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Experience with a Minimally Invasive Approach to Combined Valve Surgery and Coronary Artery Bypass Grafting through Bilateral Thoracotomies

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ABSTRACT

Background: Minimally invasive coronary artery bypass grafting (MICS-CABG) and minimally invasive valve surgery (MIVS) have been used independently to manage occlusive coronary artery disease and valvular diseases, respectively. We present 12 patients who underwent combined MICS-CABG and MIVS via bilateral mini-thoracotomies.

Methods: We retrospectively reviewed 116 consecutive valve/CABG operations by a single surgeon and compared the outcomes obtained via sternotomy with those obtained via bilateral minithoracotomies.

Results: Six patients in the MIVS group underwent aortic valve replacement (sternotomy group, n = 70), 3 patients underwent mitral valve repair (sternotomy group, n = 9), and 3 underwent mitral valve replacement (sternotomy group, n = 25). The minimally invasive valve surgeries were combined with MICS-CABG for single- (n = 2), double- (n = 9), and triple-vessel (n = 1) coronary artery disease in a single operation. The mean SD duration of cardiopulmonary bypass was 164 ± 44.6 minutes (mean time via sternotomy, 152 ± 50.5 minutes; *P* = .4146), and the mean aortic cross-clamp time was 87.8 ± 22.1 minutes (mean time via sternotomy, 105 ± 39.8 minutes; *P* = .1455). The use of perioperative blood transfusions averaged to 2.3 ± 5.6 units (mean usage via sternotomy, 2.7 ± 4.9 units; *P* = .8326). There were no conversions to sternotomy in the minimally invasive group. Patients in the minimally invasive group were extubated earlier (24 ± 11 hours; sternotomy group, 40 ± 61 hours; *P* = .3684) and discharged earlier (7 ± 4 days) than patients who underwent median sternotomy (9 ± 10 days; *P* = .4027).

Conclusion: MICS-CABG combined with MIVS via bilateral minithoracotomies yielded short-term results comparable to those for CABG and valve repair via median sternotomy. There were no operative mortalities or reoperations. The possible advantages of the minimally invasive approach included earlier extubation and earlier discharge from the hospital. Combined CABG and valve surgery can be safely performed via bilateral thoracotomies.

INTRODUCTION

As life expectancy lengthens, the incidence of concurrent occlusive coronary and valvular disease is expected to increase, with as many as 8% of cardiac surgery patients having combined valvulopathy and coronary artery disease (CAD) [Karthik 2004]. Such patients have traditionally undergone combined coronary artery bypass grafting (CABG) and valve repair surgery, which has a reported mortality rate of 4.8% to 18% [Lee 2010], although there is evidence that referral to cardiac surgery is not offered to all patients because of the perception of an unacceptably high mortality risk. One response to this problem is offered by minimally invasive cardiac surgery (MICS). MICS procedures avoid median sternotomy and its consequent morbidities. MICS-CABG has produced coronary revascularization outcomes comparable to those of standard CABG, although long-term data are not yet available [McGinn 2009; Lapierre 2011]. Similarly, repair of both aortic and mitral valve defects with minimally invasive valve surgery (MIVS) techniques has yielded excellent and reproducible results, with lower wound infection rates, reduced postoperative pain, and earlier return to normal activity [Mishra 1999; Sharony 2003; Aybek 2006; Modi 2008; McClure 2009; Korach 2010; Murzi 2012]. The use of bilateral thoracotomies to perform bilateral mammary artery harvesting has been reported [Weerasinghe 2005], and a similar approach has been taken with bilateral lung transplantation [Taghavi 1999], with satisfactory patient outcomes. We present the first reported series of 12 patients who underwent combined MICS-CABG and MIVS via the use of bilateral minithoracotomies. This experience demonstrates the technical feasibility of performing CABG in combination with either aortic valve replacement (AVR) or mitral valve repair/replacement (MVR) bilateral thoracotomies. The isolated techniques of MICS-CABG and MIVS have previously been described in the literature [Mishra 1999; Sharony 2003; Aybek 2006; Modi 2008; McClure 2009; Korach 2010; Murzi 2012]; therefore, we focus primarily on the technical considerations and differences encountered during MICS-CABG combined with MIVS.

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Table 1. Preoperative Characteristics of Patients*

Patient Characteristic	MVR/CABG			AVR/CABG		
	MINI (n = 6)	Sternotomy (n = 34)	*P*	MINI (n = 6)	Sternotomy (n = 70)	*P*
Age, years	76 ± 4	69 ± 8	.042	76 ± 6	72 ± 10	.336
Men, n (%)	5 (83.3)	18 (52.9)	.216	3 (83.3)	46 (65.7)	.657
Body mass index, kg/m^2	26.8 ± 4.2	29.7 ± 5.8	.247	27.6 ± 2.8	29.7 ± 6.5	.437
Ejection fraction, %	37 ± 14	36 ± 12	.951	43 ± 12	43 ± 12	.908
Smoker, n (%)	1 (16.7)	19 (55.9)	.182	3 (50.0)	26 (37.1)	.669
Diabetes, n (%)	2 (33.3)	5 (14.7)	.278	3 (50.0)	19 (27.1)	.348
Renal dialysis, n (%)	0	2 (5.9)		0	1 (1.4)	
Hypertension, n (%)	4 (66.7)	21 (61.8)	1.000	6 (100.0)	58 (82.9)	.582
Chronic lung disease, n (%)	1 (16.7)	10 (29.4)	.442	1 (16.7)	12 (17.1)	1.000
Peripheral vascular disease, n (%)	1 (16.7)	4 (11.8)	1.000	2 (33.3)	13 (18.6)	.338
Cerebrovascular disease, n (%)	1 (16.7)	2 (5.9)	.394	1 (16.7)	12 (17.1)	1.000
Congestive heart failure, n (%)	3 (50.0)	8 (23.5)	.319	0	7 (10.0)	
Previous CABG, n (%)	0	2 (5.9)		0	7 (10.0)	
Percutaneous coronary intervention, n (%)	2 (33.3)	6 (17.6)	.580	2 (33.3)	14 (20.0)	.600
Myocardial infarction, n (%)	1 (16.7)	15 (44.1)	.100	2 (33.3)	27 (38.6)	1.000
No. of diseased vessels	2.2 ± 0.75	2.3 ± 0.69	.670	2.2 ± 1.0	3.1 ± 0.91	**.021**

*Data are expressed as n (%) or the mean ± SD. MVR indicates mitral valve repair/replacement; CABG, coronary artery bypass grafting; AVR, aortic valve replacement; MINI-MINI, combined surgeries carried out via bilateral minithoracotomies.

METHODS

Patient Characteristics

Between January 2005 and September 2012, 116 patients underwent surgery by a single surgeon for combined CAD and valvulopathy at our institution. Twelve of these patients were selected for combined MICS-CABG and MIVS according to the surgeon's preference. The patients had no prior cardiac operations, and the operative procedures were concomitant AVR or MVR with CABG. All patients with occlusive CAD and concomitant aortic stenosis (AS) or mitral regurgitation (MR) were considered for possible combined MICS. Exclusion criteria included contraindications to MICS (morbid obesity, peripheral vascular disease affecting the femoral vessels, or prior median sternotomy), and emergency operation. The database review was approved for research by the Staten Island University Hospital's Institutional Review Board, which waived the requirement for informed consent on the condition that the patients' identities were hidden before analyses were performed. A retrospective analysis was performed on the outcomes of the perioperative period and any subsequent hospitalizations. All patients have been followed up to 1 month postoperatively.

Preoperative Evaluation

The patients' age range was 65 to 84 years (mean, 76 years) with a male-to-female ratio of 5:1 and a mean body mass index of 27.2 kg/m^2 (range, 20.8-32.9 kg/m^2). Symptomatic valve disease was present in all patients: 6 with AS (mean valve area, 0.81 cm^2) and 6 with severe MR. All patients were in New York Heart Association classes I to III.

Cardiac catheterization, which was performed before all surgeries, revealed single-vessel (n = 2), double-vessel (n = 2), and triple-vessel (n = 2) occlusive CAD. All patients were hemodynamically stable before surgery, and no surgeries were performed as emergencies. Two patients underwent placement of an automatic implantable cardioverter defibrillator or a permanent pacemaker. Three patients had undergone prior percutaneous coronary intervention.

Operative Procedure

MIVS–mitral valve annuloplasty/replacement with MICS-CABG. All patients were placed on the operating table in the supine position with their arms abducted. The primary team created bilateral 6-cm to 7-cm thoracotomies at the fourth intercostal space while a secondary team performed endoscopic saphenous vein harvesting and femoral vessel dissection in preparation for bypass catheter cannulation. The left internal mammary artery (LIMA) was harvested via the left thoracotomy, and the patient was anticoagulated intravenously with heparin.

A 6-mm subxyphoid incision was created, and a Starfish NS apical stabilizer (Medtronic, Minneapolis, MN, USA) was inserted to position the heart within the chest. Additionally, another 6-mm incision was placed in the left sixth intercostal space, and an Octopus NS epicardial stabilizer (Medtronic) was introduced. Femoral arterial and venous cardiopulmonary bypass (CPB) catheters were inserted in retrograde, and their positions were confirmed by transesophageal echocardiography (TEE). All patients were revascularized before the valve surgery, with proximal anastomoses followed by distal bypass performed via the left thoracotomy.

CPB was initiated, the aortic cross-clamp was applied via the left-side thoracotomy, and retrograde cardioplegia was administered. The mitral valve was accessed through the right thoracotomy via a left atrial incision.

MIVS-AVR with MICS-CABG. The patient was positioned as described above, and a 2-team approach was again used, with the thoracotomies created in the left fourth intercostal space and the right second intercostal space, combined with disarticulation of the third rib from the sternum. Following the initiation of CPB and retrograde cardioplegic arrest, the aorta was cross-clamped via the right thoracotomy, and the aortic valve was excised and replaced with a bioprosthetic heart valve. Next, the proximal vein anastomoses were performed via the right thoracotomy, and the conduit vein was passed retrosternally to the left incision, where the distal anastomoses were performed.

Anesthesia Management

Defibrillating pads were placed, and all patients were monitored with a pulmonary artery catheter, a radial arterial line, and TEE. One-lung ventilation was achieved with a bronchial blocker placed through a normal oral endotrachial tube. The aortic cannula, venous cannula, and coronary sinus catheter were placed with TEE guidance.

Statistical Analysis

Results are reported as the mean and SD. Descriptive statistics were used to describe patient characteristics at baseline. Categorical variables were evaluated with Fisher exact and chi-square tests. Continuous variables were analyzed with the Student t test. All comparisons were 2-tailed, with statistical significance indicated by a *P* value <.05. All analyses were conducted with SPSS Statistics 20 software (IBM, Somers, NY, USA). We determined best-fit trend lines for the operative-time data set for the minimally invasive aortic and mitral valve surgeries by selecting the method for determining a line equation that produced the largest coefficient of determination (r^2 value) over the sequence of patient operations. Excel software was used (Microsoft, Redmond, WA, USA).

RESULTS

Table 1 summarizes the patient demographic data for the 2 subgroups, the minimally invasive approach for aortic valve–CABG and mitral valve–CABG surgeries along with the demographic data obtained for the same operations carried out via the sternotomy approach. The results were compared within a single surgeon's operative history. These patient characteristics were not significantly different, with the exception that the AVR/CABG group had more diseased vessels in the sternotomy subgroup than in the minimally invasive subgroup (3.1 ± 0.9 versus 2.2 ± 1.0, *P* = .021).

Operative Characteristics

Minimally invasive MVR/CABG. There were no conversions to median sternotomy. All patients in the minimally invasive group had a LIMA-to-LAD bypass, and 5 patients underwent additional bypass with saphenous vein (0.8 ± 0.4 bypasses via MICS versus 2.0 ± 1.1 bypasses via sternotomy, *P* = .0102). The mean CPB time was lower in the minimally invasive group (142.0 ± 35.4 minutes versus 150.1 ± 47.1 minutes, *P* = .691). Aortic cross-clamp times were also lower in the minimally invasive group than in the sternotomy group, as the cross-clamp was applied after MICS-CABG, which was performed off pump (73.0 ± 5.2 minutes versus 107.3 ± 56.3 minutes, *P* = .1487). The 2 groups had similar mean levels of intraoperative blood product use and surgical operative times (Table 2). Half of the patients in the

Table 2. Operative Characteristics and Postoperative Results*

Operative Characteristics	MVR/CABG			AVR/CABG		
	MINI (n = 6)	Sternotomy (n = 34)	*P*	MINI (n = 6)	Sternotomy (n = 70)	*P*
Surgical priority						
Elective, n (%)	2 (33.3)	14 (41.2)	1.000	4 (66.7)	33 (47.1)	.425
Urgent, n (%)	4 (66.6)	20 (58.8)	1.000	2 (33.3)	37 (52.9)	.425
Surgical time, h	5 ± 2	5 ± 1	1.000	7 ± 1	5 ± 1	**.0001**
No. of bypasses	1.8 ± 0.4	2.5 ± 1.2	.225	2.2 ± 0.75	2.4 ± 1.2	.715
LIMA-LAD graft, n (%)	6 (100.0)	15 (44.1)	**.021**	6 (100)	40 (57.1)	.076
No. of saphenous vein grafts	0.8 ± 0.4	2.0 ± 1.1	**.010**	1.2 ± 0.7	1.7 ± 1.0	.227
CPB time, min	142.0 ± 35.4	150.1 ± 47.1	.691	186.5 ± 44.0	152.6 ± 52.3	.128
Aortic cross-clamp time, min	73.0 ± 5.2	107.3 ± 56.3	.149	102.5 ± 22.9	103.7 ± 28.7	.919
Intraoperative blood product use, units	1.8 ± 2.0	1.8 ± 2.2	.939	2.7 ± 3.4	2.5 ± ± 2.6	.904
Estimated blood loss, mL	476 ± 391	525 ± 542	.835	589 ± 608	492 ± 482	.644

*Data are presented as n (%) or the mean ± SD. Statistically significant *P* values (< .05) are in boldface. LIMA, left internal mammary artery; LAD, left anterior descending coronary artery, CPB, cardiopulmonary bypass. Other abbreviations are expanded in the footnote to Table 1.

Table 3. Postoperative Results*

Postoperative Characteristics	MVR/CABG			AVR/CABG		
	MINI (n = 6)	Sternotomy (n = 34)	*P*	MINI (n = 6)	Sternotomy (n = 70)	*P*
Postoperative blood product use, units	1.0 ± 1.1	3.1 ± 5.9	.397	3.7 ± 8.0	2.4 ± 4.3	.541
Intubation time, h	18 ± 4	52 ± 106	.443	29 ± 14	82 ± 335	.701
Reoperation for bleeding/tamponade, n (%)	0	4 (11.8)	—	0	7 (10.0)	—
Deep sternal infection, n (%)	0	0	—	0	0	—
Leg infection, n (%)	0	2 (5.9)	—	0	1 (1.4)	—
Septicemia, n (%)	1 (16.7)	1 (2.9)	0.280	0	3 (4.3)	—
Postoperative stroke, n (%)	0	0	—	0	3 (4.3)	—
Prolonged ventilation, n (%)	2 (33.3)	7 (20.6)	.602	2 (33.3)	21 (30.0)	1.000
Pneumonia, n (%)	0	5 (14.7)	—	0	6 (8.6)	—
Renal failure, n (%)	0	3 (8.8)	—	0	7 (10.1)	—
Atrial fibrillation, n (%)	2 (33.3)	14 (41.2)	1.000	4 (66.7)	25 (35.7)	.194
Mortality, n (%)	1 (16.7)	4 (11.8)	1.000	0	9 (12.9)	—
ICU stay, h	136 ± 30	163 ± 185	.724	170 ± 150	169 ± 284	.993
Length of stay, d	7 ± 2	10 ± 7	.308	8 ± 6	9 ± 11	.833
Discharge location						
Home	2 (33.3)	18 (52.9)	.661	4 (66.7)	35 (50.0)	.675
Nursing home	3 (50.0)	10 (29.4)	.369	1 (16.7)	20 (28.6)	1.000
Rehabilitation	0	2 (5.9)	—	1 (16.7)	7 (10.0)	1.000

*Data are expressed as n (%) or the mean ± SD. ICU indicates intensive care unit. Other abbreviations are expanded in the footnote to Table 1.

minimally invasive group underwent annuloplasty; the other half underwent mitral valve replacement (Table 4).

Table 3 summarizes data for postoperative courses and 30-day readmissions. Two patients remained ventilated for more than 24 hours. Times to extubation were lower in the minimally invasive group, but the difference was not statistically significant (18 ± 4 hours versus 52 ± 106 hours, *P* = .443). The 1 hospital death (postoperative day 6) in the group that underwent surgery with the minimally invasive approach was due to gastrointestinal complications and multiorgan dysfunction. Two patients went home and 3 patients were discharged to nursing homes.

Minimally invasive AVR/CABG. There were no conversions to median sternotomy, and all patients received a bypass of the LIMA to the left anterior descending coronary artery (LAD). Five patients underwent additional saphenous vein bypasses (mean, 1.2 ± 0.7 bypasses via MICS versus 1.7 ± 1.0 bypasses via sternotomy; *P* = .2273). The mean CPB time was greater in the minimally invasive group than in the sternotomy group (186.5 ± 44.0 minutes versus 152.6 ± 52.3 minutes, *P* = .128), and similar results were obtained for the surgical operative time (mean, 7 ± 1 hours versus 5 ± 1 hours; *P* = .0001). Aortic cross-clamp times were comparable to those for sternotomy surgeries as the cross-clamp was applied before the proximal anastomosis of the saphenous vein from the right thoracotomy access (102.5 ± 22.9 minutes versus 103.7 ± 28.7 minutes, *P* = .9186). The 2 groups were comparable with respect to the use of blood products intraoperatively (Table 2).

Postoperative courses and 30-day readmissions are compared in Table 3. There was a greater need for blood products in the minimally invasive group (3.7 ± 8 units versus 2.4 ± 4.3 units, *P* = .5411). The times to extubation in the minimally invasive group (29 ± 14 hours) were comparable to those in the sternotomy group (82 ± 335 hours, *P* = .701). The hospital

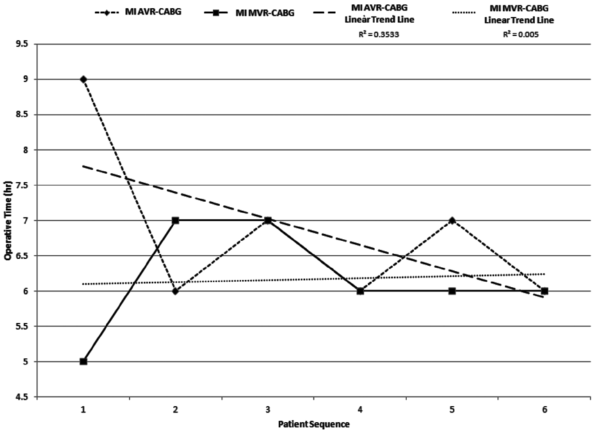

Figure 1. Operative times for minimally invasive aortic valve replacement/coronary artery bypass grafting (MI AVR/CABG) (- - - -) and minimally invasive mitral valve repair/replacement/CABG (MI MVR/CABG) (—■—) are plotted in patient operative sequence. Also shown are linear trend lines for MI AVR/CABG (–, r^2 = 0.3533) and MI MVR/CABG (⋯⋯, r^2 = 0.005).

Table 4. Perioperative Clinical Features of 12 Patients Undergoing Bilateral Thoracotomy for Minimally Invasive Valve Surgery and Minimally Invasive Coronary Artery Bypass Grafting (CABG)*

Patient No.	Age, y	Sex	Surgical Priority	Surgery Type†	No. of Diseased Vessels	LIMA-LAD	Bypass Location	Valve Surgery	Cannulation Method	CPB, min	Aortic Cross-Clamp Time, min	Operation Time, h	Length of Stay, d	Discharge
1	77	M	Urgent	AVR/CABG	3	Yes	Diagonal, OM1	R	FA/FV	258	90	9	6	Home
2	78	M	Elective	MVR/CABG	1	Yes	—	A	FA/FV	144	76	5	4	NH
3	69	M	Urgent	MVR/CABG	2	Yes	OM2	A	FA/FV	107	67	7	9	NH
4	65	M	Elective	AVR/CABG	1	Yes	—	R	FA/FV	137	103	6	4	Home
5	74	F	Urgent	MVR/CABG	3	Yes	Diagonal	A	FA/FV	133	67	7	8	Home
6	77	M	Elective	AVR/CABG	1	Yes	RCA	R	FA/FV	202	148	7	5	Home
7	80	M	Urgent	AVR/CABG	3	Yes	RI	R	LScA/FV	183	93	6	20	NH
8	82	M	Urgent	MVR/CABG	3	Yes	RI	R	FA/FV	102	73	6	8	NH
9	78	M	Urgent	MVR/CABG	2	Yes	OM	R	LScA/FV	184	75	6	6	Death
10	77	M	Elective	MVR/CABG	2	Yes	RPL	R	FA/FV	182	80	6	5	Home
11	84	M	Elective	AVR/CABG	3	Yes	PLB	R	FA/FV	144	88	7	6	Rehab
12	75	F	Elective	AVR/CABG	2	Yes	OM1	R	FA/FV	195	93	6	5	Home

*LIMA-LAD indicates graft of left internal mammary artery to left anterior descending coronary artery; CPB, cardiopulmonary bypass; AVR, aortic valve replacement; OM1, first obtuse marginal coronary artery; R, replacement; FA, femoral artery; FV, femoral vein; MVR, mitral valve repair/replacement; A, annuloplasty; NH, nursing home; OM2, second obtuse marginal coronary artery; RCA, right coronary artery; RI, ramus intermedius coronary artery; LScA, left subclavian artery; RPL, right posterolateral branch of the right coronary artery; PLB, posterior lateral branch.

†Bilateral thoracotomy approach.

mortality rate was 0%. Four patients were discharged home, and 2 patients were discharged to rehabilitative service and a nursing home.

Postoperative Characteristics

The mean intubation time postoperatively was 18 hours in the MVR/CABG group and 29 hours in the AVR/CABG group; no one required reintubation. One patient remained intubated for 45.9 hours for transient postoperative hypoxemia and hemodynamic instability. There were no cases of reoperation, wound infection, stroke, respiratory failure, renal failure, or myocardial infarction. Two MVR/CABG patients had a unilateral pleural effusion, and 2 AVR/CABG patients had bilateral effusions.

Six patients developed postoperative atrial fibrillation, and all were converted to sinus rhythm with amiodarone. One patient in the AVR/CABG group developed deep vein thrombosis.

Figure 1 shows the surgical times for each minimally invasive surgery. The linear trend line for minimally invasive AVR/CABG surgeries ($r^2 = 0.3533$) has a negative slope for the surgical times after the first case, which ranged between 6 and 7 hours. Because the r^2 value is <0.4, a larger sample size is required to further evaluate the trend. The linear trend line for the minimally invasive MVR/CABG surgeries ($r^2 = 0.005$) has a slope of zero. The first patient in this series underwent surgery after the first bilateral minimally invasive AVR/CABG and was a single-vessel graft (LIMA-to-LAD) without venous conduits and with MVR annuloplasty (Table 4). Thus, the range of surgical times after the first case is comparable to that of minimally invasive AVR/CABG. The r^2 value is <0.4; again, a larger sample size is necessary to evaluate the trend further.

Intermediate-Term Follow-up

Two patients presented to the emergency department during the follow-up period. One MVR/CABG patient was

Figure 2. Surgical field. Aortic cross-clamp via the left thoracotomy during aortic valve replacement/coronary artery bypass grafting cases (black arrow).

readmitted on postoperative day 15 for congestive heart failure requiring left thoracentesis. The second MVR/CABG patient presented to the emergency department with bleeding from the surgical site that was related to Coumadin (warfarin) treatment.

Figure 2 shows the surgical field, and Figure 3 shows the appearance at week 7 of the surgical scars on patient 4, who had undergone minimally invasive AVR/CABG. No deaths, additional surgeries, or interventions in the study group were reported.

DISCUSSION

MICS provides new options for the treatment of cardiac pathology, the potential benefits being decreased pain, a shortened hospitalization time, and elimination of the complications associated with median sternotomy. We discovered unanticipated technical advantages with this technique. Bilateral thoracotomies increase both exposure and the ability to use instruments applied from the contralateral incision, thus decreasing their interference with the operative field (eg, application of the aortic cross-clamp via the left thoracotomy in MVR cases). In addition, the proximal bypass anastomoses were created via the right thoracotomy during AVR cases, rather than via the standard left-sided approach used during an isolated MICS-CABG.

Surgical times were longer in the minimally invasive AVR/CABG group than in the sternotomy group, the use of saphenous vein grafts was significantly lower in the minimally invasive MVR/CABG group (*P* = .010), and CPB times were longer in the minimally invasive AVR/CABG group. Comparable results were seen in the minimally invasive MVR/CABG group with respect to surgical times, CPB times, and intraoperative transfusions, compared with the sternotomy subgroup. Operation times should continue to decrease as experience and familiarity with the particular steps of the procedure increase. Aortic cross-clamp times were comparable for the minimally invasive AVR/CABG and sternotomy AVR/CABG groups but were lower in the minimally invasive MVR/CABG group than in the sternotomy MVR/CABG group. There was a trend toward decreased mechanical ventilator times compared with the sternotomy group. The mean length of stay decreased by 1 day in the minimally invasive AVR/CABG group and by 3 days in the minimally invasive MVR/CABG group.

Additionally, the minimally invasive approach avoids the potential for sternal nonunion and deep sternal infection and minimizes the risk of subsequent mediastinitis (Grossi 1999, 2001). The decreased intubation time in the minimally invasive group compared with the open-surgery group may be attributable in part to the improved ventilatory mechanics provided by maintaining sternal integrity (Grossi 1999). Patients who are elderly, steroid dependent, deconditioned, and debilitated may benefit the most from a minimally invasive approach. The procedure requires selection criteria for optimal surgical benefit and satisfactory patient outcomes.

Figure 3. Patient 4 at 7 weeks after combined minimally invasive aortic valve replacement and coronary artery bypass grafting.

MICS-CABG combined with MIVS for aortic and mitral pathology is a viable treatment option for select patients. Although severe pulmonary disease had previously been listed as a relative contraindication to MICS-CABG, we believe that these patients may be the most likely to benefit from the maintenance of sternal integrity.

Limitations

Our limited sample size precludes us from making generalizations of statistical significance for comparing minimally invasive combined valve/CABG surgeries performed via sternotomy. Despite the disparity between the number of sternotomy cases and minimally invasive cases, comparison was made to ensure that the results of the newer approach were not inferior to those of the standard operation. Another limitation was patient selection. Patients undergoing emergency operations and patients with multiple, significant comorbidities were not candidates for a minimally invasive approach. Total operative times for the bilateral thoracotomy approach were difficult to compare. One would expect operative times to decrease with progression through the learning curve. Unfortunately, hospital policy changed during the course of this patient series such that a minimally invasive cardiac procedure was not recorded as finished until an intraoperative chest radiograph was taken and read to confirm the absence of retained sponges, regardless of the nurses' recorded sponge counts. In reality, the actual "skin-to-skin" time did decrease as experience increased.

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