



Modified snare technique improves left ventricular lead implant success for cardiac resynchronization therapy

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Abstract

Background: Left ventricular (LV) lead placement is the most challenging aspect of cardiac resynchronization therapy (CRT) device implantation, with a failure rate of up to 10% due to complex coronary anatomies. We describe a modified snare technique for LV lead placement and evaluate its safety and efficacy in cases when standard methods fail.

Methods and Results: A prospective study was conducted of patients indicated for a CRT implant. When LV lead delivery to the target vessel failed using standard techniques, a modified snare technique was employed. Patients were evaluated every 6 months. From 2015 to 2019, 566 CRTs were implanted (26.1% female, 72 ± 10.2 years old, follow-up duration 18.9 ± 15.8 months). The standard LV implant technique failed in 94 cases (16.6%), of which the modified snare technique was successful in 92 (97.9%). There were no differences between the modified snare and standard techniques in the rates of 30-day postimplant CRT all-cause mortality (3.2% vs. 1.7%, $p = .33$), 4-year all-cause mortality (15.9% vs. 15.5%, $p = .49$), or major acute complications (7.4% vs. 3.8%, $p = .12$). However, the 4-year procedural re-intervention rate was lower with the modified snare technique (3.2% vs. 10.2%, $p < .05$), specifically LV implant failure or dislodgement rates (0% vs. 5.3%, $p < .05$), improving the response rate (71.8% vs. 55.1%, $p < .05$).

Conclusions: For challenging coronary sinus anatomies that preclude LV lead placement by standard methods, this modified snare alternative was safe and effective, with comparable mortality and complications, but significantly lower procedural reintervention and higher response rates.

KEYWORDS

cardiac resynchronization therapy, efficacy, left ventricular lead, responders, safety, snare technique

1 | INTRODUCTION

Cardiac resynchronization therapy (CRT) has been shown to provide considerable long-term benefits to patients with moderate-to-severe heart failure (HF), prolonged QRS duration, and reduced ejection fraction (EF).^{1,2} The aim of CRT is to properly time the electrical activation of the heart via endocardial right atrial (RA) and right ventricular (RV) leads, in conjunction with a coronary sinus (CS) left ventricular (LV) lead, for efficient blood ejection. However, approximately 30%–40% of HF patients fail to clinically respond to CRT.^{3,4} One key contributor to this significant nonresponder rate is the suboptimal placement of the LV lead at implant.

While the delivery of the endocardial RA and RV leads is straightforward, successful implantation of the LV lead is highly dependent on the patient-specific coronary anatomy, which may be tortuous and complex. Consequently, transvenous LV lead placement in the target vessel is considered the most challenging aspect of CRT device implantation and is ultimately unsuccessful in 10% of attempts.^{5,6} In the event of a failed transvenous LV lead implant, 74% of European centers opt for surgical implantation of an epicardial LV lead.⁷ The general anesthesia and thoracotomy required are associated with elevated risks of complication and mortality,⁸ all with no major improvement in outcomes.⁹

Even in cases with successful transvenous LV lead implants, at least 11% of patients have suboptimal LV lead positions,⁷ compromising the efficacy of resynchronization. Beyond implant, the main midterm complications of CRT include LV lead dislodgement or diaphragmatic stimulation, accounting for 6% of procedures and leading to a procedural revision in the vast majority of cases,⁵ further elevating the risk of infection. To improve LV lead implant success rates and reduce postimplant complications, alternatives to conventional LV lead delivery techniques are needed.

One alternative transvenous technique, first introduced by Worley et al.¹⁰ in 2009, employs a standard gooseneck snare, accessible to most implanters. Briefly, in patients with collateral coronary veins that reenter the CS, a lead delivery guidewire is looped from the CS, through the target vein, back into the CS, and captured by a snare introduced from the same venous access. The snare either fixes the distal end of the guidewire in place or is used to externalize the distal end, thus facilitating a push-pull traction of the lead and guidewire to traverse narrow and/or tortuous anatomies.

In this study, a novel, modified snare technique is introduced to enhance LV lead delivery to target vessels using two CS delivery sheaths. The safety and efficacy of this modified snare technique are evaluated in a large cohort when the standard approach fails.

2 | METHODS

2.1 | Study design

This was a prospective study of consecutive patients indicated for de novo CRT implants or pacemaker-to-CRT upgrades from January 2015

to March 2019. CRT implants were performed according to the standard of care. When LV lead delivery to the target location was not possible by standard techniques, a modified snare technique was attempted, as described below. Follow-up visits were performed every 6 months, according to the standard of care of the implanting institution. Echocardiography was performed at implant and repeated 6–12 months postimplant.

2.2 | Consent

The study was performed according to the principles outlined in the Declaration of Helsinki and the Good Clinical Practice guidelines of the European Commission. All patients provided written informed consent, and the study protocol was approved by the institutional ethics committee.

2.3 | Study objectives

The main objectives of this study were to evaluate the safety and efficacy of a modified snare technique for LV lead delivery to the target vessel when standard approaches failed. Safety was quantified by 30-day and long-term postimplant all-cause mortality rate, and major acute complication rate. Major complications were defined as CRT implant-related complications classified as life-threatening or delaying hospital discharge. Efficacy was quantified by long-term, all-cause procedural reintervention rates.

Additional study objectives included evaluation of the duration of the implant procedure, duration of fluoroscopy, and echocardiographic responder rates.

2.4 | Study population

Enrollment included HF patients at least 18 years of age with NYHA functional class II–IV, QRS duration ≥ 130 ms (left bundle branch block and non-left bundle branch block), and either (1) LVEF $\leq 35\%$ despite optimal medical therapy or (2) LVEF $< 40\%$ with pacemaker-dependence and an anticipated RV pacing percentage more than 40%. Patients contraindicated for CRT implant were excluded.

2.5 | Implant procedure

All procedures were performed under local anesthesia, after patient fasting, and at least 48 h after suspending any oral anticoagulants. RA and RV lead delivery followed standard practice. In general, a lateral vein was selected as the target vessel for the LV lead (anatomy-guided), as it most frequently presents the latest activated region.^{11,12} LV pacing at the site of latest activation has been shown to enhance resynchronization and is associated with long-term HF improvement and mortality reduction,¹³ as well as improvement in functional capacity and LVEF.¹⁴

In the standard LV lead delivery technique, one 10.5-Fr peel-away introducer was first inserted in the left subclavian vein with a spare guidewire in the same hole (one puncture, two guidewires). Next, a 9-Fr outer diameter (OD) CS delivery sheath was used to cannulate the CS and perform angiography for visualization of the coronary vasculature, without routinely use of occlusive venogram. All commercial brands were considered for CS guide sheath, preferentially Attain Command from Medtronic® and Selectra from Biotronik®. If possible, the LV lead was then advanced into the target vessel using all commercially available, state-of-the-art tools and techniques. If narrow, tortuous, or otherwise complex vascular anatomies precluded LV lead delivery to the target vessel using standard techniques, a modified snare technique, described below, was used as an alternative.

2.6 | Modified snare technique

The modified snare technique is based on the Worley snare technique,¹⁰ yet is unique in that two independent 9-Fr OD CS delivery sheaths are introduced through the same venous puncture, as described before. The original Worley technique and this modified technique are illustrated in Figures 1 and 2, respectively.

We use conventional 9-Fr OD sheaths provided by all commercial brands instead of using the dedicated Worley sheath. The use of two different CS delivery sheaths allows the conversion of a standard procedure into the snare technique without losing guidewires already placed in the target vessel. In addition, it allows better control of the snare and decreases the traction exerted in the guidewire, as described in Figures 1 and 2.

The modified snare technique follows a failed standard lead delivery procedure and the existing 9-Fr CS sheath is used. A 0.014" hydrophilic guidewire is first chosen based on the diameter of the distal vessel: a 180-cm Runthrough guidewire (Terumo Medical Corporation) for smaller capillary vessels, or a 190-cm Whisper guidewire (Abbott Vascular) for larger branches. This guidewire is passed through the existing CS guiding catheter, described above for the initial lead delivery attempt. The guidewire is then advanced through the CS tributaries, passing through the target vessel, and back to the main CS in either an antegrade or retrograde direction.

In parallel to the existing 10.5-Fr introducer initially inserted in the left subclavian vein, a second 10.5-Fr introducer is then inserted using the spare guidewire. A supplementary 9-Fr OD CS sheath is inserted through this second introducer, allowing a 6-Fr endovascular Trefoil EN Snare (Merit Medical System) to be advanced. Either a 20 or 15 mm snare is chosen, depending on whether the

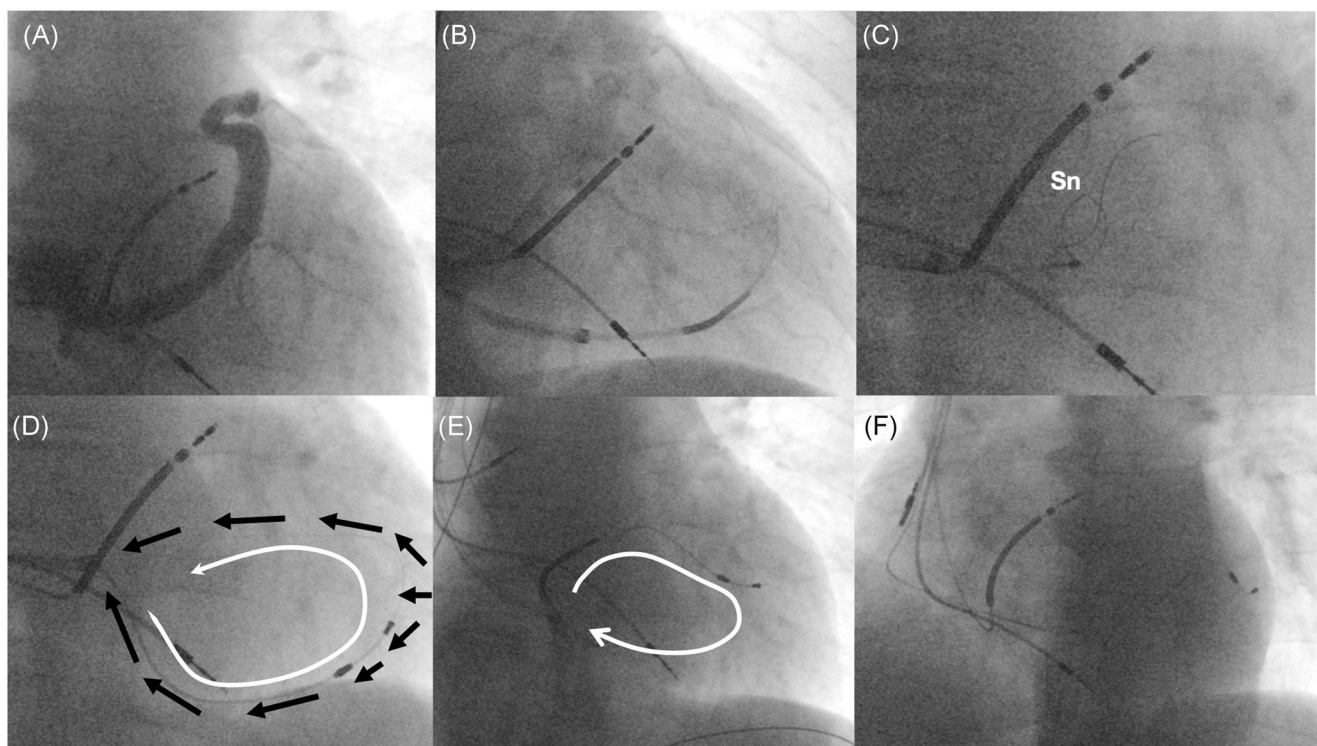


FIGURE 1 Worley snare technique. (A) Coronary sinus contrast injection, revealing two small lateral branches. (B) Cannulation of the posterolateral branch with selective contrast injection in an anastomotic vessel between posterolateral and lateral branches. (C) Gooseneck snare (Sn) capturing guidewire in the main coronary sinus. (D) Attempted insertion of left ventricular (LV) lead in antegrade direction, white arrow shows lead progression from posterolateral to the lateral position, black arrows show traction force toward a single point. (E) Insertion of LV lead in a retrograde direction, white arrow shows progression in the lateral vessel. (F) The final position of the LV lead in left anterior oblique (LAO) view

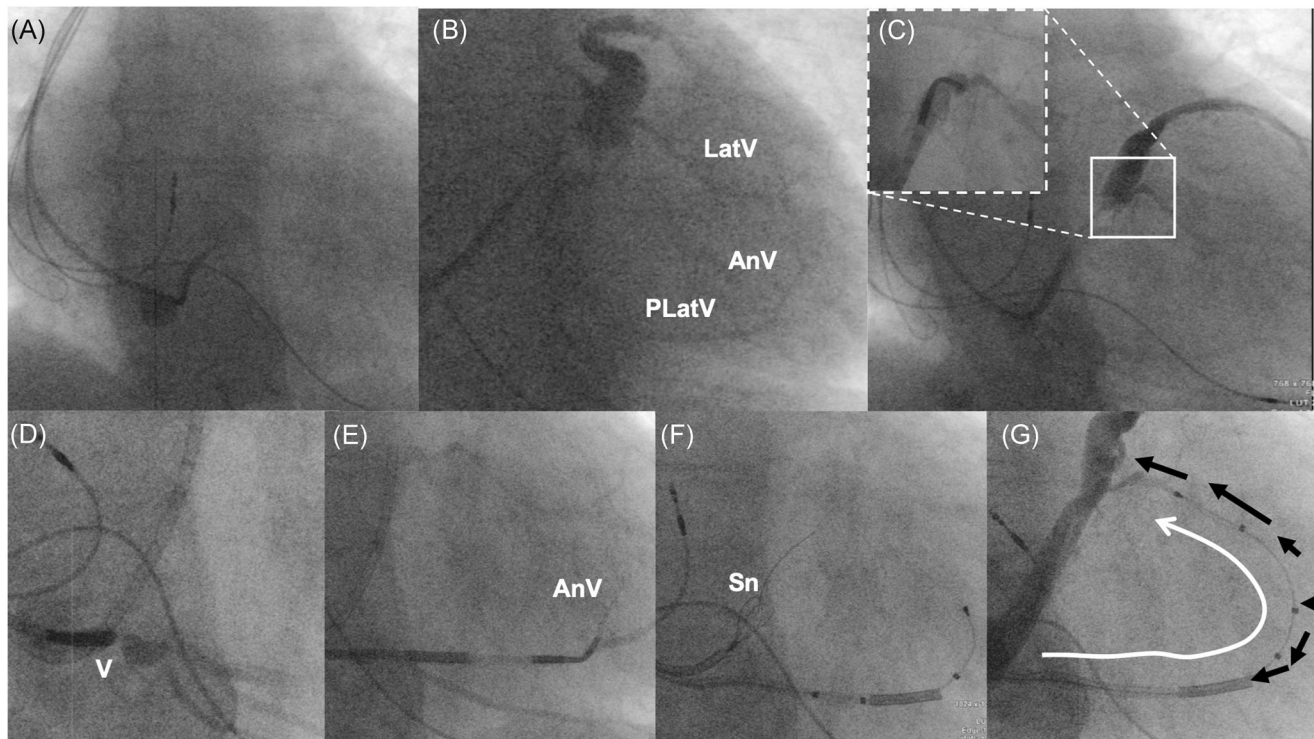


FIGURE 2 Modified snare technique. (A) Coronary sinus (CS) ostium with Vieussens valve. (B) Balloon venography showing a lateral vein (LatV), posterolateral vein (PLatV), and anastomotic vein (AnV). (C) Attempt to selectively cannulate lateral vein and failure to cross guidewire. (D) Cannulation of the posterolateral trifurcated vein, with a valve at its origin (V). (E) Selective cannulation of the upper branch of the posterolateral vein with selective contrast injection in anastomotic vein. (F) Failure to progress lead through an anastomotic vein, snare (Sn) catching guidewire in main CS. (G) Left ventricular lead traction through a lateral vein, white arrow shows lead progression, black arrows show force distribution between two points due to two separate introducers

snare would be placed in the main CS or directly in a tributary vein, respectively.

The snare is then used to capture the distal end of the guidewire and pull the tip of the guidewire out of the patient subclavian vein. Normal length guidewires are usually enough to accommodate the procedure. However, in a minor number of cases (7/94), a 150-cm Runthrough Extension wire (Terumo Medical Corporation) was used.

At this point, the guidewire had formed a loop through the target vessel, with both ends exposed through different introducers. Next, the LV lead can be advanced over the guidewire to the target vessel in either an antegrade or retrograde direction, depending on vessel dimensions, while avoiding capillary network. When lead advancement through the entrance of the target vessel is challenging despite this extra support, the guidewire in the proximal end of the lead is clamped, such that the lead can be pushed whilst pulling the clamped guidewire.

2.7 | Data collection

The following data were collected at implant: (1) patient demographic and clinical characteristics; (2) electrocardiographic metrics; (3) CRT implant characteristics; (4) procedure and fluoroscopy duration; (5) major acute CRT implant-related complications. The following data were collected every 6 months postimplant: (1)

patient demographic and clinical characteristics; (2) electrocardiographic metrics; (3) procedural reintervention events; (4) 30-day and long-term all-cause mortality; (5) response rate to CRT. In addition, echocardiography was performed preimplant and 6–12 months postimplant, with echocardiographic measurements performed by two blinded operators.

2.8 | Responder classification

Patients were evaluated with transthoracic echocardiography before CRT implant and between 6 and 12 months postimplant. Patients with EF improvement $\geq 10\%$ or LV end-systolic volume (ESV) reduction $\geq 15\%$ were classified as responders. Patients with EF improvement $\geq 20\%$ or LV ESV reduction $\geq 30\%$ were classified as super responders.

2.9 | Statistical analysis

Continuous variables were presented as mean \pm standard deviation or median with interquartile range, as appropriate. Comparisons between patient groups were performed on continuous variables using the unpaired Student's *t*-test or Mann-Whitney test, as appropriate. Categorical variables were compared using χ^2 tests. Paired

TABLE 1 Baseline characteristics of implanted patients

Population characteristics	Snare group (N = 94)	Standard group (N = 472)	p Value
Age (mean \pm standard deviation; years)	70.9 \pm 10.1	72.2 \pm 10.2	.62
Female sex, n (%)	23 (24.5%)	125 (26.5%)	.74
Ejection fraction < 30%, n (%)	62 (65.5%)	302 (64%)	.75
Comorbidities			
Hypertension, n (%)	82 (87%)	408 (86.4%)	.89
Dyslipidemia, n (%)	59 (62.7%)	276 (58.5%)	.46
Diabetes, n (%)	41 (44%)	178 (37.7%)	.33
CKD (GFR < 60 ml/min/1.73m ²), n (%)	16 (17%)	101 (21.4%)	.36
COPD, n (%)	7 (7.4%)	43 (9.1%)	.47
AF, n (%)	26 (27.6%)	148 (31.4%)	.49
NYHA functional class			
II, n (%)	72 (76.6%)	260 (55.1%)	.01
III, n (%)	22 (23.4%)	191 (40.5%)	
Heart failure etiology			
Ischemic cardiopathy, n (%)	37 (39.4%)	176 (37.3%)	.63
Dilated cardiomyopathy, n (%)	47 (50%)	269 (57.1%)	.20
Valvular cardiopathy, n (%)	4 (4.3%)	17 (3.6%)	.97
Hypertrophic cardiomyopathy, n (%)	1 (1%)	2 (0.4%)	.46
Other, n (%)	5 (5.3%)	8 (1.6%)	.02
Medical therapy ^a			
ACEi/ARB/ARNI, n (%)	79 (84.0%)	401 (85.0%)	.84
Beta-blocker, n (%)	71 (75.5%)	369 (78.2%)	.57
MRA, n (%)	52 (55.3%)	236 (50.0%)	.36
Electrocardiographic characteristics			
Left bundle branch block, n (%)	50 (53.2%)	291 (61.7%)	.01
QRS duration (median [IQR]; ms)	161 [148-177]	161 [146-177]	.76
Echocardiographic characteristics			
Ejection fraction (%)	28.2 \pm 8.2%	30.8 \pm 11.6%	.06
LV ESV (ml)	127.8 \pm 64.1	131.5 \pm 64.7	.73
Device type			
CRT-P, n (%)	31 (33%)	212 (45%)	.03
CRT-D, n (%)	63 (67%)	260 (55%)	

Abbreviations: ACEi, angiotensin-converting-enzyme inhibitor; AF, atrial fibrillation; ARB, angiotensin II receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CRT-D, cardiac resynchronization therapy—defibrillator; CRT-P, cardiac resynchronization therapy—pacemaker; GFR, glomerular filtration rate; IQR, interquartile range; LV ESV, left ventricle end-systolic volume; MRA, mineralocorticoid receptor antagonist; NYHA, New York Heart Association.

^aThe primary indication for CRT implant was heart failure in 89.2% of patients and bradycardia in 10.8%.

comparisons at different time-points were performed using the Wilcoxon test.

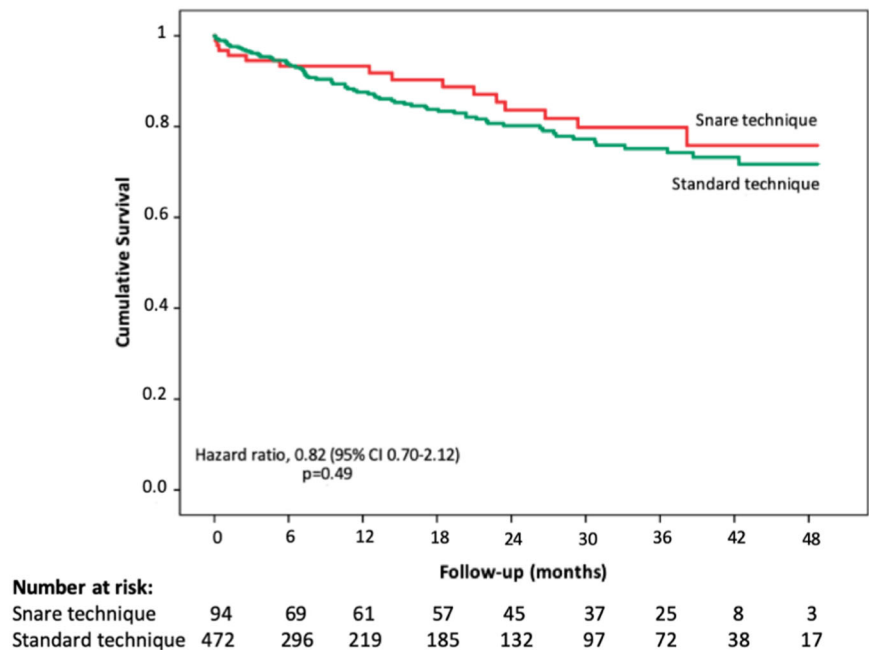
Freedom from 30-day mortality, long-term mortality, and all-cause procedural reintervention were evaluated with the Cox proportional hazards model and Kaplan–Meier analysis, with the hazard ratio (HR) and 95% confidence interval (CI) reported. Differences in the incidence of major acute complications were evaluated using χ^2 tests.

For all statistical tests, *p* value of less than .05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics 23™.

3 | RESULTS

3.1 | Baseline characteristics

Between January 2015 and May 2019, 566 CRTs were implanted (26.1% female, 72 \pm 10.2 years of age), with a mean follow-up duration of 18.9 \pm 15.8 months (22.9 \pm 15.4 months in snare group, 17.9 \pm 15.6 in the standard group, *p* < .05), range 0.0–63.3 months. Complete baseline characteristics are provided in Table 1. Of all implants, 84.6% were de novo, and 15.4% upgraded from single- or dual-chamber pacemakers. CRT-P and CRT-D devices made up

FIGURE 3 Cumulative all-cause survival rate

42.9% and 57.1% of implants, respectively. The primary indication for CRT implant was HF in 89.2% of patients and bradycardia in 10.8%. Of HF patients, the predominant etiology was dilated cardiomyopathy in 55.9% of patients, followed by ischemic heart disease in 37.6%.

The modified snare technique was used for LV lead implantation, after the standard technique failed, in 16.6% of CRT implants (94/566). In 97.9% (92/94) of these modified snare cases, the LV lead was successfully implanted in the target vessel, 94.7% (89/94) of which were lateral veins. In two cases, the LV lead was implanted in the second-best branch, one due to venous stenosis in a post coronary artery graft bypass patient and the other due to intense chest pain during the progression of the lead that we correlated to a higher risk of pericardial effusion and decided to safely implant in the second-best branch. LV lead was implanted in 76 (81%) cases using the antegrade approach and in 18 (19%) cases with a retrograde approach due to failure in the progression of LV lead with the antegrade approach.

In the standard technique, LV lead was implanted in 66.5% (314/472) in a lateral vein, 21.0% (99/472) in a posterolateral vein, and 12.5% (59/472) in an anterolateral vein.

3.2 | Safety

There was no difference in the 30-day postimplant mortality rate between patients with modified snare versus standard implant techniques (3.2% vs. 1.7%, logrank: 0.94, $p = .33$). As shown in Figure 3, there was also no difference in the 4-year all-cause mortality rate between patients with the two implant techniques (15.9% vs. 15.5%, logrank: 0.48, $p = .49$), with no sex-based differences.

Major acute complications were observed in 4.4% of all CRT implants, with no difference observed between patients with modified snare versus standard implant techniques (7.4% vs. 3.8%, $\chi^2 = 2.45$, $p = .12$). These complications were mainly characterized as contrast nephropathy or pericardial effusion. The comprehensive list of major acute complications is provided in Table 2.

3.3 | Efficacy

At 4-year postimplant, the all-cause procedural reintervention rate was lower in patients with the modified snare implant technique (3.2%, 3/94) compared to the standard implant technique (10.2%, 48/472). As shown in Figure 4, the HR in the modified snare group was 0.26 (CI = 0.08–0.84, $p = .025$), with a relative risk reduction of 74%, and a number needed-to-treat to prevent one procedural reintervention of 14. In multivariate analysis adjusted for age, sex, and ischemic versus nonischemic HF, the modified snare group demonstrated similar results (HR: 0.26, CI: 0.08–0.83, $p = .023$).

The comprehensive list of procedural re-intervention is provided in Table 2. Overall, LV implant failure or dislodgement was the predominant cause of all procedural reinterventions (47.2%). As shown in Figure 5, LV implant failure or dislodgement impacted far fewer patients when implanted with the modified snare versus standard technique (0% vs. 5.3%, logrank: 5.98, $p < .05$).

3.4 | Procedure and fluoroscopy durations

The duration of the CRT implant procedure was longer with the modified snare versus standard implant technique (111.9 ± 45.1 vs.

TABLE 2 Causes of surgical reintervention and major complication

	Snare group (N = 94)	Standard group (N = 472)	p Value
Cause of major complication			
Contrast nephropathy, n (%)	4 (4.3%)	4 (0.8%)	.59
Cardiac effusion, n (%)	3 (3.2%)	4 (0.8%)	.13
Pneumothorax, n (%)	0 (0%)	4 (0.8%)	.77
Hemorrhage, n (%)	0 (0%)	4 (0.8%)	.84
Pocket infection, n (%)	0 (0%)	2 (0.4%)	.23
Total incidence of major complications, n (%)	7 (7.4%)	18 (3.8%)	.12
Cause of surgical reintervention			
LV lead implant failure or dislodgement, n (%)	0 (0%)	25 (5.3%)	.03
RV lead dislodgement, n (%)	1 (1.1%)	9 (1.9%)	.84
RA lead dislodgement, n (%)	1 (1.1%)	6 (1.3%)	.13
Infection, n (%)	0 (0%)	6 (1.3%)	.59
Device explant, n (%)	1 (1.1%)	4 (0.8%)	.84
Total incidence of surgical reintervention, n (%)	3 (3.2%)	50 (10.6%)	.02

Abbreviations: LV, left ventricle; RA, right atrium; RV, right ventricle.

77.1 ± 47.4 min, $p < .001$), as was the fluoroscopy time (28.3 ± 20.6 vs. 15.9 ± 16.9 min, $p < .001$).

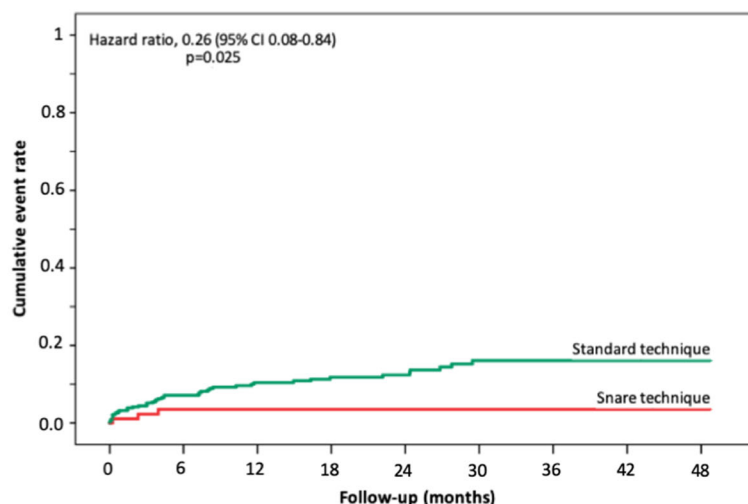
3.5 | CRT response rate

A significantly higher responder rate was observed in the modified snare group than the standard group (71.8% vs. 55.1%, $p < .05$), as illustrated in Figure 6, with similar super response rates (33.3% vs. 27.9%, $p = .482$, respectively). In the modified snare group, LV ESV decreased from 127.8 ± 64.1 to 98.9 ± 52.2 ml ($p < .01$) and EF increased from 28.2 ± 8.2% to 38.7 ± 12.6% ($p < .01$). In the standard group, LV ESV decreased from 131.5 ± 64.7 to 99.9 ± 61.2 ml ($p < .01$) and EF increased from 30.8 ± 11.6% to 36.1 ± 11.2% ($p < .05$). QRS

duration post-CRT implant reduced in the snare group from 161 [148–177] to 126 [109–139] ms and in the standard group from 161 [146–177] to 128 [116–141] ms, with a QRS duration postprocedure significantly lower in the snare group ($p = .01$).

4 | DISCUSSION

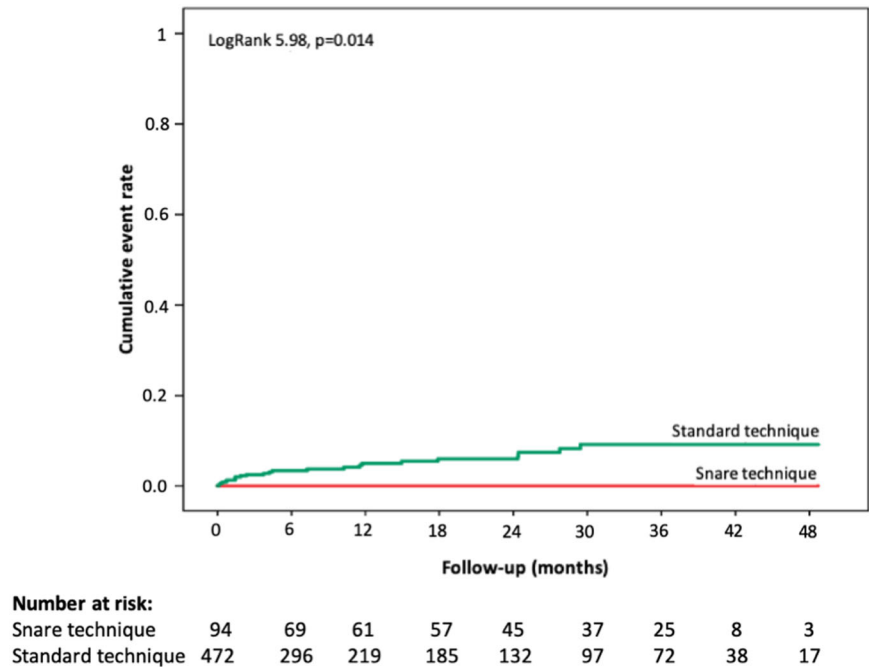
Effective CRT requires proper placement of the LV lead. Narrow, tortuous, or otherwise complex vascular anatomies often preclude LV lead delivery to the target vessel using standard implant methods. Surgical approaches for epicardial LV lead implantation come with additional risks and may not be deemed safe for all patients. Alternative transvenous techniques have been designed to facilitate LV



Number at risk:									
Snare technique	94	69	61	57	45	37	25	8	3
Standard technique	472	296	219	185	132	97	72	38	17

FIGURE 4 Cumulative all-cause procedural reintervention rate. CI, confidence interval

FIGURE 5 Cumulative procedural reintervention rate for left ventricle lead implant failure or dislodgement



lead navigation through complex anatomies, including balloon venoplasty of CS stenosis,¹⁵ retrograde access of anterolateral CS branch,¹⁶ and the use of balloons as anchors to facilitate cannulation of the CS.¹⁷ The Worley snare technique¹⁰ is one such method, with isolated reports demonstrating its success.^{18,19} However, to date, no large-scale evidence of the safety and efficacy of such a snare technique has been reported.

This study introduces a novel modification to the Worley technique, in which a secondary introducer is used to deliver the snare. This modification more evenly distributes forces on the guidewire for improved lead traction and smoother entry into tortuous target veins. The results of this study demonstrate the comparable safety and superior efficacy of an alternative, snare-based LV lead implant technique for CRT cases in which the standard technique had failed.

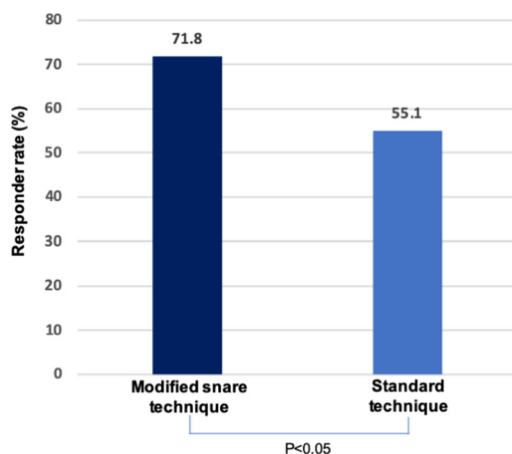


FIGURE 6 Cardiac resynchronization therapy responder rates at 6–12 months postimplant comparing the modified snare and standard implant techniques

Of the 566 CRT implants in this study, LV lead implantation following standard methods failed in 16.6% (94/566). In those failed cases, the modified snare technique was subsequently employed and resulted in 97.9% (92/94) successful delivery to the target vein. The relatively high implant failure rate⁵ observed using standard methods may be explained by the status of the investigational center as a tertiary hospital, where patients are referred for CRT implant after failure at other centers. However, once the modified snare technique has been well established for widespread use, it can be attempted during the same procedure—immediately after unsuccessful attempts using standard methods.

In terms of safety, there was no significant difference between the modified snare and standard implant techniques in (1) the 30-day post-implant mortality, (2) 4-year all-cause mortality, (3) incidence of major complications. The comparable safety profile of this modified snare technique, relative to standard methods, may be attributed to the use of two independent delivery systems. The separate secondary introducer with two different anchoring points, as opposed to the single anchoring point with the original snare technique, diverts the tractional force of the LV lead into the target vessel, reducing the cutting effect of the guidewire in the LV free wall, as illustrated in Figure 2.

Despite statistically similar complication rates, more complications were observed with the snare technique. In particular, more cases of cardiac (i.e., pericardial) effusion were observed, as the active traction used to navigate complex vascular anatomies may elevate that risk of capillary network rupture. However, the majority of patients who experienced effusion were on dual antiplatelet therapy, mainly with ticagrelor, or on anticoagulants, although the statistical correlation was not reached due to the minimal number of events. Accordingly, deep sedation should be avoided during the procedure, like chest pain during lead traction is the most predictive clinical feature of pericardial effusion complications.

As can be expected with any novel invasive technique, most complications occurred at the beginning of the operator's experience, with a decrease in complication rate observed as the learning curve was overcome. Similarly, although both the CRT implant duration and fluoroscopy time were longer with the modified snare technique than standard methods, both times tended to decrease with implanter experience.

In terms of efficacy, the modified snare technique demonstrated a significantly lower 4-year procedural reintervention rate, mainly due to a 0% versus 5.3% rate of LV lead implant failure or dislodgement. The reduced rate of LV lead implant failure or dislodgement by the modified snare technique may be attributed to the active traction (i.e., dual push-pull action) of the clamped guidewire, allowing LV lead placement in smaller diameter tributary veins.

The 72% CRT response rate exhibited by the snare group, evaluated by LV reverse remodeling criteria, is higher than in previously reported CRT reviews^{3,4} and is higher than the standard group. This interesting result may be a consequence of the implant of the LV lead on a lateral vein presenting most often the latest activated area, instead of placing the lead in a second-best branch. In addition, it should be noted that this response was achieved in a subgroup of patients that would otherwise either (1) not benefit from biventricular resynchronization or (2) would have required a surgically implanted epicardial LV lead. Due to being an advanced technique with an important learning curve, it should only be performed by an experienced operator in cases in which a lateral vein is not accessible through standard techniques. It is a transvenous alternative into placing the LV lead in the best branch, improving patient prognosis, and potentially converting CRT nonresponders to responders. Interestingly, the super response rate was higher than previously reported,²⁰ potentially due to optimal lateral vein LV lead placement in our study.

5 | LIMITATIONS

This investigation was performed at a tertiary center. Consequently, the relatively high proportion of snare technique attempts may be explained by the inclusion of referral patients in whom LV lead implantation using standard methods had been unsuccessful.

The modified snare technique was performed by a single operator. The experience accumulated over the course of the study undoubtedly reduced complications, implant failures, dislodgements, and procedural time. Experience with optimal sites for LV lead placement may have also improved CRT responder rates, which may not be attributable to the technique alone. The learning curve influence should be recognized, as with any advanced technique, and a sufficient number of procedures should be performed to establish proficiency.

In the procedures in which the operator was not proficient with the snare technique, a second-best branch was accepted and it may have contributed to the lower response rate of procedures with the standard technique. In fact, this may emphasize the importance of implanting LV lead in the target vessel.

6 | CONCLUSIONS

In patients with challenging CS anatomies that preclude LV lead placement by standard transvenous methods, this advanced snare-based CRT procedure is a safe and effective alternative with a 97.9% success rate. Relative to standard implant methods, the modified snare technique demonstrated comparable mortality and complications, with significantly lower procedural reintervention rates, particularly LV lead implant failure or dislodgement, and with an improvement in response rate.

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