Training Surgeons in Minimally Invasive Mitral Valve Repair: A Single Institution Experience

Michele Murzi, MD, Antonio Miceli, MD, PhD, Alfredo G. Cerillo, MD, Gioia Di Stefano, MD, Enkel Kallushi, MD, Pierandrea Farneti, MD, Marco Solinas, MD, and Mattia Glauber, MD

Fondazione Toscana G. Monasterio, “G. Pasquinucci” Heart Hospital, Massa, Italy

Background. We aimed to study the results of minimally invasive mitral valve repair performed by 5 young surgeons who were trained in mitral valve repair directly through a minimally invasive approach, and a senior surgeon who introduced the technique at our institution and was responsible for the training program.

Methods. This was a retrospective, observational cohort study of prospectively collected data from 595 consecutive patients who underwent minimally invasive mitral valve repair performed by 5 trainees (n = 240, 40.3%) and by our lead consultant (n = 355, 59.7%) between 2007 and 2013. Treatment selection bias was controlled by constructing a propensity score from core patient characteristics and it was included along with the comparison variable in the multivariable analyses of outcome.

Results. Patients operated on by trainees were more likely to be female (p = 0.04), older (p = 0.001), and with history of atrial fibrillation (p = 0.001). Trainees required a significant longer cardiopulmonary bypass (137 ± 56 vs 123 ± 52 minutes; p = 0.003) and aortic clamp time (97 ± 41 vs 83 ± 40 minutes; p = 0.001). I-hospital mortalities were 1.3% in the trainees group and 0.8% in the senior surgeon group (p = 0.6). The incidence of stroke (1.7% vs 2.5%; p = 0.5), conversion to sternotomy (2.6% vs 3.5%; p = 0.5), and conversion to mitral valve replacement (12.5% vs 10.9%; p = 0.6) were similar between groups. No differences were found regarding other complications. Five-year survival (88.9% vs 89.5%; p = 0.4) and freedom from reoperation (94.5% vs 95.1; p = 0.6) were similar between groups.

Conclusions. Minimally invasive mitral valve repair is a safe and reproducible surgical technique that can be taught successfully to cardiac trainees.

Accepted for publication May 14, 2014.

Address correspondence to Dr Glauber, “G. Pasquinucci” Heart Hospital, 54100 Massa, Italy; e-mail: glauber@ftgm.it.

In recent years, less invasive procedures have emerged as the new trend in mitral valve surgery. Since the first report by Carpentier and colleagues [1], the conviction that minimally invasive mitral valve surgery could be performed with similar hospital mortality versus the standard approach, but with less blood transfusion, earlier recovery of daily activities and with higher patient satisfaction, have driven its diffusion in most centers worldwide. Young cardiothoracic surgeons have therefore been confronted with the need to gain experience in these new techniques but at the same time senior surgeons face a dilemma between the duty to deliver the highest possible standard of care to their patients and the responsibility to teach these new techniques to young cardiothoracic surgeons. Various academic centers have evaluated the safety of a training surgeon to perform mitral surgery [2–5]. However, at the moment no information is available on the impact of training in less invasive mitral valve procedures. At our institution, we have started a minimally invasive mitral valve surgery program since 2003 [6] and from that moment we have operated on more than 1,500 patients with a video-assisted right minithoracotomy approach. Due to the low numbers of standard sternotomy mitral procedures performed annually at our institution, we have been forced to introduce young surgeons to mitral repair techniques directly through a minimally invasive approach. The purpose of the present study is therefore to analyze the development of our minimally invasive mitral valve repair (MIMVR) training program and to compare performance for trainees and our lead institutional consultant who was responsible for the training during the study period.

Material and Methods

Patients Selection and Data Collection

This was a retrospective, observational, cohort study of prospectively collected data. The data collection form is entered in consecutively by anesthetists, surgeons, perfusionists and intensive care unit, and ward doctors. For this study, data were extracted from the database for consecutive patients who had undergone minimally invasive mitral valve surgery between November 2007 and January 2013 and who were operated on either by the lead institutional consultant (M.G., who introduced minimally invasive mitral valve procedure to
our institution and was responsible for the minimally invasive valve surgery training program) or 1 of 5 young surgeons who started their training in mitral valve repair directly through the minimally invasive approach. The 5 young surgeons were trained directly by the consultant. Patients undergoing reoperation or emergency procedures, which are rarely carried out by surgeons in training, were excluded. The database describes the type of mitral procedure performed (repair or replacement) but not whether the original intention of the surgeon was to carry out a repair. Therefore, operative notes for all patients were reviewed to identify conversions from mitral repair to mitral replacement. Such operations were recorded as mitral repair, and the analyses were carried out according to the principle of intention to treat. Those operations that were planned for mitral valve replacement were excluded from the study. The study was approved by the clinical audit committee of the G. Pasquinucci Heart Hospital to meet ethical and legal requirements, and individual consent was waived.

**Definitions**

Perioperative death is rare after elective or urgent mitral valve operations (1.0% in our institution during the study period). It is therefore unsuitable for monitoring performance. We thus sought a more sensitive outcome, and in advance of any analyses we defined a surgical failure as the occurrence of 1 or more of the following events: (1) perioperative death (all deaths within 30 days of operation irrespective of where the death occurred and all hospital deaths after 30 days among patients who had not been discharged after the index operation); (2) intraoperative conversion to sternotomy; (3) intraoperative repair failure requiring mitral valve replacement; (4) perioperative myocardial infarction (new Q waves > 0.04 ms or a reduction in R waves > 25% in at least 2 contiguous leads on electrocardiogram); (5) neurologic events (permanent and transient strokes); (6) acute renal failure requiring hemodialysis; (7) reoperation for bleeding; (8) in hospital reoperation for early repair failure; and (9) more than trivial mitral valve regurgitation at discharge.

An operation performed by a trainee was defined as: 1) any procedure in which the senior surgeon was scrubbed in and acted as first assistant; 2) any procedure where the senior surgeon was not scrubbed in the operating theatre but was available, generally in his office.

**Anesthetic and Surgical Technique**

Our operative technique has been previously described [7]. Briefly, it consists of a small (5 to 7 cm) right anterolateral thoracotomy in the third or fourth intercostal space. After incision a soft tissue retractor is inserted and the intercostal space is gently spread with a retractor, without rib cutting. Two trocars are inserted in the thorax to allow positioning of a ventricular vent, CO₂ insufflator, camera device, and pericardial stay sutures.

Whereas at the beginning of our experience the approach involved retrograde arterial perfusion and balloon endoclamping, the procedure has evolved to a technique with ascending aorta cannulation, long femoral venous cannula drainage, and direct transthoracic aortic clamping [8]. Antegrade cold crystalloid or warm blood cardioplegia is delivered directly into the ascending aorta by a needle vent catheter. The mitral valve is approached with a traditional left paraseptal atriotomy and exposed using a specially designed atrial retractor held by a mechanical harm inserted through a right parasternal port. Mitral valve procedures were performed under a combination of direct vision and thoracoscopic assistance.

**Statistical Analysis**

Continuous data were expressed as mean ± SD, and categoric data as percentages. The Kolmogorov-Smirnov test was used to check for normality of data in the 2 groups before further analysis. Differences between senior surgeon and trainees were compared with the use of a χ² test for categoric variables and t or Wilcoxon rank sum tests, as appropriate, for continuous variables. To reduce the effect of selection bias and potential confounding in this observational study, we developed a propensity score analysis. The propensity score for being operated by trainees was determined without regard for outcome by the use of a non-parsimonious multiple logistic-regression analysis. All the variables listed in Table 1 were included in the analysis. A propensity score, indicating the predicted probability of being operated by a trainee, was then calculated from the logistic equation for each patient. The model’s reliability and its predictive ability were tested with the Hosmer-Lemeshow goodness-of-fit test (p = 0.48) and the C-index (c = 0.78), respectively. Once the propensity score is constructed for each patient, there are 3 ways of using the score for comparisons; matching, stratification, and multivariable adjustment. We decided to use multivariable adjustment because matching would have reduced the study size and stratification can be difficult to interpret. Using a propensity score as the sole means for adjusting outcomes was preferable due to the low number of events in our study and provides better adjustment for those factors driving treatment selection; the overall effect is a more complete risk adjustment [9]. The propensity score was then included along with the comparison variable (trainees or senior surgeon) in multivariable analyses of outcome producing an adjusted odds ratio (OR) with 95% confidence interval (CI). A multivariate analysis of surgical failure was performed with logistic regression in an effort to identify independent predictors. A significance level of 0.05 was used for both entry and selection. Results are reported as percentage and ORs with 95% CIs. All reported p values are 2-sided, and p values of less than 0.05 were considered to indicate statistical significance. All statistical analysis was performed with SPSS version 19.0 (SPSS, Inc, Chicago, IL).

**Results**

The study cohort included a total of 595 cases performed between 2007 and 2013. The consultant operated on 355 patients and the trainees operated on 240 (81, 77, 37, 30,
and 15, respectively for trainees 1 to 5). Preoperative patient characteristics are shown in Table 1 and were similar between groups with respect to body mass index, diabetes mellitus, chronic obstructive pulmonary disease, New York Heart Association class, peripheral vascular disease, and ejection fraction. Patients operated on by trainees were more likely to be female, older, and hypertensive. Moreover, trainees operated on patients with a significantly higher incidence of atrial fibrillation ($p = 0.001$). The majority of patients had a degenerative valve disease and regurgitation was the predominant lesion in both groups. No significant differences were noted in terms of valve pathology between the groups. Operative data are reported in Table 2. Operations performed by trainees were more likely to be performed with central aortic cannulation and transthoracic aortic clamping. However, trainees required significant longer cardiopulmonary bypass and aortic clamp times to complete the operations. The incidence of surgical failure was similar between the groups (Table 3). In-hospital mortalities were 1.3% in the trainees group and 0.8% in the senior surgeon group. The incidences of respiratory complications, neurologic complications, and renal complications were similar among groups. Eleven patients in the senior surgeon group (3.5%) and 6 patients (2.6%) in the trainees group had to undergo conversion to standard sternotomy for intraoperative problems. Intensive care unit (1.6 ± 2 vs 1.3 ± 2 days; $p = 0.3$) and hospital stays (7 ± 3 vs 6.4 ± 3; $p = 0.2$) were similar among groups. In the multivariate analysis, trainees as operator was not independently associated with the occurrence of a surgical failure (OR, 0.93; 95 Cl, 0.7 to 1.9; $p = 0.3$).

The Kaplan-Meier event-free survival curves (Fig 1) show no significant difference between the groups at 1, 3, and 5 years; the senior surgeon had event-free survivals of 98.9% ± 0.6%, 95.8% ± 0.1%, and 92.6% ± 0.1%, respectively and trainees had event-free survivals of 98.5% ± 0.1%, 93.9% ± 0.1%, and 90.2% ± 0.3% (log-rank $p = 0.48$).

Freedom from reoperation at 5 years (Fig 2) was 95% ± 0.1% for patients operated by the senior surgeon and 91.8% ± 0.2% for patients operated by the trainees (log-rank $p = 0.13$). The Kaplan-Meier freedom from reintervention curves show no significant difference between the groups at 5 years; the senior surgeon had a freedom from reoperation of 95% ± 0.1% and trainees of 91.8% ± 0.2% (log-rank $p = 0.13$).

Comment

This study reports our experience at a single institution in training cardiac surgeons to perform MIMVR. The main finding of our study is that it is safe to teach mitral valve repair techniques to young cardiothoracic surgeons directly through a minimally invasive approach. Our data indicate that residents as primary operators during complex mitral valve procedures are not associated with adverse patient outcomes. The rapid evolution of a less invasive technique in recent years has resulted in its widespread popularization as an alternative to conventional sternotomy procedures [10-12]. Within this paradigm, performance monitoring and learning effect surveillance of a minimally invasive mitral procedure have become 2 mandatory responsibilities of individual cardiac surgeons and institutions. Senior cardiac surgeons are fully aware of the importance of training the
next generation of surgeons, but at the same time they have an overriding responsibility to ensure patients’ safety and good clinical outcomes. Cardiothoracic surgical training programs vary greatly in content depending on the particular country, the interests of its staff referral, and the characteristics of the patients [2–5]. In addition, it seems clear that the majority of modern training programs have a difficult enough time providing effective clinical training in many basic open procedures, and additional training in minimally invasive and video-assisted procedures is unlikely to be possible. In Italy the training in cardiothoracic surgery is over 5 years with no specific recommendations for minimally invasive valve surgery. For these reasons, in 2007 we decided to build up an institutional minimally invasive heart valve surgery training program in an effort to train cardiac surgeons to these new techniques. From that moment, the number of minimally invasive operations performed by trainees at our institution has increased significantly. Studies such as this and others [2–5, 13–17] are important to audit trainee performance and to reassure patients that good clinical outcomes are being achieved also by young cardiac surgeons who are training. Since the beginning of our experience we have noted that a minimally invasive approach may represent an opportunity rather than an obstacle in the training course of young surgeons. Indeed, the use of video assistance allows for interactive lessons on mitral repair and the trainees have the chance to actively discuss mitral anatomy and repair techniques on live cases with senior surgeons. Moreover, with the use of video assistance, senior surgeons have the chance to actively monitor the surgical procedure even if he or she is not scrubbed in and this favors the shifting of responsibility and allows for a more rapid acquisition of proficiency. During the study period the complexity of cases performed by trainees has gradually increased as well as the number of procedures performed without direct supervision, when the consultant was not scrubbed with the trainee in the operating theatre. Our policy is to expose trainees first to institution cardiopulmonary bypass, before gradually moving to performing on a simple MIMVR case, like isolated annuloplasty or simple

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* The coefficient of the propensity score is 2.022; p = 0.22.

AF = atrial fibrillation; AVB = atrioventricular block; MI = myocardial infarction; OR = odds ratio.

Fig 1. Kaplan-Meier survival curves.

Fig 2. Kaplan-Meier freedom from reintervention curves.
posterior leaflet resection. This allows trainees to become progressively used to all the aspects of minimally invasive techniques before attempting to perform complex cases. Finally, when the trainee has gained enough proficiency (generally after 25 to 30 cases) he or she starts to perform unsupervised operation. Our data show that the trainees had significantly longer ischemic bypass times than the consultant. These data are consistent with those of other institutions [5]. We believe that these longer operating times do not compromise the patient outcome and it seems to be an acceptable price to pay for the training of future senior surgeons. In our series, trainees were more likely to use direct ascending aorta cannulation than the senior surgeon (95.8% vs 82.9%; \( p = 0.001 \)). Despite good results having been reported for both central and femoral cannulation, we and others have found that antegrade perfusion strategy during minimally invasive valve surgery could be associated with a lower risk of neurologic complications and aortic dissection when compared with retrograde perfusion [8, 19]. In addition, routine cannulation of the ascending aorta allows to expand the suitability of minimally invasive procedures also to those patients who have an absolute contraindication to femoral arterial cannulation. Our current clinical practice attempts to restrict retrograde arterial perfusion to those surgical scenarios where there is a very limited central aortic access, such as patients with strong pleural pericardial adhesion or ascending aorta calcification. Taking this into consideration, the lower rate of central aortic cannulation in the consultant group may represent a reflection of the careful patient selection by the senior surgeon in allocating cases to be operated on by trainees, reserving those with an hostile mediastinum to himself. We have demonstrated that patient outcomes are not adversely affected when the trainees act as the surgeon. These findings are consistent with those of many institutions [17, 18] that demonstrated the safety of trainee-performed isolated valve replacement. Maintaining high quality results in a cardiac surgery department over a sustainable period requires transfer of knowledge to new personnel. Indeed, MIMVR is a complex and challenging procedure that requires a strict collaboration between surgeons, anesthetists, and theatre staff. Since the beginning of our minimally invasive mitral valve program, we have developed a training program also for perfusionists and scrub nurses, which consists of theoretic and practical lessons and operative supervision. In addition, a structured operative protocol is constantly reviewed and updated by a multidisciplinary team composed of surgeons, anesthetist, and theatre staff.

The study has several limitations which are important to consider when interpreting the main findings. It is necessarily observational for both logistic and ethical reasons. The way in which cases were selected by senior surgeons for trainees is unlikely to be adequately characterized by our data. One important variable was not documented in the database; namely trainee to consultant designation as main operator. A change in the designation of trainee to consultant for unexpected findings or intraoperative complications would have led to the performance of trainees being overestimated. We do not believe that this occurred to a significant extent. However, the consultant may have intervened in an unplanned manner to perform 1 or more difficult steps. Another limit is the fact that our trainees had finished their Italian cardiac surgery residency at the time of the study and from a legal point of view they were considered to be trained operators. However, all of them had performed less than 5 standard mitral procedures at the time of the study and no one had experience in minimally invasive cardiac surgery. In the current era where traditional cardiac surgery is losing “popularity” in favor of minimally invasive techniques, which seems to gain wider applicability each day, it seems that it is essential to expose young cardiothoracic surgeons to the minimally invasive technique. We believe that at present MIMVR training programs should be implemented and developed in those institutions that perform a large number of these operations per year, with senior surgeons proficient in using the technique. Our primary aim is to encourage the evolution of less invasive cardiac surgery but at the same time maintaining a high standard of care.

References

INVITED COMMENTARY

The report by Murzi and coauthors [1] documents excellent clinical outcomes in a large number of consecutive patients (595) undergoing mitral valve repair using a minimally invasive approach over an extensive period (5 years) in the context of an academic training program. One senior surgeon mentored 5 “young” surgeons, all of whom had completed a 5-year cardiac surgery residency, but none had experience in minimally invasive cardiac surgical procedures, and none had performed more than 5 standard mitral repairs before the initiation of this study.

The overall results are excellent, and acknowledging the careful selection and assignment of cases and the longer pump and cross-clamp times for the trainees, the results for the senior surgeon, who was principal surgeon in 60% of the cases, were indistinguishable from those of the trainees as principal surgeons in all important categories including failure rate, hospital mortality, perioperative myocardial infarction, stroke, conversion to sternotomy, cumulative survival, and cumulative freedom from repeated intervention.

The authors make a strong case that minimally invasive mitral valve repair can be taught while simultaneously achieving excellent clinical outcomes. Whatever one may think of minimally invasive approaches to cardiac operations, this report reassures the ethical dilemma in which the need to train young surgeons may seem to conflict with the medical ethic to always place the interests of the patient uppermost. This article indicates convincingly that complex cardiac surgical operations can be taught while at the same time maintaining a high standard of patient care.

Daniel J. Ullyot, MD

University of California, San Francisco
1325 Howard Ave, #703
Burlingame, CA 94010

e-mail: dullyot@aol.com

Reference