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Ventricular Epicardial Lead Placement for Resynchronization by Determination of Paced Depolarization Intervals: Technique and Rationale

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Background. Cardiac resynchronization therapy has been shown to be an effective treatment to improve functional status and prolong survival among patients with advanced congestive heart failure. However, as many as 30% of patients do not respond. Nonresponse may be due to suboptimal left ventricular lead placement. Studies have indicated that leads placed in the midlateral left ventricle (LV) wall usually result in improved dP/dT and increased pulse pressure, compared with other locations. When the surgeon is placing the leads thoracoscopically, however, in a chest with multiple adhesions, anatomic landmarks can be obscured. It is desirable to have an objective physiologic method to determine optimal lead placement. The optimal LV pacing site may be best determined by locating the site with the latest depolarization.

Methods. A pacing lead attached to a pulse analyzer was introduced through a thoracoscopic port and used as a mapping electrode to electrically map exposed areas of the left ventricle. The right ventricular pacing lead was also attached to the pulse analyzer and the interval between the right ventricular pulse and the LV depolar-

ization (paced depolarization interval) was measured in 19 patients undergoing thoracoscopic LV lead placement. A site with a paced depolarization interval less than 110 ms was not accepted.

Results. Electrical mapping was possible in 19 of 29 consecutive patients in whom it was attempted. The most frequent reason for not mapping was the presence of extensive scarring. In 7 of 19 patients (36.8%) mapped, the site that would have been chosen by anatomic landmarks was not the site with the longest paced depolarization interval, and thus the lead placement was altered.

Conclusions. The site with the longest paced depolarization interval is only selected 63.2% of the time when utilizing anatomic landmarks for placement. Nonresponse may be due to suboptimal LV lead placement. Measurement of paced depolarization intervals provides a physiologic method of determining optimal LV lead placement.

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Cardiac resynchronization therapy is an established treatment for heart failure patients who have left bundle branch block. Use of this therapy has been hindered because of difficulty either in placing the left ventricular (LV) lead or in obtaining therapy response for the patient. While advancements in transvenous lead technology have improved, success rates for implanting left ventricular epicardial leads still range from as high as 96% [1, 2] to as low as 72% [3]. Tortuous coronary venous anatomy, difficult branch bifurcations, and stenotic veins from scarring all contribute to long implant times and inability to provide therapy for all patients.

The response rate of cardiac resynchronization therapy remains at 60% to 75%, despite studies and techniques to improve outcomes [4]. Various studies are under way to understand how to optimize cardiac resynchronization therapy, examining patient response rate with respect to

the latest mechanical or electrical activation of the left ventricle, tissue Doppler imaging, or pressure volume loop measurements [5, 6]. Other techniques to optimize biventricular pacing are to optimize the atrioventricular interval to help LV filling time, and to vary timing of right ventricle (RV) to LV stimulation to optimize coordination of LV free wall contraction [7–9]. Another technique is to optimize the contraction of the LV free wall with respect to the RV paced event, to ensure the most efficient contraction [10].

Surgical epicardial lead placement has emerged as an approach to successfully provide cardiac resynchronization therapy for all patients. The advantage of surgical placement is the ability to place the LV lead in any location, thereby enabling the optimization of LV free wall motion. Several papers have reported 100% success in placement of epicardial leads, and one discusses lower dislodgement rates of epicardial placement [11].

Aurichio and colleagues [7] concluded that posterolateral positioning of the LV pacing lead results in the greatest LV dP/dT and pulse pressure increases. Their results also demonstrated that, depending on the patient,

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the optimal site for increases in dPdT and pulse pressure varied greatly. Epicardial mapping of the maximum depolarization interval to determine optimal pacing site has been described by Byrd [10]. By placing the LV lead at the site of latest depolarization of the left ventricle following a paced RV depolarization, the contraction of LV free wall can be coordinated with septal contraction.

This paper describes our technique of using electrical mapping to optimize the placement of epicardial leads compared with anatomic placement; some preliminary data are presented.

Patients and Methods

Patient Population

The Institutional Review Board at Medical City Dallas Hospital approved this study and waived the need for individual consent. The study population consisted of 29 consecutive patients with class III or IV heart failure who were referred between July 2003 and October 2004 because of failed attempts at transvenous LV lead placement. All patients were indicated for biventricular pacing, and presented with RV and right atrial leads implanted, and a biventricular pacemaker or a Medtronic InSync Defibrillator (Medtronic, Minneapolis, MN). Patients were prepared for thoracoscopic placement of a Medtronic 5071 lead.

Lead Placement Technique

Since April 2002, we have been utilizing a thoracoscopic approach for LV lead placement. Whereas initially the site for LV lead placement was selected based on anatomic criteria alone, we then began to selectively utilize transthoracic echocardiography to determine the site of latest mechanical activation. With this technique, the anesthesiologist visually locates the latest site of LV contraction while the surgeon utilizes an endoscopic Kitner (Ethicon Endosurgery, Cincinnati, OH) to gently indent several spots on the epicardium until this latest site of contraction is located. This procedure was cumbersome, difficult, and imprecise, and in July 2003, we began to determine lead site placement by determining the latest site of electrical activation.

The patient was placed on the operating table in a supine position, and general endotracheal anesthesia was induced utilizing a double lumen tube. The patient was positioned in the right lateral decubitus position and prepared and draped so that the pacemaker pocket was in the surgical field. Single right lung ventilation was initiated. A scope was introduced through a 5- or 10-mm port in the fifth or sixth intercostal space at the posterior axillary line, with port location chosen based on preoperative antero-posterior radiographic examination of heart borders. Carbon dioxide insufflation was initiated to assist with visualization. Under thoracoscopic visualization, a second 5-mm port was placed in the sixth or seventh intercostal space at the midaxillary line; and through this, a long endoscopic instrument was placed to aid in dissection. Pleural adhesions were taken down

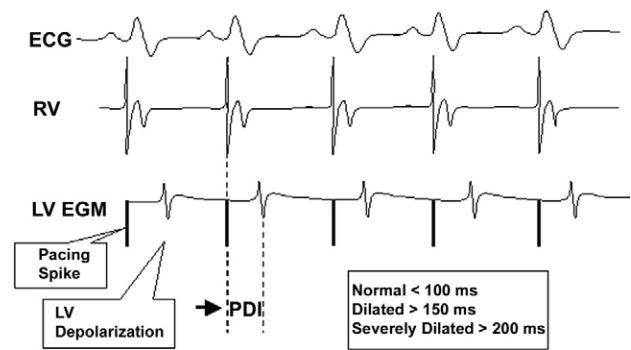


Fig 1. Measuring the paced depolarization interval (PDI). (ECG = electrocardiogram; EGM = electrogram; LV = left ventricular.)

utilizing cautery. With the lung retracted posteriorly, the likely site of lead placement on the high lateral LV wall was visualized. A spinal needle was then passed through the chest wall to locate a spot directly above the high lateral LV wall where an 11.5-mm port was placed. This port was usually located in the third or fourth intercostal space at the midaxillary line, and allowed manipulation while maintaining good visualization. Working through these ports, the pericardium was opened and adhesions to the heart taken down. We located, and made note of, the high lateral wall anterior to the phrenic nerve. This is the site where the LV lead would be placed if using only anatomic landmarks to select an LV pacing site.

After the pacemaker pocket was opened, the pulse generator was explanted; the RV lead was removed from the generator and connected with sterile alligator clips to the pacing systems analyzer. The pacing analyzer is set to record an electrocardiogram and an electrogram at 50 mm/s speed. A monopolar pacing lead was selected and introduced through the third intercostal space port and used as a sensing electrode to electrically map exposed areas of the left ventricle. This lead was attached with alligator clips to the pacing systems analyzer to record an LV electrogram. The pacing rate of the RV lead was adjusted to ensure that intrinsic depolarization did not occur.

The interval between the RV pulse and the sensed LV depolarization (paced depolarization interval) was measured in 19 patients undergoing thoracoscopic LV lead placement. The LV epicardium was mapped, starting at a predetermined anatomic location (posterolateral basal position). The maximum paced depolarization interval was found at the site where the timing between the RV paced beat and the LV sensed depolarization was longest (Fig 1). A site with a paced depolarization interval less than 110 ms was not accepted. At this location, two screw-in LV epicardial leads were placed. Pacing thresholds were obtained.

All leads were tunneled intrathoracically to avoid any traction or injury that might occur to leads brought out through an intercostal space and tunneled subcutaneously. A size 10F red rubber catheter with both ends cut off was used to help tunnel the leads. The ends of both LV leads were pushed into opposite ends of the rubber

catheter and then dropped entirely into the chest. A tonsil clamp was passed into the chest through the back of the pulse generator pocket and used to grasp the red rubber catheter. That was then pulled into the pacer pocket, thus delivering the tips of each of the leads. This technique allows us to avoid grasping the leads themselves and potentially damaging the insulation. Sufficient lead is left in the chest to allow lung expansion without traction.

A soft silicone elastomer drain was introduced through the most caudad 5-mm port and directed posterior and to the apex. All ports were removed as the lung was inflated. The RV lead and one of the LV leads were attached to the pulse generator. The spare LV lead was capped and placed in the back of the pocket. The generator was placed back into the pocket, and all wounds were closed with absorbable suture.

Follow-up telephone survey was carried out to measure changes in the patients' quality of life after institution of the biventricular pacing. Quality of life scores of those who had LV lead placement determined by mapping were compared with scores of those who had not been mapped.

Results

Placement of LV leads was successful in all patients. Two patients (7%) required conversion to minithoracotomy for lead placement. One was converted because dense pleural adhesions prohibited introduction of a thoracoscope and the other because single lung ventilation could not be attained. In 19 of these patients (66%), the maximum depolarization interval was determined by mapping the LV to determine the latest site of LV depolarization after pacing the RV. Reasons for not mapping in all patients were that 6 had too much intense scar, allowing only one spot to be cleared, 2 had unstable rhythm with induction of ventricular tachycardia when the LV was touched, and 2 required monitoring equipment that was not available.

In 7 patients (36.8%), the site chosen by determination of maximum depolarization interval was different from the site that would have been chosen on anatomic criteria alone. This site was most often in a position more posterior to the anatomic one.

Table 1. Results of Quality of Life Survey

	Mapped	Not Mapped
Patients	19	10
Mapping led to changed lead position	7 (36.8%)	0
Died	31.6% (6/19)	10% (1/10)
Lost to follow-up	10.5% (2/19)	0
QOL improved	90.9% (10/11)	66.6% (6/9)
QOL no change	0	33.3% (3/9)
QOL slightly worse	9.9% (1/11)	0

QOL = quality of life.

Quality of life was determined by survey at 1 month to 15 months (median, 247 days). Follow-up was obtained for 27 of 29 patients (93%). Seven patients (6 mapped, 1 not mapped) had died during follow-up at an average of 6 months postoperatively. Table 1 shows the results of the quality of life survey. As a comparison, in the MIRACLE (Multi-Center InSync ICD Randomized Clinical Evaluation) trial [3], 70.9% reported slight to marked improvement on the quality of life questionnaire.

Patients were also assessed by their New York Heart Association functional class. Of the 9 patients who had their leads placed without mapping, 4 improved one functional class and 5 were unchanged. Of the 11 patients who had lead location determined by measuring the point of latest depolarization, 4 improved two classes, 4 improved one class, 1 was unchanged, and 2 declined one class.

Comment

Resynchronization has been shown to result in symptomatic improvement [12, 13] and even increased longevity [14] for those patients with congestive heart failure and ventricular dyssynchrony. However, not all patients improve, and perhaps that is because not all biventricular pacing results in resynchronization. We find it intriguing that the failure rate in the MIRACLE trial was 30%, and we found that in 36.8% of patients, the site most frequently chosen for LV lead placement was not the site with the longest paced depolarization interval. Perhaps the 30% failure rate is related to improper lead placement that does not effectively resynchronize the ventricles. Indeed, our follow-up data showed that 33% of those patients who had their lead placed on anatomic criteria alone did not respond.

We were 100% successful in surgical LV lead placement. Early in this trial, however, we did not free up enough left ventricle to do adequate mapping in 5 patients with dense pericardial adhesions. We are now more aggressive in the endoscopic lysis of these adhesions to allow mapping. This endoscopic approach then allows the surgeon access to the entire LV free wall, unconstrained by the location of epicardial veins. That may lead to more optimal lead placement, resulting in a higher responder rate. Indeed, in an editorial on this subject, Schilling stated, "The results of CRT [cardiac resynchronization therapy] are likely to improve as methods for identifying likely responders and the optimum site for lead placement become more refined. However, it is becoming apparent that the choice of one or two epicardial veins suitable for lead placement is just not good enough. Systems for delivering the lead to the epicardium directly (that is, without passing transvenously first) using percutaneous approaches may be the answer to this" [15]. We concur.

We also believe that determining the optimal site for lead placement should involve a physiologic measure rather than simply choosing pacing site by anatomic criteria alone. That allows tailoring of lead placement to each individual patient's physiology. Previously we at-

tempted to determine pacing site by locating the latest site of mechanical activation on transthoracic echocardiography. Although theoretically appealing, this method is technically difficult and imprecise. Others [16, 17] have used determination of pressure-volume loops to choose the pacing site; however, that is expensive and not readily available in the operating room. The use of tissue Doppler [18] to select the lead site has also been advocated, but this technique requires specialized training and is also not readily available in most operating rooms.

Determination of the maximum depolarization interval using the paced depolarization interval technique is a simple technique that may allow optimal LV lead placement and improved outcomes. Surgical thoracoscopic epicardial LV lead placement at a physiologically determined site may be the optimal method of cardiac resynchronization therapy.

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DISCUSSION

DR CLIFFORD H. VAN METER, JR (New Orleans, LA): It is my understanding that the criteria upon which confirmation of this as a legitimate procedure by electrophysiologists was the demonstration of an additional 50 feet on a 6-minute walk test. I am curious in your quality of life studies whether you performed that. But moreover, I want to congratulate you on pointing out that this is a procedure that is more properly performed by us than by electrophysiologists, because historically they have blamed their failures on leads dislodging as opposed to misapplication of the leads, and I would wonder whether you could confirm that impression.

DR EDGERTON: Thank you, Cliff, for those kind comments and for that question. You say I do suggest in our conclusions that perhaps we may be able to attain more effective resynchronization, but of course this requires further study. And a retrospective analysis asking patients to report quality of life is not the best way to do this. Yes, the best way to do this is a 6-minute hall walk, and would that I had brought all these patients in preoperatively and performed a 6-minute hall walk and brought them back at prescribed intervals to do that postoperatively. And our plans going forward in our research group are to discuss exactly that approach, perhaps in a multi-institutional registry. Thank you for those comments.

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