Higher-risk mitral valve operations after previous sternotomy: endoscopic, minimally invasive approach improves patient outcomes

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Background: Reoperative mitral valve (MV) surgery is associated with significant morbidity and mortality; however, endoscopic minimally invasive surgical techniques may preserve the surgical benefits of conventional mitral operations while potentially reducing perioperative risk and length of stay (LOS) in hospital.

Methods: We compared the outcomes of consecutive patients who underwent reoperative MV surgery between 2000 and 2014 using a minimally invasive endoscopic approach (MINI) with those of patients who underwent a conventional sternotomy (STERN). The primary outcome was in-hospital/30-day mortality. Secondary outcomes included blood product transfusion, LOS in hospital and in the intensive care unit (ICU), and postoperative complications.

Results: We included 132 patients in our study: 40 (mean age 68 ± 14 yr, 70% men) underwent MINI and 92 (62 ± 13 yr, 40% men) underwent STERN. The MINI group had significantly more comorbidities than the STERN group. While there were no significant differences in complications, all point estimates suggested lower mortality and morbidity in the MINI than the STERN group (in-hospital/30-day mortality 5% v. 11%, $p = 0.35$; composite any of 10 complications 28% v. 41%, $p = 0.13$). Individual complication rates were similar between the MINI and STERN groups, except for intra-aortic balloon pump requirement (IABP; 0% v. 12%, $p = 0.034$). MINI significantly reduced the need for any blood transfusion (68% v. 84%, $p = 0.036$) or packed red blood cells (63% v. 79%, $p = 0.042$), fresh frozen plasma (35% v. 59%, $p = 0.012$) and platelets (20% v. 40%, $p = 0.024$). It also significantly reduced median hospital LOS (8 v. 12 d, $p = 0.014$). An exploratory propensity score analysis similarly demonstrated a significantly reduced need for IABP ($p < 0.001$) and a shorter mean LOS in the ICU ($p = 0.046$) and in hospital ($p = 0.047$) in the MINI group.

Conclusion: A MINI approach for reoperative MV surgery reduces blood product utilization and hospital LOS. Possible clinically relevant differences in perioperative complications require assessment in randomized clinical trials.

Contexte : Les réopérations de la valve mitrale (VM) sont associées à une morbidité et à une mortalité importantes. Cependant, il semblerait que les techniques chirurgicales endoscopiques à effraction minimale préservent les avantages des opérations traditionnelles de la VM tout en réduisant potentiellement les risques périopératoires et la durée d'hospitalisation.

Méthodes : Nous avons comparé les résultats de patients consécutifs ayant subi une réopération de la VM entre 2000 et 2014 selon une approche endoscopique à effraction minimale (groupe MINI) à ceux de patients ayant subi une sternotomie classique (groupe STERN). Le résultat primaire à l'étude était la mortalité intrahospitalière ou dans les 30 premiers jours, et les résultats secondaires, la transfusion de produits sanguins, la durée du séjour à l'hôpital et à l'unité des soins intensifs (USI), ainsi que les complications postopératoires.

Résultats : Nous avons retenu 132 patients : 40 (âge moyen de 68 ± 14 ans, 70 % d'hommes) dans le groupe MINI et 92 (âge moyen de 62 ± 13 ans, 40 % d'hommes) dans le groupe STERN. Les patients du groupe MINI présentaient un nombre significativement plus élevé de comorbidités que ceux du groupe STERN. Aucune différence significative n'a été observée quant aux complications, mais toutes les estimations ponctuelles pointaient vers une mortalité et une morbidité moindres dans le groupe

MINI (mortalité intrahospitalière ou dans les 30 premiers jours : 5 % c. 11 %, p = 0,35; morbidité combinée à la présence d'au moins une complication parmi 10 possibles : 28 % c. 41 %, p = 0,13). Les taux de complications individuels étaient semblables chez les patients des 2 groupes, sauf pour l'exigence de ballon de contrepulsion intra-aortique (BCIA; 0 % c. 12 %, p = 0,034). L'approche MINI a réduit significativement le taux de transfusion de sang (68 % c. 84 %, p = 0,036) ou de concentrés de globules rouges (63 % c. 79 %, p = 0,042), de plasma frais congelé (35 % c. 59 %, p = 0,012) et de plaquettes (20 % c. 40 %, p = 0,024), en plus de diminuer significativement la durée médiane d'hospitalisation (8 jours c. 12 jours, p = 0,014). En outre, une analyse exploratoire du score de propension a révélé une réduction significative du BCIA (p < 0,001) ainsi qu'une durée moyenne de séjour à l'USI (p = 0,046) et à l'hôpital (p = 0,047) plus courte dans le groupe MINI.

Conclusion : Le recours à l'approche endoscopique à effraction minimale pour les réopérations de la VM diminuerait le recours aux produits sanguins et la durée d'hospitalisation. En ce qui a trait aux complications périopératoires, il faudra procéder à des essais cliniques aléatoires pour évaluer les différences possiblement pertinentes sur le plan clinique.

Reoperative mitral valve (MV) surgery can be technically challenging and is associated with increased risks of mortality and morbidity compared with de novo intervention.[1–3] Cardiac injury on re-entry can be hazardous, particularly with patent coronary artery bypass grafts, and postoperative low cardiac output syndrome occurs more commonly as a result of prolonged ischemic time and increased technical complexity.[3] Importantly, with a sternotomy approach, adequate operative exposure of the MV can be challenging secondary to dense adhesions — particularly in patients with previous aortic valve and/or aortic root surgery.[4–6] Most patients requiring reoperative mitral surgery are older and have multiple medical comorbidities that increase their overall perioperative risk. Recently, many of these higher-risk patients have been offered or treated with novel transcatheter mitral techniques, which may be associated with inferior efficacy and have unknown durability. A minimally invasive, endoscopic right mini-thoracotomy (MINI) approach for reoperative MV surgery may reduce risk while preserving late outcomes of a conventional surgical operation. It can reduce the extent of adhesiolysis while facilitating excellent exposure of the MV. Several centres worldwide have demonstrated the feasibility and safety of this minimally invasive technique,[7–10] but its adoption in Canada has been slow.[11] Critics remain concerned about risks of iatrogenic aortic dissection and stroke[12] in minimally invasive surgery compared with conventional surgery.

We therefore sought to review our experience with the minimally invasive endoscopic, right MINI approach compared with conventional sternotomy (STERN) in order to better delineate the benefits and limitations of both techniques with respect to reoperative MV surgery in a higher-risk patient population. We used a retrospective cohort study design and hypothesized that, compared with sternotomy, a minimally invasive approach would demonstrate improved outcomes despite patients being older and sicker.

Methods

We reviewed the cases of consecutive adult patients who underwent reoperative MV repair or replacement at our institution between September 2000 and August 2014. Patients underwent MV surgery with either a MINI approach performed by 2 surgeons (M.W.C., B.K.) or conventional sternotomy (STERN) performed by 9 different surgeons, including those who performed MINI. We included patients of all urgency statuses in the present investigation; however, those undergoing concomitant coronary artery bypass grafting (CABG), aortic valve surgery and ascending aortic surgery were excluded, as these procedures must be performed only via midline sternotomy. All patients had previously undergone at least 1 open cardiac surgery via sternotomy. The protocol for this investigation was approved by the Health Sciences Research Ethics Board at Western University, which waived the requirement for individual patient consent.

Minimally invasive operative technique

Patients in the MINI group were operated in a 20° left lateral decubitus position with lung isolation. Bicaval venous cannulation was achieved via a 15- or 17-Fr percutaneous superior vena cava (SVC) cannulae inserted through the right internal jugular vein (Fig. 1A) and a 21- or 25-Fr multiport venous drainage catheter placed via the common femoral vein (Fig. 1B). Arterial cannulation was achieved with a 19- or 21-Fr arterial cannulae (2002–2009) or an 8 mm Dacron sidegraft (2009–2015) via either the common femoral artery or the right axillary artery, depending on individual patient risk factors for atheroembolism (atherosclerosis, age > 75 yr, previous stroke). A right anterolateral mini-thoracotomy incision measuring 3–4 cm (Fig. 1C) and a 5 mm endoscope were used for surgical exposure. Hypothermic, ventricular fibrillatory arrest was used for myocardial preservation and was achieved by central cooling to

28–30°C and using a fibrillator box with pacemaker wires. The perfusion pressure was maintained at 80–100 mm Hg during ventricular fibrillation, and aortic root venting was used selectively depending on ascending aortic calcification. Special long-shafted instruments were used to perform the MV repair or replacement using standard techniques, similar to those in the STERN group (Fig. 1D).

Conventional sternotomy operative techniques

Patients in the STERN group underwent a standard midline resternotomy for surgical exposure with central arterial and venous cannulation. All operations were performed with an aortic cross clamp, and myocardial protection consisted of a combination of antegrade and retrograde blood cardioplegia. Conventional instruments were used, and the MV repair or replacement was performed using standard techniques similar to those in the MINI group.

Statistical analysis

We compared preoperative characteristics and postoperative outcomes of patients in the 2 groups using the χ^2 test (for categorical variables) and either the *t* test (if visual inspection of a histogram indicated an approximately normal distribution) or the Wilcoxon rank-sum test (if visual inspection of a histogram indicated a non-normal distribution) for continuous variables. Univariable logistic regression was used to compute unadjusted odds ratios (ORs) for dichotomous outcomes. Length of stay data in patients who survived their hospitalization are presented as medians and were tested for differences using Cox regression. We used Casewise deletion for missing data.

As an exploratory analysis, we controlled for confounding by performing adjusted analyses using inverse probability weighting (IPW) based on the propensity score of receiving either the MINI approach or the STERN approach.[13] To calculate the propensity score, we constructed a logistic regression model based on covariates deemed from clinical experience or from previous literature to likely be predictive of the surgical approach used or the outcomes of interest. This included the following baseline variables: age, sex, body mass index, diabetes, previous stroke or transient ischemic attack (TIA), chronic obstructive pulmonary disease, left ventricular grade, congestive heart failure, coronary artery disease and atrial fibrillation. This model had reasonable reliability (Hosmer–Lemeshow goodness of fit [10 groups], $p = 0.08$) and had good discrimination (c statistic = 0.82). We then performed IPW-adjusted analysis of our outcomes using the "teffects ipw" package in Stata software version 14

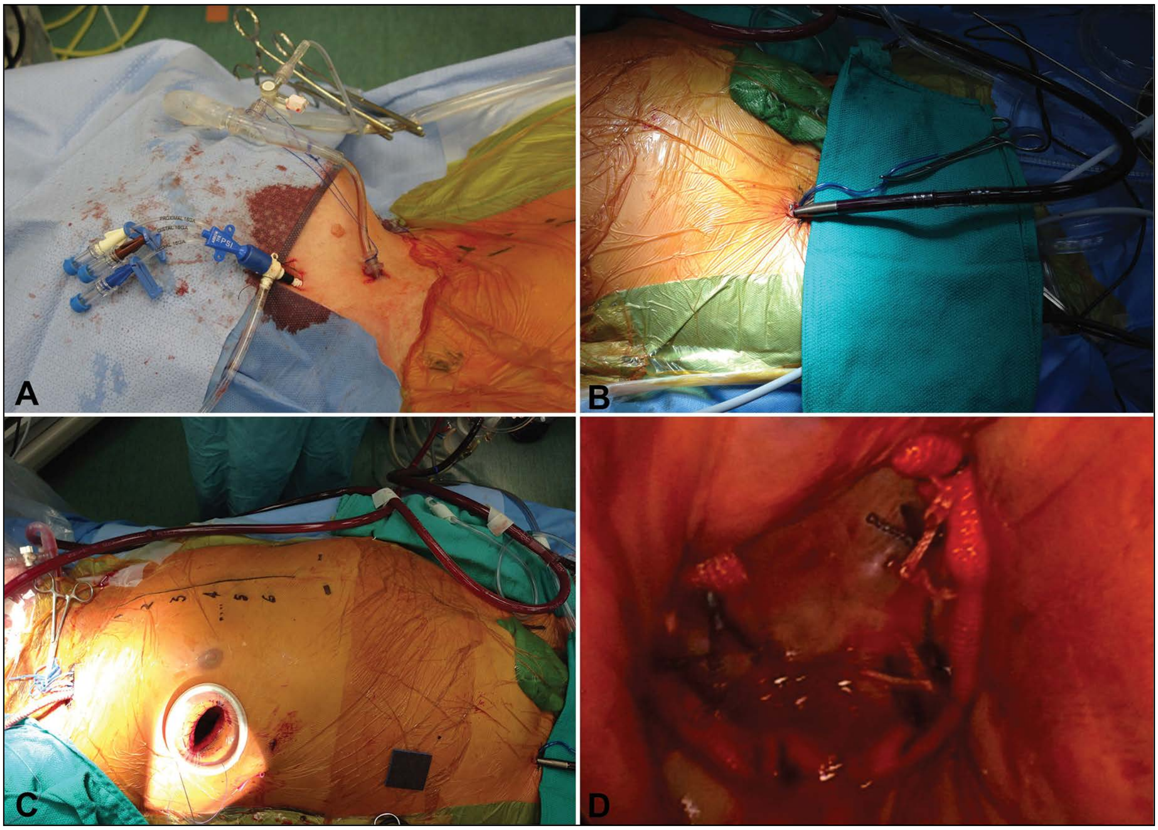

Fig. 1. (**A**) Insertion of percutaneous superior vena cava line. (**B**) Venous femoral cannulation. (**C**) Right mini-thoracotomy approach for reoperative mitral valve surgery with right axillary artery cannulation. (**D**) Intraoperative photograph of an endoscopic mitral valve repair demonstrating no intraoperative mitral regurgitation.

(StataCorp LP) and using the average treatment effect. We considered results to be significant at $p < 0.05$, 2-tailed.

Results

Patients and operative details

During the study period, 132 consecutive adult patients underwent reoperative MV repair (n = 16) or replacement (n = 116) at our institution; 40 patients received a MINI approach and 92 received conventional sternotomy. All patients had previously undergone at least 1 open cardiac surgery via sternotomy (Table 1); 106 patients had previously undergone only 1 prior cardiac surgery, 20 patients had 2 prior interventions, 2 patients had 3 prior interventions, and 3 patients had 4 previous cardiac operations. One individual in the STERN group had 5 previous cardiac surgeries. Figure 2 shows the wounds from MINI compared with previous sternotomy wounds.

Preoperative patient characteristics are outlined in Table 2. Mean patient age was significantly older in the MINI group, and there were more female patients in the STERN group. The MINI group also had more patients with moderate to severe left ventricular dysfunction, peripheral vascular disease, chronic obstructive pulmonary disease and coronary artery disease. The median number of prior surgical interventions and urgency status was similar in both groups. Despite significant differences in patient profiles, the calculated Society of Thoracic Surgery risk scores were similarly elevated. There was no statistically significant difference in proportion of patients who underwent MV repair versus replacement between the 2 groups. Additionally, there were similar proportions of patients who underwent concomitant procedures, with approximately one-third of both groups undergoing a concomitant tricuspid valve repair. There was a trend toward longer cardiopulmonary bypass times in the MINI group (on average 21 min longer), and the MINI group had longer cross clamp/ventricular fibrillation times (on average 18 min longer; Table 3).

Table 1. Previous operations

	Group; no. (%)*	
Previous surgeries	MINI (n = 40)	STERN (n = 92)
Isolated MVR/repair	7 (18)	57 (62)
MVR/repair ± other valve ± CABG	5 (13)	16 (17)
CABG	20 (50)	10 (11)
AVR/ repair ± aortic ± CABG	7 (18)	9 (5)
Other	7 (18)	9 (10)

AVR = aortic valve replacement; CABG = coronary artery bypass grafting; MINI = mini-thoracotomy; MVR = mitral valve replacement; STERN = conventional sternotomy.
*Data are rounded to the nearest integer. Values do not add to 100% as many patients had more than 1 prior cardiac surgery.

Mortality and morbidity

Unadjusted patient outcomes are presented in Table 4. In-hospital/30-day mortality was statistically similar in both groups, although it was more than 2-fold greater in the STERN group than the MINI group. Two patients in the MINI group died; 1 patient experienced a cardiac arrest due to an intraoperative type A dissection originating from the aortic root vent site, and 1 patient died from complications of heparin-induced thrombocytopenia. The causes of death in the STERN group were cardiac failure (n = 5), multisystem organ failure (n = 1), septic shock (n = 2), cardiogenic shock (n = 1) and AV groove disruption (n = 1). Significantly more patients in the

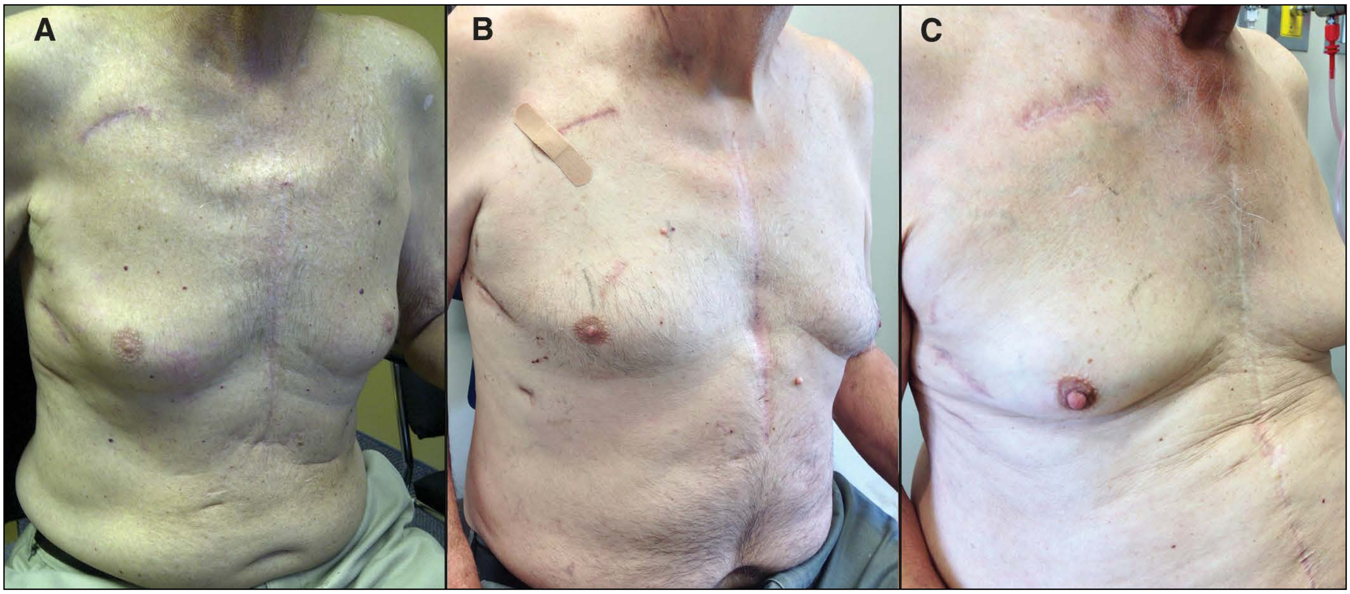

Fig. 2. Postoperative photographs demonstrating the mini-thoracotomy wounds compared with previous sternotomy wounds in 3 male patients.

STERN group required postoperative intra-aortic balloon pump (IABP) use. The rate of other individual major complications was also similar, with the most common complication being prolonged mechanical ventilation (> 48 h). There were no differences in stroke and other neurologic complications between the 2 groups. A composite outcome of any of 10 complications was also considerably less frequent in the MINI group, though this difference was not statistically significant. No patients in the MINI group required conversion to sternotomy. An exploratory propensity score analysis (Table 5) demonstrated a significant reduction in risk difference with respect to postoperative IABP requirement in the MINI group. There was also a significant reduction in risk difference for both reoperation for bleeding and renal failure requiring dialysis in the MINI group.

Length of stay

Length of stay (LOS) in the intensive care unit (ICU) was similar in both groups (MINI: mean 2, interquartile range [IQR] 1–4; STERN: mean 2, IQR 1–6; hazard ratio [HR] for discharge from ICU 1.3, 95% confidence interval [CI] 0.89–1.9, p = 0.18); however the overall hospital LOS was significantly shorter in the MINI group than the STERN group (median 8, IQR 6–13 v. median 12, IQR 8–20; HR for discharge from hospital 1.6, 95% CI 1.1–2.4, p = 0.014; Table 4). There was also a strong trend toward a significant reduction in the proportion of patients requiring any prolonged postoperative hospitalization in the MINI comopared with the STERN group (LOS > 10 d; 15 [38%] v. 51 [55%], p = 0.06). These trends were similar in the propensity score analysis, which demonstrated a significant reduction in the risk difference in both the

Table 2. Preoperative patient characteristics

	Group; no. (%), mean ± SD, or median [IQR]*		
Characteristic	MINI (n = 40)	STERN (n = 92)	p value
Male sex	28 (70)	38 (41)	0.002
Age, yr	68 ± 14	62 ± 13	0.017
BMI	29 ± 7	27 ± 5	0.15
NYHA			0.23
I	0	1 (1)	
II	0	7 (8)	
III	29 (73)	55 (60)	
IV	11 (28)	29 (32)	
STS score	15 ± 11	15 ± 11	0.96
LV grade 3/4	11 (28)	7 (8)	0.002
No. previous operations	1 [1–1]	1 [1–1]	0.53
Comorbidities			
Diabetes	11 (28)	14 (15)	0.10
CVD			0.71
TIA	2 (5)	6 (7)	
Stroke	5 (13)	16 (17)	
Recent MI	1 (3)	1 (1)	0.54
Recent CHF	15 (38)	43 (47)	0.33
COPD	16 (40)	19 (21)	0.021
Atrial fibrillation	9 (23)	16 (17)	0.49
Renal failure	3 (8)	4 (4)	0.46
PVD	18 (45)	7 (8)	< 0.001
CAD	28 (70)	22 (24)	< 0.001

BMI = body mass index; CAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CVD = cerebrovascular disease; IQR = interquartile range; LV = left ventricular; MI = myocardial infarction; MINI = mini-thoracotomy; NYHA = New York Heart Association; PVD = peripheral vascular disease; SD = standard deviation; STERN = conventional sternotomy; STS = Society of Thoracic Surgeons; TIA = transient ischemic attack.

*Data are rounded to the nearest integer.

Table 3. Operative characteristics

	Group; no. (%) or mean ± SD*		
Characteristic	MINI (n = 40)	STERN (n = 92)	p value
MV Repair	8 (20)	8 (9)	0.07
MVR	32 (80)	84 (91)	0.07
Concomitant procedure	15 (38)	40 (44)	0.52
TV	12 (30)	32 (35)	0.59
ASD	2 (5)	4 (4)	0.87
Ablation	2 (5)	4 (4)	0.87
Other	0	3 (3)	0.25
Urgency			0.049
Elective	29 (73)	45 (49)	
Urgent	11 (28)	39 (42)	
Emergent	0	4 (4)	
Salvage	0	4 (4)	
CPB time	201 ± 63	180 ± 75	0.010
XC or VF time	123 ± 37	105 ± 46	0.002

ASD = atrial septum defect repair; CPB = cardiopulmonary bypass; MINI = mini-thoracotomy; MVR = mitral valve replacement; SD = standard deviation. STERN = conventional sternotomy; TV = tricuspid repair; XC = cross clamp; VF = ventricular fibrillation.

*Data are rounded to the nearest integer.

Table 4. Postoperative outcomes and complications

	Group; no. (%), or median [IQR]*		
Outcome	MINI (n = 40)	STERN (n = 92)	p value
In-hospital/30-d mortality	2 (5)	10 (11)	0.35
Reoperation for bleeding	1 (3)	6 (7)	0.68
Respiratory failure	7 (18)	19 (21)	0.68
Postoperative IABP	0	11 (12)	0.034
Neurological complications	3 (8)	6 (7)	> 0.99
Stroke	2 (5)	2 (2)	0.58
Arrest or serious arrhythmia	1 (3)	12 (13)	0.11
Renal failure requiring dialysis	0	6 (7)	0.18
Septicemia	0	2 (2)	> 0.99
Wound infection	0	3 (3)	0.55
Any of 10 major complications	11 (28)	38 (41)	0.13
LOS			
ICU	2 [1–4]	2 [1–6]	0.40
> 4 d in ICU	8 (20)	27 (29)	0.26
Hospital LOS	8 [6–13]	12 [8–20]	0.021
> 10 d in hospital	15 (38)	51 (55)	0.06

IABP = intra-aortic balloon pump; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay; MINI = mini-thoracotomy; STERN = conventional sternotomy.

*Data are rounded to the nearest integer.

mean ICU (–3.3, 95% CI –6.6 to –0.06, p = 0.046) and hospital LOS (–4.3, 95% CI –8.6 to –0.06, p = 0.047) in the MINI group.

Blood product usage

Patients in the MINI group had a lower proportion of patients requiring any blood transfusion than the STERN group (68% v. 84%, p = 0.036), which was consistent when broken down by individual blood product (packed red blood cells [pRBC]: 63% v. 79%, p = 0.042; fresh frozen plasma [FFP]: 35% v. 59%, p = 0.012; platelets: 20% v. 40%, p = 0.024). When transfused, patients in the MINI group also received fewer units of FFP than those in the STERN group (median 4, IQR 2–6 v. median 6, IQR 4–11, p = 0.016) and strongly trended toward reduced platelet requirements (median 5, IQR 5–5 v. median 10, IQR 5–15, p = 0.06; Fig. 3).

Survival and follow-up

Survival in the MINI group was 97% at 1 and 2 years, and 58% at 5 years, whereas survival in the STERN group was 93% at 1 year, 92% at 2 years, and 84% at 5 and 10 years. Log-rank analysis revealed similar survival in both groups (p = 0.55). Clinical follow-up revealed that 6 (16%) patients in the MINI group continued to experience New York Heart Association functional III/IV symptoms at a median follow-up of 10 (IQR 4–22) months, which was similar to the 10 (14%) patients in the STERN group at a median follow-up of 30 (IQR 4–75) months (p = 0.78).

Table 5. Exploratory propensity score analysis

Outcome	Propensity score-adjusted risk difference* (95% CI)	*p* value
In-hospital/30-d mortality	–6.0% (–15.6% to 3.6%)	0.22
Reoperation for bleeding	–6.3% (–11.2% to –1.4%)	0.012
Respiratory failure	–5.2% (–19.5% to 9.0%)	0.47
Postoperative IABP	–12.9% (–19.8% to –6.1%)	< 0.001
Neurological complications	–1.6% (–9.2% to 6.0%)	0.68
Stroke	2.3% (–4.3% to 8.9%)	0.49
Arrest or serious arrhythmia	3.2% (–22.5% to 28.9%)	0.81
Renal failure requiring dialysis	–5.9% (–10.5% to –1.4%)	0.011
Septicemia	–2.0% (–4.8% to 0.7%)	0.15
Wound infection	–2.9% (–6.1% to 0.3%)	0.08
Any of 10 major complications	–8.5% (–32% to 15%)	0.49
LOS		
ICU LOS	–3.3 (–6.6 to –0.06)	0.046
> 4 d in ICU	–15.0% (–30.7% to 0.8%)	0.06
Hospital LOS	–4.3 (–8.6 to –0.06)	0.047
> 10 d in hospital	6.9% (–21% to 35%)	0.63

CI = confidence interval; IABP = intra-aortic balloon pump; ICU = intensive care unit; LOS = length of stay; MINI = mini-thoracotomy; STERN = conventional sternotomy.

*Adjusted risk differences (binary variables) and differences in means (continuous variables) obtained from inverse probability of treatment-weighted analysis. Differences in risk or means are for the MINI group relative to the STERN group. Therefore, for adverse events like death, a negative number is in favour of the MINI group.

Freedom from recurrent moderate mitral regurgitation was 94% in the MINI group and 90% in the STERN group (p = 0.71) at a median echocardiographic follow-up of 10 (IQR 2–40) months.

Discussion

Minimally invasive approaches for both primary and reoperative MV surgery are becoming increasingly accepted, as many groups continue to demonstrate low rates of complications and excellent postoperative outcomes.[7–9,14,15] The results of our present investigation provide further evidence to support the safety and efficacy of the MINI approach for redo MV surgery and should serve to assure patients that these minimally invasive options are available in Canada and are being performed with outcomes comparable to those of larger published series.

Seeburger and colleagues[7] published their experience with 181 patients undergoing reoperative minimally invasive MV surgery, reporting a cumulative mortality of 7% with neurologic complications occurring in 5% of patients. Mediastinal re-exploration for bleeding was necessary in 12% of patients in their series compared with 3% in our investigation. The incidence of low cardiac output syndrome in this group of patients was also relatively low (7%). Arcidi and colleagues[9] reported their 15-year experience with reoperative minimally invasive MV surgery in a series of 167 patients. They reported a commendable cumulative 3% mortality, with no in-hospital/30-day mortality since 2005. Meyer and colleagues[8] reported a similarly low 30-day mortality of 5% in their series of 107 patients. Neurological complications were also infrequent, with only 1 patient experiencing a stroke, and they reported 1 patient experiencing an acute type A aortic dissection.

There are few reports that have a STERN comparator group when investigating MINI for reoperative MV surgery. An earlier study by Bolotin and colleagues[16] reported the outcomes of 38 patients undergoing redo MV surgery via a minimally invasive approach versus 33 patients undergoing resternotomy. They confirmed the safety of the MINI approach; however, they found no difference in the overall operative mortality in patients undergoing MINI compared with those undergoing sternotomy (6% in both groups, p = 0.98). Similar to our findings, Bolotin and colleagues[16] demonstrated that the less invasive approach resulted in significantly reduced postoperative intubation time (p = 0.008), reduced transfusion requirements (p = 0.001) and reduced hospital LOS (p = 0.001) when compared with redo sternotomy. Mihos and colleagues[10] reported a reduction in operative mortality (3% v. 14%, p = 0.07) and significantly fewer postoperative complications (29% v. 66%, p = 0.001) in their minimally invasive (n = 59) and sternotomy (n = 29) groups, respectively. They too noted a significant reduction in postoperative intubation time and hospital LOS; however, unlike in our present investigation, there were no differences in blood product requirements between the 2 groups. We are satisfied that our present results are comparable to those of these other series. Although our results did not demonstrate a statistically significant difference between groups in early mortality or complication rates, we feel that this is likely reflective of inadequate power and that, with more patients being treated, the evidence will strongly favour the MINI approach.

We have made several technique changes to our MINI approach over the years. Early in our experience, we had 1 patient experience an acute type A aortic dissection, originating from the aortic root vent site (not from retrograde femoral perfusion). Since then, we no longer use an aortic root vent in patients with any concerning ascending aortic plaque. We continuously flood the operative field with CO_2 and rely on de-airing with a left ventricular vent placed across the mitral repair/prosthesis, until any remaining intracardiac air has been completely evacuated. Furthermore, our perfusion strategy has also evolved, and we now prefer to use an 8 mm Dacron side graft to the axillary artery for the delivery of antegrade arterial perfusion for the reoperative MINI approach. This technique allows us to avoid manipulation of often diseased femoral vessels and instead use the axillary artery, which may reduce the risk of stroke. Since implementing these changes, we have not experienced any dissections or strokes in our minimally invasive group, despite the large number of patients with peripheral vascular disease.

The reoperative MINI approach requires specialized training and instrumentation, a dedicated team and substantial surgeon experience to achieve good results in these challenging patients.[17]

Currently, there is a growing trend to refer or treat these high-risk reoperative MV patients with novel transcatheter MV replacement or repair, frequently citing prohibitive operative risk. While these novel transcatheter techniques appear promising in the initial reports, they may not have the long-term durability of conventional MV surgery. We believe that reoperative MINI MV surgery is a good alternative and should be considered before more novel techniques because of proven late outcomes. More than one-third of the patients in the MINI group were deemed inoperable by another surgeon and were referred to our centre specifically for redo MINI MV surgery. We demonstrated that the MINI approach is feasible, safe and effective and may reduce the frequency of perioperative complications and the need for blood product transfusions, while preserving the late outcomes of surgical repair.

Limitations

Our investigation has a number of limitations, including the modest sample sizes and somewhat heterogenous patient characteristics. We attempted to adjust for the imbalances in prognostic factors observed with an exploratory propensity score analysis. However, residual confounding is still likely owing to the small sample size and event rates — this is evident in the wide CIs observed for several of the propensity

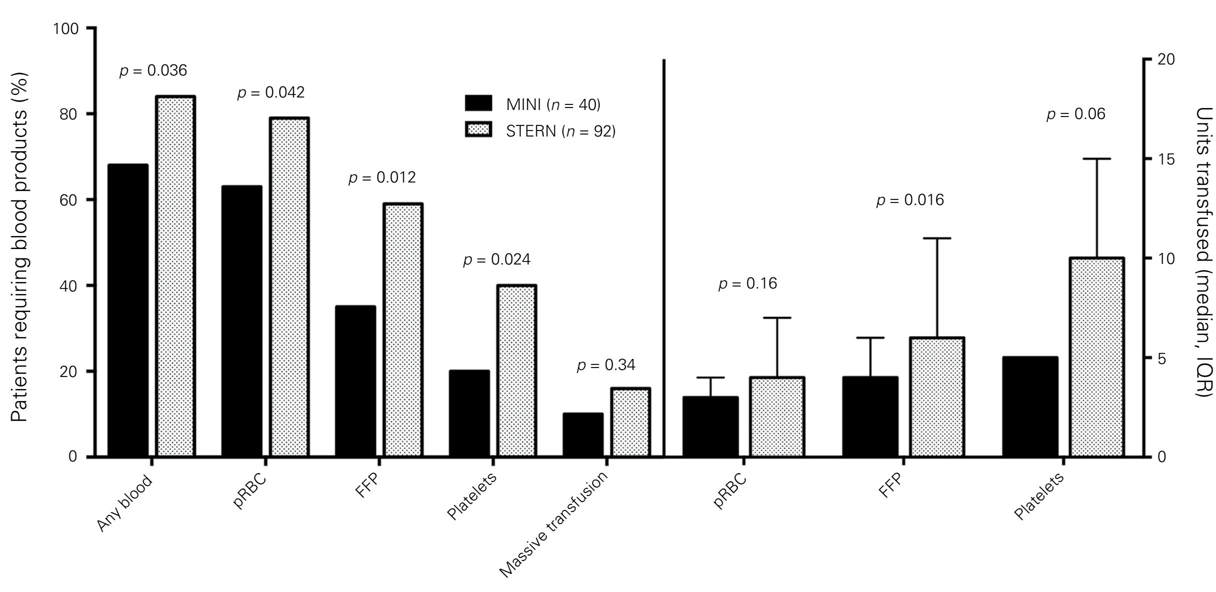

Fig. 3. Blood product requirements in patients in the mini-thoracotomy (MINI) group compared with the conventional sternotomy (STERN) group. FFP = fresh frozen plasma; IQR = interquartile range; pRBCs = packed red blood cells.

score-adjusted outcomes. The generalizability of our outcomes is limited by the single-centre data, as our surgical group had considerable pre-existing experience in minimally invasive techniques. We believe this study provides important comparative data that are missing in the current literature, as most investigations to date are limited to only the minimally invasive outcomes.

Conclusion

Our study has demonstrated that an endoscopic, right mini-thoractomy approach to reoperative MV surgery is safe and effective and provides superior postoperative outcomes than conventional sternotomy. Specifically, the minimally invasive approach likely results in fewer postoperative complications and significantly reduces both blood product requirements and hospital LOS.

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Competing interests: B. Kiaii is a consultant and proctor for and has received speaker fees from Medtronic, Symetis, Johnson & Johnson, and LivaNova. M. Chu has received speaker fees from Medtronic, Edwards Lifesciences, LivaNova and Symetis. No other competing interests declared.

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References

1. Akins CW, Buckley MJ, Daggett WM, et al. Risk of reoperative valve replacement for failed mitral and aortic bioprostheses. *Ann Thorac Surg* 1998;65:1545-51.
2. Jamieson WR, Burr LH, Miyagishima RT, et al. Reoperation for bioprosthetic mitral structural failure: risk assessment. *Circulation* 2003;108:II98-102.
3. Elahi M, Dhannapuneni R, Firmin R, et al. Direct complications of repeat median sternotomy in adults. *Asian Cardiovasc Thorac Ann* 2005;13:135-8.
4. Macmanus Q, Okies JE, Phillips SJ, et al. Surgical considerations in patients undergoing repeat median sternotomy. *J Thorac Cardiovasc Surg* 1975;69:138-43.
5. Dobell AR, Jain AK. Catastrophic hemorrhage during redo sternotomy. *Ann Thorac Surg* 1984;37:273-8.
6. Loop FD. Catastrophic hemorrhage during sternal reentry. *Ann Thorac Surg* 1984;37:271-2.
7. Seeburger J, Borger MA, Falk V, et al. Minimally invasive mitral valve surgery after previous sternotomy: experience in 181 patients. *Ann Thorac Surg* 2009;87:709-14.
8. Meyer SR, Szeto WY, Augoustides JGT, et al. Reoperative mitral valve surgery by the port access minithoracotomy approach is safe and effective. *Ann Thorac Surg* 2009;87:1426-30.
9. Arcidi JM Jr, Rodriguez E, Elbeery JR, et al. Fifteen-year experience with minimally invasive approach for reoperations involving the mitral valve. *J Thorac Cardiovasc Surg* 2012;143:1062-8.
10. Mihos CG, Santana O, Lamas GA, et al. Outcomes of right minithoracotomy mitral valve surgery in patients with previous sternotomy. *Ann Thorac Surg* 2011;91:1824-7.
11. Boesveld S. "It's my health, it's my choice," Danny Williams Says. *Globe and Mail* [Toronto]. Available: www.theglobeandmail.com/news/politics/its-my-health-its-my-choice-danny-williams-says/article4311853/ (accessed 2013 May 11).
12. Gammie JS, Zhao Y, Peterson ED, et al. Less-invasive mitral valve operations: trends and outcomes from the Society of Thoracic Surgeons adult cardiac surgery database. *Ann Thorac Surg* 2010;90:1401-8.
13. Austin PC. The performance of different propensity-score methods for estimating differences in proportions (risk differences or absolute risk reductions) in observational studies. *Stat Med* 2010;29:2137-48.
14. McClure RS, Athanasopoulos LV, McGurk S, et al. One thousand minimally invasive mitral valve operations: early outcomes, late outcomes, and echocardiographic follow-up. *J Thorac Cardiovasc Surg* 2013;145:1199-206.
15. Casselman FP, La Meir M, Jeanmart H, et al. Endoscopic mitral and tricuspid valve surgery after previous cardiac surgery. *Circulation* 2007;116:I270-5.
16. Bolotin G, Kypson AP, Reade CC, et al. Should a videoassisted minithoracotomy be the approach of choice for reoperative mitral valve surgery? *J Heart Valve Dis* 2004;13:155-8.
17. Holzhey DM, Seeburger J, Misfeld M, et al. Learning minimally invasive mitral valve surgery: a cumulative sum sequential probability analysis of 3895 operations from a single high-volume center. *Circulation* 2013;128:483-91.