Minimally invasive mitral valve surgery without aortic cross-clamping and with femoral cannulation is not associated with increased risk of stroke compared with traditional mitral valve surgery: a propensity score-matched analysis†

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Received 16 September 2014; received in revised form 9 December 2014; accepted 19 December 2014

Abstract

OBJECTIVES: Open-heart surgery with fibrillatory arrest has been reported to be associated with an increased risk of stroke. We examined whether minimally invasive mitral valve surgery with fibrillatory arrest conferred a higher risk of stroke/transient ischaemic attack (TIA) and other major complications compared with median sternotomy and cardioplegic arrest.

METHODS: Data were collected prospectively for 387 patients who had mitral valve surgery; 239 had a minimally invasive surgical approach and 148 had median sternotomy. All minimally invasive surgeries were performed by surgeons who were experienced in minimally invasive techniques. The effect of operative approach on risk of stroke/TIA and major morbidity was examined. After propensity score matching (PSM) was conducted between the two groups, 76 patients remained in each group.

RESULTS: Before matching, the incidence of stroke/TIA did not differ between patients who had minimally invasive surgery (0.5%, n = 1) and those who had median sternotomy (1.4%, n = 2; P = 0.56). Patients who had minimally invasive surgery had a lower incidence of other major morbidity (0.8%, n = 2) than patients who had median sternotomy (6.1%, n = 9; P = 0.004). After adjustment for age and Society of Thoracic Surgeons predicted risk, there was no effect of operative approach on the odds for stroke/TIA (odds ratio [OR] = 0.41, P = 0.49) or other major morbidity (OR = 0.40, P = 0.31). After PSM, patients were balanced on preoperative characteristics. No patient in either matched group experienced permanent stroke/TIA, and major morbidity did not differ between the two groups (minimally invasive, 1.3%, n = 1; median sternotomy, 1.3%, n = 1; P > 0.99).

CONCLUSIONS: A minimally invasive approach for mitral valve surgery on a fibrillating heart was not associated with a greater incidence of stroke/TIA than was median sternotomy. When performed by highly experienced surgeons, the minimally invasive approach with fibrillatory arrest did not increase the risk of perioperative stroke.

Keywords: Minimally invasive technique • Mitral valve surgery • Cardiac surgical approaches

INTRODUCTION

The development of minimally invasive techniques for cardiac surgery began to take shape in the mid-1990s, as surgeons explored the potential of these techniques to decrease cardiopulmonary perfusion times, incision size, wound infection and other complications [1, 2]. Since the first demonstration of the relative safety of minimally invasive approaches in mitral valve surgery, the variety of instruments, devices and perfusion techniques has continued to grow [3]. Today, these approaches are increasingly preferred over median sternotomy approaches [4–6]. At the same time, there has been concern that minimally invasive approaches with retrograde femoral perfusion may be associated with a higher risk of stroke/transient ischaemic attack (TIA) than median sternotomy techniques, especially in patients with significant peripheral vascular disease [4, 7, 8]. Moreover, there is a notion that performing minimally invasive mitral valve surgery on a fibrillating heart may be associated with an increased risk for morbidity and, especially, strokes, although reports from experienced centres may contradict this point [9]. In this study, we examined whether the risk of stroke/TIA with minimally invasive mitral valve surgery with fibrillatory arrest and femoral cannulation is higher than that with median sternotomy and cardioplegic arrest.

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MATERIALS AND METHODS

All patients who underwent first-time isolated mitral valve surgery between 2008 and 2014 at our centre were eligible for the present analyses (n = 387). Data were collected prospectively on 239 patients who underwent minimally invasive surgery and 148 patients who had median sternotomy surgery. All of the minimally invasive mitral valve surgeries in this sample were performed through a right minithoracotomy (5–6 cm) on a fibrillating heart with no aortic cross-clamping. This study primarily utilized data collected prospectively from our local Society of Thoracic Surgeons (STS) database and from supplemental data collected prospectively in our institutional cardiac surgery database. The primary outcomes for this study included perioperative stroke/TIA, other major morbidity and operative mortality (<30 days). All outcomes were captured according to STS definitions. Stroke was defined as ‘any confirmed neurological deficit of abrupt onset caused by a disturbance in blood supply to the brain that did not resolve within 24 h’. TIA was defined as ‘loss of neurological function that was abrupt in onset, but with complete return of function within 24 h’. Criteria for the major morbidity composite outcome were one or more of the following: perioperative myocardial infarction, wound infection, pneumonia, reoperation for bleeding, perioperative renal failure or operative mortality (<30 days).

Preoperative screening

All patients underwent cardiac catheterization to rule out coronary artery disease. Computed tomography (CT) angiography of the chest, abdomen and lower extremities was performed to identify significant aortic or peripheral atheromatous disease that would preclude femoral cannulation and retrograde perfusion.

Operative technique

All minimally invasive procedures were performed by surgeons who were experienced in minimally invasive mitral valve surgery. The minimally invasive mitral valve technique was performed on the fibrillating heart as described previously [10]. Briefly, the left femoral artery and vein were exposed and cannulated. A right anterolateral mini-thoracotomy (5–6 cm) was made and the right chest entered through the fourth intercostal space. The pericardium was opened ~2 cm anterior to the right phrenic nerve. Ventricular fibrillation was electrically induced, and a left atriotomy incision was performed. Mitral valve repair or replacement was performed under direct vision with standard minimally invasive tools. Conversion to cross-clamp and cardioplegia or conversion to sternotomy was not required in this sample. Upon completion of the open-heart procedure, the lungs were insufflated and extensive air evacuation manoeuvres were performed. The patient was rewarmed, defibrillated with external pads (Medtronic, Minneapolis, MN, USA) and weaned off cardiopulmonary bypass. The arterial and venous cannulae were removed, and the vessels repaired. The groin incision was closed, a Blake drain was placed in the right pleural chest and the thoracotomy was closed.

Statistical analysis

All analyses were conducted with SPSS Version 17.0 (SPSS, Inc., Chicago, IL, USA) and R 2.10.1 (The R Foundation for Statistical Computing; Vienna, Austria). For all analyses, a two-sided P of <0.05 was used to determine significance. Continuous data are presented as mean ± standard deviation, and categorical data are presented as frequency (percent) unless otherwise noted. Analyses comparing patient characteristics by operative approach included Student’s independent-sample t-tests and Mann–Whitney U-tests for continuous variables and χ² tests for categorical variables. The effect of operative approach on stroke/TIA and major morbidity was examined for the full sample with univariate and multivariate analyses. Univariate analyses were conducted with χ² tests, and multivariate analyses were conducted with logistic regressions adjusted for age and STS-predicted risk. The multivariate analysis for stroke/TIA was adjusted for age and STS-predicted risk for stroke, whereas the multivariate analysis for major morbidity was adjusted for STS-predicted risk for morbidity/mortality.

Propensity score matching (PSM) was conducted with the MatchIt package for R to improve covariate balance across the operative approach groups. The propensity score was estimated with a logistic model, using the following covariates: age, gender, ejection fraction, peripheral vascular disease, chronic pulmonary disease, prior cerebrovascular accident, history of atrial fibrillation or atrial flutter, mitral valve procedure (repair or replacement), body mass index, preoperative creatinine level, elective surgery status and STS risk score. Patients in the median sternotomy group were then matched on propensity score to patients in the minimally invasive group by using a caliper of 0.25 propensity score standard deviations. The sample remaining after PSM was n = 76 in each group, and the PSM procedure resulted in good covariate balance between the two groups (Fig. 1).

RESULTS

Patient characteristics

In this sample of patients who had undergone isolated mitral valve surgery, the mean age was 58 ± 13 years, 37% were female...
Full-sample analyses

Before matching, the minimally invasive and median sternotomy groups did not differ in incidence of stroke/TIA (0.4 vs 1.4%, P = 0.56), although the minimally invasive group had a lower incidence of other major morbidity (0.8 vs 6.1%, P = 0.004) and operative mortality (0 vs 2.7%, P = 0.02) (Table 3). Even though the median sternotomy group had a significantly higher incidence of operative mortality, the observed cases were still less than predicted by the STS risk score [observed-to-expected (O/E) ratio = 0.84].

After adjustment for age and STS-predicted risk for stroke, there was no effect of operative approach on odds for stroke/TIA in the full sample [OR = 0.41, 95% confidence interval (CI) = 0.03–5.34, P = 0.49]. Similarly, after adjusting for age and STS-predicted risk for morbidity/mortality, there was no effect of operative approach on odds for other major morbidity (OR = 0.40, 95% CI = 0.07–2.34, P = 0.31).

Propensity score matching analyses

After PSM, the operative risk and comorbidities in the two groups were no longer different, and outcome analyses of comparable groups of patients were now possible. No patients in either PSM group experienced a permanent stroke/TIA, and major morbidity (1.3 vs 1.3%, P > 0.99) and operative mortality (0 vs 1.3%, P > 0.99) no longer differed between the minimally invasive and the median sternotomy groups.

DISCUSSION

In the present analysis, the use of a minimally invasive approach for mitral valve surgery performed on a fibrillating heart was not associated with a greater incidence of stroke/TIA or other major
morbidity when compared with a median sternotomy procedure. We compared our minimally invasive approach for isolated mitral valve surgery and fibrillatory arrest with our experience with median sternotomy. Our collective experience includes more than 450 patients in which minimally invasive techniques have been used for various types of procedures (isolated mitral valve surgeries, mitral valve procedures combined with a Cox-Maze procedure and stand-alone Cox-Maze procedures), with only one perioperative stroke and two TIs.

Our practice of minimally invasive approaches with femoral cannulation and retrograde perfusion is performed only in cases where CT angiography findings demonstrate no evidence for significant vascular disease before the procedure. In cases of significant vascular pathology, median sternotomy or alternative access, such as axillary artery cannulation, should be considered to allow antegrade flow and minimize the risk of stroke. For this reason, patients with significant peripheral vascular disease were excluded from a minimally invasive fibrillating-heart operative approach.

The incidence of major morbidity was lower in patients who had minimally invasive procedures. After adjustment for age and STS risk, operative approach had no effect on the odds for stroke/TIA and other major morbidity. PSM was then performed in the two patient groups and resulted in comparable preoperative characteristics. After PSM, no patient in either group experienced permanent stroke/TIA, and no differences were found in the incidence of other major morbidity in the two groups.

In the immediate wake of the development of minimally invasive techniques for mitral valve surgery, some published reports expressed concern that the results of these approaches were inferior to those of median sternotomy, particularly with regard to stroke and other complications [11–13]. Since their initial development, minimally invasive techniques have consistently been shown to yield improved outcomes, including decreases in bleeding and blood product transfusion, wound infection, ventilation time, length of stay and time to return to normal activity [4, 6, 14, 15]. Recent publications have demonstrated the safety and effectiveness of minimally invasive mitral surgery with a fibrillatory arrest method [16, 17]. Even in very experienced centres, however, minimally invasive mitral valve surgery and retrograde perfusion have been found to be associated with an increased risk for stroke [9]. In this study, we were not attempting to dismiss the important data coming from programmes with extensive experience in minimally invasive mitral valve surgery, but rather to highlight the importance of patient screening and selection. Screening patients for significant vascular disease will further improve our ability to select patients and achieve excellent outcomes. Our own experience with this technique demonstrated that median sternotomy and an alternative cannulation site are safer options in patients with vascular disease [10].

We are aware of potential criticism that the information regarding the combination of retrograde perfusion and fibrillatory arrest is limited. In the past few years, we have accumulated experience with more than 450 patients that demonstrates the safety and effectiveness of this technique, as has been shown by others [10, 16]. The growing trend in the preference of minimally invasive approaches by both patients and referring physicians, together with the growing body of evidence for the safety and efficacy of such techniques, has led major centres to prefer minimally invasive techniques over median sternotomy procedures for mitral valve surgery.

In most centres, a fibrillating-heart approach is chosen only in redo cases. Thus, higher reported rates of neurological events in other series might also be applicable to redo cases, which may be associated with a higher stroke rate. Although our study was designed to evaluate only first-time cases, minimally invasive redo surgery at our centre (n = 30) resulted in a 0% incidence of stroke/TIA.

Finally, it is possible that minimally invasive mitral valve surgery without aortic cross-clamping and with fibrillatory arrest might produce stroke rates similar to those seen with minimally invasive mitral valve surgery with aortic cross-clamping and cardioplegia. This question can be adequately answered only in a prospective randomized study.

Limitations

A limitation of this study is the fact that, as mentioned previously, all patients presenting with significant peripheral vascular disease on CT screening were excluded, according to our screening protocol for minimally invasive surgery. Although this protocol makes sense from a clinical standpoint, from a scientific perspective this selection process has the potential to generate bias. Our conclusions, therefore, are valid only for patients without relevant peripheral vascular disease on CT.

This study included a relatively small series representing the experience of a single centre and was not a prospective randomized trial, in which causality rather than association can be tested. Even though the PSM technique balanced the groups in a way that simulates randomization, unmeasured factors could still confound these results. In addition, the number of events at our centre is low, which reduces power and highlights the need for future studies addressing this issue with much larger sample sizes.

CONCLUSION

A minimally invasive operative approach for mitral valve surgery performed on a fibrillating heart with femoral cannulation was not associated with a greater incidence of stroke/TIA compared with a standard median sternotomy approach. When performed in a highly experienced centre, a minimally invasive approach with fibrillatory arrest did not increase the risk of perioperative stroke.

Conflict of interest: Niv Ad, consultant for Medtronic and AtriCure. All other authors, none declared.

REFERENCES


I have two more little remarks. Isn’t it more difficult to perform surgery on the fibrillating heart? As we all know, if you do left atrial retraction, the aortic valve may become a little incompetent, and as we do a lot of intracavitary work with Gore-Tex now, I assume it is maybe a bit more difficult to go all the way to the papillary muscles.

And what you mentioned is undeniably true. It is very interesting that the auxiliary artery offers a great alternative to offer antegrade flow in patients with peripheral artery disease, for example, in redo settings.

**Dr Ad:** As I mentioned before, we are not trying to reinvent the wheel. The way we came about with this technique is just coincidental. But to answer your questions, let me start from the end and the technical aspects.

What is really intriguing with fibrillating arrest is that the cannulation process and the exposures are very straightforward and quick and you don’t need to deal with ascending aorta. So it means that there is much less dissection and all you need is a little opening of the pericardium, a couple of stitches and you’re in the left atrium after you fibrillate. The way we fibrillate is with a bipolar pacing wire that is connected to the fibrillator and then we fibrillate.

Like anything else in life, I think there is a learning curve here, but we all went through this learning curve by doing those redos on fibrillating hearts. The vast majority of our repairs are Gore-Tex loops as artificial chordae repairs. We utilise two suctions, one in the left upper vein and the other one is slit through the mitral valve. And obviously it’s easier today than it was before, but the blood is less of a problem than we all thought, believe it or not, but this is the reality.

One of the key aspects of the exposure of the mitral valve is the retraction, and this is why we developed this unique retractor. It’s flat and long where you can actually play with it so you wouldn’t divert the aortic valve and increase the AI and the amount of blood in the field. This takes some learning curve, but it’s not really over the top.

As for de-airing, extensive de-airing starts before we close the left atrium. Unlike an arrested heart, there is a lot of blood in the field when you discontinue the suction. And actually, the way we test our repair is not by injecting saline into the ventricle. You just let the ventricle fill with blood, and it is very fast. Following the filling, you de-air it quite a few times with just tapping on the repaired mitral valve, and then we leave a vent across the mitral valve while we close the left atrium. Before you cardiovert the patient, you just turn the table up and down a few times with the suction off and on, leaving some volume into the patients and inflating the lungs and de-airing through the atriotomy, then you cardiovert. You don’t let the patient eject until you are 100% sure that there are no bubbles there, and obviously there is a lot of CO₂ on the field.

But what is intriguing is the simplicity of going on bypass, and today it can be done percutaneously, as we all know, and it’s unnecessary going to the aorta and manage the aorta.

**Dr J. Obadía** (Lyon, France): You don’t put a vent on the aorta?
**Dr Ad:** No.

**Dr Obadía:** The vent you put in the left atrium?
**Dr Ad:** Yes, across the mitral valve in the ventricle.

**Dr Obadía:** Anyhow, I have the same remark as Hugo. When you put the blade, maybe you have the experience now, but when we tried, sometimes you create some aortic insufficiency, maybe it requires some expertise, because I do your technique but only for the redos, and as a consequence it is not that frequent. Maybe I don’t put my blade in the exact position. Do you have some recommendation for this blade?

**Dr Ad:** Part of the story is also the echo technology that is with us now. So the 3D echo gives you before you go in some idea of what is going on with the mitral valve. Together with 2D echo, for an experienced surgeon it gives you a really good surgical plan.

The unique part of this retractor is that it doesn’t pull the atrium up unnecessarily. You can turn it and push rather than pull all the time. You have to accept this deficiency, maybe it requires some expertise, because I do your technique but only for the redos, and as a consequence it is not that frequent. Maybe I don’t put my blade in the exact position. Do you have some recommendation for this blade?

**Dr Ad:** Port-access minimally invasive cardiac surgery increases more cerebrovascular accidents and/or TIAs over median sternotomy due to difficult de-airing and/or the retrograde flow.

A couple of questions, you mentioned that extensive air evacuation manoeuvres were performed. It is obvious that the same manoeuvres cannot be carried out through a lateral thoracotomy than during median sternotomy, so how did you do it? Did you use CO₂? If yes, which flow and how?

We all know that it takes just one heartbeat to have an air embolism at the end of the procedure when you are closing the left atrium, to have an air embolism maybe in the ascending aorta and the supra-arch vessels. So how did you prevent that from happening? Furthermore, what was the real selection process to perform MIS over median sternotomy?