Conversion to full sternotomy during minimal-access cardiac surgery: Reasons and results during a 9.5-year experience

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Objective: A hemisternotomy approach to minimal-access cardiac surgery is associated with a faster postoperative recovery because of reduced postoperative pain and improved respiratory function. Conversion to a full sternotomy is occasionally required for reasons that remain inadequately reported.

Methods: Between January 1996 and June 2005, 907 cardiac surgical patients were planned for an upper hemisternotomy and 528 for a lower hemisternotomy. We retrospectively reviewed 45 patients who required conversion to a full sternotomy.

Results: Twenty-four (2.6%) of 907 patients required a conversion from upper hemisternotomy because of bleeding ($n = 8$), ventricular dysfunction ($n = 5$), refractory ventricular arrhythmia ($n = 3$), poor exposure ($n = 2$), and other causes ($n = 6$). Eight (33.3%) of 24 patients died perioperatively. Of the 883 patients who went on to have an operation through the upper hemisternotomy approach, the mortality was 1.7% (15/883). Twenty-one (4.0%) of 528 patients required conversion from a lower hemisternotomy because of poor exposure ($n = 16$), bleeding ($n = 1$), refractory ventricular arrhythmia ($n = 3$), and a retained venous cannula ($n = 1$). None of these patients died postoperatively. Of the 507 patients who went on to have an operation through the lower hemisternotomy approach, the mortality was 1.2% (6/507).

Conclusion: Conversion to a full sternotomy occurs infrequently during minimal-access cardiac surgery. Upper hemisternotomy conversions are usually urgent after crossclamp removal and are often associated with serious morbidity and mortality. Conversely, lower hemisternotomy conversions are performed electively in the prebypass period because of poor exposure and are not associated with complications.

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Minimal-access cardiac surgery was introduced in the 1990s^{1,2} and is becoming an accepted procedure. Minimal-access cardiac surgery reduces surgical invasiveness, increases patient satisfaction, and is a better use of health care resources. Studies have shown that minimal-access cardiac surgery is associated with a shorter length of hospital stay, earlier extubation, and less blood loss or less blood transfusion requirement compared with conventional cardiac surgery.²⁻⁷

An upper hemisternotomy is the most common minimal-access approach for aortic valve, ascending aortic, arch, and root surgery. This approach can also be used for subaortic myectomy and mitral valve and tricuspid valve surgery. Lower hemisternotomy is another useful approach for mitral valve surgery, tricuspid valve surgery, and a few other cardiac operations. In the vast majority of patients, these approaches lead to the successful performance of the planned surgical procedure.

Abbreviation and Acronym

CPB = cardiopulmonary bypass

Occasionally, conversion to a full sternotomy is required for reasons that have not been well investigated or reported yet.

Our group performs an upper hemisternotomy for aortic valve, ascending aortic, arch, root, and subaortic surgery. A lower hemisternotomy is done for mitral valve surgery, tricuspid valve surgery, excision of left atrial myxomas, atrial septal defect repair, and patent foramen ovale repair. We retrospectively reviewed the intraoperative rationale for converting from an upper or lower hemisternotomy to a full sternotomy during our 9.5-year experience.

Materials and Methods**Patient Data**

Between January 1996 and June 2005, 907 cardiac surgical patients were planned for an upper hemisternotomy and 528 for a lower hemisternotomy. We retrospectively reviewed 45 patients who required conversion to a full sternotomy. Our definition for a conversion in this series was any intraoperative conversion from a partial sternotomy to a full sternotomy. All preoperative data, in-hospital outcomes, and postdischarge outcomes were collected from patient medical records and the Brigham and Women's Hospital cardiac surgery database according to The Society of Thoracic Surgeons definitions. This study was approved by the institutional review board of Brigham and Women's Hospital (protocol no. 2005-P-001686). Values of continuous variables are expressed as means $\pm$ standard deviations.

Surgical Procedure

All patients receive external defibrillator pads and undergo a transesophageal echocardiogram in the operating room.

An upper hemisternotomy incision is 6 to 8 cm long. The sternum is divided from the sternal notch down to the level of the fourth intercostal space with a regular sternal saw and then extended toward the right fourth intercostal space with an oscillating saw. Three retraction stitches are placed on the right edge of the pericardium and 1 at the top left corner. These are anchored to the subcutaneous tissue. Cardiopulmonary bypass (CPB) is established by means of direct ascending aortic or peripheral arterial cannulation and percutaneous femoral venous or direct right atrial cannulation. A retrograde cardioplegia cannula is placed into the coronary sinus through the right atrial appendage with the guidance of transesophageal echocardiography. A left ventricular vent is placed through the right superior pulmonary vein, when necessary. This approach is also used in reoperative surgery.⁸

A lower hemisternotomy incision is also 6 to 8 cm long. The sternum is divided from the base of the xiphoid process up to the level of the second intercostal space with the regular sternal saw and then extended toward the right second intercostal space with an oscillating saw. Three retraction stitches are placed on the right edge of the pericardium and 1 at the top left corner. These are anchored to the subcutaneous tissue. Both top stitches are placed

near the pericardial reflection for better exposure of the aorta; the other 2 stitches on the right pericardium are placed deep for better exposure of the mitral valve. CPB is established by means of direct ascending aortic cannulation and percutaneous femoral venous or direct bicaval cannulation. This approach is not used for reoperative surgery.

All procedures were performed without endoscopic or robotic assistance. Our detailed strategies for minimal-access cardiac surgery have been published before.³

Results**Conversion From Upper Hemisternotomy**

Twenty-four (2.6%) of 907 patients required conversion from an upper hemisternotomy (group US). These patients were converted because of bleeding ($n = 8$), ventricular dysfunction ($n = 5$), refractory ventricular arrhythmia ($n = 3$), poor exposure ($n = 2$), epicardial pacing wire placement in reoperative surgery ($n = 1$), a protamine reaction ($n = 1$), intraoperative change in the operative plan ($n = 1$), paravalvular leak ($n = 1$), undiagnosed pericarditis requiring pericardiectomy ($n = 1$), and pericardial clot evacuation ($n = 1$). Patient characteristics, diagnoses, performed procedures, and reasons for conversion in group US are shown in Table 1.

Conversion From Lower Hemisternotomy

Twenty-one (4.0%) of 528 patients required conversion from a lower hemisternotomy (group LS). These patients were converted because of poor exposure ($n = 16$), bleeding ($n = 1$), refractory ventricular arrhythmia ($n = 3$), and a retained venous cannula ($n = 1$). Patient characteristics, diagnoses, performed procedures, and reasons for conversion in group LS are shown in Table 2.

Operative Outcome

Of the 883 patients who went on to have their operations through the upper hemisternotomy, the mortality rate was 1.7% (15/883). However, 8 (33.3%) of 24 patients in group US (who were converted to a full sternotomy) died perioperatively. Four of them were converted for ventricular dysfunction, 2 for bleeding, and 1 each for epicardial pacing wire placement and pericardial clot evacuation. Three (12%) patients had reoperations for bleeding, and 4 (16%) patients had deep sternal wound infections.

Of the 507 patients who went on to have their operations through the lower hemisternotomy, the mortality rate was 1.2% (6/507). None of the patients in group LS (who were converted to full sternotomy) died postoperatively. One (4.5%) patient had a sterile sternal dehiscence. There were no other complications in this group.

Discussion

This is the first documented report of conversions from partial sternotomy to full sternotomy in minimal-access cardiac sur-

TABLE 1. Conversions from upper hemisternotomy to full sternotomy

Patient no.	Age (y)	Sex	Diagnosis	Primary procedure	Reason for conversion
1	86	M	AS	AVR	Coronary sinus perforation during placement of retrograde cardioplegia cannula
2	73	F	AS, AI	AVR	Coronary sinus perforation during placement of retrograde cardioplegia cannula
3	82	F	AS	AVR	RA perforation during placement of retrograde cardioplegia cannula
4	85	F	AS	AVR	Bleeding from RAA cannulation site after decannulation
5	89	M	AS, s/p CABG, patent LITA and vein grafts	Reoperative AVR	RV tear from pacing wire
6	81	F	AS	AVR	RV tear from pacing wire
7	69	F	AS	AVR	Hypotension caused by bleeding from femoral arterial catheterization site
8	60	F	AS, TR	AVR, TVP	Hypotension caused by iliac vein laceration from percutaneous venous cannulation
9	75	F	AS	AVR	RV failure requiring CABG to the right coronary artery
10	60	F	AS	AVR	LV failure requiring LVAD implantation
11	73	M	AS, s/p CABG, patent LITA and vein grafts	Reoperative AVR	RV failure requiring CABG to the right coronary artery
12	69	F	AS	AVR	LV failure requiring second CPB run after decannulation and IABP
13	54	M	AI, ascending aortic aneurysm	Aortic root replacement (composite valve graft)	Biventricular failure requiring CABG and then BIVAD implantation
14	68	F	AS	AVR	Refractory VF requiring internal defibrillation
15	84	M	AS, s/p CABG, patent LITA and vein grafts	Reoperative AVR	Refractory VF requiring internal defibrillation
16	73	F	AS	Aortic root replacement (stentless bioprosthetic valve)	Refractory VF requiring internal defibrillation
17	78	M	AS, s/p CABG, patent LITA and vein grafts	Reoperative AVR	Poor exposure of aortic valve
18	65	M	AS	AVR	Poor exposure of aortic valve
19	81	F	Aortic arch aneurysm	Reoperative patch repair of arch aneurysm	Failure of transvenous pacing requiring epicardial pacing wire
20	67	F	AS	AVR	Hypotension after protamine reaction requiring second CPB run
21	67	F	AS	Aortic root replacement (stentless bioprosthetic valve)	Change in procedure from mechanical valve implantation to stentless bioprosthetic valve
22	88	M	AS	AVR	Perivalvular leak requiring repeat CPB run, 3 times
23	85	F	AS	AVR	Requirement of pericardiectomy for CPB wean
24	77	F	AS	AVR	Old clot in the pericardial space requiring exploration

AS, Aortic stenosis; AVR, aortic valve replacement; AI, aortic insufficiency; RA, right atrium; RAA, right atrial appendage; s/p, status post; CABG, coronary artery bypass grafting; LITA, left internal thoracic artery; SVG, saphenous vein graft; RV, right ventricle; TR, tricuspid regurgitation; TVP, tricuspid valve repair; LV, left ventricle; LVAD, left ventricular assist device; CPB, cardiopulmonary bypass; BIVAD, biventricular assist device; VF, ventricular fibrillation.

gery. An upper hemisternotomy has been shown to be a safe and effective approach.³⁻⁷ A lower hemisternotomy has not been reported as often as an upper hemisternotomy; however, Greulich and colleagues⁹ have demonstrated excellent outcomes in a series of minimally invasive mitral valve repairs

using this approach. Doty and associates¹⁰ have reported 112 cases of valve surgery with a lower hemisternotomy approach, including double- and triple-valve operations.

In our series the incidence of converting an upper hemisternotomy was 2.6%, which is low and comparable with a

Table 2. Conversions from lower hemisternotomy to full sternotomy

Patient no.	Age (y)	Sex	Diagnosis	Primary procedure	Reason for conversion
1	48	F	MS, MR, PFO	MVP, PFO	Poor exposure of aorta
2	69	M	MR	MVP	Poor exposure of aorta
3	73	M	MR, mitral valve endocarditis	MVP	Poor exposure of aorta
4	56	F	MR, TR	MVP, TVP	Poor exposure of aorta (severe scoliosis)
5	54	F	MR	MVP	Poor exposure of aorta (pericardial adhesions)
6	65	M	MR, TR, RA tumor	MVP, TVP, RA tumor resection	Poor exposure of aorta (pericardial adhesions)
7	69	F	MR, ASD	MVP, ASD	Poor exposure of mitral valve
8	41	M	MR	MVP	Poor exposure of mitral valve
9	41	M	MR	MVP	Poor exposure of mitral valve
10	47	M	MR, TR, PFO	MVP, TVP, PFO	Poor exposure of mitral valve
11	47	M	ASD	ASD	Poor exposure of mitral valve
12	39	M	MR	MVP	Poor exposure of mitral valve
13	85	F	MR	MVP	Poor exposure of mitral valve
14	45	M	MR	MVP	Poor exposure of mitral valve
15	42	F	MR	MVP	Poor exposure of mitral valve
16	37	F	MR	MVP	Poor exposure of mitral valve
17	63	F	MR	MVP	Refractory VF requiring internal defibrillation
18	44	M	MR	MVP	Refractory VF requiring internal defibrillation and IABP
19	44	M	MR, PFO	MVP, PFO	Refractory VF requiring internal defibrillation
20	53	M	MR	MVP	Retention of femoral venous cannula requiring second CPB run
21	70	F	MR	MVP	SVC perforation from internal jugular venous cannula

MS, Mitral stenosis; MR, mitral regurgitation; PFO, patent foramen ovale; MVP, mitral valve repair; TR, tricuspid regurgitation; TVP, tricuspid valve repair; RA, right atrium; ASD, atrial septal defect; VF, ventricular fibrillation; IABP, intra-aortic balloon pump; CPB, cardiopulmonary bypass; SVC, superior vena cava.

previously reported study's conversion rate of 2.4%.¹¹ Intriguingly, conversion because of poor exposure was necessary in only 2 (0.2%) patients. The upper hemisternotomy provides excellent exposure of the aortic valve, root, ascending aorta, and arch.

Bleeding was the most common indication for conversion from the upper hemisternotomy. We recommend attention to the following technical details to avoid such a problem. A retrograde cardioplegia cannula can be placed through the right atrial appendage with transesophageal echocardiographic guidance; however, it is more difficult through an upper hemisternotomy than a full sternotomy. As a consequence, we recommend that should there be any difficulty in placing a retrograde cardioplegia cannula (particularly in elderly patients with friable tissues), the placement should be aborted or deferred until after an elective conversion to a full sternotomy. Temporary ventricular pacing wire placement on the anterior or inferior surface of the right ventricle is challenging in the upper hemisternotomy approach. We recommend that this maneuver be done very carefully on a decompressed heart during CPB. Alternatively, pulmonary arterial catheters with pacing capabilities can also be used, especially in reoperative minimal-access

surgery through an upper hemisternotomy, where exposure of the right ventricular free wall can be difficult.

Ventricular dysfunction was the next most common indication for conversion from an upper hemisternotomy. In the 2 patients with right heart failure, hemodynamics improved after bypass grafting to the right coronary system that was previously deemed unnecessary. One patient with left ventricular dysfunction was salvaged after additional rest on CPB and the insertion of an intra-aortic balloon pump. One patient each with left and biventricular failure required a left and biventricular assist device, respectively. Although myocardial protection techniques were the same in these patients as with the full sternotomy approach, ventricular dysfunction resulted because of unclear reasons. We cannot emphasize enough the importance of good myocardial protection. We use a combination of antegrade, retrograde, and direct coronary cold blood cardioplegia at 8°C administered every 20 minutes.

Appropriate and accurate positioning of external defibrillator pads is important. Occasionally, pediatric defibrillator paddles can be introduced through an upper hemisternotomy incision. In all patients with refractory ventricular fibrillation, successful cardioversion was achieved after conversion.

The lower hemisternotomy conversion rate was 4.0% (21/528). To our knowledge, there have not been any reports of conversions to full sternotomy from a lower hemisternotomy in the literature. The most common reason for a conversion was poor exposure of the aorta or the mitral valve ($n = 16$). Although conversion is recommended in these cases, axillary or femoral cannulation might be another option¹² when the aorta is not well visualized. Generally, obesity, deep chests, and small left atria make exposure challenging through this approach. In such patients we now perform a full sternotomy with a smaller skin incision. The shape of the thorax (eg, the depth of the thorax and the length of the sternum), anteroposterior and lateral views of a chest radiograph, and an echocardiogram need to be carefully examined before determining the incision. To reiterate, after a partial sternotomy, pericardial traction stitches are critical in providing a good exposure for the surgeon.

Once again, as with the upper hemisternotomy approach, appropriate and accurate positioning of the external defibrillator pads is important. Occasionally, pediatric defibrillator paddles can be introduced through a lower hemisternotomy incision.

One patient was converted to a full sternotomy after perforation of the superior vena cava during insertion of a percutaneous venous cannula through the right internal jugular vein. We have now abandoned this technique. When the venous drainage is inadequate with a percutaneous femoral venous cannula, an additional cannula is directly placed into the superior vena cava through the incision.

In group LS operative mortality was zero. One patient had a sterile sternal dehiscence. There were no other complications.

It is difficult to determine predictors of conversion in this series because there is a spectrum of causes for conversion, and the number in each category is too small for statistical significance. Nevertheless, this experience has provided us with lessons that have optimized our efficacy and safety when performing minimal-access cardiac surgery.

In conclusion, conversion from a partial sternotomy to a full sternotomy occurs infrequently during minimal-access

cardiac surgery. Conversion from an upper hemisternotomy for various reasons, most of which are emergencies, such as bleeding, refractory arrhythmias, and ventricular dysfunction, can be associated with serious morbidity and mortality. Conversely, lower hemisternotomy conversions are performed electively because of poor exposure and are not associated with complications. Several technical maneuvers outlined in this article can help reduce the incidence of such conversions. Although minimal-access valve surgery is quite safe in centers with a large body of experience, readers are encouraged to fully understand the complexities involved before undertaking such procedures.

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