Review

Reconstructive surgery of postinfarction left ventricular aneurysms: techniques and unsolved problems

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Summary

The progress in the surgical treatment of postinfarction left ventricular (LV) aneurysm surgery has reduced the operative mortality considerably, while the selection of the optimal LV repair technique remains unclear. Any of the surgical techniques presented in this review has its own advantages and disadvantages. The main goal of this study was to perform a selective literature review of LV aneurysm repair techniques, the most widespread being the linear repair and patch ventriculoplasty.

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1. Surgical techniques

1.1. The pioneering period

The surgical treatment of ventricular aneurysm was introduced in 1944, when Claude S. Beck reinforced the wall of a left ventricular (LV) aneurysm with fascia lata aponeurosis in order to reduce excessive dilatation and avoid LV rupture [1]. However, this was a palliative solution and was not applied further. Likoff and Bailey’s approach was more radical. In 1955 they performed closed ventriculoplasty by placing a large vascular clamp on the beating heart tangentially across the base of a LV aneurysm followed by resection and suture [2]. This type of surgery became the forerunner of the linear repair.

Further developments of LV aneurysm surgery lead to the use of numerous new LV reconstruction methods. The eight principal surgical techniques can be divided into two large groups: (1) the direct suture techniques and (2) the patch ventriculoplasty techniques.

1.2. The direct suture techniques

In 1958, Cooley et al. performed the first aneurysm resection and linear repair with use of cardiopulmonary bypass (CPB) [3,4]. The surgery was performed through a median sternotomy approach. Cardioplegia is used especially if additional procedures such as coronary artery bypass grafting (CABG) or valve replacement are needed. Indeed, in case of isolated LV aneurysm resection, cardioplegia is not mandatory and surgery can be performed on the beating or fibrillating heart if the aortic valve is competent. The ventriculotomy is performed by means of linear incision in the aneurismal area parallel to left anterior descending (LAD) or posterior descending (PDA) arteries depending on the localization of the aneurysm. Resection of the aneurysm is performed leaving about 1 cm in width from the scar tissue in order to enable LV wall suture. Incision closure is made by double-row suture: a first row of wide U-shaped horizontal stitch on two continuous Teflon or auto pericardial strips, followed by a second continuous blanket row (Fig. 1).

In anterior aneurysms, the interventricular septum is almost universally involved in the scar process. Since the linear reparation technique does not address correction of the septal aneurysm with the associated paradoxical movements and impairment of LV contractility, various technical solutions were proposed to solve this problem.

Cooley suggested two techniques of septoplasty that have become widespread. In the first technique [5], septal plication is performed with the help of separate stitches (Fig. 1C). With the second technique [6], Dacron patch suture of the aneurysmal septal area is used (Fig. 1D). This latter method of septoplasty can be applied to severely thinned septal aneurysms, in order to avoid septal perforation. Both...
techniques of septoplasty are effective for elimination of paradoxical motion, but create an akinetic zone in the LV. In theory, conservation of an akinetic zone could lead to worsening of congestive heart failure and could adversely affect late surgery results.

In 1973, Stoney et al. [7] suggested a modification of the resection and linear repair technique of LV anteroseptal aneurysms, which includes the scared interventricular septum in the repair and its exclusion from the contractile process (Fig. 2). After aneurismal resection, it is essential to examine the endocardial surface of the septum and identify the junction of the anterior scar with the posterior viable myocardium. The lateral edge of myocardium is sutured by continuous suture to the interventricular septum in the border zone (first row). Teflon strips are used in order to reinforce the LV lateral margin, and the stitches are brought out through the septum to the anterior wall of the right ventricle. The repair is completed by a continuous suture (second row), connecting the scar tissue along the LAD with the healthy myocardium of lateral wall of LV (overlap). This technique excludes the possibility of bypass to the LAD because of its inclusion within the suture line. It is also important to note that the most frequent complication during the postoperative period is ventricular tachyarrhythmia [7].

Another variety of LV aneurysm resection and linear repair technique is the capitonnage technique, introduced by Cabrol et al. in 1974 [8]. This technique uses capitonnage and isolation of the unresectable fibrous zone that creates a new LV cavity with only active contractile segments (Fig. 3). The capitonnage is carried out with three rows of polypropylene 2-0 suture. The first row, which is the deepest one, is placed between the LV free wall and the interventricular septum in the area of the border zone near the endocardial fibrous zone. The second row is placed over the first one between the fibrous parts of the interventricular septum and the LV free wall. The third row is superficial and epicardial, and completes the repair.

In 1984, Guilmet et al. [9] proposed the original surgical technique of the overcoat aneurysmoplasty (anévrismoplastie en paletot). The specific indication for this approach was large LV aneurysms especially when the interventricular septum was involved. The operation entails partial resection of the aneurysm sac and exteriorization of the scarred septum for its exclusion from the newly formed LV cavity (Fig. 4). This technique of repair is also known as Guilmet septoexclusion technique [10]. Incision is carried out from the top upward parallel to the interventricular septum. The partial aneurysm resection is carried out leaving about 1 cm of scar tissue from the left border of the aneurysm. Authors put two suture rows with polypropylene 2-0. The anterior free wall (left border) is sutured at an angle to the septum starting as high as possible
and to the apical limit of the sidewall using separate U-shaped sutures within the LV. This first suture row allows exclusion of about 2/3 of the scarred zone of septal dyskinesia. The second row is performed by suturing the right border of the aneurysm to the newly formed anterior wall of LV ensuring final hemostasis. Thus, this given technique of LV reconstruction resembles buttoning up a coat.

1.3. The patch ventriculoplasty techniques

Until the 1980s, the linear closure technique remained the most often used in LV aneurysm surgery. In 1979, Levinsky et al. described a technique [11] of LV reconstruction with a Dacron patch after resection of an anterior postinfarction aneurysm that rapidly became a popular new technical solution (Fig. 5). For failure of the linear repair due to suture tearing through necrotic muscle, a wider resection was carried out to reach viable LV myocardium. Since 6 cm × 12 cm defects are impossible to close by simple approximation, a Dacron patch was sutured to the defect area. Undoubtedly, this technique could be called the precursor of the further methods known under the name patch ventriculoplasty.

In 1985, Jatene and Dor independently reported fundamentally new, so called anatomic LV reconstruction methods with endoventricular circular reduction and stitching patch in the formed ventriculotomy orifice therefore called patch ventriculoplasty [12–14].

The purpose of these methods was to recreate the normal LV geometry so that fibers of healthy myocardium regained their initial orientation. Despite their similarity, both techniques have some differences.

In the LV reconstruction technique by Jatene [12], after ventriculotomy in the aneurysmal area, its resection and thrombectomy from the LV cavity, one or two rows of circular (purse-string) sutures are placed exactly on the border between normal and fibrous tissue. During surgery on the beating heart, the boundary zone is easily defined by palpation, while after cardioplegia it is more difficult to identify this border. Careful tightening of the circular stitches is carried out, reconstructing the LV cavity and reducing its size. The reduction of the orifice between aneurysm and the LV cavity by means of this circular suture prevents elongation when the fibrous rim is approximated.

Afterwards ventriculotomy closure is performed, with or without a patch. If the LV cavity is close to the desired size after circular reduction, the linear closure method, i.e. without patch, can be applied. Herein, the angle stitches are placed on Teflon felt at the transition from normal to fibrous tissue, and the intermediate stitches must leave a fibrous rim, which restores the correct geometry of the ventricular cavity. The longitudinal suture length is significantly shorter than in the usual linear closure.

On the opposite, when the LV cavity is enlarged, a double Dacron patch is stitched in the ventriculotomy orifice (Fig. 6). The endoventricular circular suture reduces the patch size and the size of the akinetic zone in the newly formed ventricular cavity. Suturing of the patch can be done either using single U-shaped stitches on Teflon pledges, or by a continuous suture. To address septal involvement, Jatene used one of the septoplastic techniques offered by Cooley as described previously.

In the endoventricular circular patch plasty by Dor [13–16], the procedure is carried out under cardioplegia. The left ventriculoplasty is performed in the akinetic or dyskinetic zone (transmural ventriculotomy), the thrombus is removed and, in case of documented spontaneous or induced VT, subtotal endocardial resection and/or cryotherapy without mapping is carried out. An endoventricular circular suture (Fontan maneuver) is placed 1 cm distal to the border of healthy muscle in order to prevent its inclusion and allows recreation of the normal shape of LV using continuous 2-0 monofilament polypropylene suture. Following this, a balloon is placed in LV cavity and inflated to the theoretical diastolic volume of 50–70 ml/m², and the circular suture is tightened and tied up. This maneuver makes the definition of the circular patch size easier, which can consist of autologous (endocardium or pericardium) or synthetic tissue. The patch size is trimmed to match the circular suture circumference after deflation of the balloon. The patch is fixed by a continuous 2-0 suture inside the LV cavity on the border labeled by the circular suture. Simultaneously, the septoexclusion is created by this patch in the presence of an interventricular septal aneurysm. The excluded fibrous sites can be partially resected and sutured over the patch.
The major advantages of the patch ventriculoplasty are recreation of the left ventricular geometry, exclusion of the retractive process, elimination of paradoxical motion and reduction of the akinetic zone. Despite its theoretical advantage, the endoventricular patch is considered an akinetic zone in a newly formed LV cavity, which could affect long-term results, due to progression of heart failure.

2. Unsolved problems

2.1. LV repair technique

Linear repair and patch ventriculoplasty are widely used in the clinical setting. A comparative study of both methods is required. The analysis of the literature shows that the hospital mortality rates range from 0 to 9.8%, the 10-year survival rate ranged from 55.7 to 74% and, overall, showed no significant difference between the linear resection and patch ventriculoplasty groups [20—23].

The analysis of published reports does not allow establishing the superiority of one surgical technique over another, as the results are quite contradictory and within the statistical error limits.

Different approaches in selection of the type of LV repair are found in the studies comparing the two principal methods. To choose the optimal repair technique, Tavakoli et al. [24] used the assumption that linear closure was preferable in cases of large LV volumes. For patients with extensive septal involvement and with lesions of the subvalvular mitral apparatus, authors favored use of the patch technique. Patch ventriculoplasty was used in patients with severely decreased left ventricular function, in accordance with the point of view of Dor et al. [25], especially in the case of large akinetic area [26].

In the work of Vural et al. [27], the circular patch plasty was performed in case of extensive and definite fibrotic aneurysmal sac with a well-formed neck. Linear closure or small plication was used in small wide-based aneurysms, when the border zone was not well defined. Patch-ventriculoplasty and linear closure supplemented by septoplasty was used in cases with extensive involvement of the septum in the fibrous process.

However, the authors of these two reports found no significant differences between the two repair methods in terms of hospital mortality and long-term survival [24,27]. The only significant difference was a better long-term functional class in the group of patients in whom patch ventriculoplasty was carried out. The left ventricular ejection fraction (LVEF) of residual segments was the main determinant factor influencing the short- and long-term results [27].

In the authors’ opinion, the choice of the LV repair technique should be adapted to each patient’s anatomical and physiological characteristics. The use of linear as well as patch repair allows satisfactory results regarding hospital mortality, functional status and long-term survival [24,27].

2.2. Concomitant coronary revascularization

Being an essential part of LV aneurysm surgery, coronary revascularization is performed in 64.6—100% of cases [10,20,21,28].

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**Fig. 7.** The endoventricular circular patch plasty (Dor procedure). (A) Anteroapical aneurysm, dotted lines show resection borders. (B) The endoventricular circular suture is placed about 1 cm higher than the border of the healthy muscle. (C) The patch is fixed by continuous suture inside the LV cavity on the border labeled by the circular suture; simultaneously the septoexclusion is completed by this patch. The excluded fibrous sites are sutured over the patch. LV: left ventricle.

**Fig. 8.** Ventricular endoaneurysmorhaphy by Cooley. (A) Anterior aneurysm, dotted lines show resection borders. (B) Elliptical Dacron patch is sutured in the defect area, thus restoring the shape and circuit of the ventricle cavity. LV: left ventricle.
In the opinion of Lundblad et al., concomitant CABG is mandatory in order to reduce or prevent angina pectoris and the risk of myocardial infarction or worsening of congestive heart failure. Secondly, revascularization of the LAD allows the improvement of septal perfusion and the control of ventricular arrhythmia [28].

Despite lack of significant improvement of long-term survival by concomitant myocardial revascularization, the majority of authors agree on the necessity of concomitant CABG, particularly in patients with the multivessel coronary artery disease [24–30]. According to Vural et al., although CABG did not influence the mortality after operation, it significantly decreased the occurrence of postoperative low cardiac output (LCO) [27].

2.3. Cardiac failure

One of the main causes of the early mortality after aneurysmectomy is LCO. LCO is the most frequent postoperative complication and occurs in 20.9–67% cases [10,21,27,30]. The need for temporary hemodynamic support with intra-aortic balloons varies from 1.8 to 17.9%, with no significant difference between the linear and patch groups [21,22,24,29]. LCO is the cause of early mortality in 44.4–86.7% after aneurysmectomy [27,31]. Low LVEF, high left ventricular end-diastolic pressure, prolonged aortic cross-clamp time are associated with postoperative LCO [20,24,27,28]. The most important predictor is the contractility of the remaining segments of the LV after resection of noncontractile aneurysmal tissues [28]. These factors also have a negative influence on long-term survival after LV aneurysmectomy, and are responsible for the 26.3–40% late mortality rate due to end stage congestive heart failure [30,32].

2.4. Ventricular tachyarrhythmias

In 1958, Couch performed the first successful surgical ablation of the ventricular tachycardia by means of LV aneurysmectomy [33], starting the era of ventricular tachyarrhythmia surgery. However, isolated aneurysmectomy was accompanied by a high rate recurrence of ventricular tachycardia with a high incidence of sudden death after surgery [31,32,34]. Baufretont et al. showed a 29.6% rate of mortality within the first 30 postoperative days caused by intractable ventricular tachycardia [31]. Matthias and Bechtel et al. investigating the surgical results of 147 patients treated by anterior LV aneurysm resection without concomitant anti-arrhythmic procedures demonstrated that sudden arrhythmic death occurred in 36.8% of deceased patients during 5 years of follow-up [32]. In this regard, LV aneurysm resection should be supplemented with one of the surgical procedures directed at destruction or isolation of arrhythmogenic focuses when VT is inducible by preoperative electrophysiologic study (EPS) or presents spontaneously, which includes circular endocardial ventriculotomy [35], subtotal endocardial scar resection [36–38], endocardial cryoablation [39–41] or laser photocoagulation [42,43]. By now, several authors have reported satisfactory results of anti-arrhythmic surgery in patients with LV postinfarction aneurysm at long-term after operation [30,37,44]. Postoperative EPS remains mandatory to ascertain the surgical results and the need for supplemental cardioverter defibrillator implantation in case of ventricular tachycardia being inducible [30].

The palliative solution of late ventricular tachyarrhythmia problem after isolated aneurysmectomy is also the implantation of cardioverter-defibrillators. Despite the results of a number of multicenter trials (MADIT, AVID, MUSTT, MADIT II), showing that automatic implantable defibrillators have significantly reduced the mortality in comparison to the drug therapy, the short- and long-term mortality after defibrillator implantation is still considerable in patients with severe ischemic cardiomyopathy [45–48].

3. Conclusion

Sixty years of evolution in post infarction LV aneurysm surgery has allowed the reduction of patient mortality to a considerable degree raising, at the same time, the issue of optimal selection of LV repair technique. The surgical techniques presented have their own advantages as well as disadvantages. Variability of indications and anatomic and physiological features in each specific case usually makes one surgeon’s choice debatable. The choice of LV repair technique and necessity of concomitant procedures should be guided by the patients’ preoperative characteristics, projected hospital mortality, clinical status and long-term survival after operation.

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References


