Minimally invasive repair of posterior leaflet mitral valve prolapse with the "respect" approach

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Submitted Jul 15, 2013. Accepted for publication Jul 30, 2013.
doi: 10.3978/j.issn.2225-319X.2013.10.11
Scan to your mobile device or view this article at: http://www.annalscts.com/article/view/2900/3816

Introduction

Prolapse of the posterior leaflet (PPL) was the first lesion accessible for repair (1) and currently represents the most common cause of mitral regurgitation in a western population. Alain Carpentier conceptualized and developed the "functional approach" for mitral valve reconstruction, which aims to restore the coaptation surface (2). Leaflet resection followed by either annulus plication or sliding leaflet plasty has been the gold standard technique to repair PPL and has demonstrated excellent long-term results (3). More recently, an approach favoring leaflet tissue preservation has evolved (4).

Over the years, mitral valve repair has been proven to demonstrate significantly better survival than mitral valve replacement (5,6). If mitral valve repair is carried out when the patient is still asymptomatic, surgery is expected to return their life expectancy to normal (7,8). Moreover, valve repair offers equivalent durability to a mechanical prosthesis without the burden of oral anticoagulation. After decades of intensive work, mitral valve repair has become the gold standard to surgically treat patients with mitral regurgitation. This major achievement has been demonstrated in patients operated via median sternotomy.

Mitral valve repair has been a dynamic field with constant improvements, one of which has been to try to reduce surgical trauma via the minimally invasive approach. Alain Carpentier was the first to report mitral valve repair through a right thoracotomy with video assistance (9), and was soon followed by similar reports from others (10). Techniques have evolved, instrumentation has improved and today minimally invasive mitral valve repair has become a standard approach. The safety of the operation is similar to that of the sternotomy approach (11) and the long term results are satisfactory (12,13).

This video describes the step-by-step repair of a PPL with a "respect" approach performed minimally invasively with total video assistance and no direct vision. The patient is a 42-year-old male patient in sinus rhythm. The patient is asymptomatic. He presented with severe mitral regurgitation, which was discovered during a routine examination. Preoperative echocardiography showed a prolapse of the PPL.

Operative techniques

The minimally invasive approach

Vessel cannulation

A 3 cm oblique incision is performed in the right groin and the anterior surface of the femoral vessels is exposed. Two 4-0 polypropylene purse string sutures are placed on the femoral artery and one on the femoral vein. After heparinization, the femoral vessels are cannulated using a Seldinger technique starting with the femoral vein.

After puncture of the femoral vein, a guide wire is placed in the superior vena cava, under trans-esophageal echocardiographic (TEE) control using a bicaval view. After dilatation of the vein, a Quickdraw venous cannula (Edwards Lifesciences, Irvine, CA) 21 or 25 Fr is introduced. The progression of the venous cannula is followed under TEE. It is essential that the cannula be placed in the superior vena cava, to ensure satisfactory venous return. A jugular cannula is placed when an associated tricuspid repair is needed, or when the patient is above 1.9 m in height or more than 100 kg in weight.

After puncture of the femoral artery, a guide wire is introduced and followed with TEE up to the descending thoracic aorta. It is necessary to control the guide wire within the lumen of the aorta, on a 0° plane and a 90° plane, to avoid the risk of aortic dissection. An 18 or a 22 Fr Medtronic EOPA cannula is inserted (Medtronic, Minneapolis, MN).

The cannulas are connected to the heart lung machine (HLM).

The thoracic step

A 3.5 to 4 cm incision is made in the right thorax just inferior and posterior to the nipple. The suitable intercostal space (ICS) to use is usually the one above the incision. The inferior edge of the pectoralis is dissected and the muscle is retracted to reach the desired ICS. At this stage, if a double lumen tracheal tube has been placed, ventilation of the right lung is stopped. If a single lumen tracheal tube has been used, the HLM is started, and ventilation is stopped.

The ICS is opened and an "Alexis" wound protector (Applied Medical, Rancho Santa Margarita, CA) is placed.

A trocar for the 5 mm and 30° angle endoscope is placed posterior to the internal ring of the Alexis protector and in the same ICS as the incision. A sideline connection in the trocar allows insufflating CO_2 in the right thorax with a 2 L/min flow.

In some patients, the right diaphragm may protrude and impair vision. A 2-0 pledgeted mattress suture is placed through the central tendon (the suture has to be superficial, the liver is right underneath). It is tied and the arms of the suture are passed through the thoracic wall with an Endo Close needle (Covidien, Mansfield, MA), inferiorly and posteriorly. This maneuver will move the diaphragm out of the way.

Once the heart is decompressed, the pericardium is opened relatively anteriorly, far away from the phrenic nerve, in order to create a large flap. Two 2-0 stay sutures are placed through the edge of the pericardium and brought with the Endo Close needle through the chest wall posteriorly and on both sides of the endoscope port. It is important that the pericardial flap be placed posteriorly to the endoscope to avoid any interference.

With scissors, and then blunt dissection, the angle between the inferior vena cava and the left atrium is set free.

It is essential at this stage to verify the position of the extremity of the venous cannula under endoscopic control. It should be precisely at the top of the superior vena cava, very close to the base of the neck. This position will ensure a satisfactory venous return during the whole procedure.

The most commonly used method of placing the transthoracic Chitwood clamp is through the transverse sinus. However, there is a risk of injury to the left appendage or the pulmonary artery and little space is left on the ascending aorta. Due to these drawbacks, we changed the positioning of the Chitwood clamp. The ascending aorta is separated from the right pulmonary artery, first with scissors, and then with blunt dissection, until the pericardium is visible on the other side. The transthoracic clamp can safely be placed through this path. After eventually removing the fat of the ascending aorta for a good landing zone, a 4-0 polypropylene purse string is placed for the cardioplegic needle. The same suture is used to place a double purse string to increase safety, and avoid bleeding when removing the needle. A 30 cm, 7 Fr, cardioplegic needle (Maquet Cardiopulmonary AG, Germany) is used and secured with a tourniquet. Instead of holding the tension of the suture through the tourniquet with a clamp, the extremity of a piece of plastic dilator is placed through the end of the tourniquet. This allows placing and leaving the tourniquet in the pericardial cavity. The extremity of the cardioplegic needle is transected and brought with a clamp under video control through the anterior chest wall approximately on the middle clavicular line.

The aorta is cross-clamped and Bretschneider cardioplegic solution is instilled. Moderate hypothermia (31-32 ℃) is maintained during the operation. After 100 minutes of ischemic time, cardioplegia may be reinjected if the clamping of the aorta is prolonged.

As a conclusion of this preparation phase, it should be emphasized that it is important that the working port is free from any line or suture that may complicate the motion of the instruments.

Mitral valve repair

Mitral valve exposure

A 2-0 suture is placed through the interatrial groove. Turning the 30° endoscope will allow visualization of the anterior wall of the chest, and the mammary vessels. A thin needle is used to select a spot to go through the chest wall anteriorly in the same ICS as the incision, not far from the mammary vessels, but avoiding them. The interatrial suture is brought through this spot; tension applied on it will neatly expose the left atrium. The shaft of the left atrial retractor is then placed in the same spot.

Incision of the left atrium is carried out starting inferiorly, followed by the insertion of the left atrial retractor blade. Most frequently the middle size blade is used. Placement of the blade is critical; it should come approximately at 1 cm above the mitral annulus, and sufficient tension should be exerted to lift up the mitral valve to open it and to expose the posterior aspect of the mitral annulus. If necessary, a shorter or longer blade has to be used. Invariably, this produces a folding of the postero-inferior wall of the left atrium, which obstructs part of the mitral valve. A 4-0 polypropylene suture is placed through the atrial wall at 5 o'clock, about 1 cm posteriorly to the annulus, and then through the pericardium below the inferior vena cava. Tying the suture will pull on the wall of the left atrium and nicely expose the mitral valve. It is essential that the exposure of the mitral valve is perfect, in the middle of the screen.

Valve analysis

Mobility of the free edge

When exposure is adequate, a thorough surgical valve analysis is performed. Usually, the antero-lateral scallop of the posterior leaflet (P1) is free from prolapse and can be used as a reference point to compare all the other segments. With the help of a nerve hook, the free edge of the anterior leaflet (A1) is compared to P1, and then A2, P2, A3 and P3. Step by step, the entire mitral valve is explored and it is possible to achieve a good three-dimensional understanding of the mitral valve. This manoeuvre clearly shows the PPL; it is located in P2 whose free edge overrides the free edge of the anterior leaflet. The result of the surgical valve analysis should be compared to the intraoperative echo findings.

Excess of tissue

Tissue excess is characteristic of degenerative mitral valve disease, and may affect the height of the posterior leaflet, thus posing a specific challenge during mitral valve repair, as it predisposes to the development of systolic anterior motion of the mitral valve (14). Excess of tissue may also involve the width of the posterior leaflet. To assess excess of tissue in width, the posterior leaflet is placed in the left ventricle, and the surface of the posterior leaflet is analyzed. In this patient, there is no folding or bulging of the posterior leaflet indicating an excess of tissue in width. In this patient, the posterior leaflet is smooth and regular and will be a very good buttress against which the anterior leaflet will come into apposition to form a good surface of coaptation.

An excess of tissue in height also needs to be detected. This is not the case in this patient.

It is also important to note that the posterior leaflet hangs vertically from the annulus, meaning that there is no mucoid material accumulated at the base of the leaflet, which would deform the base of the leaflet and could displace the surface of coaptation anteriorly.

Time spent to understand the dysfunction and to recognize lesions is critical for a successful operation. Failure to perfectly understand the mechanism of the mitral dysfunction may lead to failure of the repair. A mistake, due to lack of good exposure, or a superficial analysis, will most likely lead to a poor repair.

Placement of PTFE through papillary muscles

Exposure of the subvalvular apparatus is usually simple when operating minimally invasively. It is usually necessary to push the endoscope in the direction of the ventricular cavity to have a closer look.

A figure of eight of 4-0 e-PTFE is placed through the fibrotic part of the top of the anterior papillary muscle. The same manoeuvre is repeated at the level of the posterior papillary muscle. If the prolapsed area is greater than the middle portion of P2, additional artificial chordae may be needed. It is important that these sutures are placed through the papillary muscle head that anchor the diseased chordae to respect the geometry of the subvalvular apparatus.

Placement of PTFE through the free edge of the posterior leaflet

The two e-PTFE sutures are then brought up through the free margin of the leaflet. One suture is placed between the indentation of P1-P2 and the middle of P2 and the other between the middle of P2 and the indentation of P2-P3. The double-armed sutures are brought from the atrial side of the leaflet directly at the free edge where the original chordae are attached to the ventricular side and then back through the atrial side, 4 to 5 mm away from the free edge. The distance between the two arms of a suture should be approximately 3 mm to avoid plication of the tissue, which would impair the smoothness and regularity of the surface of coaptation.

Tying the e-PTFE at the proper length

The next step is to tie the artificial chordae at the proper length. A 4-0 polypropylene suture is placed through the free edge of P1, the reference point. It will serve as a guide to select the level of the free edge of the prolapsed area. In this case, there is no excess of tissue in height. By pulling gently on the artificial chordae, it is possible to very precisely bring the free edge of P2 to the same level as the reference point. Once the free edge has been brought to the desired level, the e-PTFE sutures are gently tied on the atrial surface (3 to 4 knots are necessary).

The role of the artificial chordae is not only to correct the prolapse, but also to position and maintain the posterior leaflet in the inflow, preventing it from moving anteriorly toward the left ventricular outflow tract. This may be the case when there is an excess of tissue height. In such a case, the artificial chordae should be made shorter by bringing the free edge of the prolapsed area 5 to 8 mm below the reference point.

The PTFE sutures are passed on the ventricular side of the leaflet

The artificial chordae are then passed again through the leaflet tissue, and are tied on the ventricular surface. Since it is a slippery material, a total of 10 to 12 knots are necessary, which leaves a prominent remnant. There are two reasons to tie the knots on the ventricular side: (I) to avoid any irregularity of the surface of coaptation due to the prominent remnant and (II) to avoid any motion of the leaflet along the artificial chordae, which may create unnecessary repeated tension.

The PTFE sutures are passed again on the atrial side of the leaflet

Prominent knot remnants are visible on postoperative echocardiography when left unattended, and in cases of postoperative elevated temperature may be mistaken as vegetations. Passing the artificial chord again through the leaflet on the atrial side immobilizes the remnants underneath the leaflet tissue, thereby obscuring from view on postoperative echo. Five knots are necessary on the atrial surface.

In this way, the surface of coaptation is as smooth as possible, with very few irregularities due to foreign material.

Suture closure of the clefts

In order to transform the posterior leaflet into a smooth and regular vertical buttress, the clefts between P1 and P2 and P2 and P3 are sutured with a 5-0 monofilament running suture whenever they are relatively deep. The physiological role of these clefts is to make it possible for the posterior leaflet to follow the diastolic dilatation of the annulus without tension. Since the annulus will be fixed into the systolic position by the implantation of a ring, the indentations serve no useful role. On the contrary, the indentions may be the cause of residual leak caused by an irregular surface of coaptation.

Ring size selection

The anterior leaflet is unfurled with the help of a hook. The surface area of the anterior leaflet is measured with specific sizers. The most important parameter is the anterior-posterior distance of the anterior leaflet.

Ring implantation and valve testing

2-0 braided sutures are passed through the mitral annulus and then into the annuloplasty ring. The sutures should be placed in a way that the geometry of the mitral valve is respected. Routinely, four sutures are placed at the level of the anterior leaflet between the two commissures. It is important that the middle of the anterior leaflet corresponds to the middle of the ring to avoid any distortion of the mitral valve.

The role of the ring is not only to reduce the size of the annulus but also to remodel the shape of the mitral valve, which has been deformed as a consequence of mitral valve insufficiency. In fixing the mitral valve in a systolic position, the ring will prevent any further annular dilatation.

After ring implantation, and before closure of the left atrium, injecting saline into the left ventricle tests the result of the repair. Two points are important: the absence of regurgitation and the aspect of the line of closure. The line of closure should be symmetrical, close to the ring and parallel to the posterior aspect of the ring. A posterior line of closure is a sign that the surface of coaptation is away from the outflow tract.

After closure of the left atrium and normal hemodynamic function is restored, an echocardiographic analysis will monitor the quality of the result. The absence of regurgitation as well as a free outflow tract signifies a successful repair.

Comments

Quadrangular resection is supposed to be a "straightforward technique" that any surgeon should be able to apply. However, a surgeon may face a myriad of questions during the course of such an operation: "How large should the resection be?" "What if the prolapse involves a very large P2?" "Should an annulus plication be performed with its subsequent deformation of the subannular area?" "Should a sliding plasty be undertaken to have a more regular distribution of stresses and minimize the risks of systolic anterior motion in case of excess tissue?"

On the other hand, a respect rather than resect approach cannot be applied in all cases, due to anatomical variations of the posterior leaflet.

A surgical strategy relying on the blind implementation of one technique, either resect or respect, cannot meet the requirements of the modern guidelines: that is, the likelihood of mitral valve repair should be more than 90% in case of degenerative mitral valve disease (15).

The goal of the surgical community should be to repair 100% of PPL. Evidently, a shift in our understanding is needed. To reach this goal, the surgical mindset should not be focused on the surgical technique, but on the goal. This was prophesized by Sun Tzu (6th century BCE), "Strategy without tactics is the slowest route to victory, but tactics without strategy is the noise before defeat". We should concentrate on the goal, that is, to remodel the posterior leaflet to create the best surface of coaptation as possible, using the most appropriate technique(s). Moreover the surface of coaptation should be located and maintained in the inflow of the left ventricle to avoid postoperative systolic anterior motion (8,16). While a tailored and limited resection is usually enough to ensure a regular and smooth posterior leaflet, it may not totally correct the leaflet prolapse and the adjunct use of artificial chordae may be necessary. The repair of PPL, guided by anatomical considerations, should become a patient-specific spectrum of techniques ranging from respect to resect. In our practice, localized resection is necessary in 35% of the patients, highlighting the necessity of variety in the choice of surgical techniques.

In conclusion, the successful outcome of mitral valve repair for PPL is predicated upon a team effort between cardiologist and surgeon. Many surgical techniques have shown their efficacy in achieving stable long-term results. The challenge we have to face is to be able to repair all mitral valves presenting with PPL efficiently and safely. There is no doubt that, when selecting the technique to be used, an open mind is necessary, and that it should be focused on one goal: the remodeling of the posterior leaflet to create the best coaptation surface possible. A minimally invasive approach offers the patient a significant reduction of surgical trauma, associated with limited post-operative pain and accelerated recovery.

Acknowledgements

Disclosure: The authors declare no conflict of interest.

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Cite this article as: Perier P, Hohenberger W, Lakew F, Batz G, Diegeler A. Minimally invasive repair of posterior leaflet mitral valve prolapse with the “respect” approach. Ann Cardiothorac Surg 2013;2(6):833-838. doi: 10.3978/j.issn.2225-319X.2013.10.11

