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Comparison of Ministernotomy with Minithoracotomy Regarding Postoperative Pain and Internal Mammary Artery Characteristics

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ABSTRACT

Purpose: This prospective clinical study focuses on postoperative pain and internal mammary artery (IMA) characteristics after ministernotomy versus left anterior minithoracotomy.

Method: Patients were studied in two groups. Group A consisted of 267 consecutive single vessel (IMA to left anterior descending artery (LAD)) minimally invasive direct coronary artery bypass (MIDCAB) patients using ministernotomy from the tip of the xiphoid to the fourth intercostal space. Group B consisted of the same number of MIDCAB patients operated on through anterolateral minithoracotomy. Pain was graduated using the visual analog scale (VAS). Internal mammary artery (IMA) characteristics were compared in both the groups.

Results: Postoperative pain was not significant statistically on postop day (POD) 1 in either of the groups ($p = 0.07$). From POD 2 onwards Group A patients had less pain than Group B patients ($p < 0.05$), and the pain medication requirement from POD 2 onwards was less in Group A than in Group B. Length of harvested IMA was 15.6 ± 2.1 cm in Group A as compared to 10.4 ± 2.2 cm in Group B ($p < 0.05$). Free flow of IMA in group A was 56 ± 16 ml/min., whereas in Group B the flow was 50 ± 14 ml/min. ($p = 0.04$).

Conclusion: Compared to patients undergoing MIDCAB using ministernotomy, anterolateral minithoracotomy patients suffer more pain from POD 2 onwards and their postoperative pain medication requirement is also higher. Length and free flow of IMA is better in patients operated on for MIDCAB using ministernotomy. Thus, ministernotomy is a better approach than minithoracotomy in terms of postoperative pain and IMA characteristics for single-vessel MIDCAB patients.

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INTRODUCTION

Since the inception of coronary revascularization, coronary bypass surgery on the beating heart has been practiced. With the advent and evolution of the heart-lung machine and cardioplegia, the realm of bypass surgery on a still heart expanded and beating heart surgery took a backseat. With the recent interest in minimally invasive procedures, the beating heart surgical techniques have been revived. The minimally invasive direct coronary artery bypass (MIDCAB) has been used primarily for grafting the left internal mammary artery (LIMA) to the left anterior descending artery (LAD) through left anterior thoracotomy, and has gained acceptance as a less invasive option.

To combine adequate access with a smaller scar, less pain and reduced respiratory discomfort as well as shorter hospital stay, the ministerotomy approach has been proposed. We began using ministernotomy approach for MIDCAB at the Escorts Heart Institute and Research Centre in October 1998. The aim of the present study is to present our experience with ministernotomy approach and a comparison between ministernotomy and left anterior minithoracotomy.

PATIENTS AND METHODS

From October 1998 until December 1999, ministernotomy was performed at our institute on 267 patients and compared with the same number of patients operated on

by left anterior minithoracotomy. Informed consent was obtained from all the patients, and approval was obtained from the institutional review board.

ANESTHESIA TECHNIQUE

All patients received tablet lorazepam and morphine sulfate intramuscularly as premedication. Anesthesia was induced with midazolam, fentanyl citrate, thiopentone sodium, and orotracheal intubation was facilitated with vecuronium bromide. Anesthesia was maintained with fentanyl and isoflurane in oxygen and intermittent vecuronium. Hypothermia was prevented by use of warming fluids and a warm water mattress. Monitoring consisted of pulse oxymetry, capnography, ventilatory parameters, two-lead EKG (II and V5) with ST trending, direct arterial pressure, pulmonary artery pressure, segmental wall motion anomaly with transesophageal echocardiography (TEE), and urine output and rectal temperature.

Patients were extubated when they met extubation criteria.

SURGICAL TECHNIQUE

Minithoracotomy

The patients are positioned supine with slight elevation of the side to be operated. Left anterior thoracotomy is performed through the fourth intercostal space (ICS) for LIMA dissection. In the initial patients fourth left costal cartilage was excised to facilitate LIMA harvesting, but this was abandoned subsequently.

The internal mammary artery (IMA) is always harvested under direct vision. The Chestwall retractor or the Cardio Thoracic Systems (CTS) (Cardio Thoracic Systems, Inc. Cupertino CA) or Genzyme stabilizer system (Genzyme Surgical Products, Cambridge MA) is used to facilitate IMA harvesting. A vertical incision is then made into the pericardium and stay sutures placed. Traction on these sutures elevates the heart into the incision, improving visualization of the LAD. After administration of heparin sulfate (1.5 mg/kg), a 3-0 polypropylene suture with a silastic rubber bolster is placed proximal to the target area on the LAD or right coronary artery (RCA) to be bypassed. The internal mammary artery is prepared for the anastomosis and local stabilization of the target vessel is done either by the CTS or Genzyme stabilizer. The anastomosis between LIMA to LAD is performed using two 7-0 polypropylene sutures separately for the heel and apex. During anastomosis, the operating field is kept clear of blood by blowing moist oxygen through a sterile intravenous cannula. A pleural drain is placed and the wound is closed in layers.

Ministernotomy

A vertical midline skin incision 6-8 cm in length is made starting from the fourth intercostal space (ICS) to the tip of the xiphoid process. The soft tissue overlying the sternum is mobilized and a median sternotomy from the tip of the xiphoid process to the fourth ICS is performed. If the sternum is very stiff, the lateral extension of the sternotomy is done on the left or right side depending upon which mammary artery is to be harvested, with the help of an oscillating saw. The complete length of the IMA can be harvested with the help of a long-tip electrocautery under direct vision. Heparin (1.5 mg/kg) is administered, and the mammary artery is divided distally and prepared for grafting. The pericardium is incised vertically and heavy sutures are applied to elevate the heart. Almost the whole length of the LAD can be visualized. An appropriate site of the LAD is selected for the anastomosis and, proximal to the site of the anastomosis, occlusion of the LAD is done with a 3-0 polypropylene suture with a silastic rubber bolster. If there are any hemodynamic or ECG changes, an appropriate-sized intracoronary shunt is used to allow distal perfusion during the anastomosis. Distal occlusion is never used. The local area is then stabilized with a mechanical stabilizer (CTS or Genzyme) and an arteriotomy is performed. A bloodless field is obtained with the use of a blower. The internal mammary artery is divided proximal to the bifurcation and prepared for the anastomosis. The mammary artery to coronary artery anastomosis is performed with a running 7-0 polypropylene suture. The IMA pedicle is tacked to the epicardium after completion of anastomosis, and a trough is cut in the pericardium to prevent kinking of the IMA pedicle. Hemostasis is ensured. A chest tube is then placed in the pericardium well extending into the pleura, or a separate chest tube is placed in the pleura.

Assessment of Surgery

In both minithoracotomy and ministernotomy, patency of the graft is assessed by Doppler flow prior to the chest closure, and angiography is performed on the fourth postoperative day.

Pain was assessed with a visual analog scale (VAS) score on a scale of 0 to 10, with 0 referring to no pain and 10 referring to unbearable pain. The patients had been instructed in the use of the scale preoperatively. Postoperatively, after endotracheal extubation, the VAS score was noted every two hours for the next 12 hours, and thenceforth every four hours until the fourth postoperative day. Scores were recorded by independent nurse observers who were blinded to the technique used. All analgesic dosages were administered based on the VAS score, as noted by blinded nurse observers. After endotracheal extubation, analgesia was provided with 30 mg of intramuscular ketrolac tromethamine (Ranbaxy Labs, Delhi, India). The need for the initial dose and repeat dose in either group was determined by a VAS score of 6 or more.

Free flow of the IMA was measured after harvesting and dividing the distal end of the IMA. The internal mammary artery was allowed to flow freely in a bowl for 30 seconds and the amount of the blood collected is measured. The length of the harvested IMA is measured with the help of black silk thread.

Table 1. Preoperative patients' characteristics

Parameter	Group A Ministernotomy N=267	Group B Minithoracotomy N=267	P Value
Gender			
Male	187 (70.03%)	182 (68.16%)	0.078
Female	80 (29.97%)	85 (31.84%)	
Age (Years)	62.8 ± 19.6	64 ± 19.3	0.524
BSA (m^2)	1.68 ± 0.2	1.64 ± 0.3	0.073
EF (%)	49 ± 26	46 ± 22	0.151
Diabetes			
Mellitus	91 (34.08%)	97 (36.39%)	0.697
COPD	5 (1.87%)	7 (2.62%)	0.770
Hypertension	107 (40.07%)	115 (43.0%)	0.539
Obesity	94 (35.2%)	98 (36.70%)	0.787
Post PTCA	42 (15.53%)	38 (14.23%)	0.716
Hybrid Revascularization	8 (2.99%)	6 (2.24%)	0.786

BSA = body surface area, EF = ejection fraction, COPD = chronic obstructive pulmonary disease, PTCA = percutaneous transluminal coronary angioplasty

STATISTICAL ANALYSIS

The Student's t-test was applied for continuous variables between the two groups. Comparison of categorical variables between two groups was conducted using cross tables with Pearson's Chi-Square test if expected values were small, and the Fisher exact test was used if the expected values were high. A p value of < 0.05 was considered statistically significant.

RESULTS

Preoperative patient characteristics are shown in Table 1 (◎). There was no statistically significant difference in preoperative patient parameters. Preoperative risk factors are depicted in Table 2 (◎). Of patients older than 70 years, 56 (20.97%) were in the ministernotomy group and 52 (19.47%) were in the minithoracotomy group. Forty-eight patients (17.97%) in the ministernotomy and forty-two patients (15.73%) in the minithoracotomy group had left ventricular ejection fractions (LVEFs) below 30%. These factors did not reach statistical significance.

During anastomosis, six patients in the ministernotomy group and four patients in the minithora-cotomy group had ST elevation in chest leads without any hemodynamic instability or regional wall motion abnormality on TEE. In all these patients, ECG changes reverted to normal on completion of the anastomosis and release of the snare and the bulldog clamp applied on the LIMA. However two patients in the ministernotomy group and three patients in the minithoracotomy group had hemodynamic instability with regional wall motion abnormality on TEE along with ECG changes, which required conversion to full sternotomy and cardiopulmonary bypass (CPB).

Table 2. Pre-operative risk factors

Parameter	Group A Ministernotomy N=267	Group B Minithoracotomy N=267	P Value
Age >70 Years	56 (20.97%)	52 (19.47%)	0.746
Atheromatous Disease of Aorta	36 (13.48%)	38 (14.23%)	0.900
Renal Dysfunction	23 (8.61%)	19 (7.11%)	0.630
Unstable Angina	26 (9.73%)	22 (8.23%)	0.650
Low Ejection Fraction (<30%)	48 (17.97%)	42 (15.73%)	0.563

The harvested LIMA was significantly longer in ministernotomy patients than in patients operated on through minithoracotomy (Table 3, ◎). None of the patients required IMA extension in the ministernotomy group. In the minithoracotomy group, four patients required IMA extension; the inferior epigastric artery (IEA) was used for the IMA extension in one patient and the reversed saphenous vein was used in three patients.

Postoperative results and clinical outcome are presented in Table 4 (◎). More ministernotomy patients than minithoracotomy patients were extubated in the operating room. Total blood loss was greater in patients operated on through ministernotomy than in minithoracotomy patients ($p < 001$). This may be due to more loss of blood from the sternotomy.

A postoperative Doppler flow study of LIMA-to-LAD was performed on all patients. Diastolic flow was excellent in 264 ministernotomy patients and in 263 minithoracotomy patients. However, there was no diastolic flow in three ministernotomy patients (1.12%) and four minithoracotomy patients (1.49%), which was confirmed on angiography. One hundred and ten patients in each group underwent postoperative angiography during their hospital stay, and the LIMA was found to be patent in all patients except those mentioned above. One patient in the ministernotomy group and two patients in the minithoracotomy group required reoperation, for which the radial artery was used as a conduit.

Table 3. Internal mammary artery characteristics

Parameter	Group A Ministernotomy N=267	Group B Minithoracotomy N=267	P Value
Length of Harvested IMA (cm)	15.6 ± 2.1	10.4 ± 2.2	<0.001*
Free Flow of IMA (ml)	56 ± 16	50 ± 14	<0.001*
IMA Extension	NIL	4	0.124

IMA = internal mammary artery

* Significant statistically

Table 4. Postoperative results and clinical outcomes

Parameter	Group A Ministernotomy N=267	Group B Minithoracotomy N=267	P Value
Ventilation (h)	6.0 ± 3.3	6.3 ± 3.6	0.787
Extubated in Operating Room	127(47.56%)	87(32.58%)	<0.001*
ICU Stay(h)	18 ± 4.8	21 ± 4.6	<0.001
Blood Loss (ml)	268 ± 116	230 ± 110	<0.001*
Average Blood Units (per Patient)	0.8	0.6	0.786
Superficial Wound Infection	6(2.22%)	11(4.11%)	<0.05*
Re-exploration for Bleeding	4	3	1.00
Mortality	1	1	1.00

ICU = intensive care unit

*Significant statistically

Table 5. Trend of VAS for first 12 hours

VAS Score	Ministernotomy Group A	Minithoracotomy Group B
2 Hrs*	2.25 ± 1.38	3.56 ± 1.29
4 Hrs	4.00 ± 1.36	4.36 ± 1.66
6 Hrs	4.68 ± 0.82	4.72 ± 1.08
8 Hrs	4.57 ± 1.57	4.96 ± 1.24
10 Hrs	4.32 ± 1.25	4.34 ± 1.72
12 Hrs	4.75 ± 1.46	4.68 ± 1.46

*P < 0.05, VAS = visual analog scale

The mean VAS scores for the first 12 hours were not different statiscally in both groups but did not reach statistical significance except at the first two hours (Table 5, ◎). From second postoperative day (POD) onwards pain was significantly greater in patients operated on through minithoracotomy as compared with ministernotomy ($p < 0.05$) (Figure 1, ◎). By the time of discharge, pain levels had decreased in almost all the patients.

The mean postoperative ketorolac requirements were found to be lower in the ministernotomy group (32.57 ± 14.67) than in the minithoracotomy group (48.27 ± 18.42), a difference that was found to be statistically significant ($p < 0.05$).

One patient in each group (0.37%) died during hospital stay. The patient operated on through ministernotomy had acute renal shutdown, and the minithoracotomy patient experienced massive gastrointestinal bleeding following surgery.

Mean follow-up was 10 ± 1.5 months, with a follow-up rate of 95.88% (256 of 267 patients) in the ministernotomy group and 94.38% (252 of 267 patients) in the minithoracotomy group. Two hundred and fifty patients in the ministernotomy group and 248 patients in the minithoracotomy group were in functional class I and had good diastolic flow on Doppler flow evaluation of the mammary coronary anastomosis. Six patients in the ministernotomy group and four patients in the minithoracotomy group are in angina class II and are on medical therapy.

DISCUSSION

Less invasive procedures for surgical revascularization are being proposed as a means of reducing operative trauma and the sequel of cardiopulmonary bypass (CPB) [Westaby 1996, Coulson 1998a]. These new techniques attempt to reduce surgical trauma and thus postoperative pain, and give better cosmetic results. By avoiding CPB, cerebrovascular, renal, and bleeding complications are significantly reduced. However, not all minimally invasive coronary operations are performed with reduced surgical trauma. Lateral thoracotomies can be quiet painful even if small in length. The thoracotomy approach, due to trauma to costal cartilages, may induce more pain than that resulting from a median sternotomy [Heres 1998]. Intercostal nerve injury can cause very significant pain, chest wall splinting, hypoventilation, and respiratory compromise. Complete mobilization of the IMA through a limited thoracotomy is difficult and time-consuming.

By moving away from sternotomy, MIDCAB surgeons have revisited the known problems of thoracotomy and the side effects of pain management. In order for less invasive cardiac procedures to become universally accepted by surgeons and patients alike, refinements are needed.

Coulson et al. [Coulson 1998b] have described an alternative technique, the "T-MIDCAB" procedure. By grafting a short segment of radial artery or saphenous vein between the undisturbed IMA and target coronary artery, complete thoracotomy is avoided and chest wall retraction and perioperative pain are minimized. This procedure, however, is technically more demanding and requires an additional anastomosis between the donor vessel and the IMA.

The median sternotomy was originally described by Milton in 1897 and was popularized by Jullian in 1957 [Jullian 1957]. It eventually became the universal method of exposure for most cardiac procedures. Surgeons quickly realized that median sternotomy provided good exposure to every region of the heart, the great vessels, and the mediastinum. As its frequent use attests, surgeons are comfortable with the median sternotomy because of the exposure of cardiac structures that it provides. Until recent years, concerns about wound trauma and the final appearance of the surgical scar were a low priority. However, now that the minimally invasive and "off-pump" surgeries have become widely practiced, other considerations are surfacing. Cosmetic disadvantages of the full median sternotomy are obvious — a large and visible scar that remains a permanent reminder of an otherwise low-risk procedure. The safety advantages of reduced surgical trauma remain a cardinal feature of all the modified techniques.

Several alternatives are currently available for accessing the thoracic cage that achieve adequate access with a smaller scar, less pain, and reduced respiratory discomfort as well as shorter hospital stay. We have used lower

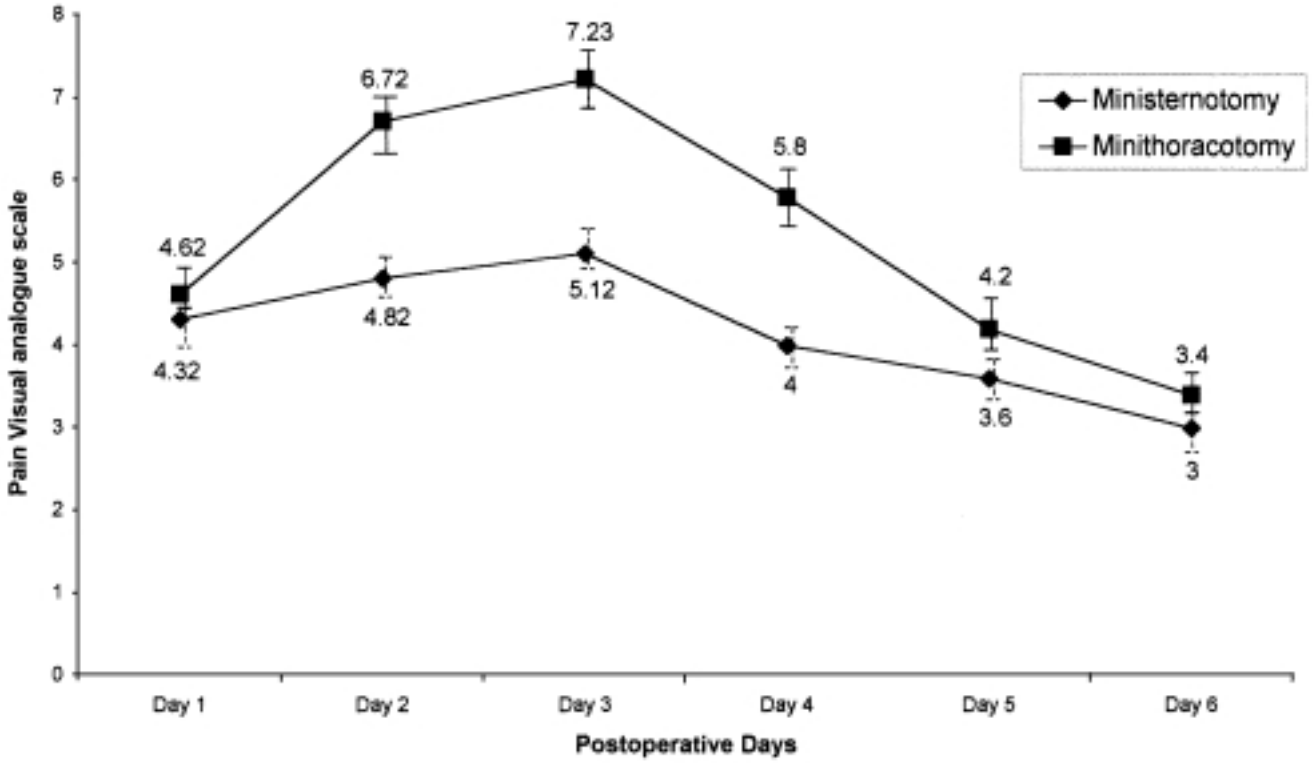

Figure 1. Post-operative pain during first six days after the surgery measured on a daily basis using the Visual Analogue Scale (VAS).

ministernotomy primarily for grafting the LIMA to the LAD from the tip of the xiphoid process to the fourth ICS. To create the exposure for harvesting the IMA and for the subxiphoid approach, we have used the Rultract retractor (Rultract Inc., Cincinnati, OH) for providing vertical lift of the lower sternal bone (Figure 2, ◎), or we used the same Genzyme (Genzyme, Inc., Cambridge, MA) retractor that we used for local stabilization of the heart. A simple upward tilt exposes the IMA, which can be easily harvested. Complete visualization of the IMA as well as the LAD is achieved with great ease. In our study, the length of the harvested IMA was significantly longer in ministernotomy than in minithoracotomy. In minithoracotomies, the length of the harvested IMA is a great limiting factor; at times it may be very difficult to harvest even a few centimeters more, especially in a laterally situated LAD.

These results are achieved without debilitating musculoskeletal trauma. In addition, conversion to either an extended transverse incision or a standard median sternotomy can be done anytime that the need arises. All of these advantages are limited if surgery is done through minithoracotomy for a LIMA to LAD anastomosis.

Another advantage of ministernotomy for IMA harvesting and LIMA to LAD anastomosis is the lower learning curve as compared with the minithoracotomy approach. The same technique is used for IMA harvesting and for the anastomosis as in the standard median sternotomy approach.

The port access system (Heart Port, Inc., Redwood City, CA), which has also been used for coronary artery bypass grafting (CABG) by some surgeons [Ribakove 1998], has the advantage of a limited incision while still providing the comfort to perform the anastomosis on an arrested heart in a bloodless surgical field. Factors that limit this technique are the necessity of establishing extracorporeal circulation through femoral vessels and placement of the endoaortic clamp, in addition to the additional expenses for special instrumentation and the cardiopulmonary circuit kit. Video-assisted endoscopic instrumentation [Nataf 1996] and robotic assistance are also employed for minimally invasive CABG operations, but these techniques are quite expensive, require special training and are highly operator-dependent, and are not easily reproducible.

In the lower partial ministernotomy approach, the upper part of the sternum and the sterno-clavicular and manubriosternal joints are not disturbed, so the chances of sternal dehiscence are low, especially in elderly patients and those with chronic obstructive pulmonary disease (COPD). Because the chest is not widely opened, there is less risk of traction injuries to the brachial plexus. In addition, the smaller incision and lower wound morbidity yield a more acceptable cosmetic result for patients (Figure 3, ◎). In our series we did not observe any sternal wound dehiscence in patients operated on by ministernotomy.

It may be claimed that for single vessel disease, percutaneous transluminal coronary angioplasty (PTCA), with or without stenting, is the treatment of choice. The data from

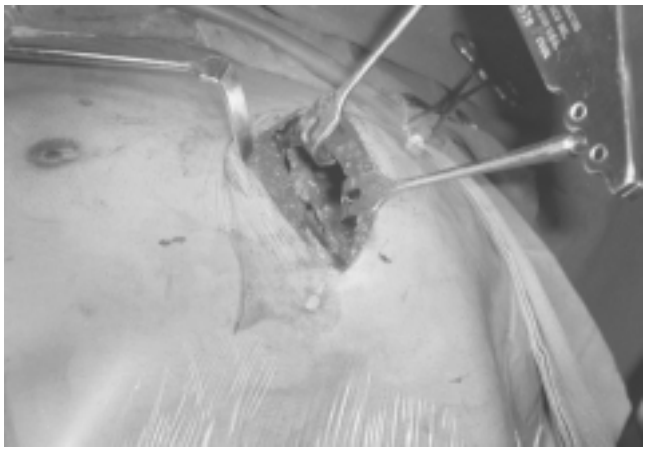

Figure 2. Rultract retractor for providing vertical lift of the lower sternal bone (note the harvested internal mammary artery).

Figure 3. Post-operative scar of the ministernotomy patient.

randomized studies comparing PTCA with CABG consistently showed a similar incidence of death and myocardial infarction at one, three, and five years after PTCA and CABG [Pocock 1995, BARI 1996]. Both treatment modalities were equally effective in relieving angina [Pocock 1995]. The angina relief, however, is achieved in patients treated with PTCA at the cost of a significantly higher need for repeat revascularization during the first year [Pocock 1995, BARI 1996]. Obviously, PTCA does have its own intrinsic limitations. At the same time, significant improvements in CABG techniques are being made, which renders PTCA and CABG complementary rather than strictly exclusive techniques, especially in high-risk patients for whom a combination of the techniques (hybrid revascularization), may be more effective. We performed hybrid revascularization in eight patients (2.99%) in the ministernotomy group and in six patients (2.24%) in the minithoracotomy group, for whom complications included diffusely diseased atheromatous aorta and impaired renal function. One of the limitations of PTCA is that the device must cross the target lesion in order to perform its specialized function. In patients with chronic totally occluded arteries, distal lesions, and tortuous or small coronary arteries, and patients with complex type C lesion(s), this is particularly challenging. These patients are difficult to treat despite improvements in catheter technology (guide-wire design, balloon profile and material, and laser technology) [de Jaegere 1997]. Another limiting factor for PTCA is late luminal renarrowing or restenosis, which imposes a significant medical and financial burden on the patient. In our series, 42 patients (15.73%) required MIDCAB following PTCA in the mini-sternotomy group and 38 patients (14.23%) in the minithoracotomy group.

Perception of pain is individualized. Nevertheless partial quantification of these subjective symptoms can be provided by the use of scoring systems [Westin 1997], which provide a framework for comparing the two approaches. In our series, on the first POD, pain was found to be the same in both groups, but on subsequent days pain was significantly greater in patients operated on through left anterior minithoracotomy. Stretching of the intercostal nerves, muscles, and parietal pleura may be the a contributory factor for the greater pain in the thoracotomy group. In the median sternotomy, once the sternum is approximated and there is no sternal instability, there is not much pain. Since the entire sternum is not incised, patients operated on through partial sternotomy do not experience significant pain and muscular tension in the back.

Adequate pain control is one of the important considerations for MIDCAB and is essential for reducing the length of stay in ICU and the hospital. Severe pain is know to cause reduction in respiratory mechanics and mobility, and to increase sympathetic hormonal and metabolic activity [Sabanathan 1990]. If pain relief is not adequate after MIDCAB surgery, then all its advantages may be negated due to the adverse effects of postoperative pain. Various analgesic techniques are used after MIDCAB, which include nonsteroidal anti-inflammatory drugs, intrathecal opioids, intercostal blocks, intrapleural analgesia, and thoracic epidural analgesia [Mehta 1998]. In our series, the nonsteroidal anti-inflammatory agent ketorolac was found to provide adequate pain control postoperatively, although the analgesic requirement was greater in the minithoracotomy group.

In conclusion, in terms of post operative pain and IMA characteristics, significant differences can be seen between the results of left anterior minithoracotomy and ministernotomy. From the first POD onwards, patients having a ministernotomy perceive less pain, and the significantly longer IMA in ministernotomies can be a major advantage over minithoracotomy. Conversion to standard median sternotomy from a ministernotomy is much easier should the need arise, and the procedure has a shorter learning period for the surgeon and does not require specialized instrumentation.

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