Minimally Invasive Thoracoscopic Technique for LV Lead Implantation in CRT Patients

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Abstract

Background: Epicardial placement of the left ventricular (LV) lead is an alternative approach to the standard cardiac resynchronization therapy (CRT) procedure. In our center we developed a minimally invasive thoracoscopic technique. We reviewed our experience to evaluate the long-term safety and effectiveness of the technique.

Methods: The procedure is performed under general anesthesia with oro-tracheal intubation and right-sided ventilation, and requires 3 thoracoscopic ports (two 5-mm and one 15-mm). We analyzed 94 consecutive patients referred to our center for epicardial LV lead implantation.

Results: Five patients were excluded because of concomitant conditions precluding surgery or lack of indication for CRT. The remaining 89 patients underwent the procedure. Of these, 57 had undergone previous unsuccessful LV lead implantation (Group 1). In the remaining 32 patients, effective CRT was discontinued owing to LV lead dislodgment (Group 2). LV lead implantation was successful in all patients (median pacing threshold 0.8V, IQR: 0.6-1.2, at 0.5 ms, no phrenic nerve stimulation) and CRT was successfully established in all but one patient. No complications were reported, except for 2 cases of transitory peri-electrode bleeding and 3 cases of ventricular fibrillation induced during the procedure (no sequelae). The median procedure time was 75 min (IQR: 55-95). During a median follow-up of 24 [IQR: 13-39] months, 21 patients died and 4 additional device-related complications were reported (comparable rates between groups).

Conclusions: Our thoracoscopic approach proved to be safe and effective. It is a viable alternative to the standard transvenous approach in the case of failed de novo implantation and in those patients who positively respond to CRT but experience LV lead dislodgment.

Keywords: CRT; LV lead epicardial implantation; Video-assisted thoracoscopic technique

Introduction

Epicardial placement of the left ventricular (LV) lead is an alternative approach in the case of failure of the transvenous approach during cardiac resynchronization therapy (CRT) device implantation [1]. In our center, we have developed a minimally invasive thoracoscopic technique in which the patient is placed in the right lateral decubitus position (90°). We reviewed our experience to evaluate the safety and effectiveness of this video-assisted thoracoscopic technique (VAT) and assessed the long-term outcomes of two groups of patients: patients who had experienced failed de novo transvenous LV lead implantation (group I, De novo CRT group) and patients who had positively responded to CRT but experienced LV lead failure or dislodgment judged not amenable to a standard transvenous approach (Restored CRT group, group II).

Methods

Patient selection

The study was approved by the Institutional Review Board and all subjects provided written consent. Patients underwent baseline evaluation, which included demographics and medical history, clinical examination, 12-lead electrocardiogram and echocardiogram. They also underwent computed tomography evaluation to rule out any...
Surgical technique and approach

The procedure was performed under general anesthesia and orotracheal intubation by means of a double-lumen tube and right-sided ventilation. The patient was placed in the right lateral decubitus position (90°) with both arms anteriorly extended. The minimally invasive procedure required three thorascopic ports:

- A Veress needle was inserted into the VI-VII intercostal space, along the line that passes through the inferior angle of the scapula, 2-3 cm distally. Once negative pleural pressure had been found, 500 ml di CO₂ was insufflated. A 15-mm valved trocar was inserted through the access and a 5-mm 30° camera was introduced. Subsequently, two operating ports were placed under direct vision. CO₂ insufflation, with a Pmax of 8-10 mmHg, was maintained in order to obtain complete left lung collapse and diaphragm caudalization.
- The second 5-mm port was created at the IX-X intercostal space, on the same sagittal plane as the first one.
- The third 5-mm port was made on the anterior axillary line, at the level of the VII-VIII intercostal space.

Mini-invasive tool

The MyoPore® sutureless myocardial pacing lead (Greatbatch Medical, NY, USA) was anchored via a thorascopic approach by means of the FasTact™ Flex (Greatbatch Medical) steerable lead implantation tool. The steering capability of this tool facilitates access to the target area in the postero-lateral basal region of the LV epicardial surface.

Implantation technique

The thorascopic camera was moved to the second access in order to visualize the third access. In the case of significant cardiomegaly, pulmonary ligament dissection was necessary in order to expose the pericardial surface located beyond the inferior pulmonary vein. In this way, the pericardium was directly incised in the epicardial target area. Before the device was anchored, sensing and pacing measurements were taken by placing the electrode in contact with the epicardium. A maximal pacing threshold value of 4 V at 0.5 ms was considered acceptable, to ensure a reliable chronic pacing capture. The spiral electrode was then screwed in (2 and 1 1/4 clockwise rotations). The pericardial window did not usually require any suture to prevent the spiral electrode from detaching. The electrode followed a pathway parallel to the cardiac outline until just above the diaphragm, and was then pulled out through the anterior port. The electrode was anchored to the skin by means of Steri-Strips™ and then covered with gauze and a sterile drape to maintain sterility. Finally, the patient was returned to the supine position and the operating field was rearranged to include the pectoral pocket that had to be opened. The electrode was tunneled to the pectoral pocket and connected to the device (Figure 1).

Patient management

The patients were extubated in the operating room or in the Intensive Care Unit. The chest tube was removed 12-24 h after surgery. After discharge, clinic visits were scheduled every 6 months.

Endpoints

In the two study groups, we analyzed the time to death due to any cause and time to the combined endpoint of death or hospitalization. We also analyzed all procedure- and device-related complications. In addition, the effects of CRT on the patients’ clinical and functional status were evaluated by comparing the baseline clinical and echocardiographic parameters with those at the last in-clinic follow-up visit. Specifically, the degree of LV reverse remodeling was assessed by measuring changes in LV ejection fraction and volumes, while variations in functional status were indicated by changes in NYHA class. The adequacy of pacing parameters was assessed on implantation and on long-term follow-up.

Statistical analysis

Descriptive statistics are reported as means ± SD for normally distributed continuous variables, or medians with 25th to 75th percentiles in the case of skewed distribution. Differences between mean data were compared by means of a T-test for Gaussian variables. The Mann-Whitney test and the Wilcoxon non-parametric test were used to compare non-Gaussian variables for independent and paired samples, respectively. Differences in proportions were compared by applying Chi-square analysis or Fisher’s exact test, as appropriate. Event rates were summarized by constructing Kaplan–Meier curves. The log-rank test was applied to evaluate differences between trends. A p value<0.05 was considered significant for all tests. All statistical analyses were performed by means of SPSS’ Statistics, software, version 20 (IBM Corp, New York, NY, USA).

Results

Study population

From January 2008 through December 2016, 94 consecutive patients with standard CRT indications were referred to our center for thoracoscopic LV lead implantation. After pre-operative assessment, 5 patients were excluded because of concomitant conditions that...
precluded surgery. The remaining 89 patients underwent the surgical procedure (Table 1). Of these, 57 had undergone previous unsuccessful LV lead implantation or were deemed unsuitable for transvenous implantation because of their venous anatomy (coronary sinus or subclavian access) or extreme lead instability during the procedure (De novo CRT group, Group I). In the remaining 32 patients, effective CRT was discontinued during follow-up, owing to LV lead dislodgement/failure, phrenic nerve stimulation, or extraction because of an infection (Restored CRT group, Group II).

In both groups, LV lead implantation was successful in all patients and CRT was successfully established in all but one patient at the end of the procedure. The median pacing threshold was 0.8 V at 0.5 ms (IQR 0.6-1.2) and no phrenic nerve stimulation was reported at the final electrode position. A basal LV segment was reached in 80 (90%) patients (Table 2). The median total procedure time was 75 min (IQR 55-95) and the time to epicardial lead fixation was 30 min (IQR 15-40). The procedure time was significantly longer in the presence of pleural or pericardial adherence (Table 3). No complications were reported, except for 2 cases of transitory peri-electrode bleeding and 3 cases of ventricular fibrillation induced during the procedure. No sequelae were reported after these events. During the post-operative hospital stay, 12 complications occurred in 9 patients: 5 cases of worsening heart failure, one followed by death, 4 pocket or chest wall hematomas (only one requiring intervention), 1 episode of ventricular tachycardia correctly interrupted by the ICD, 1 episode of atrial fibrillation, and 1 dislocation of the right ventricular defibrillation lead, causing inappropriate shocks. The median hospital stay after the procedure was 5 days (IQR 3-7).

### Table 1: Demographics and baseline characteristics of the study population

| Parameter                          | CRT de novo (57) | CRT restored (32) | p-value |
|------------------------------------|------------------|-------------------|---------|
| Male gender, n (%)                 | 36 (63)          | 26 (81)           | 0.057   |
| Age, years                         | 70 (64-75)       | 75 (69-78)        | 0.029   |
| Ischemic cardiomyopathy, n (%)     | 24 (42)          | 17 (52)           | 0.412   |
| Dilated cardiomyopathy, n (%)      | 22 (39)          | 12 (38)           | 0.919   |
| NYHA class III or IV, n (%)        | 42 (74)          | 19 (59)           | 0.163   |
| QRS duration, ms                   | 160 (158-190)    | 160 (158-189)     | 0.906   |
| LBBB morphology, n (%)             | 32 (56)          | 15 (47)           | 0.483   |
| RBBB morphology, n (%)             | 3 (5)            | 1 (3)             | 0.599   |
| AF on implantation, n (%)          | 16 (28)          | 9 (28)            | 0.989   |
| History of AF, n (%)               | 31 (54)          | 17 (53)           | 0.522   |
| Hypertension, n (%)                | 38 (67)          | 22 (69)           | 0.841   |
| Diabetes, n (%)                    | 16 (28)          | 12 (38)           | 0.358   |
| COPD, n (%)                        | 15 (26)          | 7 (22)            | 0.641   |
| Chronic kidney disease, n (%)      | 24 (42)          | 18 (56)           | 0.2     |
| Previous cardiac surgery, n (%)    | 22 (39)          | 9 (28)            | 0.32    |
| ACE-i/ARB, n (%)                   | 38 (67)          | 28 (88)           | 0.031   |
| B-blockers, n (%)                  | 48 (84)          | 30 (94)           | 0.189   |
| MRA, n (%)                         | 31 (54)          | 21 (66)           | 0.302   |
| Anticoagulants, n (%)              | 28 (49)          | 16 (50)           | 0.937   |
| Antiarrhythmic drugs, n (%)        | 17 (30)          | 11 (34)           | 0.657   |
| LVEF, %                            | 27 (20-30)       | 29 (21-33)        | 0.204   |
| LVEDV, ml                          | 183 (138-241)    | 187 (150-224)     | 0.598   |
| LVESV, ml                          | 130 (102-190)    | 122 (105-160)     | 0.467   |
| Follow-up, months                  | 21 (8-39)        | 30 (18-36)        | 0.269   |

### Table 2: Pacing threshold parameters and final position of the LV lead

| Parameter                          | CRT De novo (57) | CRT Restored (32) | p-value |
|------------------------------------|------------------|-------------------|---------|
| LV lead pacing parameters          |                  |                   |         |
| Threshold (V a 0.5 ms)             | 0.8 (0.5-1.4)    | 0.8 (0.6-1.1)     | 0.467   |
| Impedance (Ω)                      | 585 (449-706)    | 633 (533-709)     | 0.9     |
| Position of LV lead tip in LAO view|                  |                   |         |
| Posterior                          | 22 (39%)         | 10 (31%)          | 0.139   |
| Postero-lateral                    | 35 (61%)         | 21 (66%)          |         |
| Lateral                            | 0 (0%)           | 1 (3%)            |         |
| Antero-lateral                     | 0 (0%)           | 0 (0%)            |         |
| Anterior                           | 0 (0%)           | 0 (0%)            |         |
| Position of LV lead tip in RAO view|                  |                   |         |
| Basal                              | 54 (95%)         | 26 (81%)          | 0.038   |
| Mid                                | 3 (5%)           | 5 (16%)           |         |
| Apical                             | 0 (0%)           | 1 (3%)            |         |

### Table 3: A comparison of total procedure time between patients with and without pleural adherence or pericardial adherence

| Parameter                          | YES | NO | p-value | YES | NO | p-value |
|------------------------------------|-----|----|---------|-----|----|---------|
| Total time (min)                   | 127 ± 47 | 71 ± 25 | <0.001 | 115 ± 48 | 74 ± 30 | 0.004 |
| Time to lead fixation (min)        | 54 ± 20 | 29 ± 16 | 0.001 | 46 ± 9 | 31 ± 18 | 0.112 |

### Follow-up

During a median follow-up of 24 months (IQR, 13–39), 12 patients in group I and 8 in group II died. The rates of death due to any cause were comparable between the groups (Figure 2; log-rank test,
p=0.829), as were the rates of the combined endpoint of death or cardiovascular hospitalization (Figure 3; log-rank test; p=0.843).

Figure 2: Kaplan-Meier estimate of time to death due to any cause in patients with de novo and restored CRT (log-rank test, p=0.829); §- CRT de novo, *- CRT restored.

Figure 3: Kaplan-Meier estimate of time to the first event (death due to any cause or hospitalization). (log-rank test, p=0.843); §- CRT de novo, *- CRT restored.

In both study groups, significant reverse remodeling of the LV was observed in terms of increased LV ejection fraction and reduced LV volumes. Patients in both groups improved in their functional status to a similar degree, as measured by a reduction in the proportion of patients in NYHA class III-IV at the last observation (Table 4).

| Parameter          | CRT de novo (57) | CRT restored (32) | p-value F-U |
|--------------------|------------------|-------------------|-------------|
| NYHA III or IV     | Basal            | F-U               | p-value     |
|                    | 42 (74%)         | 16 (28%)          | <0.001      |
|                    | (21-34)          | (11-184)          |             |
| Left Ventricular Ejection Fraction (%) | 28              | 38 (32-46)       | <0.001      |
|                    | (21-34)          | (30-33)           |             |
| Left Ventricular End Diastolic Volume (ml) | 156             | 145 (111-184)    | 0.185       |
|                    | (120-210)        | (111-184)         |             |
| Pacing Threshold (V a 0.5 ms) | 0.6 (0.5-1.4)   | 1.3 (0.8-2.0)    | 0.236       |
|                    | (0.5-1.4)        | (0.8-2.0)         |             |
| Impedance (Ω)      | 437 (380-662)    | 376 (280-463)     | 0.353       |
|                    | (380-662)        | (280-463)         |             |
| LVESV (ml)         | 109 (80-133)     | 91 (59-114)       | 0.032       |
|                    | (80-133)         | (59-114)          |             |
| LVEDV (ml)         | 138 (115-199)    | 143 (92-180)      | 0.021       |
|                    | (115-199)        | (92-180)          |             |

Table 4: A comparison of clinic and echocardiographic characteristics between the two groups; Basal and follow up

After hospital discharge, 4 additional device-related complications were reported during the follow-up period: 2 pocket infections (one requiring removal of the lead and subsequent re-implantation), one pocket wound dehiscence, and one replacement of a generator under safety advisory. The risk of device-related complications was comparable between the groups. Figure 4 shows the Kaplan–Meier event-free curves of device-related complications (log-rank test; p=0.759).

During follow-up, the pacing parameters remained satisfactory in both groups (Table 4).

Discussion

The present study showed that epicardial implantation through the VAT approach was feasible, safe and effective in patients with previous unsuccessful LV lead implantation or late LV lead dislodgment or failure.

The standard first-line approach to LV lead implantation during a CRT procedure is transvenous lead positioning through a side branch of the coronary sinus. The final position of the LV lead depends on the anatomy of the CS, the performance and stability of the pacing lead and the absence of phrenic nerve stimulation. Despite improvements in leads and tools for transvenous implantation, the implantation failure rate remains high (5-10%) [2]. Similarly, discontinuation of CRT during follow-up, due to late failure of the lead or other causes, has been described in about 10% of patients at one-year follow-up [3].
Alternative approaches have been proposed; except for some preliminary experiences of endocardial LV pacing via the trans-septal route [4], they all require epicardial positioning of the lead. Most frequently, the epicardial lead is positioned through an open chest access: median sternotomy, left thoracotomy, mini-thoracotomy, VAT and robotically assisted surgery [1]. The advantages of these approaches are: direct visual control and the possibility of choosing the lead-tip position, less fluoroscopy use and the avoidance of intravenous contrast material; the disadvantages are the need for general anesthesia, and the risk of greater procedural difficulty due to the presence of epicardial fat and adhesions.

Previous studies have shown the efficacy of the VAT technique (Supplemental Table shows the details of the published studies) [5-17]. In the present study, we analyzed the largest population of VAT-treated patients ever considered. The VAT technique described here causes less postoperative pain and requires smaller incisions. The technique was performed under general anesthesia, single-lung ventilation and on the beating heart. Although the presence of pleural or pericardial adhesions was indicated in the literature, the presence of epicardial fat and adhesions. Moreover, we recorded comparable outcomes and postoperative pain and requires smaller incisions.

In the VAT procedure, the lateral approach makes the target area of the LV easier to reach, as the pericardium is opened laterally to the neurovascular phrenic bundle and the epicardial lead is screwed into the target wall region of the LV (basal postero-lateral). In the present experience, the basal LV segment was reached in 90% of patients, acceptable pacing parameters were achieved and no phrenic nerve stimulation occurred. It has been demonstrated that pacing from the site of maximum electrical delay contributes to improving patient outcomes [19], and current guidelines advocate targeting the regions of latest activation [20]. As the VAT procedure circumvents the limitations of the CS anatomy, it allows easier access to the optimal pacing site, according to the values of pacing parameters and, if possible, to the degree of the electrical delay.

In the present study, we included both patients who had undergone unsuccessful de novo transvenous LV lead implantation and patients who had responded positively to therapy but had experienced CRT discontinuation due to transvenous LV lead failure. In both groups, the VAT implantation procedure proved safe and was associated with few complications in the post-operative phase and during follow-up. Moreover, we recorded comparable outcomes and significant improvements in clinical and echocardiographic parameters in both groups. The VAT procedure therefore seems to be a viable approach, as it not only ensures that all patients with previous unsuccessful LV lead implantation receive CRT, but also enables therapy to be restored in the case of discontinuation due to late complications. Further studies are required in order to determine whether the VAT approach should be limited to patients in whom effective CRT is discontinued, as in the present study, or whether it can also be considered an option for therapy optimization in patients who do not initially improve on CRT.

In this regard, the Alternate Site Cardiac Resynchronization (ALSYNC) study recently evaluated the feasibility and safety of left ventricular endocardial pacing not only in patients in whom previous conventional LV lead implantation had failed, but also in CRT non-responders [4]. The implantation procedure was successful in 89% of the patients, and 6 months post-implantation 82% remained free of complications. The NYHA class improved in 59% of patients, and 55% had a 15% or greater reduction in LVEFSV. Those patients enrolled after CRT non-response showed similar improvement. Our findings show that the safety profile of VAT implantation is even better than that of endocardial pacing. Therefore, in our opinion, a study to ascertain the efficacy of this approach to correcting CRT non-response is justified.

Study limitations

The main limitation of the present study is the observational design of the analysis. Moreover, the present results should be interpreted with care, as this study reports the experience of a single operator who had experience in this technique. Thus, generalizability of the results requires validation.

Conclusions

In patients with previously failed transvenous LV lead implantation or late LV lead dislodgment or failure, the VAT epicardial procedure could be a preferential alternative technique for LV lead implantation.

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