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Comparison of the safety and efficacy between minimally invasive cardiac surgery and median sternotomy in a low-risk mixed Asian population in Singapore

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ABSTRACT

Introduction: Minimally invasive cardiac surgery (MICS) has attracted increasing attention, with institutions increasingly adopting this approach over conventional median sternotomy (MS). This study aimed to describe the outcomes of minimally invasive cardiac surgery in our institution as the only centre with an established MICS programme in Singapore.

Methods: Patients who had undergone cardiac procedures such as heart valve replacement or repair, coronary artery bypass grafting or atrial septal defect repair were included in the study. We analysed 4063 patients who had undergone MS and 390 patients who had undergone MICS between January 2009 and February 2020.

Results: Over the years, the number of MICS procedures performed increased, along with an increase in MICS operations with two or more concomitant cardiac procedures and a decrease in postoperative length of stay. Compared with patients who underwent MS, those who underwent MICS had shorter length of postoperative hospital stay ($p < 0.001$). On multivariate analysis, patients who underwent MICS had lower rates of atrial fibrillation ($p = 0.021$), reoperation ($p = 0.028$) and prolonged ventilation ($p < 0.001$). However, the rates of other postoperative complications were comparable between patients who underwent MICS and those who underwent MS.

Conclusion: In our institution, MICS is a safe, reproducible and efficacious technique that yields superior outcomes compared with conventional MS procedures, in some aspects. The results of this study provide further evidence and support towards adopting the minimally invasive approach to cardiac surgery in a carefully selected group of cardiac patients in Singapore.

Keywords: cardiac surgery, database, heart surgery, minimally invasive surgery, open heart surgery

INTRODUCTION

The advent of minimally invasive approaches is deemed as a remarkable advancement in the surgical field. Cardiac surgery has seen unprecedented innovations in techniques, as evidenced by the rise of less invasive approaches. Minimally invasive cardiac surgery (MICS) refers to a group of procedures utilising alternative smaller incisions to access the heart, thereby reducing surgical trauma. Nevertheless, combinations of procedures can still be undertaken via such access, including, but not limited to, valvular replacements and repairs, coronary artery bypasses, other surgeries on the heart and surgeries involving the aorta.

The potential benefits of such procedures include lower incidences of postoperative atrial fibrillation[(1,2)] and stroke[(3)], and reduced blood transfusion.[(4,5)] Similar cardiopulmonary bypass, aortic cross clamp time and length of ICU stay[(6-8)] were also observed between minimally invasive cardiac surgery and open heart surgery. In addition, MICS approaches have been shown to be associated with less postoperative pain, shorter recovery to premorbid status, better quality of life and overall higher patient satisfaction.[(9)] However, MICS is often misconceived as risky, compromising quality, bearing technical challenges such as exposure of the target structure, and associated with a long and prohibitive learning curve, for our local relatively low-volume programmes.

Our institution pioneered a complete and comprehensive MICS programme in Singapore that offered patients less invasive and more personalised cardiac surgery,[(9)] tailored towards improving outcomes and reducing overall recovery time. In the face of a steep learning curve and a general entropy to change, our centre has successfully established a programme that is sustainable, innovative and patient-centric. Although MICS can be carried out across patients with different preoperative risks, more than 60% of patients who undergo cardiac surgery in our institution have low preoperative risk (EuroSCORE II < 2%). Hence, a sizeable proportion of patients who underwent MICS in this study had low risk. Herein, we share our observations and experience of MICS in our institution to establish its role as a modern cardiac surgical facility in delivering non-compromising standards of clinical care in a multi-ethnic population.

METHODS

This retrospective comparative cohort study was approved by the National Healthcare Group Domain Specific Review Board (DSRB No#2020/00547), Singapore. Medical records of patients who underwent cardiac surgery at our institution in Singapore between January 2009 and February 2020 were retrospectively analysed. The study included patients who underwent coronary artery bypass grafting, single valve surgeries, double valvular repair or replacement surgeries comprising mitral and tricuspid valves, atrial fibrillation surgeries, atrial septal defect repairs and cardiac myxoma resections. Patients who underwent triple valvular surgeries or procedures involving the thoracic aorta and double valve surgeries comprising the aortic valve were excluded, as these procedures cannot be conducted through an MICS approach. Patients with a high preoperative risk or those who required emergency operations were also excluded from the study, as MICS is not the ideal choice of access for this group of patients. High-risk patients were defined as those having EuroSCORE II > 5%, according to the national audit definition in Singapore.

Preoperative demographics and perioperative outcomes of patients who underwent conventional median sternotomy (MS) were compared with those of patients who underwent MICS. Baseline characteristics, perioperative parameters and postoperative outcomes of patients were retrieved from the electronic database in the institution. The primary outcome was 30-day mortality. Secondary outcomes consisted of length of operation; duration of cardiopulmonary bypass; duration of aortic cross clamp; postoperative length of stay; patient status at discharge and postoperative complications such as prolonged ventilation, atrial fibrillation, pericardial effusion, reoperations, transient ischaemic attacks, stroke, surgical site infections, renal impairment and pulmonary complications. Stroke was defined as a permanent neurological deficit associated with infarct or bleed on radiological imaging. Prolonged ventilation was defined as requiring > 24 h on the ventilator. Acute renal impairment was defined as a rise in creatinine level above the upper limit of baseline. Surgical site infection was defined as sternal infections for MS and thoracotomy/cannulation site infections for MICS.

Categorical data was represented as frequencies and percentages. Continuous non-ordinal data was expressed as mean (standard deviation), while ordinal variables were expressed as median [interquartile range]. Patients were stratified by procedure type (MS vs MICS). All patients initially scheduled to undergo MICS who underwent conversion to MS for clinical reasons were excluded from the final analysis in the MICS group. Mann-Whitney *U* test was used for continuous variables and chi-square test was used for categorical variables. Multivariate analysis using multiple backward logistic regression was conducted to determine whether MICS was associated with the postoperative outcomes, expressed as odds ratio. Variables included in the analysis were age, gender, race, diabetes mellitus, hypertension, hyperlipidaemia, renal disease, chronic obstructive pulmonary disease, previous cardiovascular intervention, previous percutaneous coronary intervention, peripheral vascular disease, ejection fraction, operative urgency, type of cardiac procedure and weight of the intervention. A secondary analysis of the clinical outcomes of patients who underwent MICS will be conducted to evaluate the effects of a learning curve. All statistical analyses were conducted using R Studio (Team R. RStudio, 2015: Integrated Development for R. Boston, MA, USA).

RESULTS

From January 2009 to February 2020, 5,285 patients who underwent cardiac surgery met the inclusion criteria. 816 patients were excluded, as they had either EuroSCORE II > 5%, required emergency operation or met other exclusion criteria. Of the operations conducted before 2017, 12 out of 165 patients (7.3%) who were initially scheduled to undergo MICS converted to MS. Four patients converted owing to inadequate exposure of the surgical area, while the other eight converted owing to bleeding. After 2017, only five out of 242 patients (2.1%) who were scheduled to undergo MICS converted to MS, one of whom converted because of inadequate exposure of the surgical area and four because of bleeding. These 16 patients who converted to MS were excluded. The final study population comprised 4,063 patients who underwent MS and 390 patients who underwent MICS. Fig. 1 shows the distribution of cases performed across the years. Notably, the number of MICS operations with two or more concomitant cardiac procedures performed increased over the years, while the mean postoperative length of stay decreased across the years.

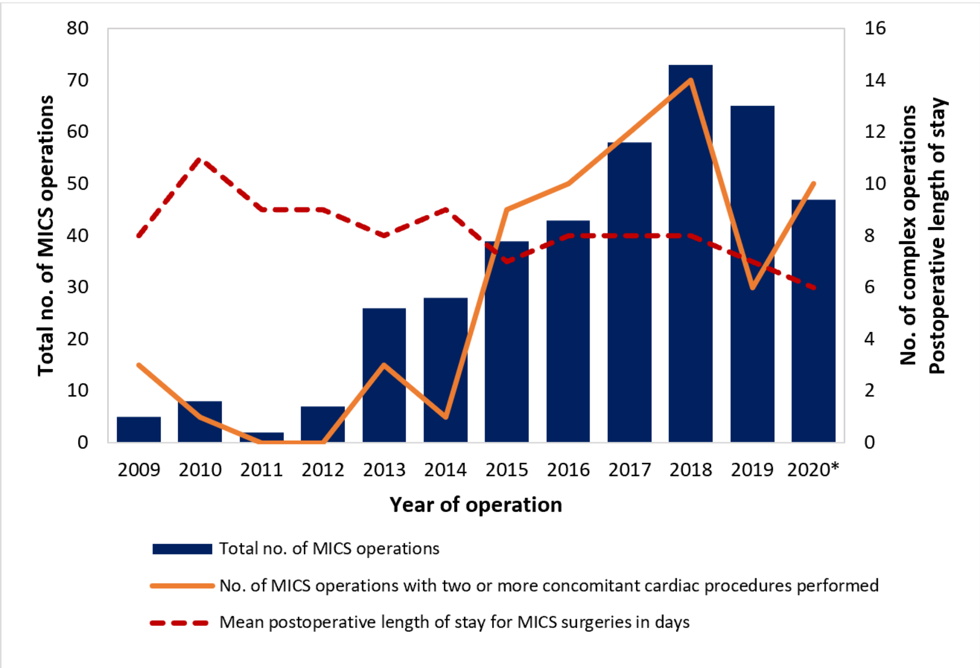

Fig. 1 Histogram shows the total number of cases of minimally invasive cardiac surgery (MICS), the number of operations with two or more concomitant cardiac procedures performed and the mean postoperative length of stay across the years. *Data for year 2020 was collected until February 2020.

The baseline characteristics of the patients are summarised in Table I. The preoperative baseline ejection fraction (%) estimated visually via transthoracic echocardiography showed that patients who underwent MICS had higher ejection fraction values (MS: 66.3% [45–60] vs MICS: 86.4% [55–65], $p < 0.001$), with a lower proportion of patients having poor (EF < 30%) left ventricular ejection fraction (MS: 7.2% vs MICS: 1.5%, $p < 0.001$). Consistent with global practice, most patients who underwent MICS were generally younger, with fewer comorbidities.[10] The perioperative parameters of the patients are summarised in Table II.

Table I. Baseline demographics of patients who underwent median sternotomy (MS) or minimally invasive cardiac surgery (MICS).

Variable	No. (%)		p-value
	MICS (n = 390)	MS (n = 4,063)	
Age at operation* (yr)	54.96 ± 14.40)	60.03 ± 9.80	< 0.001
Male gender	279 (71.5)	3287 (80.9)	< 0.001
Weight† (kg)	66.10 (14.19)	67.96 (13.09)	0.008
Height† (m)	165.09 (12.60)	164.24 (8.16)	0.064
Body mass index† (kg/m^2)	24.06 (4.27)	25.15 (4.29)	< 0.001
Family history of coronary artery disease	19 (4.9)	315 (7.8)	0.051
Never smoked	269 (69.0)	1973 (48.6)	< 0.001
Chronic obstructive pulmonary disease	7 (1.8)	78 (1.9)	1.000
Hypertension	204 (52.3)	3032 (74.7)	< 0.001
Diabetes mellitus	82 (21.0)	1917 (47.2)	< 0.001
Hyperlipidaemia	223 (57.2)	3342 (82.3)	< 0.001
Renal disease	20 (5.1)	240 (5.9)	0.608
Last preoperative creatinine level* (µmol/L)	82.86 ± 36.38	108.48 ± 118.81	< 0.001
Highest creatinine level* (µmol/L)	90.37 ± 40.31	141.19 ± 203.64	< 0.001
Ejection fraction*	57.29 ± 9.49	51.40 ± 13.43	< 0.001
Peripheral vascular disease	10 (2.6)	248 (6.1)	0.006
Carotid disease	7 (1.8)	236 (5.8)	0.001
Extracardiac arteriopathy	10 (2.8)	369 (9.1)	< 0.001
Poor mobility	4 (1.0)	102 (2.5)	0.096
Neurological dysfunction	4 (1.0)	29 (0.7)	0.706
Extensive aortic atherosclerosis	13 (3.3)	298 (7.3)	0.004
Active endocarditis	13 (3.3)	50 (1.2)	0.002
Cerebrovascular disease	34 (8.7)	427 (10.5)	0.307
Previous percutaneous coronary intervention	13 (3.3)	42 (1.0)	< 0.001
Previous cardiovascular intervention	51 (13.1)	758 (18.7)	0.008

Data presented as *mean ± standard deviation or †median (interquartile range).

Table II. Operative details of patients who underwent median sternotomy (MS) or minimally invasive cardiac surgery (MICS).

Variable	No. (%)		p-value
	MICS (n = 390)	MS (n = 4,063)	
EuroSCORE II*	1.35 ± 0.86	1.71 ± 1.09	< 0.001
Intra-aortic balloon pump inserted			< 0.001
None	367 (94.1)	3348 (82.4)	
Preoperation	1 (0.3)	296 (7.3)	
Intraoperation	18 (4.6)	374 (9.2)	
Postoperation	4 (1.0)	45 (1.1)	
Operative urgency			< 0.001
Elective	351 (90.0)	2835 (69.8)	
Urgent	39 (10.0)	1228 (30.2)	
Cardiac procedure			< 0.001
CABG only	115 (29.5)	3190 (78.5)	
Valve only	195 (50.0)	359 (8.8)	
Other	21 (5.4)	65 (1.6)	
Valve + other	53 (13.6)	108 (2.7)	
CABG + valve	1 (0.3)	198 (4.9)	
CABG + other	4 (1.0)	112 (2.8)	
CABG + valve + other	1 (0.3)	31 (0.8)	
Off pump procedure	54 (13.8)	116 (2.9)	< 0.001
Cumulative bypass duration* (min)	138.96 ± 48.49	145.25 ± 68.18	0.105
Cumulative cross clamp duration* (min)	78.52 ± 31.83	83.56 ± 39.40	0.037
Length of procedure* (min)	278.44 ± 74.57	285.58 ± 75.78	0.076

Note: Postoperative intra-aortic balloon pump insertion was performed after the patient reached the intensive care unit and not after coming off cardiopulmonary bypass in the operating theatre.
*Data presented as mean ± standard deviation. CABG: coronary artery bypass grafting

There is a steady rise in the number of MICS procedures performed throughout the years, with an increase in complexity but a reduction in postoperative length of stay (Fig. 1). A comparison of MICS cases performed before and after 2017 showed that the cumulative cross clamp duration increased by a mean of eight minutes, while postoperative length of stay decreased by a median of one day (p = 0.019; Table III). Otherwise, no significant difference in postoperative complications was observed between the two groups of patients. The composition of the types of cardiac surgeries performed before and after 2017 is summarised in Fig. 2. The nature of valvular surgeries performed among patients who underwent MICS and MS is summarised in Table IV.

Table III. Comparison of operative and postoperative outcomes among patients who underwent minimally invasive cardiac surgery (MICS) before and after 2017.

Variable	No. (%)		p-value
	Before 2017 (n = 153)	2017 and later (n = 237)	
EuroSCORE II*	1.34 ± 0.80	1.36 ± 0.89	0.815
Cardiac procedure			0.469
CABG only	38 (24.8)	77 (32.5)	
Valve only	84 (54.9)	111 (46.8)	
Other	8 (5.2)	13 (5.5)	
Valve + other	21 (13.7)	32 (13.5)	
CABG + valve	0 (0.0)	1 (0.4)	
CABG + other	1 (0.7)	3 (1.3)	
CABG + valve + other	1 (0.7)	0 (0.0)	
Length of procedure* (min)	271.54 ± 68.44	282.92 ± 78.11	0.141
Cumulative bypass duration* (min)	138.03 ± 51.33	140.33 ± 44.14	0.677
Cumulative cross clamp duration* (min)	75.05 ± 32.12	83.81 ± 30.77	0.025
Postoperative length of stay†(day)	7.00 (5.00, 9.00)	6.00 (5.00, 8.00)	0.019
30-day mortality	2 (1.3)	0 (0.0)	0.299
Atrial fibrillation	19 (12.4)	30 (14.9)	0.615
Re-operation owing to cardiac or bleeding problems	6 (3.9)	8 (3.4)	0.997
Surgical site infection	0 (0.0)	4 (1.7)	0.271
Prolonged ventilation	4 (2.6)	0 (0.0)	0.071
Pleural effusion requiring drainage	0 (0.0)	4 (2.0)	0.214
Pneumothorax requiring intervention	0 (0.0)	3 (1.5)	0.353
Acute renal impairment	3 (2.0)	8 (3.4)	0.610

Data presented as *mean ± standard deviation or †median (interquartile range). CABG: coronary artery bypass grafting

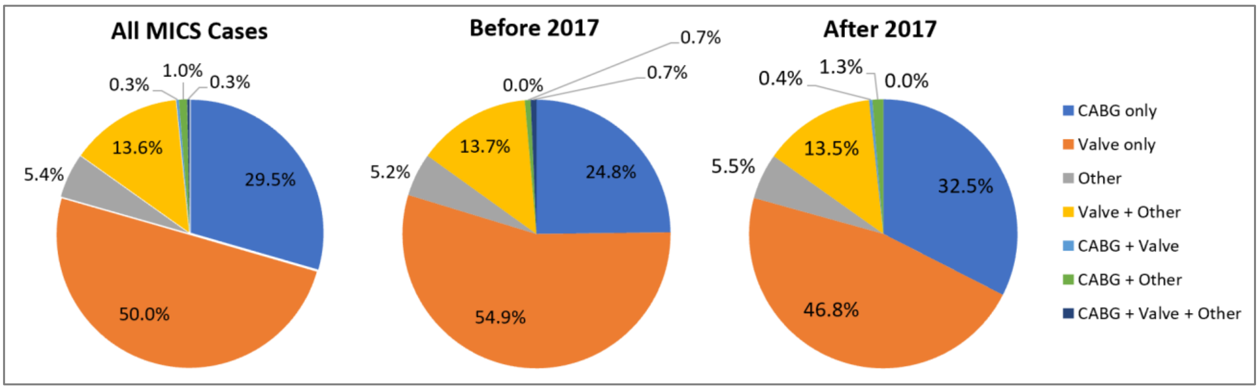

Fig. 2 Pie charts show the distribution of minimally invasive cardiac surgery (MICS) procedures throughout all the years, before 2017, and 2017 and later.

Table IV. Summary of composition of valvular surgeries.

Valvular surgery	No. (%)	
	MICS	**MS**
Mitral valve replacement	63 (22.7)	214 (77.3)
Mitral valve repair	102 (36.0)	181 (64.0)
Aortic valve replacement	56 (24.0)	177 (76.0)
Aortic valve repair	0 (0.0)	1 (100.0)
Tricuspid valve replacement	5 (26.3)	14 (73.7)
Tricuspid valve repair	19 (20.7)	73 (79.3)
Pulmonary valve replacement	7 (70.0)	3 (30.0)
Single valve operation	238 (30.0)	556 (70.0)
Double valve operation	7 (9.5)	67 (90.5)

MICS: minimally invasive cardiac surgery; MS: median sternotomy

Between patients who underwent MICS and MS, the duration of procedure (278.44 ± 74.57 min vs. 285.58 ± 75.78 min; $p = 0.076$) and duration of cardiopulmonary bypass (138.96 ± 48.49 min vs.145.25 ± 68.18 min; $p = 0.105$) were comparable. Aortic cross clamp duration was significantly shorter in the MICS group than in the MS group (78.52 ± 31.83 min vs. 83.56 ± 39.40 min; $p = 0.037$).

The postoperative outcomes and complications are summarised in Table V. The postoperative length of hospital stay in the MICS group was shorter by a median of two days ($p < 0.001$). The rates of atrial fibrillation ($p = 0.024$) and prolonged ventilation, defined as ventilation for > 24 hours postoperatively ($p < 0.001$), were lower in the MICS group. Re-operation, neurological complications, surgical site infection and acute renal impairment rates were comparable between the two groups of patients.

The odds of the MICS group developing various complications as compared to the MS group on multivariate analysis are summarised in Table VI. Notably, MICS was associated with lower rates of re-operation ($p = 0.028$), atrial fibrillation ($p = 0.021$) and prolonged ventilation ($p < 0.001$).

Table V. 30-day postoperative outcomes and complications of patients who underwent median sternotomy or minimally invasive cardiac surgery.

Postoperative outcome	No. (%)		p-value
	MICS (n = 390)	MS (n = 4,063)	
Postoperative length of stay* (day)	6.00 (5.00, 9.00)	8.00 (6.00, 10.00)	< 0.001
30-day mortality	2 (0.5)	70 (1.7)	0.110
Postoperative percutaneous coronary intervention within the same admission	1 (0.3)	3 (0.1)	0.742
Atrial fibrillation	49 (13.8)	764 (18.8)	0.024
Heart block requiring permanent pacemaker	3 (0.8)	59 (1.5)	0.486
Pericardial effusion	1 (0.3)	45 (1.1)	0.231
Re-operation owing to cardiac or bleeding problems	14 (3.6)	245 (6.0)	0.064
Transient ischaemic attack	1 (0.3)	28 (0.7)	0.569
Surgical site infection	4 (1.0)	74 (1.8)	0.346
Urinary tract infection	6 (1.7)	132 (3.2)	0.142
Bacteraemia	3 (0.8)	60 (1.5)	0.466
Pneumonia	7 (2.0)	128 (3.2)	0.282
Prolonged ventilation	4 (1.1)	249 (6.1)	< 0.001
Pleural effusion requiring drainage	4 (1.1)	25 (0.6)	0.423
Pneumothorax requiring intervention	3 (0.8)	12 (0.3)	0.218
Acute renal impairment	11 (2.8)	168 (4.1)	0.260

*Data presented as median (interquartile range).

Table VI. Multivariate analysis showing the odds ratios of 30-day postoperative outcomes and complications of patients who underwent minimally invasive surgery (MICS) with reference to those who underwent median sternotomy (MS).

Postoperative outcome	OR (95% CI) MICS with reference to MS*	p-value
Atrial fibrillation	0.69 (0.50–0.94)	0.021
Re-operation owing to cardiac or bleeding problems	0.62 (0.45–0.84)	0.028
Urinary tract infection	0.43 (0.16–0.95)	0.055
Prolonged ventilation	0.18 (0.05–0.44)	< 0.001

*Patients who underwent MS are used as the reference. Adjusted by difference in age, gender, race, diabetes mellitus, hypertension, hyperlipidaemia, renal disease, chronic obstructive pulmonary disease, previous cardiovascular intervention, previous percutaneous coronary intervention, peripheral vascular disease, ejection fraction, operative urgency, type of cardiac procedure and weight of the intervention. CI: confidence interval; OR: odds ratio

DISCUSSION

Our study showed that MICS approaches in heart surgery, in addition to bearing advantages of minimal invasiveness (better cosmetics, less trauma, better mobility), conferred benefits of shorter postoperative length of stay, lower reoperation rates, lower atrial fibrillation rates and lower rates of prolonged ventilation. In addition, the 30-day mortality rates were comparable to the MS group.

Our study demonstrated comparable procedure and cardiopulmonary bypass duration, and shorter aortic cross clamp times in patients who underwent MICS. This is in contrast to the results of a systematic review and meta-analysis of eight studies on patients who underwent MICS, which revealed significantly longer operative time in the MICS group.(8) MICS procedures are believed to take longer during the initial stages, as they require a steep learning curve and employment of long shafted surgical instruments, which requires a period of adaptation.(7) However, the duration of operation was noted to decrease with intense proctorship and increasing surgical experience.(11) While advances such as using Cor-Knot or long-acting cardioplegia may contribute to the shorter cross-clamp times, our results suggest that operative data pertaining to MICS access is, in the least, comparable to that of MS. Introduction of new surgical techniques in small-volume centres invariably encounters a steep learning curve. The presence of an established MICS program, with increasing patients undergoing MICS in our institution, may also have contributed to the difference.

The shorter postoperative length of stay in MICS is consistent with other studies.(6,12) However, the overall postoperative length of stay of patients who underwent MICS in our institution was slightly greater than that reported in other MICS series. Previous studies on mixed valvular and multivessel CABG MICS procedures reported shorter mean postoperative length of stays ranging from 5.8 days to 7 days.(13-16) The longer duration in our cohort is likely attributable to a variety of medical and social factors. Medical factors include that of anticoagulation to achieve therapeutic levels, and strict institutional discharge protocols centring on rehabilitation progress, which pose a challenge to discharging patients earlier into the community. Such discharges/transfers to step-down care in our ecosystem often come with serious delays. Similarly, the transfer from the ICU to the general ward is a perennial issue in our institution, owing to limited beds and the ensuing bottleneck situation. In addition, social factors such as availability of caregivers and step-down care facilities often incur additional postoperative length of stay. Hence, while we offer a less invasive patient experience, we are often faced with artificial delays, which offset the anticipated impact of our MICS programme on the length of stay. Nevertheless, increased experience with MICS and focus towards a fast-track recovery programme likely contributed to the improved length of stay in the patients after 2017.

Postoperative atrial fibrillation was significantly less common in the MICS group. Studies by Santana et al and Mihos et al reported similar observations.(1,12) Santana et al also showed that patients with postoperative atrial fibrillation were associated with higher incidences of concomitant complications such as prolonged intubation, acute renal failure, pneumonia and need for reintubation.(1)

The rates of reoperation were lower among patients who underwent MICS than in those who underwent MS. The rates among patients who underwent MICS in our study were comparable to the reported incidence in multiple studies.(11,12,17,18) This may partly be attributable to a higher proportion of MICS valve surgeries in patients who were not on any perioperative antiplatelets, and also to less bleeding because of a smaller incision.

The reduced incidence of prolonged ventilation among patients who underwent MICS may be explained by the less traumatic and invasive access to the heart, which minimises disruption to the clavi-pectoral girdle. Previous studies have reported similar observations.(1,3,8,19) Reduced pain and faster healing from a smaller incision likely contributed to improved breathing mechanics in the MICS group and, hence, less requirement for invasive ventilation.

Patients who underwent MICS had lower nonsurgical infection rates (urinary tract infection, bacteraemia, pneumonia) than those who underwent MS did, although none of them reached statistical significance (Table VI). Studies on nonsurgical infections in patients who underwent MICS are limited. The reduced incidence of nonsurgical infections may be attributable to early mobilisation and a shorter postoperative length of stay among patients who underwent MICS, resulting in less exposure to nosocomial pathogens.

Our overall conversion rate was 3.9%, with the majority conversions occurring prior to 2017 (conversion rate of 7.3% prior to 2017 and 2.1% after 2017), suggesting a lower incidence of conversion with increasing MICS experience. It is our practice to keep our threshold for conversion low and not attempt to stop profuse bleeding tenaciously. Exposure or target vessel quality was another reason for conversion, to avoid compromising the quality of anastomosis or the relevant surgical purpose. With increasing experience, our lead surgeon is also training younger surgeons, who are progressing through their learning curve.

In our institution, more than 60% of patients who undergo cardiac surgery have low preoperative risk (EuroSCORE II < 2%). However, this does not mean that MICS cannot address patients with moderate- and high-risk surgical conditions. An analysis of the performance of MICS in high-risk groups in our local context will be conducted in our next study.

The MICS programme of our institution has been steadily growing and is supported by educational, research and innovation outputs, with strong organisational support and industry liaisons. Since the induction of the programme, it has already laid the foundation for two ‘Centres of Excellence’. It has also attracted numerous visiting teams and offered rich proctorships in the region, providing impetus for further healthcare financing discussions and adaptations with authorities. This study provides convincing evidence that MICS is beneficial for our patients, while retaining surgical safety and efficacy. With continued growth in this programme, MICS can become a new gold standard for selected patients scheduled to undergo cardiac surgery and selected conditions, if provided appropriate in-situ and in-silico training.

This study has some limitations. Firstly, this was a single-centre retrospective analysis, with a relatively low volume of patients. Secondly, while the compared study cohorts were adjusted for EuroSCORE II, the performance of EuroSCORE II in Asian populations was found to underestimate the postoperative mortality rate in patients with combined cardiac procedures and multiple valvular surgeries, as well as in high-risk patients.[(20-22)] This may limit the use of EuroSCORE II to reflect the operative risk of a multiracial Asian population in Singapore, leading to underestimation of preoperative risk. Thirdly, the two groups were not pair-matched, and a heterogeneity was observed in the baseline characteristics and procedures performed in both groups, which may confound the analysis of patient outcomes. This finding correlates with global observations, wherein patients who underwent MICS were generally younger, with fewer comorbidities. Lastly, both groups comprised procedures performed by multiple surgeons with varied surgical experience.

In conclusion, our study demonstrates that it is possible to establish a Singapore-based MICS programme comparable with other leading MICS programmes that is able to confer a high standard of care without compromising safety. More data in matched populations is required to provide further evidence regarding the benefits of MICS in our mixed-ethnic population.

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