Papillary Muscle Sling Placement for Functional Mitral Regurgitation During Minimally Invasive Valve Surgery

Alexandre M. Benjo, MD,* Franscisco Y.B. Macedo, MD,† Orlando Santana, MD,* and Joseph Lamelas, MD‡

Abstract: Herein, we report a case of a 39-year-old woman with an 18-month history of peripartum cardiomyopathy. Transthoracic echocardiography revealed severe functional mitral regurgitation and a left ventricular ejection fraction of 20%. Despite optimal medical therapy, she was in New York Heart Association heart failure class IV, with dyspnea on minimal exertion. The patient underwent minimally invasive mitral valve repair with placement of a papillary muscle sling, which improved her symptoms.

Key Words: Minimally invasive, Mitral valve repair, Papillary muscle sling.

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In patients with left ventricular systolic dysfunction and functional mitral regurgitation, the surgical treatment of the mitral insufficiency is a challenging issue. Most of these individuals have a structurally normal mitral valve, but the valve is incompetent because left ventricular remodeling has disturbed the relationship between the subvalvular apparatus and the mitral valve leaflets. Therefore, more attention is being paid to correcting the papillary muscle displacement when these individuals undergo mitral valve repair. One of these approaches involves the placement of a sling around the papillary muscles. This technique has been previously reported as being performed via median sternotomy. We report a case in which it was performed during minimally invasive valve surgery.

CASE REPORT

A 39-year-old woman with an 18-month history of peripartum cardiomyopathy was in New York Heart Association heart failure class III to IV. A transthoracic echocardiogram performed demonstrated a dilated cardiomyopathy with an ejection fraction of 20% and severe functional mitral regurgitation.

A preoperative transesophageal echocardiogram confirmed the above-mentioned findings (preoperative video available at http://links.lww.com/INNOV/A27), and she underwent minimally invasive mitral valve repair with placement of an annuloplasty ring along with the placement of a 4-mm Gore-Tex tube (W. L. Gore & Associates, Inc, Flagstaff, AZ USA) around the papillary muscles, drawing them together, correcting their lateral and downward displacement (Fig. 1). A femoral platform was used to establish cardiopulmonary bypass. A longitudinal 2- to 3-cm incision was made superior to the inguinal crease, and the femoral artery was cannulated with a 16F arterial cannula (Edwards Lifesciences, Inc, Irvine, CA USA); and the femoral vein, with a 25F venous cannula (Bio-medicus; Medtronic, Inc, Minneapolis, MN USA). With the aid of transesophageal echocardiography, the venous cannula was placed in the superior vena cava. A 5- to 6-cm skin incision was made in the right fourth to fifth intercostal space lateral to the anterior axillary line (Fig. 2). Using transesophageal echocardiography guidance, a retrograde coronary sinus catheter was inserted into the right atrium directly through the incision. One dose of antegrade cold blood cardioplegia was given to establish electromechanical arrest of the heart. Thereafter, retrograde cold blood cardioplegia was given throughout the procedure at 20-minute intervals. A left lateral atriotomy was performed through Waterston’s groove to enter the left atrium. An atrial lift retractor and an atrial exposure blade were used for visualization of the mitral valve. A specially designed papillary exposure device was used to visualize the infravalvular apparatus. We do not place the mitral annular sutures first because this impairs visualization. A long shafted curved clamp was used to encircle all sets of papillary muscles. This needs to be performed carefully to not penetrate the muscle. In addition, the clamp needs to be as close to the base of the papillary muscles as possible. Different-sized clamps are required depending on the width of the muscles. Care is taken to avoid encircling the ventricular trabeculae. This maneuver needs a lot of time for...
it to be performed properly. This will prevent the graft from slipping superiorly and entrapping the chordae. A 4-mm Gore-Tex graft was then placed around the base of the papillary muscles. The edges of the sling are approximated as tightly as possible and tied with a 4-0 Prolene (Ethicon, Inc, Somerville, NJ USA) suture in a mattress fashion and then in a continuous over-and-over fashion. This may require several sutures to apply the maximum tension to approximate the graft. At the completion, the tightly approximated papillary muscles should not allow a suction catheter to be placed between them. Thereafter, the mitral valve repair was carried out in the standard fashion. The size of the anterior leaflet was used to determine the size of the annuloplasty ring. We do not undersize the ring. A 4-0 Prolene suture was used to close the left atrium. Carbon dioxide was infused into the operative field during the entire procedure.

With the heart empty, a ventricular pacing wire was placed. After discontinuing cardiopulmonary bypass and administering protamine, decannulation was performed. The purse-string sutures were tied, and the femoral artery was reinforced using 5-0 Prolene suture. A single chest tube was left in the pleural space. For pain relief, an On-Q pain relief system was inserted (I-Flow Corporation, Lake Forest, CA USA). Two catheters were placed to continuously deliver 0.25% of bupivacaine for 72 hours. The thoracotomy incision was closed in the routine fashion.

**FIGURE 1.** Placement of a 4-mm Gore-Tex tube around the papillary muscles.

**FIGURE 2.** A 5-cm skin incision was made in the right fifth intercostal space at the anterior axillary line.

**FIGURE 3.** Preoperative (A) and postoperative (B) transesophageal four-chamber view demonstrating a preoperative mitral valve tenting height (solid arrow) of 0.8 cm, which was reduced to 0.3 cm (solid arrow) after mitral valve repair with papillary muscle sling placement (striped arrow).
Postoperatively, no mitral regurgitation was noted immediately (postoperative video available online at http://links.lww.com/INNOV/A28) or on the echocardiogram done 2 weeks later. There was a decrease in the mitral valve tenting height from 0.8 cm to 0.3 cm (Fig. 3). She had significant improvement of her symptoms, being in New York Heart Association heart failure class II at the time of discharge and at 7 months follow-up. The echocardiogram performed 4 months after the surgery demonstrated no mitral regurgitation and a decrease in the end-systolic and end-diastolic diameters from 6.2 cm to 5.5 cm to 5.7 cm and 5.2 cm, respectively. The ejection fraction improved slightly to 25%, and the mitral valve tenting height remained at 0.3 cm.

**DISCUSSION**

Functional, or secondary, mitral insufficiency in patients with reduced left ventricular systolic function is usually a result of annular dilatation and papillary muscle displacement, with the mitral leaflets being anatomically normal. Whether to perform mitral valve surgery in patients with severe mitral regurgitation and advanced heart failure is controversial, with the published data showing mixed results. Presently, the most common type of surgery performed in these cases is an undersized mitral annuloplasty, which was popularized by Bolling and colleagues. In this technique, a small (size, 24–26 mm) mitral annuloplasty ring is used, which causes a reduction in the anteroposterior (septalateral) diameter of the mitral valve, increasing the surface of coaptation. The drawback with the undersized annuloplasty technique is a high rate of failure. In a study of 585 patients who had undersized annuloplasty surgery during a 17-year period, the authors noted that at least moderate mitral regurgitation developed 6 months postoperatively in 28% of the patients.

To reduce the mitral valve repair failure rates in these patients, a number of innovative approaches have been developed, which include the use of geometrically shaped annuloplasty rings, anterior leaflet augmentation, second-order chordal cutting surgical relocation of the posteroomedial papillary muscle, and the use of external restraint devices. Some have focused their attention on fixing the subvalvular apparatus in an attempt to reduce the recurrence of mitral regurgitation. Hvass and colleagues were the first to report the use of a 4-mm Gore-Tex tube encircling the trabecular base of both papillary muscles in patients with ischemic functional mitral regurgitation. They presented the results of 37 patients with ischemic mitral regurgitation who underwent this procedure. A moderately undersized mitral annuloplasty ring was placed in most patients, with the last 10 patients of the study receiving a normal-sized prosthetic mitral ring. All patients also underwent coronary artery bypass graft surgery. The mean age of the patients was 56 years; all were in New York Heart Association heart failure class III to IV; had a mean (SD) ejection fraction of 29.5% (5.5%), left ventricular end-diastolic diameter of 70 (0) mm, and left ventricular end-systolic diameter of 55 (5.6) mm; and had pulmonary hypertension of higher than 60 mm Hg. Early residual regurgitation was none to trivial in 31, was mild in 2, and was moderately severe in 2. At 1-year follow-up, the ejection fraction improved to a mean (SD) of 49% (6%), the mean (SD) end-diastolic and end-systolic diameter were 56 (5.5) and 50 (5.5), and the mean (SD) pulmonary artery systolic pressure was reduced to 45 (11) mm Hg.

All of the above-mentioned procedures were performed via a standard median sternotomy. Minimally invasive valve surgery, when compared with median sternotomy, has been shown to decrease complications and reduce hospital length of stay, use of resources, and mortality, especially in high-risk patients such as the elderly and persons with obesity. Thus, the possibility of combining both techniques is promising because it has the potential of reducing the surgical trauma with minimally invasive surgery and may improve the short- and long-term results of the mitral valve repairs in these high-risk individuals. Another underestimated benefit is the improved visualization of the infravalvular apparatus via a minithoracotomy approach. The patients who we select for this procedure are those with severe, functional mitral regurgitation who have ejection fractions of less than 40%.

**CONCLUSIONS**

We demonstrated the feasibility and the safety of a minimally invasive approach for papillary muscle sling placement during mitral valve repair for functional mitral regurgitation. The durability of this technique and its long-term effects need to be further evaluated.

**REFERENCES**

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