



Contents lists available at ScienceDirect

Indian Pacing and Electrophysiology Journal

journal homepage: www.elsevier.com/locate/IPEJ

Lead related complications in quadripolar versus bipolar left ventricular leads



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ARTICLE INFO

Article history:

Received 19 August 2016

Accepted 21 October 2016

Available online 24 October 2016

Keywords:

Cardiac resynchronization therapy

Left ventricular lead

Quadripolar

Bipolar

Complications

ABSTRACT

Background: Quadripolar left ventricular (LV) leads are capable of pacing from four different electrodes which allows for easier and more stable intra-operative lead positioning with optimal pacing parameters. We therefore investigated the rate of combined intra-operative and post-operative LV lead related events in quadripolar vs. bipolar LV lead cardiac resynchronization therapy (CRT) recipients in the real world setting.

Methods: We retrospectively collected data for N = 1441 patients at our institution implanted with quadripolar (n = 292) or bipolar (n = 1149) LV leads from 2012 to 2014 and followed them to the primary end-point of composite lead outcome defined as intra-operative lead implant failure or post-operative lead dislodgement or deactivations.

Results: Patients implanted with a quadripolar lead were younger (70.6 ± 11.4 vs 72.5 ± 11.6 , $p = 0.014$) and had higher incidence of diabetes (41.8% vs 32.8% , $p = 0.004$) compared to those with bipolar leads. All other baseline characteristics were comparable. Patients implanted with a quadripolar were significantly less likely to reach the primary endpoint in the first 12 months after LV lead implantation (Hazard Ratio 0.22, 95% Confidence Interval 0.08–0.60, $p = 0.001$). There were no differences between the two groups in rates of hospitalization for any cause or in mortality.

Conclusion: In this real world study, quadripolar LV leads have significantly lower rates of implantation failure and post-operative lead dislodgement or deactivation. These results have important clinical implications to CRT recipients.

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1. Introduction

Congestive heart failure is a leading cause of morbidity and mortality with a 20%–30% death rate at 3 years [1,2,3]. Cardiac resynchronization therapy (CRT) is an effective adjunctive therapy for many heart failure patients [4,5]. CRT is achieved by pacing both the right (RV) and left (LV) ventricles with the LV lead usually placed in a branch of the coronary sinus through a transvenous approach [6]. Anatomical challenges occasionally result in failure of LV lead placement during the procedure or in lead dislodgement in the post-operative period, necessitating reoperation for repositioning [7,8,9]. The major reasons for reoperation are LV lead

dislodgement with loss of capture, phrenic nerve stimulation (PNS), and increased LV pacing thresholds without obvious lead dislodgement [9]. Recently, approved quadripolar LV leads have provided more options for LV pacing, giving operators more choices for LV lead positioning with less compromise in lead stability. It remains however unclear whether these technological advances translate into better procedural or clinical outcomes for CRT recipients. We therefore sought to investigate differences in the rates of combined intra-operative and post-operative LV lead related complications in patients receiving quadripolar versus bipolar LV leads in real-world clinical practice and examine potential differences in longer term clinical outcomes.

2. Methods

This is a single center, observational study comparing differences in patient outcomes after CRT based on the type of the

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Peer review under responsibility of Indian Heart Rhythm Society.

implanted LV lead LV (Quadripolar vs. Bipolar). The study was approved by the Institutional Review Board of the University of Pittsburgh. All patients who had an attempt at CRT defibrillator (CRT-D) or pacemaker (CRT-P) device implantation at the hospitals of the University of Pittsburgh Medical Center (UPMC) between 2011 and 2014 were included in this study. Both *de novo* CRT implantations and upgrades from other devices to CRT were included. Baseline demographic and clinical variables including pre-procedural assessment of left ventricular ejection fraction (EF) were collected. Institutional reports to the National Cardiovascular Data Registry - ICD registry together with the UPMC electronic health records (EHR) were used as sources of information.

The index procedure was the *de novo* or upgrade CRT procedure. Operative notes were reviewed to identify patients with failed attempts at LV lead placement. EHR were reviewed to capture all instances of procedural or LV lead related complications. Outcomes including hospitalization for any reason (device-related complications, heart failure, and arrhythmia) were abstracted from the EHR. Phrenic nerve stimulation (PNS) during follow-up visits was also recorded. Mortality data was obtained from the electronic medical records, including scanned death certificates, as well as from the Social Security Death Index records through October 2015.

The choice of the model and manufacturer of CRT devices and LV leads was left to the discretion of the implanting physician. Quadripolar LV leads included the Food and Drug Administration approved St. Jude Medical (Sylmar, CA) 'Quartet' lead and the Medtronic (Minneapolis, MN) 'Attain Performa' family of leads.

The implantation procedure was performed by electrophysiologists who were experienced in performing CRT procedures. All operators had no less than 3 years of experience in implanting LV leads from different manufacturers. The site of LV pacing was chosen by the implanting physician based on lead stability, the absence of PNS, and favorable pacing parameters. Device programming was at the discretion of the implanting physician. A failed attempt at LV lead placement was defined as abandoned LV lead implantation during the index procedure.

Patients were followed to the primary composite end-point of LV lead implant failure, dislodgment, or LV pacing deactivation for PNS in the first 12 months after the index procedure. Secondary outcomes include all-cause hospitalizations, device-related hospitalizations, hospitalization for arrhythmia, hospitalization for heart failure, and all-cause mortality. Hospitalizations were defined as at

least one overnight stay in the hospital under admission or observation status. Patients were followed by the device clinic at UPMC. All patients presented to the clinic 2 weeks after the index procedure for a surgical wound check at the site of device implantation. Their follow-up thereafter consisted of clinic visits every 6 months or clinic visits once a year with scheduled home monitoring downloads every 3 months.

Baseline characteristics were presented as mean \pm standard deviation for continuous variables and as n (%) for categorical variables. Differences between patients receiving quadripolar vs. bipolar LV leads were compared using the Student's *t*-test and chi-squared tests, respectively. Incidence of time-to-event outcomes was analyzed using Kaplan-Meier analyses and compared between quadripolar and bipolar LV lead recipients using the log-rank test. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary NC).

3. Results

A total of 1441 patients (292 quadripolar and 1149 bipolar) were implanted with a CRT device between January 2011 to December 2014. They were followed-up for a mean of 609 ± 480 days. Of the overall cohort, 1220 (85%) patients had at least 1 year of follow-up. Table 1 shows the baseline characteristics of the overall cohort and of the quadripolar vs. bipolar groups. Compared to patients receiving a bipolar LV lead, patients receiving quadripolar leads were younger (70.6 ± 11.4 vs. 72.5 ± 11.6 , $p = 0.01$) and had more Diabetes mellitus (42% versus 33%, $p = 0.004$). All other baseline characteristics were comparable between the two groups. Among the implanted quadripolar LV leads, 224 were from St. Jude Medical (Sylmar, CA) and 68 from Medtronic (Minneapolis, MN). There were no differences in LV lead complications or patients outcomes by lead model or manufacturer.

There were a total of 28 failed attempts at LV lead placement [1 (0.3%) in the quadripolar group vs. 27 (2.3%) in the bipolar group, $p = 0.029$]. There were no instances of switching from a quadripolar to a bipolar LV lead or *vice versa* during the index procedure. Over 12 months of follow-up, the composite endpoint of LV lead related complications occurred significantly less in the quadripolar compared to the bipolar group [8 (2.7%) compared to 78 (6.8%), $p = 0.009$]. The individual components of the composite end point of LV lead related complications and their rates between the two

Table 1
Pre-Implant Characteristics of N = 1441 patients (2011–2014).

	Overall Cohort	Bipolar	Quadripolar	P-Value
Number of Patients	1441	1149	292	
Age	72.1 \pm 11.6	72.5 \pm 11.6	70.6 \pm 11.4	0.014
BMI	29.5 \pm 9.9	29.5 \pm 10.6	29.5 \pm 6.3	0.932
Diabetes Mellitus	499 (34.6%)	377 (32.8%)	122 (41.8%)	0.004
Hypertension	1059 (73.5%)	840 (73.1%)	219 (75.0%)	0.569
Prior myocardial Infarction	667 (46.3%)	545 (47.4%)	122 (41.8%)	0.076
Prior PCI	355 (24.6%)	285 (24.8%)	70 (24.0%)	0.750
Prior CABG	441 (30.6%)	357 (31.1%)	84 (28.8%)	0.429
Prior Heart Failure	1266 (87.9%)	1011 (88.0%)	255 (87.3%)	0.669
Prior Heart Failure Hosp.	492 (34.1%)	387 (33.7%)	105 (36.0%)	0.084
NYHA Class				0.178
1	84 (5.8%)	70 (6.1%)	14 (4.8%)	
2	251 (17.4%)	189 (16.4%)	62 (21.2%)	
3	791 (54.9%)	639 (55.6%)	152 (52.1%)	
4	47 (3.3%)	39 (3.4%)	8 (2.7%)	
Atrial Fibrillation	756 (52.5%)	616 (53.6%)	140 (47.9%)	0.073
QRS Width	150 \pm 31.4	150 \pm 31.4	150 \pm 31.4	0.957
Creatinine	1.32 \pm 0.88	1.30 \pm 0.85	1.37 \pm 0.99	0.224
Pre-Implant LVEF	28.4 \pm 11.6	28.4 \pm 11.6	28.1 \pm 11.3	0.652
CRT Upgrade Procedure	572 (39.7%)	476 (41.4%)	96 (32.8%)	<0.001
Total Follow Up Time (Days)	609 \pm 480	698 \pm 490	256 \pm 189	<0.001

groups are shown in Table 2. Although there were no statistically significant differences in the individual components of the composite endpoint of LV lead related complications, except for lead placement failures, the combined composite endpoint was reached significantly less (Hazard Ratio 0.22, 95% Confidence Interval 0.08–0.60, $p = 0.001$) in quadripolar vs. bipolar LV lead recipients (Fig. 1).

As shown in Table 3, there were no statistically significant differences in the secondary endpoints of the study. The rates of mortality and hospitalizations (Fig. 2) for any cause were comparable between recipients of quadripolar and bipolar LV leads. As shown in Table 3, there were a total of 79 patients who experienced PNS in the first year after implantation: 65 (5.7%) with bipolar leads and 14 (4.8%) with quadripolar leads. In these patients, 59 of 65 (91%) in the bipolar lead group and 12 of 14 (86%) in the quadripolar lead group had resolution of PNS with adjustment of the pacing settings.

4. Discussion

Our findings demonstrate that the use of quadripolar LV leads

Table 2
Lead placement failure, lead dislodgement, and lead deactivations.

	Overall Cohort	Bipolar	Quadripolar	P-Value
Number of Patients	1441	1149	292	
Lead Placement Failure	28 (1.9%)	27 (2.3%)	1 (0.3%)	0.029
Lead Dislodgement				
Within 30 Days	24 (1.7%)	23 (2.0%)	1 (0.3%)	0.067
Within 60 Days	27 (1.9%)	26 (2.3%)	1 (0.3%)	0.028
Within 90 Days	30 (2.1%)	29 (2.5%)	1 (0.3%)	0.019
Within 6 Months	37 (2.6%)	33 (2.9%)	4 (1.4%)	0.211
Within 1 Year	41 (2.8%)	35 (3.0%)	6 (2.1%)	0.435
Lead Deactivation				
Within 30 Days	9 (0.6%)	9 (0.8%)	0 (0.0%)	0.218
Within 60 Days	10 (0.7%)	10 (0.9%)	0 (0.0%)	0.227
Within 90 Days	12 (0.8%)	12 (1.0%)	0 (0.0%)	0.140
Within 6 Months	15 (1.0%)	14 (1.2%)	1 (0.3%)	0.329
Within 1 Year	17 (1.2%)	16 (1.4%)	1 (0.3%)	0.221

reduces the combined intra-operative and post-operative LV lead related complications over a 12 months follow-up period. Judging by the early curve separation demonstrated in Fig. 1, the superior performance of the quadripolar lead seems to be mainly driven by less intra-operative failures of placement or early post-procedural LV lead dislodgement or deactivation for PNS. The implications of our findings are that quadripolar LV leads, by virtue of the

Table 3
Phrenic nerve stimulation, hospitalizations, and mortality outcomes.

	Full Cohort	Bipolar	Quadripolar	P-Value
Number of Patients	1441	1149	292	
Phrenic Nerve Stimulation				
Within 30 Days	51 (3.5%)	43 (3.7%)	8 (2.7%)	0.481
Within 60 Days	59 (4.1%)	49 (4.3%)	10 (3.4%)	0.620
Within 90 Days	67 (4.6%)	55 (4.8%)	12 (4.1%)	0.755
Within 6 Months	74 (5.1%)	61 (5.3%)	13 (4.5%)	0.656
Within 1 Year	79 (5.5%)	65 (5.7%)	14 (4.8%)	0.666
HF Hospitalization				
Within 30 Days	35 (2.4%)	25 (2.2%)	10 (3.4%)	0.206
Within 60 Days	61 (4.2%)	46 (4.0%)	15 (5.1%)	0.415
Within 90 Days	82 (5.7%)	64 (5.6%)	18 (6.2%)	0.672
Within 6 Months	124 (8.6%)	98 (8.5%)	26 (8.9%)	0.815
Within 1 Year	176 (12.2%)	145 (12.6%)	31 (10.6%)	0.423
Arrhythmia Hospitalization				
Within 30 Days	18 (1.2%)	13 (1.1%)	5 (1.7%)	0.386
Within 60 Days	35 (2.4%)	28 (2.4%)	7 (2.4%)	1.000
Within 90 Days	46 (3.2%)	39 (3.4%)	7 (2.4%)	0.459
Within 6 Months	66 (4.6%)	58 (5.0%)	8 (2.7%)	0.115
Within 1 Year	99 (6.9%)	84 (7.3%)	15 (5.1%)	0.242
Any Hospitalization				
Within 30 Days	140 (9.7%)	108 (9.4%)	32 (11.0%)	0.438
Within 60 Days	241 (16.7%)	191 (16.6%)	50 (17.1%)	0.860
Within 90 Days	296 (20.5%)	243 (21.1%)	53 (18.2%)	0.291
Within 6 Months	397 (27.6%)	325 (28.3%)	72 (24.7%)	0.240
Within 1 Year	521 (36.2%)	429 (37.3%)	92 (31.5%)	0.065
Mortality				
Within 30 Days	30 (2.1%)	26 (2.3%)	4 (1.4%)	0.490
Within 60 Days	42 (2.9%)	36 (3.1%)	6 (2.1%)	0.435
Within 90 Days	52 (3.6%)	46 (4.0%)	6 (2.1%)	0.157
Within 6 Months	99 (6.9%)	85 (7.4%)	14 (4.8%)	0.121
Within 1 Year	147 (10.2%)	126 (11.0%)	21 (7.2%)	0.065

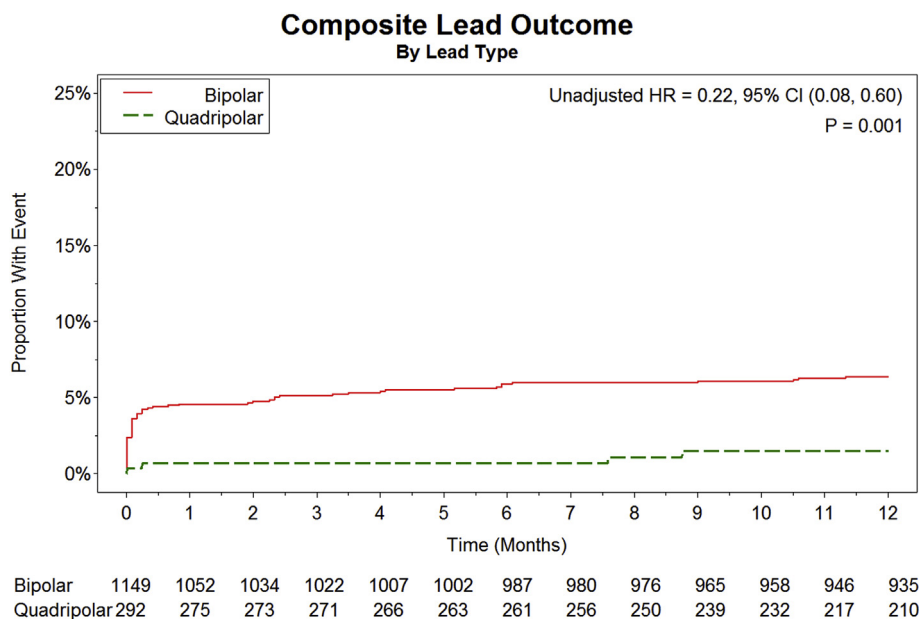


Fig. 1. Incidence of the composite endpoint of failed lead placement, lead dislodgement, or lead being turned off over one year post-implantation for quadripolar and bipolar LV leads in CRT recipients.

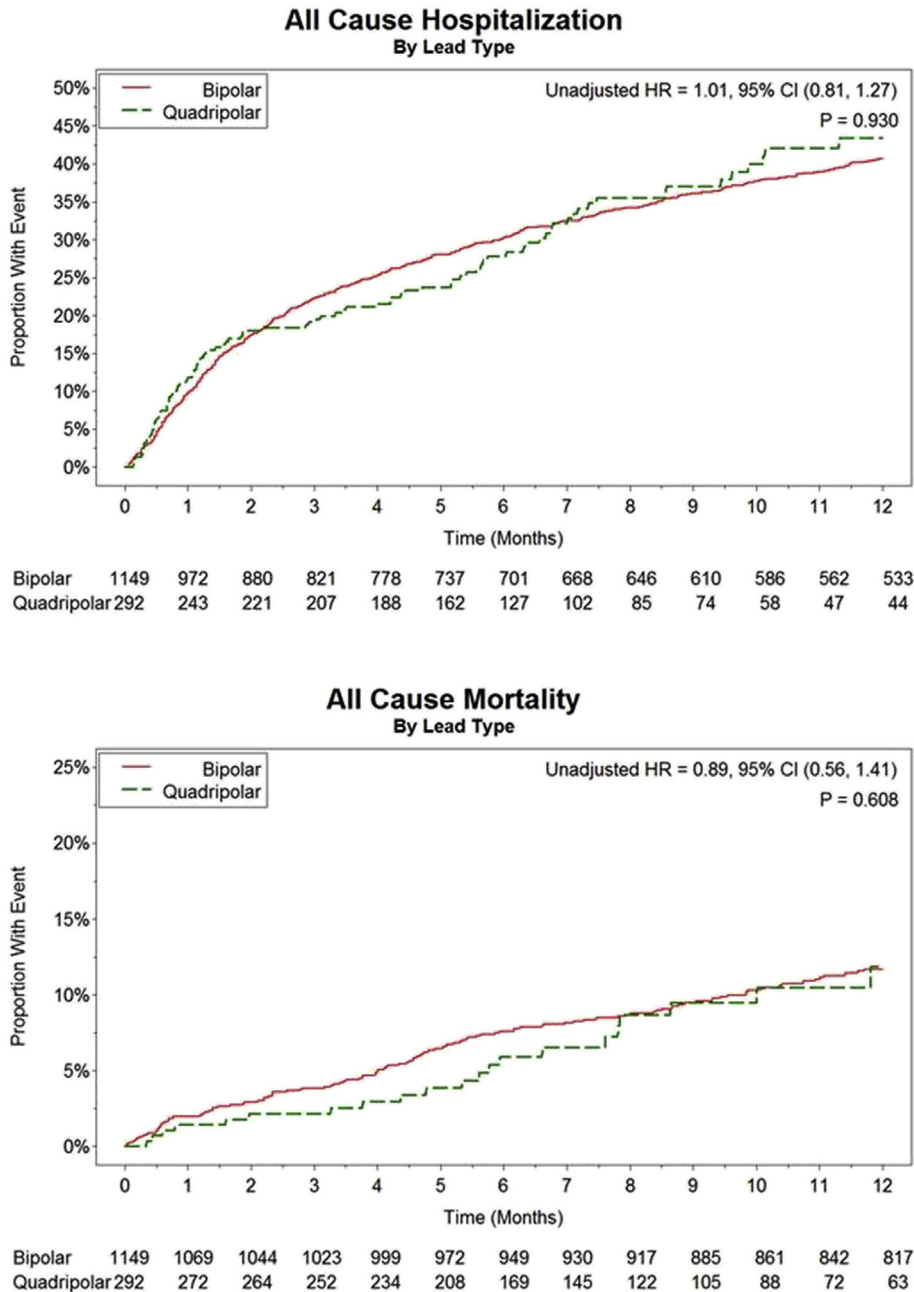


Fig. 2. Incidence of all-cause hospitalizations (upper panel) and all-cause mortality (lower panel) over one year post-implantation for quadripolar and bipolar LV leads in CRT recipients.

numerous pacing vector options that they provide, allow for higher success rates of LV lead placement in more stable positions, thus translating into fewer lead dislodgements and lead deactivations in follow-up.

Our findings are consistent with some but not all findings from other comparable smaller [10,11] and larger [12,13] studies. The randomized MORE-CRT trial [12,13] showed an increased procedural success and reduced intra- and post-operative complications with the use of quadripolar LV leads. Contrary to the results of previous work however, our study does not show a difference in mortality or rates of hospitalizations for heart failure or PNS in recipients of quadripolar versus bipolar LV leads [11,14,15]. It is worth noting however that our study was based exclusively on our institutional records, independent of data sponsored by industry. In

addition, our study is the first to look at the combined performance of quadripolar leads from two manufacturers as all prior studies focused on one lead model from a single manufacturer [13,16]. Lastly, our study has included LV leads implanted with CRT-D and CRT-P devices, unlike all other similar studies that focused exclusively on CRT-D recipients.

Our current study has limitations. First, it is retrospective and therefore may inherently have selection and information bias. The type of LV lead implanted was dependent on operator choice as well as the availability of quadripolar leads in the United States, which started 2011. There is a possibility of selection bias but we have included in our analysis all patients who were implanted with bipolar or quadripolar LV leads over the study period, without any exclusion to minimize bias. Moreover, the baseline clinical

characteristics between the two study groups were generally similar. Another limitation is that our study was conducted at a single hospital system, so our results may not be reproducible at other institutions or in other clinical settings. However, it is worth noting that CRT implantation and subsequent management of LV lead-related complications are typically performed at tertiary centers with similar levels of expertise to those available at our institution. In addition, although all operative notes were reviewed and none mention switching LV lead type or shape during the index procedure due to difficult anatomy of other procedural considerations, we cannot exclude that this may have happened but not dictated in the operative note. Lastly, although quadripolar leads were implanted in 292 patients in our study, no patient received LV multipoint pacing.

5. Conclusion

In the real world setting, quadripolar LV leads have significantly lower rates of implantation failure and post-operative lead dislodgement or deactivation. These results which have important clinical implications to CRT recipients need to be validated in larger multicenter data.

Conflict of interest disclosures

Samir Saba: Research support from St Jude Medical, Boston Scientific, and Medtronic.

References

- [1] Meta-analysis Global Group in Chronic Heart Failure (MAGGIC). The survival of patients with heart failure with preserved or reduced left ventricular ejection fraction: an individual patient data meta-analysis. *Eur Heart J* 2012;33:1750–7.
- [2] Eriksson H. Heart failure: a growing public health problem. *J Intern Med* 1995;237:135–41.
- [3] Roger VL. Epidemiology of heart failure. *Circulation Res* 2013;113:646–59.
- [4] Bristow MR, Saxon LA, Boehmer J, et al. Cardiac-resynchronization therapy with or without an implantable defibrillator in advanced chronic heart failure. *N Engl J Med* 2004;350:2140–50.
- [5] Cleland JG, Daubert JC, Erdmann E, et al. Cardiac Resynchronization-Heart Failure (CARE-HF) Study Investigators. The effect of cardiac resynchronization on morbidity and mortality in heart failure. *N Engl J Med* 2005;352:1539–49.
- [6] Morgan JM, Delgado V. Lead positioning for cardiac resynchronization therapy: techniques and priorities. *Europace* 2009;11(suppl 5). v22–8.
- [7] Gras D, Böcker D, Lunati M, et al. Implantation of cardiac resynchronization therapy systems in the CARE-HF trial: procedural success rate and safety. *Europace* 2007;9:516–22.
- [8] Borleffs CJ, van Bommel RJ, Molhoek SG, de Leeuw JG, Schalij MJ, van Erven L. Requirement for coronary sinus lead interventions and effectiveness of endovascular replacement during long-term follow-up after implantation of a resynchronization device. *Europace* 2009;11:607–11.
- [9] León AR, Abraham WT, Curtis AB, et al. Safety of transvenous cardiac resynchronization system implantation in patients with chronic heart failure: combined results of over 2,000 patients from a multicenter study program. *J Am Coll Cardiol* 2005;46:2348–56.
- [10] Forleo GB, Della Rocca DG, Papavasileiou LP, Di Molfetta A, Santini L, Romeo F. Left ventricular pacing with a new quadripolar transvenous lead for CRT: early results of a prospective comparison with conventional implant outcomes. *Heart Rhythm* 2011;8:31–7.
- [11] Forleo GB, Di Biase L, Panattoni G, et al. Improved implant and postoperative lead performance in CRT-D patients implanted with a quadripolar left ventricular lead. A 6-month follow-up analysis from a multicenter prospective comparative study. *J Interventional Cardiac Electrophysiol* 2015;42:59–66.
- [12] More options available with a quadripolar LV lead provide in-clinic solutions to CRT challenges (MORE-CRT) 2014. 14 Dec. 2015. <https://www.clinicaltrials.gov/ct2/show/NCT01510652>.
- [13] Boriani G, Connors S, Kalarus Z, et al. Cardiac resynchronization therapy with a quadripolar electrode lead decreases complications at six months: results of the MORE-CRT randomized trial. *JACC Clin Electrophysiol* 2016;2:212–20 [Abstract].
- [14] Behar JM, Bostock J, Zhu LA, et al. Cardiac resynchronization therapy delivered via a multipolar left ventricular lead is associated with reduced mortality and elimination of phrenic nerve stimulation: long-term follow-up from a multicenter registry. *J Cardiovasc Electrophysiol* 2015 May;26(5):540.
- [15] Forleo GB, Di Biase L, Bharmi R, et al. Hospitalization rates and associated cost analysis of cardiac resynchronization therapy with an implantable defibrillator and quadripolar vs. bipolar left ventricular leads: a comparative effectiveness study. *Europace* 2015 Jan 1;17(1):101–7.
- [16] Crossley GH, Biffi M, Johnson B, et al. Performance of a novel left ventricular lead with short bipolar spacing for cardiac resynchronization therapy: primary results of the Attain Performa Quadripolar Left Ventricular Lead Study. *Heart Rhythm* 2015 Apr 30;12(4):751–8.