Original Article

Angiographic Assessment of Surgical Reconstructions for Left Ventricular Asynergy with Indices of Abnormally Contracting Segments

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Background: In surgical reconstruction for left ventricular asynergy after myocardial infarction, the conventional linear closure technique second to simple resection and endoventricular circular patch plasty, which is the so-called Dor technique, are commonly utilized. We assessed these techniques using an abnormally contracting segment (ACS) in the left ventriculogram.
Methods: We reviewed 10 and 15 patients who underwent the linear technique (group L) and the Dor technique (group D), respectively. %ACS was determined as the percent ratio of both akinetic and dyskinetic chords among the total chords in the centerline method of regional wall motion analysis. A difference between preoperative and postoperative ejection fraction (EF) was generated by preoperative EF and this percentage ratio was determined as %EF.
Results: Postoperative EF improved from 31% to 41% in group L and from 33% to 49% in group D ($p<0.05$). Postoperative EF in group D was higher than in group L ($p<0.05$). %ACS decreased from 41% to 34% in group L and from 41% to 19% in group D ($p<0.05$). Postoperative %ACS was lower in group D than in group L ($p<0.05$). The significant correlation between preoperative %ACS and %EF was negative in group L and positive in group D ($p<0.05$).
Conclusions: The Dor technique is more effective for the postoperative systolic function than the linear technique because more extensive reduction in %ACS is possible with the Dor technique than with the linear technique. Dor technique becomes more crucial to the postoperative systolic function as the preoperative %ACS becomes larger. (Ann Thorac Cardiovasc Surg 2001; 7: 346–51)

Key words: left ventricular asynergy, abnormally contracting segment, endoventricular circular patch plasty, linear closure

Introduction

The left ventricular asynergy caused by transmural myocardial infarction imposes overwork on the residual noninfarcted myocardium through the modification of the myocardial fiber in its direction and dimension. The ischemia coexisting in the noninfarcted myocardium furthermore deteriorates myocardial oxygen efficiency. As the result of this vicious circle, the asynergy impairs the global pump function. The turbulent blood flow in the asynergic cavity also leads to the formation of thrombi. Therefore, surgical management for the left ventricular asynergy requires the elimination of the negative hemodynamic effect of asynergy as well as revascularization of the residual noninfarcted myocardium. For a left ventricular aneurysm, linear closure after simple aneurysmectomy has been the standard operation,[1] though the postoperative hemodynamic effects and the long-term

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Table 1. Clinical characteristics

Group	L	D	p value
Age (year)	58 ± 7	69 ± 9	0.004
Gender (male / female)	7 / 3	13 / 2	NS
Risk factor			
inotropes dependency	4	6	NS
mitral regurgitation	0	0	NS
diabetes melitus	4	6	NS
hyperlipidemia	3	4	NS
hypertension	2	3	NS
Preoperative cardiac function parameter			
LVEDVI (ml/m^2)	122 ± 45	113 ± 29	NS
LVESVI (ml/m^2)	87 ± 38	76 ± 21	NS
LVEF (%)	31 ± 6	33 ± 5	NS
%ACS (%)	41 ± 10	41 ± 6	NS
NYHA	3.0 ± 0.8	3.2 ± 0.6	NS
Operative data			
aortic clamping time (min)	69 ± 31	83 ± 21	NS
number of bypass (/pt)	1.8 ± 0.9	2.5 ± 0.5	0.029

LVEDVI: left ventricular end-diastolic volume index, LVESVI: left ventricular end-systolic volume index, LVEF: left ventricular ejection fraction, ACS: abnormally contracting segment, NYHA: New York Heart Association functional class, NS: not significant.

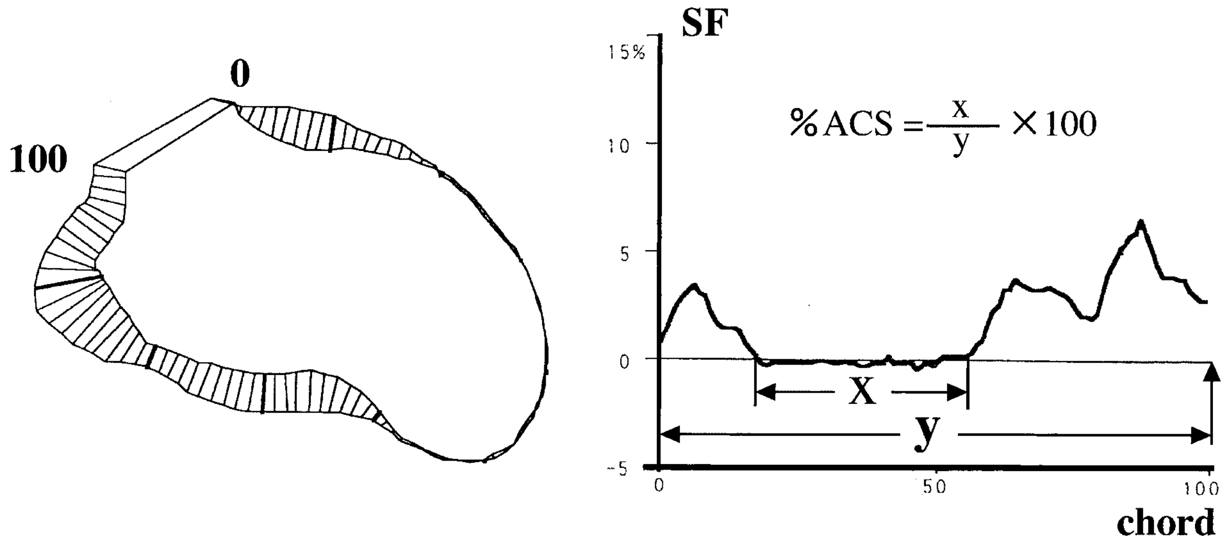
outcome remain controversial.[2,3] It is also unclear if this linear technique is beneficial to reconstruction of left ventricular asynergy. The physiological shape is the most efficient for the systolic function in the left ventricle.[4] The endoventricular circular patch reconstruction, which is the so-called Dor technique,[5] has been gaining acceptance in the last decade because it can not only reconstruct the physiological shape, but also exclude the asynergy. The aim of this study was to assess these two techniques using an abnormally contracting segment (ACS)[6] in the left ventriculogram.

Material and Methods

The 43 consecutive patients were subjected to operations for left ventricular asynergy arising from the course of myocardial infarction in our hospital between 1985 and 2000. The linear closure technique was performed in 20 patients. In May 1998, we switched our operative technique to the Dor technique and since then, have performed it in 23 patients. We excluded 18 patients from this study, because concomitant operations for ventricular septal perforation or ventricular free wall perforation were performed, or because the ventriculogram was not performed before nor after the operation. Consequently, the linear closure technique (group L) and the Dor technique (group D) were investigated in 10 and 15 patients, respectively. The clinical characteristics are shown in Table 1 and no significant differences between the groups were found except for age. Indications for operation were both angina and heart failure classified as more than New York Heart Association class III.

All operations were conducted using a cardiopulmonary bypass and aortic cross-clamping. The incision and following reconstruction of the left ventricle were performed under ventricular fibrillation at a rectal temperature of about 25°C. In group L, the aneurysmal portion was resected and closed by means of horizontal mattress sutures buttressed by a Teflon felt strip, followed by over and over continuous suture. In group D, circumferential purse-string suturing in the endomyocardium was performed at the borderline between the scarred and normal myocardium. Secondly, a glutaraldehyde-treated or bovine pericardial patch was inserted and fixed, and then the ventriculotomy was closed. After closing the left ventricle, the temperature was raised to moderate hypothermia (about 30°C). The heart was arrested with antegrade and retrograde intermittent cold blood cardioplegia, followed by coronary revascularization. The operative data are shown in Table 1. The number of grafts in group D was significantly greater than in group L. The grafting to the left anterior descending artery was done in 5 in group L, and in 15 in group D.

No postoperative complications such as cereberal vas-



a b

Fig. 1. a: Right anterior oblique view of the left ventriculography.
The left ventricular wall is divided into 100 chords along the circumference. The regional wall motion was measured along 100 chords constructed perpendicular to the centerline. Motion at each chord was normalized by the end-diastolic perimeter to yield a shortening fraction (SF).
b: The horizontal axis presents each chord and the vertical axis presents a SF corresponding to each chord. The value of SF less than 0 represents the motion of asynergy in the chord. This horizontal length among asynergic chords is normalized by all horizontal lengths between 1 and 100 chords to yield a percentage of abnormally contracting segment (%ACS).

cular event and fatal arrhythmia were found in any patients. During cardiac catheterization, no inotropic support was used. Left ventricular regional wall motion was quantitatively analyzed using the centerline method (right anterior oblique 30° projection). End-diastolic and end-systolic endocardial contours of the left ventricle were superimposed and the centerline between two contours was constructed. The wall motion was measured along 100 chords constructed perpendicular to the centerline (Fig. 1a). Motion at each chord was normalized by the end-diastolic perimeter to yield a shortening fraction (SF). The values of SF at each chord were plotted and then the graph between the chord and SF was produced (Fig. 1b) with special software (Wallmotion, ver. 2.01, Japan). We expressed left ventricular asynergy as the percent length of akinetic or dyskinetic length against the total length in the horizontal axis, and this ratio was determined to be a percentage of abnormally contracting segment (%ACS) (Fig. 1). The difference between the preoperative and postoperative EF was generated by the preoperative EF and this percentage ratio was determined as %EF.

All hemodynamic data were expressed as mean ± standard deviation. Statistical analysis for continuous variables consisted of Student's t test. Discrete data were analyzed with a Fisher's exact test. The correlation between two factors within each group was assessed using simple regression analysis. The level of significance was set at a p value of less than 0.05. All statistical analyses were carried out using special software of StatView 5.0 for Macintosh (SAS Institute Inc. USA).

Results

There were no significant differences in any of the preoperative values between the two groups. EF improved significantly from 31% to 41% in group L and from 33% to 49% in group D, postoperatively (Fig. 2a). Postoperative EF in group D was significantly higher than in group L (Table 2). End-diastolic volume index (EDVI) decreased significantly from 123 ml/m^2 to 94 ml/m^2 in group L and from 113 ml/m^2 to 76 ml/m^2 in group D after the operation, respectively (Fig. 2b). Although there was no significant difference in postoperative EDVI between both groups, postoperative ESVI in group D was significantly lower than in group L (Table 2). The %ACS decreased significantly from 43% to 34% in group L and from 41% to 19% in group D, respectively (Fig. 2c).

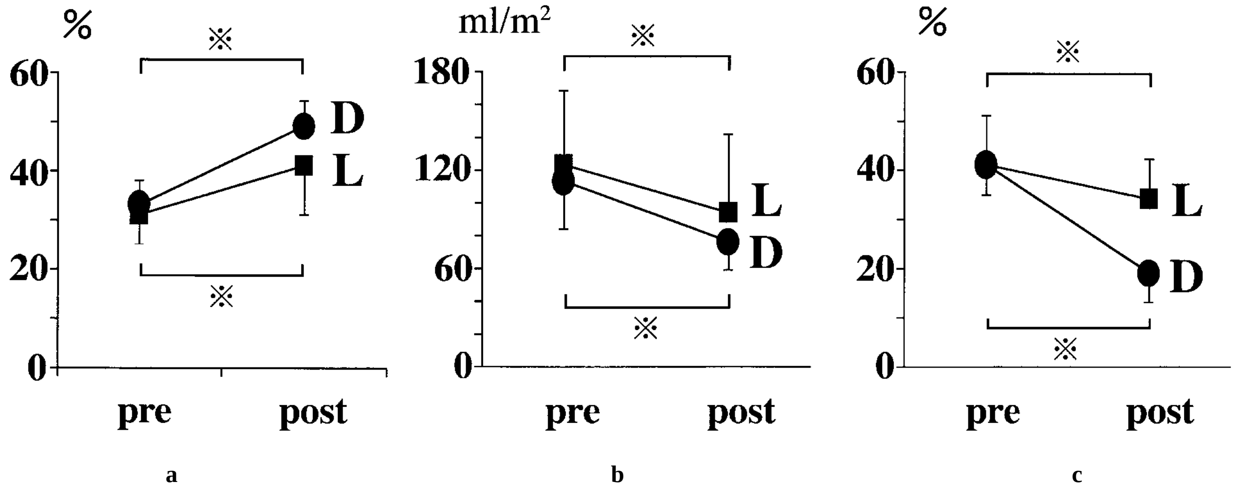


Fig. 2. a: Changes in ejection fraction. EFs significantly improved in both groups postoperatively.
b: Changes in the left ventricular end-diastolic volume index. EDVIs significantly decreased in both groups after the operation.
c: Changes in %ACS. %ACS significantly decreased in both groups postoperatively.
L: group L, D: group D, pre; preoperative value, post: postoperative value, EF: ejection fraction, EDVI: end-diastolic volume index, ACS: abnormally contracting segment, *p<0.05.

Postoperative %ACS was significantly lower in group D than in group L (Table 2). Both preoperatively and postoperatively, there were trends for negative correlations between %ACS and EF in both groups. Although a significant negative correlation between preoperative %ACS and %EF was observed in group L (Fig. 3a), a significant positive correlation between preoperative %ACS and %EF was observed in group D (Fig. 3b).

Discussion

Myocardial infarction often produces a deformity and a dilatation in the left ventricular cavity.[7] The physiological shape is the most efficient for the left ventricular pump function. The deformity modifies the direction of the residual normal muscle fibers and imposes overwork on the residual noninfarcted myocardium.[4] The dilatation increases the wall stress in the left ventricle according to the law of Laplace. Consequently, in the residual noninfarcted myocardium, not only the increase in the myocardial oxygen consumption, but also the coexisting ischemia due to coronary lesions deteriorates the myocardial oxygen efficiency and impairs the global pump function. Therefore, surgical management for the left ventricular asynergy should involve both reconstruction of the left ventricular geometry and revascularization to the noninfarcted myocardium. For the left ventricular aneurysm, the linear closure after simple aneurysmectomy has been a standard technique since the first successful operation by Cooly.[1] In this linear technique, no prosthetic material is used in the ventricular cavity and the ventricular volume can be decreased,[1-3] thereby reducing the myocardial oxygen consumption.[8] However, deformity of the left ventricle mostly occurs postoperatively because of the linear suture.[4] Therefore, physiological reconstruction as near as possible to the left ventricular asynergy has been noted in the last decade. The Dor technique enables not only the exclusion of asynergy including the infarcted septal portion, but also reconstruction of the optimum physiological shape in the left ventricle. Furthermore, coronary revascularization as complete as possible can be performed because of endoventricular reconstruction.[5] There have been many reports on the good early results of the Dor technique in comparison to the linear technique,[9-11] although the indications of the Dor technique are still unclear. There-

Table 2. Postoperative hemodynamic parameters

Group	L	D	p value
LVEDVI (ml/m^2)	94 ± 47	76 ± 17	0.195
LVESVI (ml/m^2)	59 ± 37	39 ± 10	0.026
LVEF (%)	41 ± 10	49 ± 5	0.011
%ACS (%)	34 ± 8	19 ± 6	<.0001

LVEDVI: left ventricular end-diastolic volume index, LVESVI: left ventricular end-systolic volume index, LVEF: left ventricular ejection fraction, ACS: abnormally contracting segment.

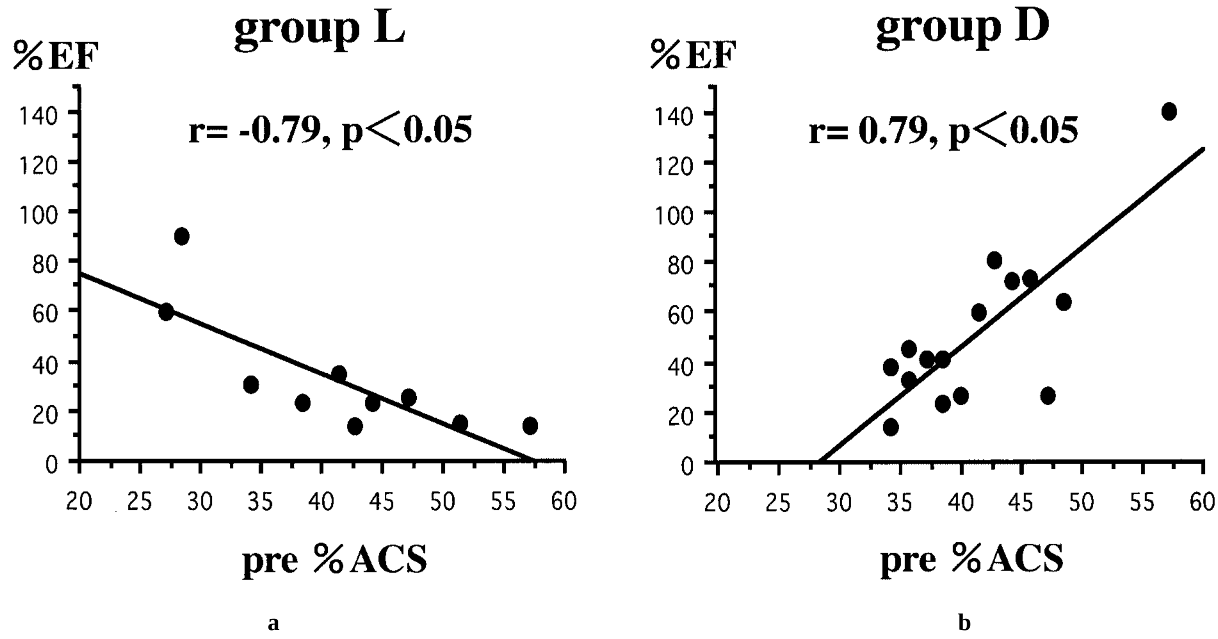


Fig. 3. a: Relationship between preoperative %ACS and %EF in group L. The correlation between preoperative %ACS and %EF was significantly negative.
b: Relationship between preoperative %ACS and %EF in group D. The correlation between preoperative %ACS and %EF was significantly positive.
pre %ACS: preoperative %ACS, r: correlation coefficient.

fore, surgical reconstruction for the left ventricular asynergy also remains controversial.

In the present study, the linear and Dor techniques were both effective for the postoperative systolic function because EF significantly improved after the operation in both groups. The comparison between the two groups, however, revealed more significant improvement in EF and ESVI in group D postoperatively than in group L, although there was no significant difference in the postoperative EDVI. These results suggested that an improvement in the systolic function could not result from simple reduction in left ventricular volume. The linear asynergy necessarily was "produced" or remained as a suture line postoperatively in the linear technique whereas a neo-apex was produced with the endoventricular purse-string suture in the Dor technique. Therefore, a greater level of asynergy usually could be reduced with the Dor technique than with the linear technique, and the Dor technique involved better physiological reconstruction than the linear technique. Consequently, the postoperative %ACS in group D was significantly lower than in group L in the present study. The postoperative residual asynergy could disturb the motion of the revascularized noninfarcted myocardium. Therefore, we considered that more extensive elimination of the ventricular asynergy contributed to a greater improvement in the postoperative systolic function. The number of grafts in group D was significantly greater than in group L. These resulted from especially performing more graftings to the left anterior descending artery in group D than in group L, which was one of the benefits of the endoventricular plasty[4,5] in contrast to the linear technique. In the Dor technique, therefore, more extensive reduction in %ACS as well as more complete revascurarization could contribute to the improvement in the global systolic function as compared with the linear technique.

In the present study, there was a significant negative correlation between the preoperative %ACS and %EF in group L. This correlation demonstrated that the linear closure persisted as a longer closure line and deformed the postoperative ventricular geometry to a larger extent as the preoperative %ACS became larger. On the other hand, in group D, there was a significant positive correlation between them. The Dor technique reduces the ACS by the neo-apex produced with the purse-string suture, and leads to a more efficient physiological shape. Therefore, these results demonstrated that the left ventricular geometry after reconstruction became more crucial on postoperative systolic function as the preoperative %ACS became larger.

The reason why we used %ACS to assess the degree of ventricular asynergy in the present study is that it can be calculated easily in routine left ventriculography. However, the degree of asynergy could not be evaluated exactly with %ACS by the method described here because %ACS was calculated in a single view alone in this study. Therefore, more detailed evaluation of the left ventricular asynergy should be conducted using the biplane view in the left ventriculography to assess the septal motion. The detailed indications of the Dor technique for left ventricular asynergy could not be decided in this study. Neverthless, we believe that the Dor technique becomes more effective for postoperative systolic function than the linear technique as the preoperative %ACS becomes larger.

We concluded the following: 1) The Dor technique becomes more effective for postoperative systolic function than the linear closure technique as the preoperative %ACS becomes larger. 2) The Dor technique is more efficient in physiological reconstruction than the linear technique because the %ACS can be reduced more extensively by the Dor technique than by the linear technique postoperatively. 3) The Dor technique is recommended especially for left ventricular asynergy with a large %ACS.

References

1. Cooley DA, Collins HA, Morris GC Jr, Chapman DW. Ventricular aneurysm after myocardial infarction: surgical excision with use of temporay cardiopulmonary bypass. *JAMA* 1958; **167**: 557–60.
2. Mangshau A, Simonsen S, Abdelnor M, Laake B, Geiran O. Evaluation of left ventricular aneurysm resection: a prospective study of clinical and hemodynamic characteristics. *Eur J Cardiothorac Surg* 1989; **3**: 58–64.
3. Coltharp WH, Hoff SJ, Stoney WS, et al. Ventricular aneurysmectomy. A 25-year experience. *Ann Surg* 1994; **219**: 707–14.
4. Jatene AD. Left ventricular aneurysmectomy-resection or reconstruction. *J Thorac Cardiovascular Surg* 1985; **89**: 321–31.
5. Dor V, Saab M, Kornaszewska M, Montiglio F. Left ventricular aneurysm: a new surgical approach. *Thorac Cardiovasc Surg* 1989; **37**: 11–9.
6. Field BJ, Russell RO, Dowling JT, Rackley CE. Regional left ventricular performance in the year following myocardial infarction. *Circulation* 1972; **46**: 679–89.
7. Dor V, Di Donato M. Ventricular remodeling in coronary artery disease. *Current Opinion in Cardiology* 1997; **12**: 533–7.
8. Kawachi K, Kitamura S, Kawashima Y, et al. Changes in myocardial oxygen consumption and coronary sinus blood flow before and after resection of left ventricular aneurysm after myocardial infarction. *J Thorac Cardiovasc Surg* 1987; **94**: 566–70.
9. Dor V, Sabatier M, Di Donato M, Maioli M, Toso A, Montiglio F. Late hemodynamic results after left ventricular patch repair associated with coronary grafting in patients with postinfarction akinetic or dyskinetic aneurysm of the left ventricle. *J Thorac Cardiovasc Surg* 1995; **110**: 1291–301.
10. Shapira OM, Davidoff R, Hilkert RJ, Aldea GS, Fitzgerald CA, Shemin RJ. Repair of left ventricular aneurysm: long-term results of linear repair versus endoaneurysmorrhaphy. *Ann Thorac Surg* 1997; **63**: 701–5.
11. Di Mattia DG, Di Biasi P, Salati M, Mangini A, Fundaro P, Santoli C. Surgical treatment of left ventricular post-infarction aneurysm with endoventriculoplasty: late clinical and functional results. *Eur J Cardiothorac Surg* 1999; **15**: 413–8.