

The feasibility of grafting the RCA branches through a subxiphoid approach was reported by Akhter et al and Fonger et al while LAD grafting was reported by Dullum et al and

Benetti et al. This current report documents the first successful circumflex marginal graft using a subxiphoid approach without partial sternotomy or detachment of the abdominal musculature. Now all 3 major territories have been successfully grafted using a short midline subxiphoid incision, suggesting a bigger frontier is close at hand. The ideal combination of least invasive incision, excellent surgical exposure, standarge beating heart techniques, and full arterial reconstruction have now been achieved. The rapid and nearly painless recovery of this patient confirms that subxiphoid multiarterial grafting is headed in the right direction for the future of the profession. When combined with extubation at the conclusion of the case, outpatient multivessel CABG is now a realistic goal while still offering long term freedom from future events that is superior all other forms of treatment.

ADDENDUM

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