

Minimally Invasive Surgical Implantation of Left Ventricular Epicardial Leads for Ventricular Resynchronization Using Video-Assisted Thoracoscopy

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Background and objectives. Cardiac resynchronization via left ventricular or biventricular pacing is an option for selected patients with ventricular systolic dysfunction and widened QRS complex. Stimulation through a coronary vein is the technique of choice for left ventricular pacing, but this approach results in a failure rate of approximately 8%. We describe our initial experience with minimally invasive surgical implantation of left ventricular epicardial leads using video-assisted thoracoscopy.

Patients and method. A total of 14 patients with congestive heart failure, NYHA functional class 3.2 (0.6) and mean ejection fraction 22.9 (6.8)% were included in this study. Left bundle branch block, QRS complex >140 ms and abnormal septal motion were observed in all cases. Epicardial leads were implanted on the left ventricular free wall under general anesthesia using video-assisted thoracoscopic surgery.

Results. Lead implantation was successful in 13 patients. Conversion to a small thoracotomy was necessary in one patient. All patients were extubated in the operating room. None of the patients died during their hospital stay. Follow-up showed reversal of ventricular asynchrony and significant improvement in ejection fraction and functional class.

Conclusions. Minimally invasive surgery for ventricular resynchronization using video-assisted thoracoscopy in selected patients is a safe procedure that makes it possible to choose the best site for lead implantation and provides adequate short- and medium-term stimulation.

Key words: Heart failure. Cardiac resynchronization. Surgery. Video-assisted thoracoscopy. Epicardial lead.

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Implante de electrodos epicárdicos en el ventrículo izquierdo para resincronización mediante cirugía mínimamente invasiva asistida por videotoracoscopia

Introducción y objetivos. La resincronización cardíaca mediante estimulación ventricular izquierda o biventricular es una alternativa en pacientes seleccionados con disfunción sistólica y complejo QRS ensanchado. El implante del electrodo en una vena coronaria es la técnica habitual para estimular el ventrículo izquierdo y conlleva un índice de fracasos próximo al 8%. Se describe la experiencia inicial con el implante de electrodos epicárdicos en el ventrículo izquierdo mediante cirugía mínimamente invasiva asistida por videotoracoscopia.

Pacientes y método. Se intervino a 14 pacientes con insuficiencia cardíaca en clase funcional de la NYHA de 3,2 ± 0,6, fracción de eyección del 22,9 ± 6,8%, bloqueo de rama izquierda, complejo QRS >140 ms y movimiento septal anómalo. Bajo anestesia general y mediante videotoracoscopia se implantó un electrodo epicárdico en la pared libre del ventrículo izquierdo.

Resultados. En 13 pacientes, el implante del electrodo se realizó con éxito, y fue necesario reconvertir uno de los casos a minitoracotomía. El umbral de estimulación intraoperatorio fue de 1,21 ± 0,9 V a 0,5 ms. No se observaron complicaciones perioperatorias. Todos los pacientes fueron extubados en el quirófano y no hubo mortalidad hospitalaria. En el seguimiento se ha constatado mejoría del sincronismo mecánico ventricular, así como del estado clínico y de la función sistólica.

Conclusiones. La colocación de electrodos epicárdicos en el ventrículo izquierdo mediante cirugía mínimamente invasiva asistida por videotoracoscopia en pacien-

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tes seleccionados es un procedimiento seguro que permite escoger el lugar más adecuado para el implante y proporciona un estímulo eficaz a corto-medio plazo.

Palabras clave: *Insuficiencia cardíaca. Resincronización. Cirugía. Videotoroscopia. Electrodo epicárdico.*

INTRODUCTION

Nearly 30% of patients with heart failure present intraventricular conduction disorders that result in loss of mechanical ventricular synchrony.¹ Ventricular desynchronization results in a delay in the contraction of the left ventricle free wall in relation to the septum, causing underuse of the energy generated by the heart and systolic and diastolic dysfunction.^{2,3}

Left ventricular pacing or biventricular pacing makes mechanical resynchronization possible between the septum and the free wall.⁴⁻⁶ Multicenter studies have shown that 70% of patients undergoing this procedure experience clinical improvement, whereas there is no significant change in the rest.^{7,8}

In selected patients with heart failure and intraventricular conduction disorders resynchronization improves functional class, exercise tolerance and ventricular function,⁷⁻¹⁰ as well as reducing in ventricular volume and mitral regurgitation.^{11,12}

Left ventricular pacing is usually accomplished by percutaneous implantation of leads in one of the epicardial veins of the heart. It is a technically difficult procedure requiring a long learning period and has a failure rate of around 8%.^{7,8} This has led to interest in alternative techniques, such as implanting epicardial leads in the left ventricle via a small thoracotomy^{13,14} or using video-assisted thoracoscopy with or without robotic assistance.¹⁵⁻¹⁷ No series has been published to date that specifically deals with the fundamentals, technique and results of the video-assisted thoracoscopy approach. Thus, the purpose of this work is to present our experience with this procedure.

PATIENTS AND METHODS

Fourteen consecutive patients were included in the study with advanced heart failure and widened QRS complex treated with implantation of left ventricular epicardial leads using video-assisted thoracoscopy for cardiac resynchronization between January 2001 and July 2003. The patients were sent for video-assisted thoracoscopy without previous attempts at intravenous implantation.

Intervention criteria included: symptomatic heart failure despite optimal medical treatment, left bundle branch block and QRS complex >140 ms, left ventri-

cular ejection fraction <35% and abnormal septal movement. Heart surgery, previous left thoracotomy and ischemic heart disease with extensive transmural infarction were contraindications for the procedure.

The patients' age range was 36-79 years. All patients were treated prior to surgery with diuretics, ACE inhibitors or ARA II, beta-blockers, and digitalis. Six patients presented at least moderate mitral regurgitation. Table 1 presents the demographic and clinical characteristics of the patients included in the study.

The intervention was done in all cases under general anesthetic and orotracheal intubation with a double lumen tube for selective pulmonary ventilation. Placement of the endotracheal tube was confirmed by bronchoscopy during the procedure. Monitoring included continuous electrocardiography, pulse oximetry, central venous pressure, transesophageal echocardiography, and invasive and non-invasive blood pressure. Upon induction of anesthesia a continuous intravenous perfusion of 0.1 µg/kg/min of levosimendan without loading dose was initiated, which was maintained until discharge from the post-anesthesia care unit.

In each of the 10 patients an intravenous bipolar lead was implanted in the right atrium under fluoroscopic guidance using the standard technique while in sinus rhythm (Merox 53-JBP, Biotronik, Germany). Next, the patient was placed in the right decubitus lateral position at 30°–60°. Once the surgical fields were prepared, three incisions 1–1.5 cm long were made at the height of the fourth and eighth left intercostal spaces prepared as the vertexes of a triangle. To introduce the trocar incisions were made between the anterior and posterior axillary line, although in the last patients

TABLE 1. Characteristics of the Patients Included in the Study*

No. of patients	14
Age, years	68.7±13.9
Sex, n (%)	
Males	9 (64)
Females	5 (36)
Etiology, n (%)	
Dilated cardiomyopathy	13 (92)
Ischemic cardiomyopathy	1 (8)
NYHA functional class	3.2±0.6
Rhythm, n (%)	
Sinus	10 (71)
Atrial fibrillation	4 (29)
Left bundle branch block, n (%)	14 (100)
Duration QRS complex, ms	164±21
LVEF, %	22.9±6.8
Abnormal septal movement, n (%)	14 (100)

*NYHA indicates New York Heart Association; LVEF, left ventricular ejection fraction.

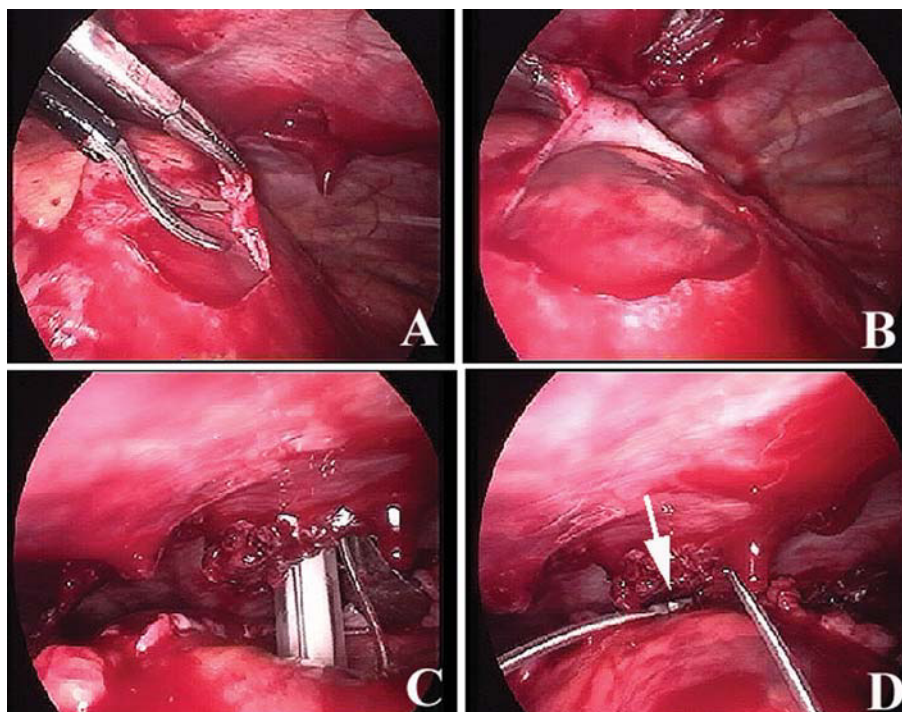


Fig. 1. Intraoperative image obtained via video-assisted thoracoscopy. A: incision in the parietal pericardium. B: the surface of the lateral wall of left ventricle is exposed. C: epimyocardial lead implant. D: once the lead is implanted (arrow), a segment is fixed in the pleural cavity with sufficient length to avoid the traction by the lung.

the sites for thoracoscopy were moved backwards. A 1.2-cm diameter trocar was introduced through each incision into the thoracic cavity after collapsing the left lung and under video-assisted thoracoscopy. One of the openings was used to introduce the thoracoscope (standard 30°) connected to the light source and a video camera connected to a screen. After identifying the parietal pericardium and the phrenic nerve, a left pericardiotomy was done. A 2×4-cm fragment of the parietal pericardium was resected. Once the lateral wall of the left ventricle was exposed and the marginal arteries identified, a unipolar epicardial lead was implanted (ELC 54-UP, Biotronik, Germany; Figure 1). A sustained Valsalva maneuver of the right lung was done during implantation to aid exposure and immobilization of the ventricular wall. After taking threshold measurements, the tip of the lead was definitively placed and a 20–25-cm segment introduced into the thoracic cavity to avoid traction from lung expansion. The proximal tip of the lead was directed into the exterior of the thorax through the anterior thoracoscopy opening. Next, with the assistance of a rigid guide, it was advanced through the subcutaneous cellular tissue up to the pectoral region, where a dual chamber pacemaker was implanted (Logos, Biotronik, Germany), and the atrial and ventricular leads were connected to it in patients with sinus rhythm. In patients with atrial fibrillation, the ventricular lead was connected to a single chamber pacemaker (Axios SR, Biotronik, Germany)

implanted in the subcostal area. Upon completion of surgery, one of the thoracoscopy openings was used to introduce a pleural drain connected to a water seal, which was kept in place for 6–18 h in the postoperative phase.

Once the resynchronization system was in place, continuous perfusion of esmolol 30 µg/kg/min was administered, adjusted to obtain a heart rate lower than 70 beats/min to prevent both tachycardia and the native rate from competing with the pacemaker. Esmolol perfusion was replaced by p.o. beta-blocker.

Echocardiography was done before discharge to adjust atrioventricular delay in patients with a dual chamber pacemaker. Postoperative follow-up was done on an outpatient basis, with clinical, electrocardiographic and echocardiographic exploration every 3 months.

The results are presented as mean ± standard deviation. Student *t* test was used to compare the mean values observed before and after the intervention. *P* values <.05 were considered statistically significant.

RESULTS

There was no surgical or hospital morbidity and mortality in this series. The average duration of the left ventricular lead implant procedure from the time of skin incision until stitching the openings was 92.4±31 min (range, 48–125 min). Conversion to a



Fig. 2. Postoperative image.



Fig. 3. Postoperative chest x-ray.

small thoracotomy was necessary in the third patient in the series due to the impossibility of implanting the lead via the thoracoscopy opening. From the point of

TABLE 2. Clinical Evolution of Patients*

	Baseline	3 Month Follow-up
NYHA functional class	3.2±0.6	2.3±0.4 [†]
LVEF, %	22.9±6.8	30.6±4.9 [‡]
Duration QRS complex, ms	164±21	139±30 [†]
Pacing threshold, V at 0.5 ms	1.21±0.9	1.8±1.1 (NS)
Impedance, Ω	925±310	864±279 (NS)
R wave voltage, mV	9.75±2.9	9.16±3.2 (NS)

*NYHA indicates New York Heart Association; LVEF, left ventricular ejection fraction; NS, non-significant.

[†] $P < .05$. [‡] $P < .01$.

view of hemodynamics and ventilation, collapse of the left lung during the procedure and selective ventilation of the right lung were well tolerated in all cases. All patients were extubated in the operating room and remained in the post-anesthesia unit for less than 24 h.

Convalescence was satisfactory largely due to the minimally invasive technique (Figures 2 and 3), although mean postoperative stay was relatively long at 4.2 ± 1.7 days (range, 3-9 days) with the aim of optimizing control of the heart rate and atrio-ventricular delay programming before discharge. In all patients chronic treatment with vasodilators and beta-blockers was maintained. In fact, we were able to increase the dose of beta-blockers in 4 patients, whose heart rate prevented this in the preoperative phase.

The mean intraoperative pacing threshold of the left ventricular lead was 1.21 ± 0.9 V at 0.5 ms. Good intraoperative pacing parameters were obtained in all cases, although the initial localization of the ventricular lead had to be changed in one patient to achieve a threshold lower than 2 V.

Mean follow-up time was 14.6 months (range, 3-32 months). During this period there was significant clinical improvement. The clinical evolution of the patients is presented in Table 2. One patient died 7 months after the intervention due to pneumonia. Doppler echocardiography demonstrated at least partial recovery of mechanical synchrony between the septum and the ventricular free wall in all cases. A reduction in the level of mitral regurgitation was observed in 3 patients. Left ventricular lead pacing parameters at follow-up did not change statistically significantly compared to intraoperative values. There was no failure in left ventricular pacing or displacement of the lead in any patient.

DISCUSSION

The technique of choice for left ventricular pacing in ventricular resynchronization is the insertion of a lead through the coronary sinus, progressing until implanting it in a ventricular epicardial vein.² This involves a percutaneous procedure which is difficult and

may have serious complications. In the MIRACLE study⁸ the ventricular lead could not be implanted in 7.53% of patients, and early reimplantation and substitution was necessary in 3.78% and 1.8% of cases, respectively. In the MUSTIC study,⁷ the implantation technique failed in 8% of patients and there were 13.5% early displacements. Overall, the failure rate of left ventricular pacing via intravenous implantation ranges between 8% in the MIRACLE study and 12.5% in the MUSTIC study. Training makes it possible to shorten implantation time, decrease complications and reduce failure rate, although there are some variables that depend on the great variability of the venous anatomy of the heart, rather than on the physician's experience.

The implantation of leads directly in the epicardial surface of the left ventricle has been the most frequently used technique for ventricular resynchronization.^{18,19} Surgical implantation has been superseded by the insertion of leads into the epicardial veins of the left ventricle, due to high morbidity and mortality during intervention and poor pacing parameters.²⁰ At present, surgery is considered a salvage technique for patients in whom the percutaneous procedure fails.^{13,15,16}

The surgical approach to the left ventricle for resynchronization can be carried out through small thoracotomy or with a minimally invasive technique via thoracoscopy. Thoracotomy is a procedure that involves greater morbidity and mortality than thoracoscopy.²¹ For this reason, thoracotomy is infrequently used in ventricular resynchronization,¹³ is hardly ever the first choice, and is almost always a salvage procedure for failed thoracoscopy.¹⁵

Video-assisted thoracoscopy for resynchronization is a less invasive technique when the intravenous route is not feasible. It enables rapid postoperative recovery and prevents complications. Recently, robotic technology such as the da Vinci system (Intuitive Surgical Inc., USA) has been added to video-assisted thoracoscopy.^{15,16} This system contributes advantages to standard video-assisted thoracoscopy, such as three-dimensional vision, tremor elimination and the possibility of stitching the lead in place; however, it is extraordinarily expensive and is not currently available in Spain.

Lead implantation with minimally invasive surgery under video-assisted thoracoscopy with or without robotic support has, in comparison with the percutaneous technique, several advantages and drawbacks.

Video-assisted thoracoscopy permits greater freedom of access to lateral and posterobasal segments of the left ventricle,¹⁶ and several studies have shown more effective mechanical resynchronization than that obtained by the stimulation of anterior segments.²² In any case, the selection of the intravenous implantation site is limited by the layout and size of the epicardial veins, and sometimes this limit means the lead is im-

planted in an unsuitable site. This fact can make the results of clinical resynchronization unpredictable and difficult to reproduce.

Surgery with video-assisted thoracoscopy enables direct visualization of the epicardium, aids in choosing the most suitable surface, and helps avoid epicardial fat and areas of fibrosis that can cause artefacts in pacing parameters. It also aids in secure placement with stitches or screws. No postoperative lead displacement has been reported in our work or in any other published surgical series.

Despite being a minimally invasive procedure, video-assisted thoracoscopy has some disadvantages compared to the percutaneous technique. It requires general anesthesia, placing the patient in the lateral decubitus position with a collapsed lung and maintaining single-lung ventilation for a considerable period. In our series there were no serious hemodynamic or ventilation complications during the procedure, although it required expert anesthetic management.

Implantation with video-assisted thoracoscopy is a difficult technique which carries the risk of complications.^{15,16,19} Procedural times are significantly lowered with more experience.¹⁶ However, intrathoracic manipulation of the instruments, as well as insertion of the lead, can cause lacerations in the epicardium that necessitate salvage thoracotomy.¹⁵ Conversion to thoracotomy indicates failure of the thoracoscopic technique and, in the published series, is a determining factor for the appearance of postoperative complications, usually respiratory.¹⁶ Despite this, implantation failure rate is lower with minimally invasive surgery than with the percutaneous technique.^{15,16}

In one of the first patients in our series, the procedure had to be converted to a mini thoracotomy to permit lead implantation. The lack of specific instrumentation for the placement of the lead through the thoracoscopy trocar is the main hindrance in this procedure. Recently, industry has developed instruments designed for this, such as the flexible, semiautomatic, metal arm (10626-Epicardial Lead Implant Tool; Medtronic, USA), that facilitates spatial orientation of the lead within the thorax.

The presence of pleural or pericardial adhesions can hinder the procedure and even force conversion from thoracoscopy to thoracotomy.¹⁵ For this reason, we consider that previous cardiothoracic surgery is a contraindication for video-assisted thoracoscopy.

In the first cases in our series openings for thoracoscopy were made on the mid-axillary line. However, we observed that access to the lateral and posterior segments of the left ventricle is easier when shifting to posterior access for thoracoscopy; thus we gradually adopted this approach, which is described in more detail in the literature.¹⁶ The most suitable intercostal space for access lies between the second-third¹⁵ and the ninth space.¹⁶ We normally insert the video camera

through the seventh–eighth space and, after exploring the thoracic cavity, we make incisions for the other two openings, located between the fifth and the seventh intercostal space.

Intravenous and surgical lead implantation for resynchronization provides very similar acute and chronic pacing parameters.^{13,15} In our series a left ventricle pacing threshold lower than 2 V was observed, similar to those in other series.^{13,15,16} The presence of ischemic cardiomyopathy does not seem to influence the threshold obtained with epicardial pacing.¹⁶

In our series we preferred single-site left ventricular pacing to biventricular. No consensus currently exists regarding the need for biventricular pacing to achieve the positive effects of resynchronization.³ A comparison of the two types of pacing was not the aim of this work. Our criterion was based on studies that have shown that left ventricular pacing provides similar results to biventricular pacing^{4,23-25} and that electrical resynchronization should be dropped in favor of mechanical resynchronization confirmed by hemodynamics or echocardiography.^{5,6,26}

CONCLUSIONS

Implantation of epicardial leads in the left ventricle via minimally invasive video-assisted thoracoscopy is a safe and effective procedure. The postoperative complication rate is reduced with expert anesthetic management. Pacing parameters, clinical improvement and ventricular function have been satisfactory in the short- and medium term. Comparative studies with the intravenous technique will make it possible to determine the role of video-assisted thoracoscopy in ventricular resynchronization.

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