Minimally-invasive coronary artery bypass grafting offers superior outcomes compared to conventional median sternotomy: a propensity-score matched study

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Abstract

Introduction

This study aims to compare the outcomes of minimally invasive coronary artery bypass grafting surgery (MICS CABG) versus median sternotomy (MS CABG) within an established minimally invasive cardiac surgical programme in Singapore.

Methods

We retrospectively analysed 111 propensity-score matched pairs of patients who underwent MICS CABG or MS CABG between January 2009 and February 2020 at the National University Heart Centre, Singapore. Minimally invasive direct coronary artery bypass (MIDCAB) patients were matched to single or double graft MS CABG patients (Group 1) while multivessel MICS patients were matched to MS CABG patients with the corresponding number of grafts (Group 2).

Results

111 propensity matched pairs were obtained. The EuroSCORE II in the matched group cohorts were comparable (p=0.846).

In both single and multivessel groups, MICS patients experienced shorter postoperative length of stay (p<0.001) and lower rates of prolonged ventilation (p=0.041) . Intraoperative transfusion rates and other postoperative outcomes were comparable between MICS and MS patients in the single and multivessel groups.mortality, reintervention heart failure rates were also comparable at 1 year follow up.

In Group 1, no significant differences in procedural duration (p=0.574) and cardiopulmonary bypass duration (p=0.699) were noted. Moreover, MIDCAB patients had a smaller drop in postoperative haemoglobin levels (p<0.001).

In Group 2, cardiopulmonary bypass (p=0.097) and length of procedure (p<0.001) were longer among multivessel MICS patients but did not translate to adverse postoperative events.

Conclusion

MICS CABG is a safe and effective approach for surgical revascularisation of coronary artery disease.

Keywords: Minimally invasive cardiac surgery, coronary artery bypass grafting, propensity score

Introduction

Coronary artery bypass grafting surgery (CABG) has shown superior outcomes compared to percutaneous coronary intervention (PCI) in specific groups of patients with coronary artery disease [1], and remains the recommended treatment for patients with complex multivessel coronary artery disease (CAD) [2]. The conventional approach to CABG via median sternotomy (MS) is invasive and often entails a prolonged recovery period lasting over 6 weeks to return to premorbid status. Modern surgical technologies have enabled less invasive access for CABG via a mini-thoracotomy approach. Minimally invasive coronary artery bypass grafting (MICS CABG) has since expanded from single vessel disease [3] to multivessel CAD[4].

The performance of MICS CABG has improved over the years. Long-term outcomes of MIDCAB have shown comparable anastomotic patency rates to that of the conventional sternotomy [5]. In addition, MICS CABG has been proven to shorten postoperative length of stay along with less postoperative complications such as new onset atrial fibrillation and surgical site infections [6–10]. At the time of launch of the M.I.S.T. trial[11], it will be compelling to introduce subgroup data and techniques arising from a mixed Asian population. Our cohorts' adverse anatomy of small-chested patients, with high diabetes load and diffuse coronary disease of minute vessels, our experience may indeed lower the threshold for adopting MICS. Herein we present the results of minimally invasive coronary artery bypass grafting surgery (MICS CABG) performed at the National University Heart Centre, Singapore.

Patients and Methods

118 patients underwent MICS CABG between January 2009 and June 2020 at the National University Heart Centre, Singapore. Seven patients required conversion to sternotomy and were excluded from the analysis. We retrospectively analysed the remaining 111 patients. The study was approved by the local ethics review board [#2020/00547] and the requirement for individual patient consent was waived. Propensity-score matching was carried out with 3633 patients within the institution's database who underwent conventional MS CABG between January 2009 and December 2018. Patients were matched for age, gender and Euroscore II.

Propensity Score Matching

We further divided the MICS patients into MIDCAB and multivessel CABG groups.

As there were fewer single graft MS CABG operations than MIDCAB, the remaining unmatched MIDCAB patients were matched to double graft MS CABG patients (Group 1). Multivessel MICS CABG patients comprised double or triple grafts and were matched with MS CABG with the respective number of grafts (Group 2).

Baseline characteristics, intraoperative data, postoperative outcomes and 1-year follow-up outcomes were compared between the MICS and MS groups.

Primary and Secondary Outcomes

The primary outcome of this study was postoperative length of stay. Secondary outcomes included operative times, intraoperative transfusion requirements, laboratory indices, 30-day postoperative complications as well as mortality and cardiac events at follow up. Postoperative complications included stroke, prolonged ventilation, new onset atrial fibrillation, renal impairment and pulmonary complications. Stroke was defined as a permanent neurological deficit associated with ischaemic infarct or haemorrhage on radiological imaging. Prolonged ventilation was defined as requiring >24hours of ventilation.

Renal impairment was defined as rise in creatinine above the upper limit of baseline or requiring new-onset dialysis. Surgical site infection was defined as sternal infections for MS and thoracotomy/cannulation site infections for MICS. Non-surgical infections comprised urinary tract infection or septicaemia. Mortality and adverse cardiac events including reintervention requiring percutaneous coronary intervention, myocardial infarction, heart failure and New York Heart Association Functional Classification (NYHA) were analysed up to one year postoperatively.

Statistical analysis

All statistical analyses were performed using R Studio (RStudio Team 2015, Boston, MA). Categorical data were represented as frequencies and percentages. Continuous data were tested for normality via Shapiro-Wilk's method. Normally distributed continuous variables were expressed as mean (standard deviation). Propensity scores between the MICS and database patients were estimated using logistic regression with 1:1 matching. MS patients with poor matching propensity scores were excluded from the analysis. For non-matched cohorts, categorical variables were compared using the Chi-square test while continuous variables were analysed using the student's t-test or Mann-Whitney U test where appropriate. For propensity-score matched pairs, categorical variables were compared using Mcnemar's test and continuous variables were compared using Wilcoxon's paired signed-rank test.

Surgical technique

Majority of patients in the MS group underwent conventional on-pump coronary artery bypass grafting with individual aortocoronary anastomosis performed via side-clamping of the aorta. Few patients in the MS group had off-pump or on-pump beating heart surgeries. Patients who underwent MICS underwent either MIDCAB or multivessel grafting. MIDCAB operations were predominantly performed off-pump, while patients who required multivessel grafting were performed either on an arrested heart or on a beating heart with CPB support. Standard aortic and 2 stage right atrial cannulation was performed for cardiopulmonary bypass for MS cases, while femoral arterial and venous cannulation were performed in on-pump MICS cases.

Results

111 matched pairs were analysed. This comprised 60 MIDCAB patients who were matched to 34 single graft and 26 double graft MS CABG patients (Group 1), and 51 multivessel MICS CABG patients who were matched with MS CABG patients having respective number of grafts (Group 2) (*Figure I*).

Baseline characteristics of the matched pairs are summarised in Table 1. All preoperative patient demographics and comorbidities were comparable except race and history of smoking. A higher proportion of MICS patients in Group 2 were Chinese, and more MS patients were smokers. Operative risk as evaluated by EuroSCORE II was comparable between both MICS and MS patients (MICS: 1.20 (±0.61) vs MS: 1.18 (±0.63), p-value=0.846) after matching.

Intraoperative Details

Procedural details of matched pairs are summarised in Table 2.

In Group 1, a larger proportion of MS patients underwent urgent operations, defined as surgeries performed within the same admission, compared to the MIDCAB (p=0.013). More

MIDCAB patients underwent off-pump and on-pump beating heart (p<0.001). The length of procedure and cardiopulmonary bypass time were comparable between both subgroups.

In Group 2, on-pump beating procedures were more common among MICS patients (p<0.001). The length of procedure was markedly longer in MICS patients in Group 2 compared to MS patients (p < 0.001), as was the cardiopulmonary bypass time (p= 0.097). However, the aortic cross clamp timings were comparable (p=0.237).

Intraoperative transfusion and laboratory results

Transfusions and laboratory results are summarised in Table 3. Overall, the proportions of patients who received transfusions for packed red blood cells, platelets and fresh frozen plasma, were comparable in both groups. The volume of each type of transfusion product administered were also similar. There was no significant difference in pre- and postoperative creatinine and postoperative lactate among the groups.

In Group 1, MIDCAB patients suffered a smaller drop in postoperative haemoglobin compared to MS patients (p<0.001).

Postoperative outcomes

In both groups, 30-day mortality rates were comparable between the MICS and MS patients. Both MIDCAB and multivessel MICS patients experienced significantly shorter postoperative length of hospital stay (p<0.001) (Table 4). Rates of reoperation and neurological complications were generally low in all patients. Reoperation, postoperative atrial fibrillation and neurological complications appeared lower among MICS patients but did not reach statistical significance.

Moreover, patients who underwent MIDCAB or multivessel MICS were extubated earlier than MS patients (p=0.041). Other respiratory complications such as pneumonia and pleural effusion requiring drainage were comparable. The rates of permanent pacemaker insertion, surgical site infections, non-surgical site infections and acute renal injury were comparable among Groups 1 & 2.

Follow-up outcomes

Follow-up outcomes are summarised in Table 5. None of the patients required surgical reintervention on follow up. One MS patient developed myocardial infarction in the first year and required reintervention in the form of percutaneous coronary intervention. Mortality and heart failure rates at 1 year were comparable. A higher proportion of MS patients were NYHA class 2 and above at 1-year follow-up. *Figure II* illustrates a Kaplan-Meier survival curve comparing the survival probability between MICS and MS patients; no significant difference was found (p=0.710).

Discussion

Postoperative recovery was superior in MICS patients regardless of number of grafts, mainly contributed by significantly shorter need for hospitalisation and ventilation. The similarity of clinical outcomes between MICS and MS patients have been reported in multiple previous studies[12-15]. MICS patients are able to enjoy shorter postoperative length of stay, blood loss, and comparable perioperative outcomes.

The longer procedural times is consistent with previous studies, which showed that the operative duration of minimally invasive CABG was longer than the standard MS CABG[12,13]. This is often attributed to technical challenges associated with a limited access and a

learning curve for MICS procedures. While operative times generally took longer for MICS surgeries, these did not translate to any clinical significance as demonstrated by a tendency towards superior clinical postoperative outcomes in MICS patients overall.

The duration of MICS CABG in this study appears to be longer than both the STET trial and the study by Rabindranauth et al. This variation could be attributed to surgical and institutional factors. Institutional factors include varying protocols, while surgical factors such as surgeons' experience in MICS and difference in surgical practices and procedures may play a role in altering the operative duration. Introducing MICS to valve surgeries first may have also familiarised surgical staff more with minimally invasive procedures overall making it easier to implement MICS CABG. Information regarding CPB and ACC durations were less widely reported as most MICS CABG procedures were compared to off-pump median sternotomy CABG.

Fewer patients in the MIDCAB (Group 1) required intraoperative packed red cell transfusion, although this did not reach statistical significance. A similar trend was observed in other studies[10,12]. The STET trial reported few patients requiring red blood cell transfusions; only 2 patients (2%) in the off-pump CABG group and no patients in the thoracotomy CABG (ThoraCAB) group required transfusion[13] . The variation in the incidence of intraoperative transfusions and red blood cell transfusions could be attributed to the comparison with off-pump CABG.

The significant difference in haemoglobin drop was also observed in the STET trial[13]. This is likely attributed to lesser surgical trauma from smaller incisions in MICS. A limitation of this finding is that some MIDCAB patients were matched with double graft MS CABG patients who may have experienced more blood loss. Also, information regarding autologous cell saver usage was not available.

Postoperative atrial fibrillation was comparable in this study with a trend towards superiority in MICS CABG. Previous studies observed comparable rates of postoperative atrial fibrillation, or even higher than MS patients[6,12]. The STET trial on the other hand, reported rates of postoperative arrhythmias, and not atrial fibrillation. It showed incidence of arrhythmia was higher among MS off-pump coronary artery bypass patients than ThoraCAB[13].

Single lung ventilation in the setting of MICS CABG did not increase risk of pulmonary complications. This is consistent with a previous review of five non-randomised control trials which found that MICS benefits postoperative lung function in patients with known respiratory problems[16]. More recently, continuous full-lung ventilation during MICS CABG which improves postoperative lung function has been described[17]. More studies are warranted to determine its efficacy.

The shorter length of postoperative stay among MICS patients was consistently reported in literature[12,13]. The shorter postoperative length of stay observed in MICS patients may be contributed by the shorter recovery needed with smaller incisions. Strict postoperative protocols and less surgical trauma derived from MICS in our institution could be contributing factors. Despite this, it is important to note that discharge protocols from ICU and from the hospital varies between centres.

A long-term, 7-year follow-up study of 1300 MICS CABG patients by Holzhey et al. showed that short-term reintervention rates were 4.1%[18]. Teman et al. conducted a propensity score-matched MICS CABG and conventional MS CABG comparison, and observed that reintervention rates were higher among MICS patients[15]. This is in contrast with the low rates of reintervention in our institution, which may be explained by surgical experience. Majority of the MICS CABGs were performed by a single, experienced surgeon.

Approximately 50% of MICS and MS patients had NYHA class 2 or more preoperatively. At 1-years follow-up, this proportion dropped to 2.0% in MICS patients and 10.1% in MS patients. This finding hints at the success of a minimally invasive approach to coronary artery bypass grafting.

Our study demonstrated that both single and multivessel MICS vs MS had comparable outcomes. This provides stronger evidence of our success at a minimally invasive approach to coronary artery bypass grafting. Our performance was consistent, even among the multivessel group. We perceive our approach a realistic and reproducible one: a mere transfer of the same techniques employed through median sternotomy to the lateral mini-thoracotomy setting. We do not condemn CPB nor combat aortic crossclamping, in a mixed Asian population of small chested patients with diffuse coronary artery disease. This lowers the threshold for adoption, produces sound outcomes, and prevents frequent hybrid bailouts and conversions. Still the patients benefit in certain postoperative aspects. As Singapore's pioneering minimally invasive cardiac surgery centre, these results serve as an affirmation to the educational, innovation and research progress we have achieved.

Limitations

First, the sample size is limited and not powered for comparison. Second, as the study was performed based on data collected in a surgical registry, certain clinical information regarding MICS patients were not accessible. Notably, information regarding laboratory data was not complete for patients whose operation was performed before 2015. Third, in the 12 years since MICS was first introduced in this institution, multiple surgeons have provided MICS and MS cardiac operations. We did not account for differences in performance and experience between various surgeons. Finally, this study is a retrospective single-centre study in a tertiary hospital. Given that different centres have differing clinical practices pertaining to perioperative management, the results reported in this study cannot be generalised to other centres.

Conclusion

In conclusion, our study demonstrates that MICS CABG is a safe and effective alternative to conventional MS CABG and may provide superior outcomes that have the potential to improve the patient's overall quality of life and decrease hospital stay. Our small but increasing case volume may provide a better perspective on our performance in subsequent studies.

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