AN HISTORICAL APPRAISAL OF THE TECHNIQUES OF LEFT VENTRICULAR VOLUME REDUCTION IN ISCHEMIC CARDIOMYOPATHY: WHO DID WHAT?

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Abstract

Resection or exclusion of scars following a myocardial infarction on the LAD territory started even before the beginning of the modern era of cardiac surgery. Many techniques were developed, but there is still confusion on who did what. The original techniques underwent modifications that brought to a variety of apparently new procedures that, however, were only a "revisitation" of what described before. In some case old techniques were reproposed and renamed, without giving credit to the surgeon that was the original designer. Herein we try to describe which are the seminal procedures and some of the most important modifications, respecting however the merit of who first communicated the procedure to the scientific world.

INTRODUCTION

Surgery for exclusion of scars following LAD infarction started during the '40s, but changed over time due to a better knowledge of the pathophysiology of the disease and to the technical improvements in cardiopulmonary bypass, oxygenators and myocardial protection.

However, many of the techniques described during the last 70 years were changed, or even copied, and named differently without giving credit to the surgeon(s) who conceived the original procedure. This peculiar aspect of the history of left ventricular surgical reshaping (LVSR) has never been focused correctly. This is evident in reviews about LVSR techniques[1-3], where similar procedures have different names, generating confusion.

In this report we want to describe the original techniques described during the decades, that are at the basis of all the procedures applied in this field, even if differently named.

TECHNICAL EVOLUTION OF LVSR

First attempts without cardiopulmonary bypass.

The first surgical approach was due to Beck[4] in 1944. He incised the pericardium around the aneurysm leaving the pericardium adherent to the lesion. A fascia lata graft was then sutured to the adherent pericardium and plication sutures were taken centrally to reduce the size of the aneurysm and graft. The patient died five weeks later with empyema and encephalomalacia. In 1955 Likoff and Bailey[5] described a case successfully treated with a tangential exclusion with a specially designed side clamp. In 1958 Bailey[6] reported 6 similar cases with 5 survivors. As the problem of embolization could be easily controlled flushing out the thrombi, if any, the Authors concluded that the use of an open technique using cardiopulmonary bypass was not justified.

The era of the open correction.

Cooley et al in 1958 started the modern era of LVVR reporting the first case of linear resection of an anterolateral aneurysm using the cardiopulmonary bypass[7] (fig. 1A,B), describing more cases soon after[8]. The Author used this technique extensively and his experience was of 1572 cases in 1981[9] and rose to 4298 in 1992[10]. He started to treat the diskinetic septum using a dacron patch which replaced a diskinetic area with a smaller akinetic area[9] (fig. 1C-E). It is noteworthy that the linear resection of the anterior wall with/out a patch on the septum includes the incredible work performed by Cooley among the techniques aimed to reduce the LV volume preserving the conical shape. The linear LV reconstruction was further developed by Mickleborough et al.[11]. The Authors, in presence of a scarred, thinned and aneurysmal septum, performed a septoplasty using a patch, part of which, differently from Cooley, was included in the final suture (fig. 2).

In 1973 **Stoney** et al reported 29 cases of anteroseptal ventricular aneurysms (the first case done most likely in 1971) where the technique of LVVR was completely original and conceptually different from what was done till then[12]. After the incision of the aneurysm, the junction of anterior scar tissue with the posterior viable myocardium was identified and the lateral edge of myocardium was then advanced down to the junction of scar and functioning myocardial tissue in the septum with a continuous suture line. Teflon strips were used to reinforce the lateral margin of the left ventricle, and the sutures were brought out through the septum to the anterior wall of the right ventricle. A second continuous suture line completed the closure (fig. 3). This is the first technique described in the literature where the septum was considered as important as the free wall. In the Introduction the Authors stated that "Conventional anterior aneurysmectomy in the past has confined excision and repair to diseased myocardium located to the left of the anterior descending coronary artery. Restudy of these patients in our institution has shown inadequate reduction of aneurysm size with residual akinetic myocardium remaining in the ventricular septum. Attempts to revascularize the anterior descending artery in patients with an anteroseptal aneurysm have been equally disappointing."

A modification if this technique was introduced by Calafiore et al[13] in 2003 who proposed, to make simpler the procedure, a direct suture of the border of the scar in the anterior wall to the border of the scar in the septum (linear septoexclusion, fig. 4A). If the resulting cavity was perceived to be too small, an elliptical patch could be used from the beginning of the septal scar to the new apex[14] (septal reshaping, fig. 4B-D). Interestingly, the Authors referred to the Stoney technique as Guilmet technique[15], as this latter Author redescribed in the 1984 the same procedure described by Stoney.

In 1985 **Jatene** reported 508 patients operated on between September 1977 to September 1983[16]. His approach to the septum, intially similar to Cooley's technique[9], was changed. He used two or three mattress stitches buttressed with Teflon felt to reduce the elongation of the septal wall. But he was the first to introduce the concept of intracavitary purse string. It was placed on the free-wall endocardium at the junction of the endocardial scar and normal endocardium, never involving the papillary muscles. This free-wall suture was continued around the anterior base of the aneurysm until it reaches the junction of the anterior free-wall and anterior septum at the base of the aneurysm. The other end of the purse-string suture was continued onto the distal septum at the apex and then proximally up the anterior septum at its junction with the free-wall. Both ends of the purse-string suture were then passed transmurally through the anterior left ventricular free-wall and tied over a felt pledget. Because the purse-string suture was placed on the anterior edge of the septum and around the apex onto the free-wall, the septum was incorporated and remained a part of the wall of the left ventricular cavity. After the purse string has been tied, the opening could be closed, at the level of the purse string, with direct suture or with a patch (fig. 5). Jatene's concept was revolutionary, as he introduced the concept of geometrical LV reconstruction, using a surgical intracavitary remodeling by a purse string associated with the treatment of the diskinetic septum, maintaining a conical LV shape. The use of a patch of a direct suture allowed to decide the volume of the cavity, even if this decision, according to the Author, was defined "empirical".

In 1989 **Dor** proposed a technique that he started to use in 1984[17]. The key points of the procedure were 1) resection of dyskinetic or akinetic LV free wall and thrombectomy when indicated; 2) dacron patch lined with pericardium secured at the junction of the endocardial muscle and scarred tissue, thereby excluding non-contractile portions of the LV and septum; 3) myocardial revascularization, in particular of the proximal LAD segments (fig. 6). To avoid excessive volume reduction, in 1999 Dor suggested to use a rubber balloon filled with water (50 to 70 ml/m^2)[18]. As described initially, this technique was focused on volume reduction, as the patch was located at the base of the aneurysm and was as large as the base was, but the shape was often more rectangular than elliptic. The Dor procedure was initially perceived as functional amputation of the ventricle with exclusion of the entire akinetic or dyskinetic scar, leading to increased sphericity of the ventricle in some patients[19]. This consequence was considered irrelevant by Dor et al[20], who stated that "The improvement of contractility is not related to shape. Although Buckberg and associates[21] have suggested that a spherical cavity is less contractile than an elliptic one, the dogma of elliptic shape was established without convincing physical or physiologic data." Nevertheless, this technique was widely applied, but faced a number of modifications that improved those perceived as weak points.

Cooley in 1989 published 6 cases with the same principles, but the excision of the free wall scar (which favored bleeding) was avoided. The scar was maintained and sutured over the patch, as it is done till now[22].

An important modification was performed by Fontan[23]who suggested to reduce the size of the patch applying a purse string (the Fontan's stitch) to limit the size to the normal size of the LV at the level of the insertion of the papillary muscles. The Author used an oval patch sized 25 to 30 mm, with 2-3 mm used for suturing. This variation was incorporated into the technique and is used till now.

Another important improvement was the use of a LV conical shaper introduced by Menicanti et al[19] with two purposes. The first one was to avoid an excessive volume reduction, the second one was to maintain a shape as conical as possible. The volume of the shaper ranged from 60 to 75 ml/m^2 and the internal correction was completed with a patch (not larger than 30 mm) or with direct sutures over the shaper (fig. 7). In his later experience Menicanti et al[24] reduced the volume to 50-60 ml/m^2.

The original Dor technique, as originally described, today does not exist anymore, as all the modifications changed substantially the surgical procedure.

CONCLUSION

The techniques previously reported are at the basis of all techniques described thereafter. Many surgeons re-reported a previously described technique either after limited and irrelevant changes or simply renaming the procedure. Original techniques depend on the development of new concepts and changing the position or the shape of a patch or the number of purse strings is not enough to identify something new. The memory of the cardiac surgeons is often short!!

The most innovative techniques reported in the literature are surely the Stoney technique (the first one that addresses the septum in every patient) and the Jatene technique, that introduced the concept of geometric repair of the LV anatomy, described the use of a purse string to reduce obliquely the cavity and addressed the septum that was changed from dyskinetic to akinetic with a reduced surface by means of interrupted sutures. However, we must recognize that the concept to exclude the dyskinetic septum and to reduce its surface was present since the early times of the LVSR. Cooley and his group reported 421 cases operated on between 1969 and 1979[9]. The Dor technique was aimed to exclude the scarred septum, but without a purse string and a shaper the remaining cavity would be more rectangular than conical. However, Dor's concept moved ahead in a new direction a complex surgery.

All the surgical solutions aimed to solve the problem of LVSR tried to maintain a conical shape (as much as possible) and a reduction of volume such to improve the contractility without compromising the diastolic function. This aspect was evaluated by Lee et al[25], who demonstrated that, in patients undergone the Dor technique, the postsurgical improvement in systolic function was compromised by a decrease in diastolic distensibility in all investigated patients. Worsening of the diastolic function was due to increase of sphericity index, with consequent reduction of stroke volume. By simulating a restoration of the left ventricle back to its measured baseline sphericity, the Authors showed that both diastolic and systolic function improved. The benefit in maintaining a conical shape was demonstrated by us after a follow up of 15 years in propensity matched patients[26].

These results are consistent with the speculation proposed in the Surgical Treatment for Ischemic Heart Failure trial[27]for the neutral outcome, that "the lack of benefit seen with surgical ventricular reconstruction is that benefits anticipated from surgical reduction of left ventricular volume (reduced wall stress and improvement in systolic function) are counter-balanced by a reduction in diastolic distensibility." There is no doubt that, independently from the surgical procedure applied, postoperative diastolic function remains the Achille's heel of the left ventricle reshaping.

The anatomical spectrum of LV aneurysms changed over time. Lack of early reperfusion selected patients who were able to survive with large scars, that were, in expert hands, easy to resect or exclude. Nowadays, the increased use of early coronary reperfusion made the infarcted area become akinetic rather than dyskinetic, making more difficult patients' selection and less predictable the clinical results. But this aspect is outside the purpose of this report.

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FIGURES

Fig. 1 –Linear excision of an anterolateral aneurysm. A, the aneurysm is incised and its surface is almost completely excised. B, the defect is sutured over 2 teflon stripes. In presence of a scarred and dyskinetic septum (C), a patch was sewn over the septum (D) to reduce the septal surface and to eliminate the systolic bulging (E).

Fig. 2 – In presence of a septoapical aneurysm (A), a pericardial patch is sewn on the borders of the healthy septum on three sides. The anterior portion of the patch is pulled tight and incorporated in the modified linear closure as indicated by the arrows (B). The patch excludes the aneurysmal portion of the septum and helps to maintain a conical shape (C).

Fig. 3 – A, the aneurysm is incised and almost completely excised. The lateral wall of the left ventricle is sutured down in the septum at the border of the scar with interrupted sutures that are brought out at the right ventricle. B, a second line of suture is necessary to connect the scar close to the LAD to the healthy myocardium.

Fig. 4 – Simplification of the Stoney technique. Linear septoexclusion. A, the border between the scarred and the healthy portion of the anterior wall is sutured with the border between the scarred and healthy septum till the apex. Part of the apical scar, if necessary, is included in the remaining LV cavity to obtain a longitudinal axis as long as possible. Septal reshaping (B-D). B, stitches are passed at 4 positions in the septum: at the highest point where the anterior and septal scars meet (1); at the level of the new apex (2); deep in the septum at the border between the scar and the healthy posterior septum (3); and in the anterior wall, again at the limit of the scar (4). C, a dacron or bovine patch is tailored and fixed with the 4 stitches previously placed. D, a new ventricular chamber is created, that has a shape as conical as possible. Apical scars are often included.

Fig. 5 – The Jatene technique. A, the septal dyskinesia is treated by means of e few U stitches, passed in both directions. A purse string follows the border of the scar, but includes the septum inside the new cavity. B, Once the purse string is tied, the opening can be closed directly of by a patch (C).

Fig. 6 – The Dor technique as originally described. In presence of an anteroseptal aneurysm (A), the scar is excised as well as the septal endocardial scar. A patch, of the same size of the defect, is trimmed (B) and sutured to close the defect (C).

Fig. 7 – Menicanti's modification of the Dor technique. A, to obtain a conical shape, a shaper is inserted inside the LV. B, if the inferior region is severely dilated, it is plicated, placing the apex in a more anterior position. A circular suture (Fontan stitch) to exclude the affected anterior and septal tissue starts from this new apex, and the plane of suture is more oblique with a resultant elliptical shape. C, the shaper is out from the ventricle and the defect is closed with a patch.

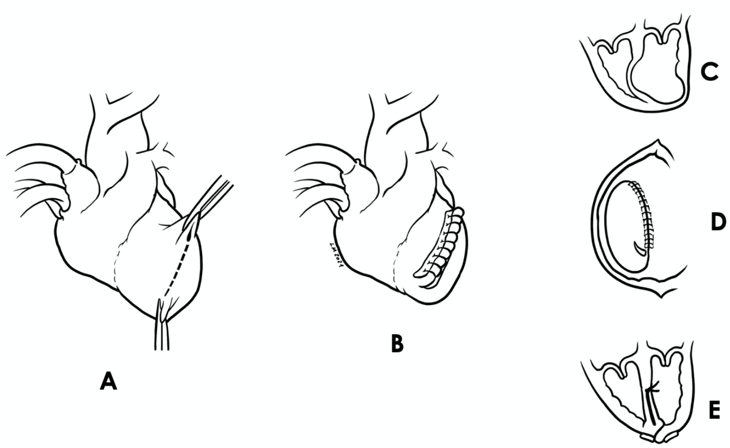


Fig. 1

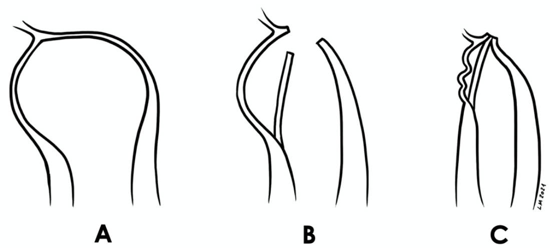
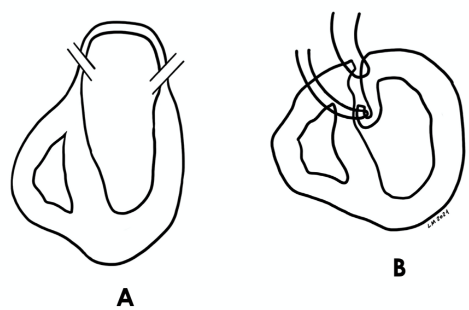


Fig. 2



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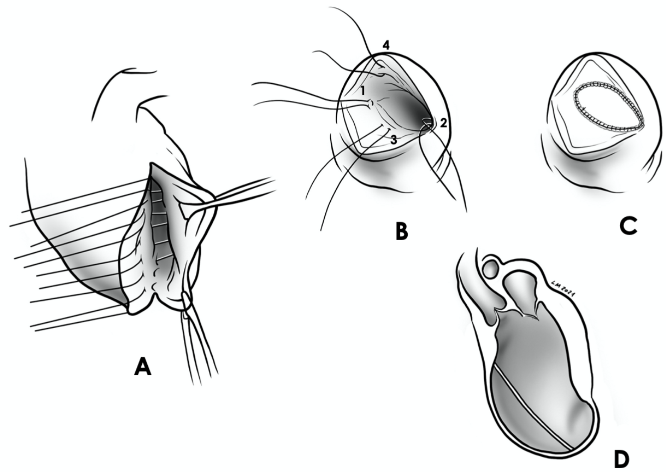

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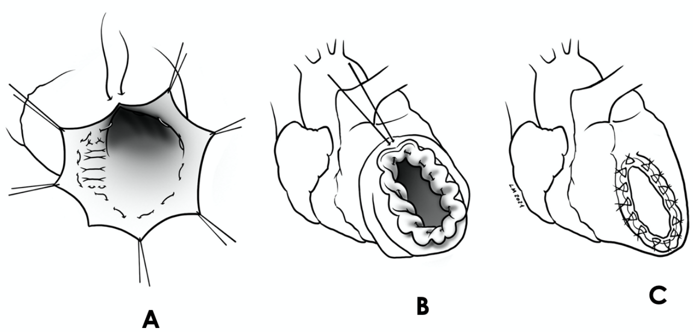

Fig. 5

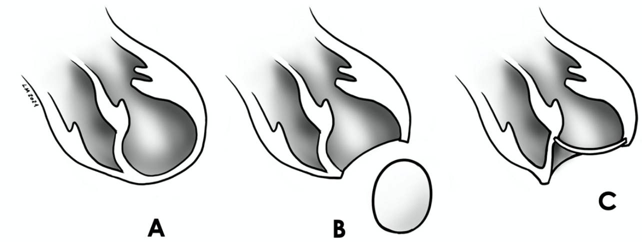

Fig. 6

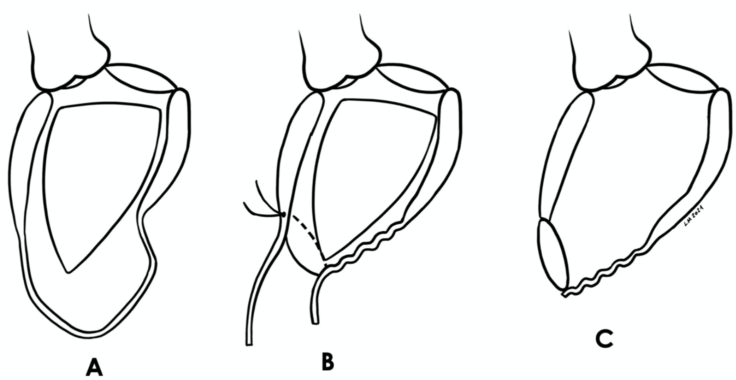

Fig. 7