High incidence of sudden death late after anterior LV-aneurysm repair

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Abstract

Objectives: Sudden death due to ventricular arrhythmias occurs frequently among patients with dilated cardiomyopathy and congestive heart failure (CHF). In patients with left ventricular (LV) aneurysms, LV-aneurysm repair (LVAR) reduces LV-size and ameliorates symptoms of CHF, but the incidence of late sudden death is unknown, especially after LVAR without concomitant anti-arrhythmic therapy.

Methods: Between June 1993 and June 1999, 147 patients (70% males; 62 ± 9 years) with CHF (median: NYHA III) due to anterior LV-aneurysms underwent LVAR. None of the patients underwent anti-arrhythmic surgical procedures concomitant to LVAR. Ninety percent of the patients had additional myocardial revascularization. Hospital records and laevocardiograms were reviewed, and follow-up information was obtained.

Results: In-hospital mortality was 4.1% (n = 6). The median follow-up was 3.7 years (0.1–73.4 months; overall 462 patient-years). At follow-up, the patients had significantly less symptoms than preoperatively (median: NYHA II, P < 0.001). Nineteen patients had died (5-year survival rate 78%). Of these late deaths, 84% (n = 16) were cardiac-related, among which sudden death was most frequent (n = 7). Predictors of sudden death were a bypass graft to the right coronary artery (P = 0.0100), ventricular tachyarrhythmias early postoperatively (P = 0.0315), and cross-clamp time (P = 0.0496). Conclusions: Although the survival and functional state of most patients were good after LVAR without concomitant anti-arrhythmic surgery, we observed a high incidence of late sudden death, which was—among others—significantly associated with postoperative ventricular tachyarrhythmias. To further improve outcomes, intra- and postoperative anti-arrhythmic therapy is advisable in patients undergoing LVAR.

Keywords: Surgery; Ventricles; Aneurysm; Sudden death; Follow-up studies

1. Introduction

Left ventricular (LV) aneurysms may develop after myocardial infarctions even in the era of rapid myocardial reperfusion [1] and can cause thrombembolism, congestive heart failure (CHF), and ventricular arrhythmias. In postinfarct patients, LV-size [2,3] and ventricular arrhythmias [4], which may cause sudden death [5–7], are important determinants of late mortality.

LV-aneurysm repair (LVAR) reduces LV-size [8,9] and may thus also reduce the incidence of late arrhythmias because myocardial stretching is thought to contribute to the development of arrhythmias [10]. However, a recent review concluded that it is not known whether LVAR without concomitant anti-arrhythmic surgical procedures is sufficient for prevention of late arrhythmias or sudden death [11]. Heart failure and thus surgery for heart failure is expected to increase in frequency, therefore, the incidence of arrhythmias after LVAR with and without concomitant anti-arrhythmic surgery is of interest with regard to the optimal treatment for patients with LV-aneurysms.

For many years, we have performed LVAR without additional arrhythmia ablation procedures. We therefore reviewed our own results after LVAR only, obtained follow-up information in order to determine the incidence of sudden death and investigated its predictors.

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2. Material and methods

2.1. Patients

Between June 1993 and June 1999, 147 patients (103 males, 44 females; mean age 62 ± 9 years) underwent anterior LV-aneurysm (median: NYHA III, minimum – maximum: NYHA II – IV). For this analysis, medical and surgical records of the patients were reviewed and preoperative patient characteristics and the in-hospital outcome were recorded using standardized definitions. Table 1 summarizes the clinical patient characteristics.

2.2. Surgery

LVAR was considered indicated in a symptomatic patient with anterior LV-aneurysm and apparently sufficient contractile function of the remote myocardium. Viability studies were not performed routinely. Surgery was performed through a median sternotomy. Standard cardiopulmonary bypass (nasopharyngeal temperature, 28 °C) and Cooley’s technique was used [12]. In brief, the aneurysm was opened parallel to the left anterior descending coronary artery. The non-viable segments of the septum and the LV free-wall were identified by inspection and palpation, which allowed identification of the neck of the aneurysm. Then, an oval patch was trimmed to fit the dimensions of the neck. This patch usually had an effective area of 2 × 3 cm² (with an additional 1 cm margin at all sides for suturing). The type of patch material was chosen at the discretion of the surgeon (autologous pericardium 32%; synthetic 68%). The patch was sutured with 3/0 Prolene into the firm tissue of the transitional zone so that the scar was almost completely excluded from the LV-cavity. Care was taken that the LV cavity was shortened in both the transverse as well as the longitudinal axes. No encircling suture was used. No procedures for arrhythmia ablation were performed. The ventricle was then closed with 3–0 Teflon-reinforced sutures. LVAR was performed after completion of the distal anastomoses and/or valve surgery. In 53% of the patients, LVAR was performed after cross-clamp release, whereas in the rest it was performed on the arrested heart (antegrade St. Thomas solution in 86%).

2.3. Analysis of the LV-angiograms

The 30° right anterior oblique (RAO) view of the preoperative LV cineangiograms was analyzed using a software (QCA-CMS; Medis; Leiden, Netherlands) that allows manual tracing of the LV outlines. To derive data on regional left ventricular function, the centerline method was applied to the endsystolic and enddiastolic LV outlines. LV-aneurysms were classified according to the predominating regional wall motion abnormality with the following definitions: dyskinetic if absolute motion of contiguous chords was less than zero (80%) and akinetic (20%) if equal to zero. The extent of non-contracting muscle or asynergy was calculated as the percent length of LV-perimeter showing fractional shortening below two SDs from mean normal values; the percent length of the LV-perimeter that showed akinesia and dyskinesia, respectively, was also recorded. To obtain absolute ventricular volumes, the Area Length method and a regression equation according to Kennedy (to correct for differences between an ellipsoid model and the actual LV shape) was applied to the ventricular outlines of the RAO view [13,14]. Because of the different methodology (a monoplane as compared to a biplane method in most other studies), ventricular volumes are not directly comparable to other studies. Ventricular volumes were then normalized for body-surface area. LV-ejection fraction and stroke volume were calculated from enddiastolic and endystolic volumes. Table 2 summarizes the laevocardiographic characteristics.

Table 1

<table>
<thead>
<tr>
<th>Preoperative characteristics of 147 patients undergoing LVAR</th>
<th>n/available data</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes mellitus</td>
<td>29/146</td>
<td>20</td>
</tr>
<tr>
<td>History of myocardial infarction</td>
<td>140/145</td>
<td>97</td>
</tr>
<tr>
<td>History of more than one myocardial infarction</td>
<td>32/144</td>
<td>22</td>
</tr>
<tr>
<td>Obesity</td>
<td>20/145</td>
<td>14</td>
</tr>
<tr>
<td>Smoking</td>
<td>34/144</td>
<td>24</td>
</tr>
<tr>
<td>Cerebro-vascular disease</td>
<td>15/143</td>
<td>10</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>13/142</td>
<td>9</td>
</tr>
<tr>
<td>Impaired renal function</td>
<td>15/140</td>
<td>11</td>
</tr>
<tr>
<td>Respiratory insufficiency</td>
<td>81/137</td>
<td>59</td>
</tr>
<tr>
<td>Ventricular arrhythmias, LOWN-classification ≥ III</td>
<td>15/125</td>
<td>12</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>36/109</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Laevocardiographic characteristics</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV-ejection fraction</td>
<td>38 ± 12</td>
</tr>
<tr>
<td>Enddiastolic LV-size (ml/m² body-surface area)</td>
<td>102 ± 41</td>
</tr>
<tr>
<td>Endystolic LV-size (ml/m² body-surface area)</td>
<td>70 ± 31</td>
</tr>
<tr>
<td>Asynergy %</td>
<td>51 ± 14</td>
</tr>
<tr>
<td>Dyskinesis %</td>
<td>18 ± 12</td>
</tr>
<tr>
<td>Akiness %</td>
<td>33 ± 14</td>
</tr>
</tbody>
</table>

* RAO view (30°).
* Relative to LV-circumference on 30° RAO.
2.4. Follow-up

Follow-up data were obtained by contacting the hospital-survivors and/or personal physicians either in person or by telephone. Survival status could be determined in all but five of the hospital-survivors (96.5% complete), and \( n = 125 \) (88.7%) could be interviewed personally. Overall follow-up was 462 patient-years. The median follow-up of hospital-survivors was 3.7 years (minimum–maximum 0.1–73.4 months). Medical records and reports from the next of kin were reviewed in an attempt to determine the cause of death.

2.5. Definition of sudden death

Sudden death was defined as death within 1 h after the onset of symptoms or death after a witnessed cardiac arrest or abrupt collapse that was not preceded by symptoms lasting more than 1 h [15]. If there were any symptoms prior to death, only those deaths were classified as sudden in which the symptoms prior to death were not typical of myocardial infarction.

2.6. Statistical methods

Ordinal variables are presented as absolute numbers and relative frequencies. Continuous data are presented as mean \( \pm SD \), except where otherwise stated. Univariate analysis for continuous data was performed using the Mann–Whitney \( U \)-test. A survival curve was constructed using the Kaplan–Meier method. Univariate analysis of all variables given in the text or tables in order to assess their relation with late mortality was performed by the log-rank test or the Cox proportional hazards method. Multivariable analysis excluding factors with large \( P \)-values in univariate tests was performed by Cox proportional hazards. The proportional hazards assumption was assessed by checking that there was no significant evidence of the need to include cross-product terms involving covariates and the logarithm of survival time. \( P < 0.05 \) was chosen to indicate statistical significance. For analyses, SAS, release 6.12 (SAS institute, Cary, NC), or Minitab, release 12 (Minitab Inc., State College, PA), were used.

3. Results

3.1. Procedural data

Concomitant to LVAR, 133 patients (90%) had bypass surgery: 113 of these patients (85%) had venous grafts (median: one venous graft, range 0–4), and the internal thoracic artery was used in 66 (50%) of the patients. The left anterior descending coronary artery was grafted in 71\% \( (n = 104) \) of the patients, and the right coronary artery (RCA) in 49\% \( (n = 33) \). Mitral valve replacement was performed in one patient with grade IV mitral valve insufficiency. The mean duration of ECC and cross-clamping were 101 \( \pm 43 \) and 39 \( \pm 21 \) min, respectively.

3.2. Perioperative results

Six patients (4.1%) died perioperatively, four from ongoing low-output syndrome and two after multiorgan failure had developed. Thirty-six patients experienced ventricular tachyarrhythmias necessitating treatment in the first postoperative days. In five patients, defibrillation for ventricular fibrillation was needed.

3.3. Follow-up period

At follow-up, the patients had significantly less symptoms (median: NYHA II, minimum–maximum: NYHA II–IV, \( P < 0.001 \)). During follow-up, 19 patients died (linearized mortality rate including surgery 5.4%/year). The Kaplan–Meier estimate of 5-year survival was 78\% (Fig. 1). The majority of deaths during follow-up were cardiac-related (84\%). Most cardiac deaths were sudden \( (n = 7) \). Other causes of late cardiac death were worsening CHF \( (n = 5) \); and documented acute myocardial infarction \( (n = 4) \).

Risk factors for late sudden death on univariate analysis were:

- bypass graft to the RCA \( (P = 0.0100) \); of 46 in-hospital survivors who received a bypass graft to the RCA, 38 were alive at follow-up; eight had died, five of whom were sudden,
- postoperative presence of ventricular tachyarrhythmias necessitating treatment \( (P = 0.0315) \); of 34 in-hospital survivors who experienced ventricular tachyarrhythmias early postoperatively, 26 were alive at follow-up; eight had died, three of whom were sudden,
- the duration of aortic cross-clamping \( (P = 0.0496) \); the cross-product term of this variable and the logarithm of survival time was significant \( (P = 0.048) \) indicating that the duration of cross-clamp is initially associated with

![Fig. 1. Survival probability (and 95% confidence interval) of 147 patients undergoing LVAR.](image-url)
a higher chance of sudden death, but that this effect vanishes with time).

Multivariate analysis did not provide additional information. No incidence of near-missed death could be elucidated. During follow-up, one patient received implantation of an automated cardioverter/defibrillator (ICD).

4. Discussion

Our study demonstrates that LVAR without concomitant anti-arrhythmic procedures is associated with a significant amelioration of symptoms and a good mid-term prognosis. Furthermore, we found that sudden death was the most common single mode of death (37%) during follow-up. The incidence of arrhythmias and sudden death late after LVAR and their determinants, especially when performed without concomitant anti-arrhythmic surgery, has not yet been studied in detail [11].

LV-aneurysm resection for therapy of ventricular arrhythmias was first published in 1959 [16], and several subsequent reports suggested that LV-aneuysmectomy may be a reliable treatment for refractory malignant ventricular arrhythmias [17,18]. This finding can probably be explained by the reduction of LV-size created by LVAR resulting in decreased wall tension and oxygen demand. This theory fits experimental data that suggest that increased wall tension may play an essential part in arrhythmia pathogenesis [10].

However, we observed a high incidence of sudden death late after LVAR and a significant association between late sudden death and ventricular tachyarrhythmias early postoperatively. Our finding indicates that arrhythmogenic foci may be present after LVAR in the freshly decompressed heart. This is supported by reports that identified ‘silent’ ventricular tachycardias in patients who had undergone aneuysmectomy for treatment of ventricular tachycardias [19] or showed that recurrent ventricular arrhythmias involved an anatomic substrate, usually within the border zone of the infarction [20]. Therefore, many groups today combine LVAR with endocardial resection and/or cryoablation in patients with clinical and/or inducible ventricular arrhythmias [9,21] with documented success [22,23]. The etiology of late death, however, is explicitly addressed in only two current large studies on LVAR. In both studies, LVAR had been extensively combined with arrhythmia ablation (in 40 [21] and 50% [22] of the patients). In these reports, the frequency of sudden deaths appears to be lower than in our study: Mickleborough [21] found the majority of deaths to be due to CHF (19/31) and only four (13%) deaths to be either sudden or due to documented ventricular arrhythmias. Di Donato [22] reports on 48 late deaths, nine (19%) of which were sudden. This preventive approach, however, may add to the complexity and risk of the operation.

The perioperative mortality rate in our study is quite low when compared to other groups [8,9,22]. Contrary to other studies, we operated upon a series of patients with a high prevalence of ‘classic’ dyskinetic LV-aneurysms (80% in our study vs. 33% in the recent restore-group [8]). However, the size of the LV-aneurysm (as expressed by the extent of non-functioning myocardium or asynergy) appears to be comparable to other studies. In our study, the mean extent of asynergy was 51% as compared with 42–60% in other studies [21,24]. On the other hand, the ejection fraction was slightly higher than in other studies [8,9,21] reflecting a considerable preservation of the contractile function of remote myocardium. We believe that this was crucial for obtaining the low in-hospital mortality and has also contributed to the low prevalence of significant concomitant mitral valve regurgitation. Theoretically, however, the less invasive surgical approach (by omitting concomitant anti-arrhythmic surgery) may also have contributed to the results.

There is another option besides prevention, i.e. treatment of late arrhythmias using an ICD. This approach is very attractive because arrhythmias developing after LVAR may not have been inducible preoperatively [22]. In addition, the MADIT-II trial demonstrated that postinfarction patients had a significantly improved prognosis after implantation of an ICD [7]. Patients in the MADIT-II trial had severely reduced LV-function and therefore most likely overlap with patients who undergo LVAR. Nevertheless, the results of the MADIT-II study cannot be easily applied to patients who had undergone LVAR because MADIT-II excluded all patients who had undergone coronary revascularization (almost always concomitant to LVAR) within 3 months before enrollment and patients with NYHA class IV (23% of the patients in our study). So far, it has not been tested which approach (concomitant arrhythmia ablation procedure vs. prophylactic ICD) to patients undergoing LVAR is more efficacious, but such studies are strongly encouraged.

A strange and unexplained finding of our study is the fact that patients who received a bypass graft to the RCA had an increased chance of dying suddenly. All patients who died suddenly and who received a bypass graft to the RCA had either a right dominant or balanced coronary circulation. We therefore can only speculate that occlusion of the venous graft may have resulted in undetected myocardial infarction leading to lethal arrhythmias. If a myocardial infarction occurs late after LVAR, even previous arrhythmia ablation procedures may not be able to prevent this kind of new lethal arrhythmia, and, overall, placement of an ICD may be the most efficacious approach.

4.1. Limitations of the study

Ideally, a prospective, randomized multicenter trial would be desirable to clarify the best treatment with regard to anti-arrhythmic treatment for patients with LV-aneurysms. However, there are shortcomings regarding the generalizability and practical difficulties in performing such a randomized trial. Carefully conducted observational studies are also of significant value [25], and studies as ours may help
to increase knowledge in as much as all our LVAR-patients were treated without concomitant anti-arrhythmic surgery compromising a comparably large, uniform patient cohort.

This retrospective study lacks objective data on arrhythmias. However, sudden death is usually arrhythmogenic in nature [5,6], and we observed a significant association between late sudden death and ventricular tachyarrhythmias necessitating treatment in the first postoperative days. This finding provides some reassurance that the observed sudden deaths were likely caused by arrhythmias. Our study also lacks data on postoperative ventricular dimensions. We therefore cannot exclude that residual ventricular dilatation may have contributed to the supposed arrhythmogenic deaths.

5. Conclusion

Although the overall survival and functional status of the patients undergoing LVAR without concomitant anti-arrhythmic procedures were good, we observed a high incidence of late sudden death. Our retrospective study suggests that some patients who died suddenly during follow-up, especially those who had perioperative ventricular arrhythmias, could probably have been identified as at risk and been treated. Strategies towards ventricular arrhythmia detection and intra- and postoperative anti-arrhythmic treatment appear to be indicated in patients referred for LVAR.

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References