Prospective Randomized Study of Early Pulmonary Evaluation of Patients Scheduled for Aortic Valve Surgery Performed by Ministernotomy or Total Median Sternotomy

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Objective: **The purpose of this study was to compare the respiratory function of patients operated either with a ministernotomy or with a conventional sternotomy for an aortic valve replacement.**

Design: **A prospective randomized study.**

Setting: **A single-institution university hospital.**

Participants: **Seventy-eight patients scheduled for aortic valve replacement.**

Interventions: **Patients were assigned to have minimal sternotomy access (ministernotomy) or conventional median total sternotomy. Pulmonary function was measured using a mobile respiratory spirometric device preoperatively and after 1 (POD1), 2 (POD2), and 7 days (POD7) postoperatively.**

Measurements and Main Results: **There was no significant difference in any respiratory parameter measured between the 2 groups of patients. Almost all respiratory volumes decreased significantly with the same intensity in the 2 groups on POD1 ($p < 0.05$), by about 50% from baseline. Only functional residual capacity was unchanged from baseline in the postoperative period, except for a small but significant reduction of this parameter to 60.3% ± 27.4% in the standard sternotomy group on POD1 and 60.9% ± 27.1% and 58.8% ± 30.4%, respectively, in the ministernotomy and the standard group at POD7. The only significant difference concerned the intraoperative blood loss measured at 450 ± 280 mL and 720 ± 450 mL, respectively, in the ministernotomy and the standard group ($p < 0.05$), but this was not significantly associated with a reduction of total blood use.**

Conclusion: **This study failed to show any improvement of respiratory function by a smaller chest incision. However, it showed a significant reduction in intraoperative bleeding but without a reduction in transfusion. Further investigations are required to assess whether this procedure could improve the outcome of cardiac surgery patients with a greater predicted risk score or pulmonary diseases.**

KEY WORDS: aortic valve, cardiopulmonary bypass, heart valve prosthesis implantation, postoperative complications, prospective studies, sternum, surgical procedures, minimally invasive, cardiac surgery, lung volume measurements, postoperative hemorrhage

AORTIC VALVE REPLACEMENT leads to functional improvement with left ventricular reverse remodeling within 6 months after surgery.[1] However, regardless of the type of surgery, median total sternotomy is associated with a substantial reduction in lung volume that persists even after a few months of rehabilitation, thereby compromising the outcome of aortic valve surgery. The mechanisms of this deterioration are not understood clearly but may include chest wall restriction, decreased diaphragm course, or diffusion impairment.[2,3] Total median sternotomy also contributes to increased postoperative bleeding and pain. By reducing the size of the sternotomy, minimally invasive surgery for aortic valve disease aims to improve outcomes and, especially, pulmonary function. However, evidence of this improvement is sparse and conflicting in the literature. Only one study in 2002 by Bonacchi et al[4] showed postoperative beneficial effects of ministernotomy on spirometric pulmonary function data at 5 days after an aortic valve surgery, but only on pulmonary volumes and not on forced expiration volume at the first second (FEV_1) or any other parameter. These results were not confirmed by an earlier study using ministernotomy for coronary artery bypass.[5] All these studies evaluated respiratory performance 1 week after surgery, but no data are available for the immediate postoperative period concerning a reduction in sternal incision length. The duration of rehabilitation after surgery is probably related to this decrease in pulmonary function, but also may be related to other events like inflammation, bleeding, and pain.

The main objective of the present study was to compare respiratory parameters of patients scheduled for aortic valve surgery performed either by total median sternotomy or ministernotomy and secondarily to evaluate bleeding, transfusion, and pain status.

MATERIAL AND METHODS

From 2003 to 2007, 78 patients scheduled for aortic valve replacement (75% for aortic valve stenosis, 24% for aortic valve regurgitation, and 1% for aortic valve disease) were randomized to receive minimal sternotomy access (MS) or conventional access (ST) in a 1:1 ratio according to a computer-generated randomization system with a 6-per-block design. The randomization list was drawn up by the statistician. Numbered sealed envelopes were placed at the surgeon's disposal in the operating room. The surgeon was the only one who randomized the patients. The inclusion criteria for participation were any patient over 18 years old, strictly less than or equal to American Society of Anesthesiologists (ASA) 3 (severe systemic but not incapacitating disease), providing informed signed consent,

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Table 1. Preoperative Patient Characteristics

Variable	Minimal Access (MS) (n = 38)	Conventional Access (ST) (n = 39)
Male sex (%)	23 (60.5)	27 (69.2)
Age (y)	70.9 ± 11.4	70.8 ± 10.2
Weight (kg)	73.1 ± 14.9	75.3 ± 15.0
Height (cm)	165.6 ± 8.4	166.9 ± 8.7
LVEF (>50%) (%)	36 (94.7)	34 (87.2)
Obesity (BMI ≥30) (%)	6 (15.8)	9 (23.1)
EuroSCORE	5.4 ± 1.9	5.2 ± 1.8

NOTE. Continuous variables are expressed as mean ± standard deviation.

Abbreviations: LVEF, left ventricular ejection fraction; BMI, body mass index.

and having left ventricular ejection fraction above 40%. Exclusion criteria were redo, combined surgery, ASA score more than or equal to 4, acute pulmonary edema, chronic obstructive pulmonary disease (COPD), endocarditis, chronic renal failure, antiplatelet discontinuation less than 7 days before surgery, and no known hemostatic abnormality. This monocentric prospective study was performed thanks to national hospital clinical research project funding by the French Ministry of Health (PHRC[6]) and after approval by the local ethical committee (Comité de Protection des Personnes, CHU Bordeaux, Bordeaux, France). Thirty-nine patients were randomized to receive MS and 39 to ST. Finally, 38 were allocated to the ST group (1 patient was excluded for nonconformity on the consent form) and 39 to the MS group.

All patients received the same anesthetic regimen and normothermic cardiopulmonary bypass (CPB) management. The anesthetic regimen was based on target-controlled infusion of propofol and remifentanil (STANPUMP Program, S. Shafer, Stanford University, Palo Alto, CA). Patients were intubated and ventilated with a neuromuscular blockade achieved by cisatracurium that was interrupted at sternal closure time with steel wires. They received preoperative prevention of postoperative excessive fibrinolysis by aprotinin at the incision and immediately before beginning CPB. CPB anticoagulation was achieved by 300 U/kg of unfractionated heparin to reach an anticoagulation time (ACT kaolin) of 400 seconds, which was reversed after CPB termination with protamine sulfate (ratio 1:1). The authors noted the amount of intraoperative blood lost by surgical suction including that stored in compresses and drapes that were evaluated by weighing. Total amounts of postoperative blood loss by chest-drainage system, infusions, and transfusions were noted. Conventional CPB was primed by a crystalloid solution. Allogeneic red blood cell transfusion was performed by the anesthesiologist to achieve a minimal hematocrit of 28% before and after CPB and 25% during CPB. Hemodynamic parameters were monitored by using a PiCCO catheter (Pulsion Medical Systems, Munich, Germany) to measure invasive arterial pressure, cardiac output, and extravascular lung water (EVLW). EVLW was determined by transpulmonary thermodilution curve on the basis of measurement data collected at the patient, with estimation of the patient's intrathoracic thermal volume (ITTV) and intrathoracic blood volume (ITBVapprox) from the transpulmonary thermodilution curve by the formula EVLW = ITTV − ITBV). Hemodynamic parameters were assessed at induction, on arrival in the intensive care unit (ICU), on postoperative day (POD) 1, and on POD2.

All patients were operated on by the same surgeon from the beginning until the end of surgery and with the same technique apart from the chest incision. In the MS group, after a 6- to 10-cm midline skin incision, the chest was opened using a reversed-L sternal incision to the 4th intercostal space. In the ST group, a midline skin incision from the sternal notch to the xiphoid appendage was made with a full-length median sternotomy. Chest closure was performed in the 2 groups using the same technique in which the sternum was consolidated edge to edge with steel wires followed by conventional skin suture.

The right atrial appendage and the ascending aorta were cannulated and connected, respectively, with the venous and the arterial catheter of the CPB. Cardioplegia was performed with Bretschneider's solution. After a standard technique of aortic valve replacement and aortotomy closure, the heart was filled and deaerated with a suction vent placed at the top of the aorta. Mediastinal drainage tubes were inserted immediately before closing the sternum with steel wire.

For both groups, multimodal analgesia was used to treat postoperative pain on a visual analog scale less or equal to 40 mm. This was obtained with 1 g of paracetamol intravenously every 6 hours and patient-controlled analgesia (PCA) with morphine infusion during the 2 planned days of stay in the ICU. A PCA pump delivered 1 mg of morphine on demand with a lockout time of 7 minutes but without continuous infusion. Lockout time was increased to 10 minutes if sedation score was more than 2 (0 = alert, 1 = sometimes drowsy/easily roused, 2 = often drowsy/easily roused, and 3 = often drowsy/difficult to rouse). After 2 hours, if the sedation score was always more than 2, PCA was stopped. Total amounts of morphine and paracetamol administered were noted. If both morphine and paracetamol doses were insufficient, a nonsteroidal anti-inflammatory drug was infused additionally (ketoprofen, 50 mg every 8 hours). Times to extubation and ICU and hospital length of stay were recorded. Patients were transfused with allogeneic red blood cells if hematocrit was less than 28%; by fresh frozen plasma if international normalized ratio (INR) was greater than 3; and by platelet concentrate if platelet count was less than 50×10^9/L.

Pulmonary function was measured or calculated by using a mobile spirometric device (Hyp'Air; Medisoft, Dinant, Belgium). Spirometry was assessed by simple volume displacement or pneumotachograph, and volumes were calculated by numeric integration. Total pulmonary capacity was measured by closed-circuit helium dilution with compensation for O_2 and CO_2 absorption. Depending on each test, concentrations of inspiratory gases were 0.29% of CO, 21% of O_2, 9.95% of He, and the balance N_2 for a total gas mixture of 1. Gases were collected in a 5-L bag during the inspiratory

Table 2. General Intra- and Postoperative Data

	Minimal Access (MS) (n = 38)	Conventional Access (ST) (n = 39)	*p* Value
CPB time (min)	77.1 ± 13.4	71.3 ± 20.4	0.15
Aortic clamp time (min)	55 ± 9.3	50.6 ± 11.9	0.1
Operation time (min)	159 ± 51.2	173.1 ± 48.8	0.1
Mechanical ventilation time (min)	375 ± 175	348 ± 228	0.19
ICU stay (d)	2 ± 0	2.04 ± 0.5	0.53
Hospital stay (d)	6 ± 0.32	6.18 ± 1.5	0,46
Complications			
SIRS (n)	0	1	—
Re-exploration for bleeding (n)	0	2	—
Death (n)	0	1	—

NOTE. Continuous variables are expressed as mean ± standard deviation.

Abbreviation: SIRS, systemic inflammatory response syndrome.

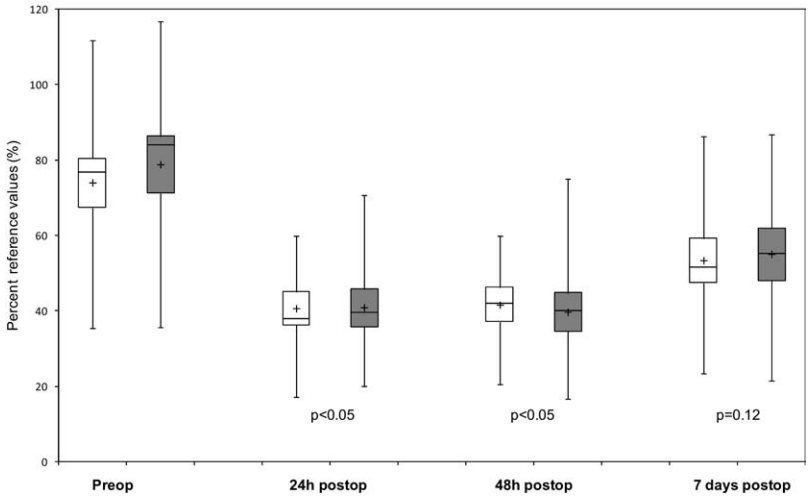

Fig 1. The FEV1 in the minimal access group (white boxes) and the conventional access group (gray boxes). The shown data are expressed in percent reference values (%); *p* values of Wilcoxon test assessed the relative changes between preoperative and each postoperative time for the pooled 2 groups. The mean is represented by +; median, first and third quartiles by the box; and minimum and maximum by the whispers.

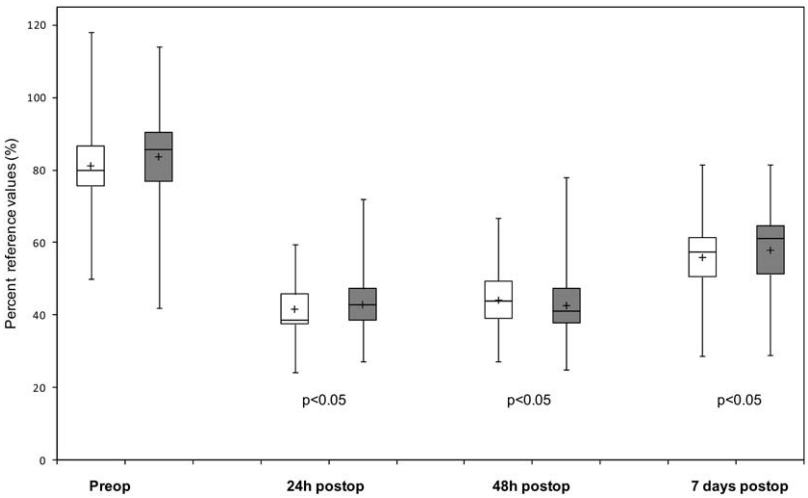

Fig 2. The FVC in the minimal access group (white boxes) and the conventional access group (gray boxes). The shown data are expressed in percent reference values (%); *p* values of Wilcoxon test assessed relative changes between preoperative and each postoperative time for the 2 groups taken together.

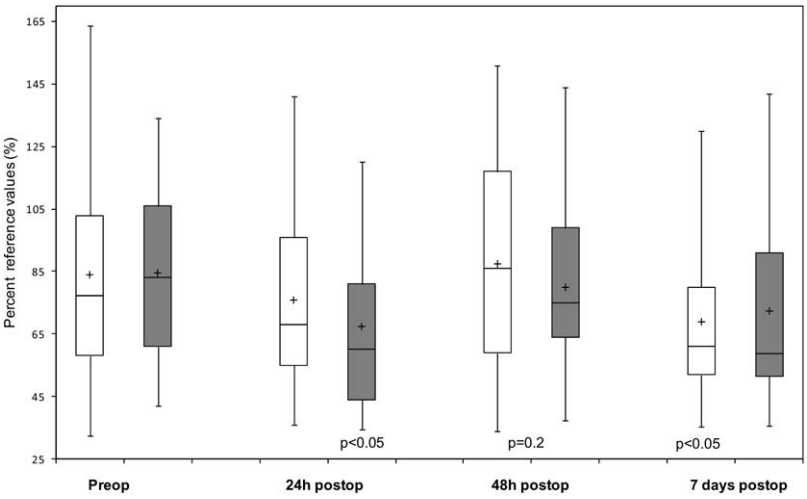

Fig 3. The postoperative evolution of FRC in the minimal access group (white boxes) and the conventional access group (gray boxes). The shown data are expressed in percent reference values (%). Mean is represented by +; median, first, and third quartiles by the box; and minimum and maximum by the whiskers; *p* values of Wilcoxon test assessed relative changes between preoperative and each postoperative time for the two groups taken together.

Table 3. Blood Gas Data and Pulmonary Measurement Preoperatively and on POD1

	Preoperatively			POD1		
	MS	ST	*p* Value	MS	ST	*p* Value
PaO_2 (mmHg)	330 ± 126	379 ± 116	0.1	132 ± 44	141 ± 58	0.44
$PaCO_2$ (mmHg)	36.3 ± 5.1	35.5 ± 4.5	0.46	42.3 ± 6.2	42.2 ± 5.7	0.94
FEV_1 (% expected)	73.9 ± 18.2	78.8 ± 21	0.27	40.7 ± 11.2	40.8 ± 13.3	0.97
FEV_1 (L/s)	1.7 ± 0.5	1.9 ± 0.5	0.1	0.98 ± 0.33	0.97 ± 0.33	0.89
FVC (% expected)	81.1 ± 16.1	83.6 ± 19.4	0.53	41.7 ± 10.1	43 ± 11.5	0.59
FVC (L)	2.5 ± 0.8	2.7 ± 0.9	0.32	1.4 ± 0.4	1.4 ± 0.4	0.71
FRC (% expected)	77.3 ± 35	83.2 ± 35.4	0.46	68 ± 33.3	60.3 ± 27.4	0.26
FRC (L)	2.5 ± 0.8	2.7 ± 0.9	0.32	2.4 ± 0.9	2.2 ± 0.8	0.3

NOTE. Continuous variables are expressed as mean ± standard deviation.

maneuver. Gas analyzers measured inspired concentrations of CO, He, NO, and O_2. Functional residual capacity was determined by the closed-circuit helium dilution method with oxygen compensation to maintain circuit volume. Carbon monoxide diffusion capacity (DLCO) was estimated by using the helium trace gas. After systematic volume and gas calibration of the lung diffusion system before each testing session, each patient enrolled in the study had a determination of tidal volume, inspiratory reserve volume, expiratory reserve volume, residual volume, forced expiratory volume in 1 second (FEV_1), forced vital capacity, and FRC. These measures were determined preoperatively and after 1 (POD1), 2 (POD2), and 7 days (POD7) postoperatively. Preoperatively, patients came to the ICU and performed the pulmonary spirometric measurements sitting upright, breathing through a single-use mouthpiece, and sealing their lips, after verifying closure of the nose with a clip. All assessments were performed by the same trained investigators. The subjects breathed through a 3-way pneumatic valve during a standardized subject procedure on every session. Measurements were performed with an instrument deadspace of 140 mL (mouthpiece, valves, and filters). Anatomic deadspace (in mL) was estimated as body weight in kilograms × 2.2. On POD1 and POD2, measurements were assessed by using the same procedures but in the ICU beside the patient's bed and in a well-tolerated sitting position. At POD7, the procedure was identical to that performed preoperatively. All measurements were computerized continuously and stored after each session in a computer for subsequent analysis.

Based on previous studies in the field, an initial sample size of 160 was required to evidence a difference of at least 7% for forced vital capacity (FVC) and 10% for FEV_1 (2-sided $\alpha = 0.05$, $1\text{-}\beta = 0.85$). Given the recruitment difficulties encountered in this trial, a formal re-estimation of sample size was made in January 2004. It showed a larger standard deviation than expected for FVC and narrower standard deviation for FEV_1 among the first patients included in the trial. These data were taken into account for a statistically appropriate re-estimation of the sample size[7] that was blinded to the outcome results. This yielded a total sample size of 254 for FVC and 78 for FEV_1.

Quantitative data were reported by their mean and standard deviation. The figures show a description of respiratory data per group at each measurement time using box and whisker plots. Qualitative data were reported by their frequency and proportion. Comparison between groups of patients was made with the Student *t* test or the nonparametric Wilcoxon test when data were not normally distributed. Comparison between preoperative and each postoperative time for the 2 pooled groups was done with the Wilcoxon test on intraindividual relative differences. Analyses were performed by using the intention-to-treat strategy with replacement of missing data by values reflecting failure (minimal value or minimal relative difference for the pooled 2 groups). All analyses were performed with SAS Software v9.1.3 (SAS Institute, Cary, NC).

RESULTS

The 2 groups of patients were comparable regarding preoperative characteristics. The cardiac preoperative risk assessed by the EuroSCORE was low and not significantly different between the 2 groups (Table 1). CPB time, aortic clamp time, and total surgery time were not different (Table 2), and all patients could be weaned from CPB without any mechanical or inotropic support.

Spirometric respiratory data analysis failed to show any difference between MS and ST groups regardless of the parameters studied. Preoperative spirometric measurements showed a reduction in the percentage of predicted value of FEV_1 (73.9% ± 18.2% and 78.8% ± 21%, respectively, in

Table 4. Blood Gas Data and Pulmonary Measurement on POD2 and POD7

	POD2			POD7		
	MS	ST	*p* Value	MS	ST	*p* Value
PaO_2 (mmHg)	106.3 ± 51.4	104.1 ± 25.5	0.81	83 ± 20	87 ± 15	0.31
$PaCO_2$ (mmHg)	38.6 ± 4.4	38.9 ± 4.2	0.76	35.4 ± 3.1	37.5 ± 4.7	0.07
FEV1 (% expected)	41.7 ± 10.9	39.7 ± 13.2	0.57	53.4 ± 15.6	55 ± 16	0.72
FEV1 (L/s)	0.97 ± 0.37	0.96 ± 0.34	0.71	1.3 ± 0.5	1.4 ± 0.5	0.75
FVC (% expected)	44.2 ± 11.4	42.8 ± 12.1	0.7	55.9 ± 14.1	57.9 ± 15.2	0.64
FVC (L)	1.4 ± 0.4	1.4 ± 0.6	0.88	1.7 ± 0.6	1.9 ± 0.7	0.67
FRC (% expected)	86.1 ± 36.1	75.1 ± 29.3	0.08	60.9 ± 27.1	58.8 ± 30.4	0.74
FRC (L)	2.8 ± 1	2.6 ± 0.8	0.27	2.3 ± 0.8	2.3 ± 1.1	0.93

NOTE. Continuous variables expressed as mean ± standard deviation.

Table 5. Postoperative Pain Evaluation and Analgesia

	POD1			POD2		
	MS	ST	*p* Value	MS	ST	*p* Value
VAS (mm)	25 ± 26	29 ± 23	0.47	16 ± 31	12 ± 19	0.49
Total morphine infusion (mg)	—	—		39.3 ± 21.2	50.2 ± 20.4	0.06
Total NSAID infusion (mg)	—	—		43.4 ± 54.1	63.1 ± 77.2	0.19

NOTE. Continuous variables expressed as mean ± standard deviation.
Abbreviations: VAS, visual analog scale; NSAID, nonsteroid anti-inflammatory drugs.

the MS and ST groups, Fig 1), of FVC (FVC 81.1% ± 16.1% and 83.6% ± 19.4%, respectively, in the MS and ST groups, Fig 2), and of FRC (FRC 77.3% ± 35% and 83.2% ± 35.4%, respectively, in the MS and ST groups, Fig 3), but the values were not significantly different between the 2 groups (Table 3). In comparison to preoperative measurements, almost all respiratory volumes decreased significantly at POD1 ($p < 0.05$) by about 50% and identical in the 2 groups (Table 3). Only FRC remained unchanged from baseline in the postoperative period, except for a significant reduction in this parameter to 60.3% ± 27.4% in the ST group at POD1 and to 60.9% ± 27.1% and 58.8% ± 30.4%, respectively, in the MS and ST groups at POD2 (Fig 3, Table 4). No significant difference in FVC was found at POD2 (44.2% ± 11.4% and 42.8% ± 12.1% of the preoperative reference value, respectively, in the MS and ST groups).

One patient developed lethal multiorgan failure in the ST group 7 days after an immediate postoperative re-exploration for bleeding and a systemic inflammatory syndrome. Another patient in the ST group was reoperated on for acute postoperative bleeding 3 hours after his arrival in the ICU. Except for these 2 patients, there was no difference in the incidence of postoperative complications (Table 2). Postoperative ventilation time was 375 ± 175 minutes in the MS group and 348 ± 228 minutes in the ST group (not significant), and ICU and hospital length of stay were similar (Table 2). Postoperative pain evaluated by the analog visual score was weak and not different between the 2 groups, but with a trend for lower consumption of analgesic drugs in the MS group. However, the difference was not significant (Table 5).

The only significant difference noted between the 2 groups concerned intraoperative blood loss, which was 450 ± 280 mL and 720 ± 450 mL, respectively, in the MS and the ST groups (Table 6, $p < 0.05$). There was a lower tendency for bleeding in the first postoperative 24 hours in the MS group (386 ± 179 mL/24 hours) compared with the ST group (557 ± 416 mL/24 hours), but the difference was not significant ($p = 0.07$). The total use of blood products was not different either, even if there were fewer patients transfused in the MS group (not significant, Table 6).

There was no difference regarding the hemodynamic parameters evaluated by the PiCCO. Measurements of cardiac index made soon after anesthetic induction showed low values but with no difference between the groups. The cardiac index increased at POD1 and remained stable thereafter in both groups (Tables 7 and 8).

DISCUSSION

This study did not find any benefit in pulmonary function by reducing the chest incision. On the other hand, it did lead to a significant reduction in intraoperative blood loss but not to a decrease in allogeneic blood transfusion.

The design of the present study was to perform pulmonary analysis using a special device at the patient's bedside early at POD1 and POD2, without requiring any physical effort from the patient. Preoperative and POD7 respiratory assessment were performed in an ambulatory mode using the same device. In theory, reduction of the skin incision and postoperative sternum mobility should lead to improved respiratory function and blood gas parameters, faster rehabilitation, and less pain.[8] The role of pulmonary dysfunction because of aortic valve myocardiopathy compared with that related to chest incision in the outcome of patients with aortic stenosis is not well known. It is not certain that future percutaneous heart valve studies will throw light on the role of sternum preservation on pulmonary function compared with classic surgery. To date, data on pulmonary function as a result of a shorter sternal incision in cardiac surgery have been sparse. Only one study compared pulmonary function before and after coronary artery bypass,[5] whereas 2 concerned aortic valve replacement.[4,9] Like other authors, the present study found a severe reduction in all pulmonary volumes leading to a restrictive syndrome but without any difference between patients operated on with ministernotomy or standard sternotomy. This reduction in volume concerned all the respiratory parameters at all times, except for FRC, which underwent a small but significant decrease at POD1 from

Table 6. Bleeding and Transfusions

	Minimal Access (MS) (n = 38)	Conventional Access (ST) (n = 39)	*p* Value
Intraoperative blood loss	452 ± 283.9	724 ± 449.3	0.02
First 24 hours mean chest drainage (mL)	386 ± 179	557 ± 416	0.07
Patients transfused with RBCs (n)	18	20	0.73
Patients transfused with FFP (n)	2	3	—

NOTE. Continuous variables are expressed as mean ± standard deviation.
Abbreviations: SIRS, systemic inflammatory response syndrome; RBCs, red blood cells; FFP, fresh frozen plasma.

Table 7. Intraoperative and ICU Arrival Data Obtained by PiCCO Device

	Preoperatively			ICU Arrival		
	MS	ST	*p* Value	MS	ST	*p* Value
CI (L/min/m²)	1.9 ± 0.5	1.7 ± 0.4	0.07	2.7 ± 1	2.8 ± 0.9	0.64
dP/dt	600 ± 430	558 ± 297	0.61	1,257 ± 561	1,094 ± 371	0.13
SVR	2,769 ± 904	3,183 ± 1,159	0.08	2,550 ± 1,337	2,290 ± 774	0.29
EVLW (mL/kg of body weight)	7.2 ± 3.3	7.6 ± 3.2	0.58	6.3 ± 2.1	6.2 ± 2.1	0.83

NOTE. Continuous variables are expressed as mean ± standard deviation.
Abbreviations: CI, cardiac index; SVR, systemic vascular resistance.

baseline. Postoperative deterioration in respiratory function is well known with the standard median sternotomy approach.[2] It leads to a reduction of approximately 50% to 60% of all lung volumes[10,11] except for residual volume.[3] Permanent deterioration in respiratory function remains to be proved, with a persistent 6% decrease in FRC a few months after surgery in some reports. Only the study performed by Bonacchi et al[4] in 2002 randomizing 80 consecutive patients to MS or ST groups found an improvement in postoperative spirometric parameters at day 5 and an earlier extubation and hospital discharge when the sternal incision was shorter. They also showed a return to baseline spirometric values after 1 month. Interestingly, however, improvement concerned only total lung capacity and maximum inspiratory and expiratory pressure, whereas there was no difference in FEV_1. Like the present study, all other studies failed to show any improvement in pulmonary function. One possible explanation could be that the study of Bonacchi et al concerned 2 sternotomy techniques, one preserving upper and lower sternum stability ("reversed C"). That study did not clearly show whether patients with a reversed C incision experienced better recovery of pulmonary function than the others. Furthermore, it is important not only to consider mechanical alterations underlying respiratory impairment but also any reduction in diffusion capacity (assessed by single-breath diffusing capacity for carbon monoxide DLCO, which was not done in the present study) and diaphragmatic failure. DLCO reflects diffusion impairment because of the interstitial accumulation of fluid, which could be assessed in the present study by measuring EVLW. There was no difference in this parameter between the 2 groups. The hypothesis that ministernotomy causes less pain was not confirmed in the present study because it was not possible to show any difference in pain score at any time between the 2 groups, even if there was a slight decrease in analgesic consumption at POD 2.

The main positive finding was a significant reduction in intraoperative blood loss (450 ± 280 mL in the MS group *v* 720 ± 450 mL in the ST group, $p < 0.05$), leading to nonsignificant reductions in postoperative bleeding and transfusion. These decreases in bleeding and transfusion were found in other studies on ministernotomy, but most of the time it did not reach significance because of the small number of patients included.[12] The authors were unable to show whether this could lead to the lower number of complications frequently associated with bleeding and transfusion. Reoperations for bleeding were necessary in 2 patients in the ST group, one of whom had a severe respiratory complication. Therefore, the reduction in chest access in the MS technique did not decrease the quality of surgical hemostasis. On the other hand, it cannot be concluded whether the association of a shorter chest incision and reduced intraoperative blood loss is in part associated with a decrease in inflammation. The lack of difference in EVLW measurements between the groups was probably because of a clinically nonsignificant difference in inflammation response. Although the authors did not perform specific biologic examinations, other studies also failed to show any significant difference in inflammation between a standard and a minimally invasive approach.[13] The role of inflammation in the reduction of intraoperative blood loss was probably limited simply because the duration of the surgery was not long enough to allow changes in the hemostasis related to this inflammation.

In summary, ministernotomy is safe for aortic valve replacement. Although the present authors failed to show any benefit for this technique to improve respiratory function, there was a significant reduction in intraoperative bleeding and nonsignificant reductions in postoperative bleeding and morphine consumption. However, it did not lead to any reductions in transfusion, pain score, or in-hospital outcome. Further investigations are required to assess whether this procedure improves the outcome of cardiac surgery in patients with a greater risk score or pulmonary diseases.

Table 8. Data Obtained by the PiCCO Device at POD1 and POD2

	POD1			POD2		
	MS	ST	*p* Value	MS	ST	*p* Value
CI (L/min/m²)	2.6 ± 0.7	2.8 ± 0.7	0.21	2.9 ± 0.7	2.8 ± 0.7	0.52
dP/dt	1,204 ± 358	1,084 ± 322	0.12	1,154 ± 384	1,075 ± 350	0.34
SVR	2,302 ± 701	2,277 ± 832	0.88	2,225 ± 857	2,210 ± 761	0.93
EVLW (mL/kg of body weight)	6 ± 2.5	5.7 ± 1.5	0.51	6.8 ± 3.2	6.9 ± 1.9	0.86

NOTE. Continuous variables are expressed as mean ± standard deviation.
Abbreviations: CI, cardiac index; SVR, systemic vascular resistance.

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