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DEVICES

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# Diagnostic and therapeutic value of implantable loop recorder: A tertiary care center experience

Deepak Padmanabhan MD[1] | Krishna Kancharla MBBS[1] | Majd A. El-Harasis MBBS[2] | Ameesh Isath MBBS[1] | Nayani Makkar[1] | Peter A. Noseworthy MD[1] | Paul A. Friedman MD[1] | Yong-Mei Cha MD[1] | Suraj Kapa MD[1]

[1]Department of Cardiovascular Diseases, Mayo Clinic, Rochester, MN, USA

[2]Division of Internal Medicine, Mayo Clinic, Rochester, MN, USA

**Correspondence**
Suraj Kapa, MD, Department of Cardiovascular Diseases, Mayo Clinic College of Medicine, 200 First St SW, Rochester, MN 55905.
Email: kapa.suraj@mayo.edu

## Abstract

**Background:** Implantable loop recorders (ILRs) are effective in achieving symptom-rhythm correlation. However, diagnostic yield in routine clinical practice is not well established.

**Methods:** Patients undergoing ILR implantation between April 2010 and May 2015 were included. All devices were enrolled in remote monitoring with automatic arrhythmia detection and P sense algorithms switched "ON." Symptom-rhythm correlation was assessed and changes in management were recorded.

**Results:** A total of 312 patients (57% male, age 53 ± 22 years; median CHADS2VaSc score = 1) were included in this study. ILRs were implanted for evaluation of syncope in 206 (66.0%), presyncope in 23 (7.4%), unexplained palpitations in 51 (16.3%), and cryptogenic stroke in 27 (8.7%) patients. ILR monitoring yielded a diagnosis that changed management strategy in 146 (46.8%) patients over a median of 12 (1-42) months. Out of 163 (52.2%) patients with symptoms during the monitoring period, 100 (61.3%) had an arrhythmia. ILR was useful in ruling out an arrhythmic cause for symptoms in 63 (38.7%) patients. ILR results led to pacemaker implantation in 23 patients (7.4% overall and 11.2% of those with syncope) after median follow-up of 3 months. A new diagnosis of atrial fibrillation was made in 38 (12.2%) patients, 11 of whom were initiated on oral anticoagulants. ILR results led to pacemaker implantation in 31 patients (9.9% overall and 19.0% of those with syncope) after median follow-up of 3 months. A new diagnosis of atrial fibrillation was made in 38 (12.2%) patients, nine of whom were initiated on oral anticoagulants. Overall, ILR led to a change in management in 47% patients with a number needed to implant of 2.1 to change management.

**Conclusion:** ILR monitoring is effective in achieving symptom-rhythm correlation and results in changes in management in nearly half of implanted patients. Additional studies are needed to evaluate cost efficacy of ILR and the optimal monitoring duration.

KEYWORDS
arrhythmia, implantable loop recorder, stroke, syncope

## 1 | INTRODUCTION

Diagnosis of the underlying cause of episodic syncope, dizziness, and/or palpitations can be challenging. These episodes result from a variety of conditions and cardiac monitoring can help in teasing out rhythm-related causes such as bradyarrhythmias and tachyarrhythmias. Effective diagnosis of these conditions has the potential to change management and improve quality of life.

When suspecting an underlying bradyarrhythmia or tachyarrhythmia, healthcare providers often pursue a battery of tests including electrocardiography, 24-h Holter monitoring, or longer duration event monitoring. However, underdetection of infrequent events is common.

The limited diagnostic yield of existing monitors led to the development of implantable loop recorders (ILRs), which have the capacity to detect arrhythmias over the course of 2–3 years. Use of these devices has shown to improve detection of arrhythmias relevant to

a host of clinical conditions. For example, ILR-guided cardiac monitoring can detect atrial fibrillation (AF) of >30 s duration in up to an additional 12.9% of ambulatory, otherwise previously undiagnosed patients, resulting in an incremental use of appropriate anticoagulation in up to 13.6% of those patients, potentially in turn improving long-term stroke prevention.[1] In patients with unexplained syncope, ILR usage has been shown to be efficacious in diagnosis compared to patients undergoing conventional in-clinic evaluations, event or other limited period monitoring, and tilt-table testing.[1]

While there are trial data available to support the utility of ILR in specific patient presentations, the diagnostic yield of ILR usage in routine practice is less well studied. Cardiovascular symptoms overlap at presentation. Current prospective studies may not account for many of these clinical situations. The diagnostic and therapeutic yield of ILR in patients presenting with a broad spectrum of symptoms has not been previously evaluated. However, given the potential costs of longer-term monitoring using an ILR device, it is of paramount importance to evaluate its value in aiding patient care.

We aimed to evaluate the diagnostic and therapeutic yield of cardiac monitoring with an ILR by performing a retrospective analysis of all patients implanted with an ILR at our tertiary care referral center.

## 2 | METHODS

### 2.1 | Study population and data collection

We reviewed the medical records of patients who underwent implantation of ILRs at Mayo Clinic, Rochester, Minnesota, between April 2010 and May 2015 for a variety of reasons. The study was approved by the Mayo Clinic Institutional Review Board.

Medical records were reviewed to obtain epidemiologic characteristics, indications for implantation, tests done prior to the implantation of the ILR, and the type of ILR implanted (Medtronic Reveal XT/Medtronic Reveal LINQ, Medtronic, Minneapolis, MN, USA). Complications related to the implantation were recorded. The diagnostic information from the ILR leading to change in management was obtained during follow-up. If extraction of ILR was performed during follow-up, indication leading to the decision was recorded.

### 2.2 | Implantation approach

Loop recorder implants were all performed in an electrophysiology (EP) lab setting under sterile conditions with local anesthetic only, unless requested otherwise by the patient. They are performed with a plan for same-day discharge unless the patient is an inpatient already. No prior skin preparation (eg, chlorhexidine skin washes) is performed on the night before operation. Prophylactic antibiotics are routinely used (one-single preincision dose of cefazolin unless allergy exists, in which case clindamycin is used).

### 2.3 | Remote monitoring and verification of rhythm

All the implanted ILR devices were enrolled into the Carelink remote monitoring program with automatic arrhythmia detection programs and P sense algorithms switched "ON" when available. All the records of ILR-detected abnormal rhythm and symptom episodes transmitted by the patient are evaluated by a pacemaker nurse with physician oversight. Specifically, our center employs over a dozen full-time pacing nurses who take overnight calls and also are updated via an internal alert system whenever remote transmissions are submitted. These transmissions are reviewed by the pacing nurses who subsequently have a protocol in place to identify them as urgent (pauses confirmed to be actual asystole, ventricular arrhythmias, atrial arrhythmias with heart rate greater than 180) and the on-call electrophysiologist is notified, and the patients are called by the nurses to determine associated symptoms. In the case of all other transmissions, patients are called the next business day to identify correlating symptoms, and then the strips and data are supplied to the physician reviewing pacemaker reports that day and any relevant actions (patient follow-up to initiate medications, etc) are coordinated with administrative staff. Symptom-rhythm correlation was assessed for accuracy and changes in management following the event were recorded based on review of the clinical records.

### 2.4 | Analysis

All analyses were performed by an independent observer blinded to the outcomes using SAS 9.4 software (SAS Institute, Cary, NC, USA). Variables were expressed in mean ± standard deviation or median (interquartile range [IQR]) where appropriate. Subgroup analyses were performed based on the implant indication and the effect of findings from the ILR on any change in management.

## 3 | RESULTS

### 3.1 | Patient characteristics

A total of 312 patients underwent ILR implantation over 5 ± 2 years. Mean age was 53 ± 22 years and 57% were men. The median CHADS2VaSc score was 1 (IQR = 1 -3). The baseline clinical and electrocardiogram characteristics in the study cohort are summarized in Table 1. Forty-four (14.1%) patients had abnormal QRS morphology due to conduction disturbances as shown in Supporting Information Table 1.

### 3.2 | Indications for implantation

A total of 206 (66.0%) patients had syncope as the indication for implantation of the device with 23 (7.4%) additional patients suffering from presyncopal symptoms. Fifty-one (16.3%) patients had unexplained palpitations and 27 (8.65%) patients had ILR implanted after cryptogenic stroke to monitor for AF. A total of 39 patients (12.5%) had more than one indication for ILR implantation, with syncope or presyncope being the most common in 33 (10.5%) patients. Miscellaneous indications formed 10.5% (33 patients) of the entire cohort and included monitoring for arrhythmias in patients with long QT syndrome (11 patients, 33.3%) as the predominant indication.

**TABLE 1** Baseline clinical characteristics of the study cohort and the subgroups

| Variable | Total cohort ($n$ = 312) | Variable | Syncope ($n$ = 206) | Variable | Cryptogenic stroke ($n$ = 27) |
|---|---|---|---|---|---|
| Mean age (SD) | 53 (22) | Mean age (SD) | 53 (23.4) | Mean age (SD) | 61 (14) |
| Gender (F) | 133 (43%) | Gender (F) | 90 (44%) | Gender (F) | 11 (41%) |
| Diabetes mellitus | 38 (12%) | Diabetes mellitus | 29 (14%) | Diabetes mellitus | 4 (15%) |
| COPD | 12 (4%) | COPD | 9 (4%) | COPD | 2 (7%) |
| Liver disease | 4 (1%) | Liver disease | 3 (1%) | Liver disease | 0 |
| Chronic kidney disease | 26 (8%) | Chronic kidney disease | 17 (8%) | Chronic kidney disease | 1 (4%) |
| Coronary artery disease | 58 (18%) | Coronary artery disease | 47 (23%) | Coronary artery disease | 4 (15%) |
| Hypertension | 133 (43%) | Hypertension | 95 (46%) | Hypertension | 12 (44%) |
| Hyperlipidemia | 122 (39%) | Hyperlipidemia | 82 (40%) | Hyperlipidemia | 15 (56%) |
| Structural heart disease | | Structural heart disease | | Structural heart disease | |
| Dilated cardiomyopathy | 2 (1%) | Dilated cardiomyopathy | 2 (1%) | Dilated cardiomyopathy | 3 (11%) |
| Valvular heart disease | 36 (12%) | Valvular heart disease | 25 (12%) | Valvular heart disease | 2 (7%) |
| Prior MI | 19 (6%) | Prior MI | 14 (7%) | Prior MI | 1 (4%) |
| Others | 13 (4%) | Others | 4 (2%) | Others | 27 |
| Stroke/TIA | 30 (10%) | Stroke/TIA | 6 (3%) | Stroke/TIA | 0 |
| Epilepsy | 14 (4%) | Epilepsy | 13 (6%) | Epilepsy | 0 |
| Thyroid disorder | 2 (1%) | Thyroid disorder | | Thyroid disorder | 3 (11%) |
| Hyperthyroidism | 36 (11%) | Hyperthyroidism | 0 | Hyperthyroidism | 0 |
| Hypothyroidism | 32 (10%) | Hypothyroidism | 25 (12%) | Hypothyroidism | 3 (11%) |
| Anxiety | 55 (18%) | Anxiety | 20 (10%) | Anxiety | 2 (7%) |
| Depression | 33 (10.6%) | Depression | 39 (19%) | Depression | |
| Prior AF | 3 (1%) | Prior AF | 14 (7%) | Prior AF | |
| Mean baseline EF (SD) | 59 (8.2) | Baseline EF (SD) | 60 (7.9) | Baseline EF (SD) | 58 (7.2) |
| Mean PR interval (SD) | 162 (33.9) | Mean PR interval (SD) | 163 (35.3) | PR interval (SD) | 164 (33.4) |
| Mean QRS duration (SD) | 99 (19.9) | QRS duration (SD) | 98 (18.9) | QRS duration (SD) | 95 (19.6) |

AF = atrial fibrillation; COPD = chronic obstructive pulmonary disease; EF = ejection fraction; MI = myocardial infarction; SD = standard deviation; TIA = transient ischemic attack.

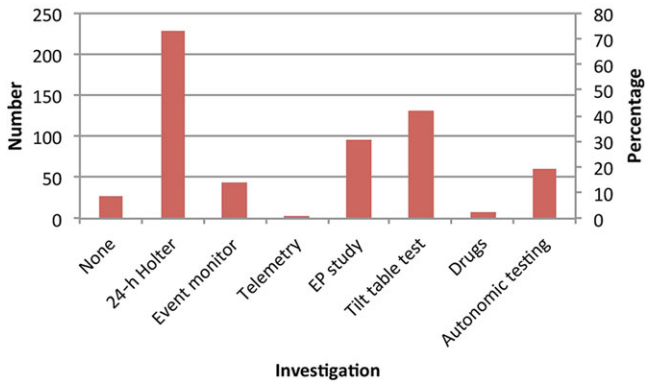



**FIGURE 1** Investigations prior to the implantation of the loop recorder. EP study = electrophysiological study [Color figure can be viewed at wileyonlinelibrary.com]

## 3.3 | Pre-ILR investigations

Most (91.3%) patients were evaluated for rhythm abnormalities using ambulatory monitoring before ILR implantation. Distribution of the various investigations done prior to the implantation of the ILR is shown in Figure 1. Median number of investigations done per patient was 2 (IQR = 1-3). Holter monitoring was done in 229 (73.4%) patients with 72 (23.1%) patients having only a Holter monitor prior to the implantation of the ILR. In 173 (55.4%) patients, who had more than one investigation, the two most common combinations were that of a 24-h Holter and tilt table test in 32 patients (18.5%), and 24-h Holter and EP study in 25 patients (14.5%).

## 3.4 | Device details

A total of 159 (51%) patients were implanted with a Medtronic Reveal XT device, whereas 153 (49%) patients were implanted with the Medtronic Linq device. Mean duration of follow-up was 13.9 ± 9.2 months. Device extraction data were available for 63 devices. The distribution of the reasons for removal is shown in Table 2. Local pain and infection post-ILR implantation necessitating removal was noted in six patients. These patients were implanted with Medtronic Reveal XT devices.

## 3.5 | Findings on monitoring

The distribution of the findings of monitoring is summarized in Supporting Information Figure 1 and Supporting Information Table 2. A

**TABLE 2** Etiology for removal of the implantable loop recorder

| Reason for removal | Number $n = 63$ (%) |
|---|---|
| Postdiagnosis | 30 (48) |
| End of life | 10 (15.9) |
| No yield | 7 (11.1) |
| Local infection | 6 (9.5) |
| Postmortem | 5 (8) |
| Patient request | 4 (6.3) |
| Imaging related | 1 (1.6) |
| Systemic infection | 1 (1.4) |

total of 18 (5.7%) patients were lost to follow-up. **One hundred sixteen** (39.4%) patients did not have any symptoms during the monitoring period with the ILR and were classified as inconclusive, whereas 46 (15.7%) patients had no arrhythmia correlating with their symptoms and were classified as nonarrhythmic etiology. A total of 142 (48%) patients had at least one bradyarrhythmia or tachyarrhythmia diagnosed due to ILR monitoring. The most common arrhythmic issue diagnosed was atrial arrhythmia in 49 (16.7%) patients, of whom 38 had AF. Twenty (7%) patients had asymptomatic arrhythmias, of which AF was seen in two patients. More than one arrhythmia was seen in 23 (7.8%) patients during the monitoring period.

## 3.6 | Symptomatic correlation with arrhythmia

In addition to the 18 patients lost to follow-up, seven (2.2%) patients did not provide details on symptoms during ILR monitoring (did not initiate remote monitoring and were not seen again at our center). A total of 163 (52.2%) patients had symptoms during the monitoring period. Of these 163 symptomatic patients, 100 (32.1%) had correlation with an arrhythmia, whereas 63 (21.5%) patients had no correlation with an arrhythmia. In seven (1.9%) patients, this conclusion could not be drawn owing to the inability of the patient to correlate symptoms accurately (ie, lack of clarity on the timing of symptoms relative to timing of the recorded arrhythmia).

## 3.7 | Change in management post-ILR monitoring

A total of 146 (46.8%) patients had a change in management due to results of ILR monitoring. Among these, a cardiac intervention was pursued in 62 (42.5%) patients with a number needed to treat of 2.4. Cardiac drug therapy or a pacemaker implant was pursued in 23 (15.8%) and 23 (15.8%) patients, respectively. Anticoagulant therapy was started in 11 (7.5%) patients and antiarrhythmic medications were started in 12 (8.2%) patients. A nonarrhythmic etiology was confirmed due to ILR monitoring in 39 (26.7%) patients and alternative management was pursued in these patients (Figure 2).

## 3.8 | Utility of ILR monitoring toward change in management

Overall, the indication that resulted in the highest rate of cardiac change in management was palpitations (56.3%), followed by syncope

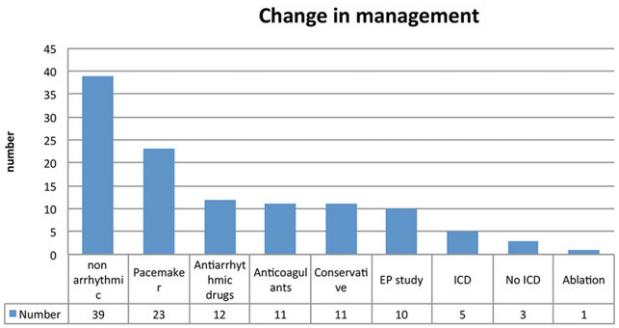



**FIGURE 2** Absolute number and percentage of patients having a change in management after monitoring with implantable loop recorders [Color figure can be viewed at wileyonlinelibrary.com]

(50%). Palpitations also had a higher rate of correlation between symptoms and arrhythmia (63.6% compared to 56.7% in syncope). However, those who had an ILR implanted to investigate syncope had a slightly higher rate of invasive procedures performed as a result of monitoring findings (pacemaker/implantable cardioverter defibrillator [ICD] implantation or ablation) than those who had it implanted for palpitations (12.6% vs 11.8%, respectively). Only 7.4% patients needed additional monitoring at the end of 36 months (Figure 3).

## 3.9 | Condition-driven analysis

### 3.9.1 | Syncope

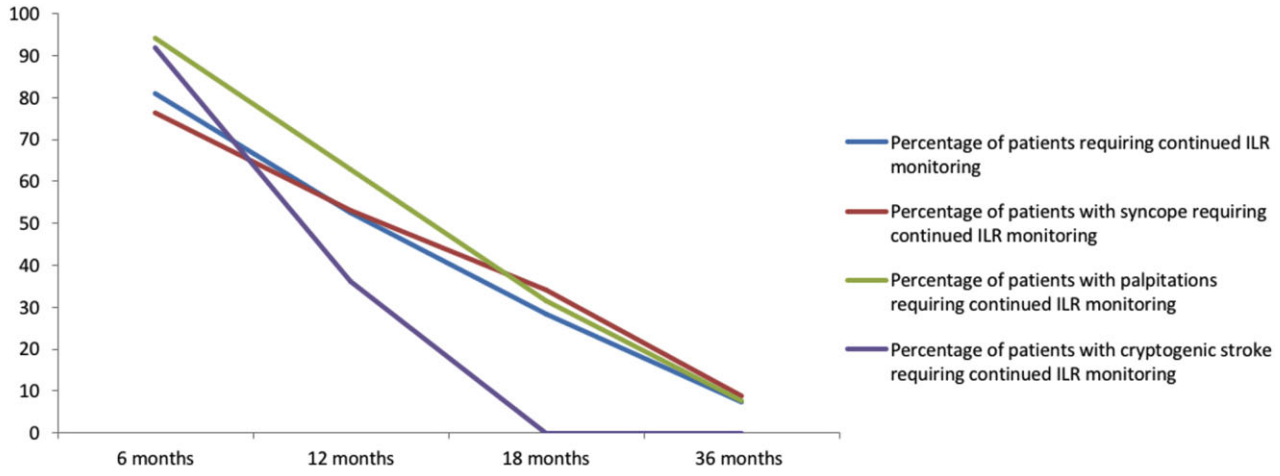
A total of 206 patients of 312 (66.0%) patients had syncope as an indication for ILR implantation. Ninety (43.7%) of these patients had an arrhythmia detected. Of those patients, 71 (78.9%) reported symptoms during the monitoring period and 51 (56.7%) had a correlation between symptoms and an arrhythmia. Seventeen patients (18.9%) did not have a correlation between arrhythmia and symptoms, with the remaining patients being indeterminate due to symptom details either not being available or not being clearly delineated temporally with their incident arrhythmia. Figure 4A summarizes the changes in management resulting from ILR findings. Number needed to treat for a cardiac change in management was 4.9 while number needed to treat to result in an invasive intervention (eg, pacemaker, ICD) was 7.9 (Figure 5).

### 3.9.2 | Palpitations

A total of 51 patients of 312 (16.3%) patients had unexplained palpitations as an indication for ILR implantation. Thirty-three of fifty-one (64.7%) patients had an arrhythmia detected. Thirty of thirty-three (90.1%) patients reported symptoms and 21 of 33 (63.6%) patients had a correlation between symptoms and an arrhythmia. Figure 4B summarizes the changes in management occurring as a result of ILR findings. Number needed to have a change in cardiac management was 2.8 and number needed to treat to result in an invasive intervention (ablation, pacemaker, ICD) was 8.5.

### 3.9.3 | Cryptogenic stroke

In 27 patients, the indication for implantation of the ILR was cryptogenic stroke with a median CHADS2VASc score of 3 (IQR = 2-4). All




| | 6 months | 12 months | 18 months | 36 months |
|---|---|---|---|---|
| Percentage of patients requiring continued ILR monitoring | 80.8 | 52.5 | 28.3 | 7.4 |
| Percentage of patients with syncope requiring continued ILR monitoring | 76.4 | 53.2 | 34 | 8.9 |
| Percentage of patients with palpitations requiring continued ILR monitoring | 94.1 | 62.7 | 31.4 | 7.8 |
| Percentage of patients with cryptogenic stroke requiring continued ILR monitoring | 92 | 36 | 0 | 0 |

**FIGURE 3** Need for continuous ILR monitoring stratified by indication for ILR implant. IRL = implantable loop recorder [Color figure can be viewed at wileyonlinelibrary.com]

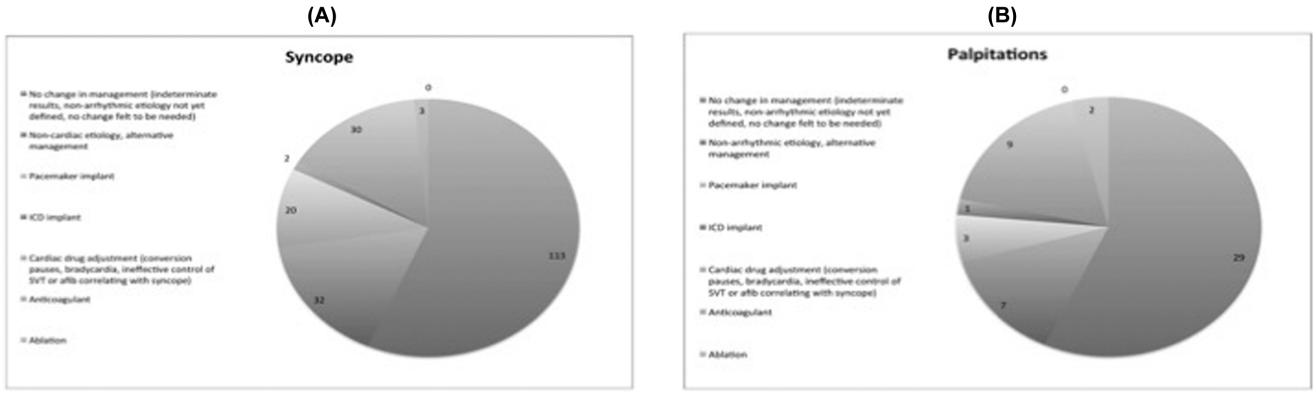



**FIGURE 4** (A, B) Summarize the distribution of interventions occurring as a result of implantable loop recorder findings based on initial implant indications of syncope (A) or palpitations (B)

but four of these patients had a Holter monitor prior to implantation of the device with 24 of 27(88.9%) patients also having an electrocardiogram at the time of implantation showing sinus rhythm. The majority of patients were monitored for 6–12 months (16/27, 59.2%), with seven of 27 (26%) patients monitored for more than 12 months. A total of 12 of 27 (44.4%) patients had an arrhythmia detected. Of these patients, five of 12 (41.7%) patients reported symptoms and four of 12 (33.3%) patients had a correlation between their symptoms and an arrhythmia. Five of twelve (41.7%) patients were diagnosed as having new AF and all of them were initiated on anticoagulant drug therapy. Median time to AF detection in this group of patients was 2 (IQR = 1.8-4.5) months. A total of seven patients had a cardiac change in management with a number needed to treat of 4.5.

## 3.10 | Outcomes-driven analysis

### 3.10.1 | AF/atrial tachycardia on monitoring

A total of 44 patients (14.10%) had AF ($N = 38$) or atrial tachycardia ($N = 6$) episodes detected on their ILR over follow-up, 34 of whom did not have previously recognized atrial arrhythmias. Six of these patients had permanent AF. The median age was 73 years and the median CHADS2VaSc score was 4. The average time for the detection of the first AF episode was 5.53 months. The longest duration of arrhythmia was 143.1 min. Of the 25 patients for whom a burden of atrial arrhythmia was recorded, the mean burden was 7.2%. Of the 16 patients who had a final diagnosis of AF as etiology for their symptoms, 15 of 16 (93.75%) had a change in their management of which

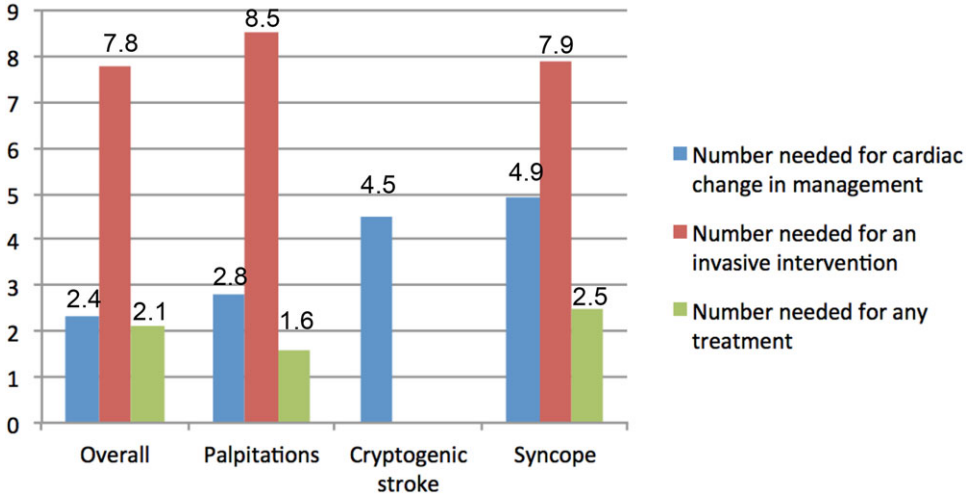



**FIGURE 5** Distribution of the number to treat based upon overall and individual subgroup analysis [Color figure can be viewed at wileyonlinelibrary.com]

the majority (10 patients; 62.5%) had addition of medications. Two patients had a pacemaker implanted after diagnosis for postconversion pauses and one patient underwent AF ablation. Nine patients (56.3%) were newly initiated on anticoagulation following the diagnosis of AF.

### 3.10.2 | Pacemaker/ICD implantation

Twenty-three (11.2%) patients were implanted with a pacemaker after monitoring. Median age was 71 years (53-78). The median follow-up was 3 months (2-7) prior to findings indicating implantation of a pacemaker. Syncopal or presyncopal symptoms were present in 20 of 23 (87.0%) patients. The most common indication for the implantation of a pacemaker was symptomatic sinus bradycardia (13/23, 56.5%). Ten of twenty-three (43.5%) patients implanted with a pacemaker postmonitoring had a bundle branch block noted on their electrocardiogram at baseline.

Three patients were implanted with an ICD at a median monitoring period of 12 months (IQR = 6.75-14.25). Median age of this population was 54 years (42.5-57). The most common indication was syncope (2/3 patients). Two of three patients had sustained VT and one of three patients had nonsustained VT. All patients recorded symptoms that were correlated with arrhythmias and were treated with beta blockers.

## 4 | DISCUSSION

In this study, we report the therapeutic utility of ILR in a large cohort of patients who had failed conventional diagnostic testing for a variety of presumed cardiac symptoms. This study is the largest retrospective study to date in addressing the therapeutic benefit of ILR without limiting to a specific symptom indication.[1,2]

The main findings of the study are that in patients who underwent ILR, over a mean follow-up of 14 months, an arrhythmia was documented in 48% patients, with symptom arrhythmia correlation noted in 32% patients. This led to a change in cardiac management in 42% patients with a number needed to result in a change in management of 2.3 within 14 months of implant. Most patients who required a pacemaker/ICD had syncope/presyncope as an indication for the ILR. The number of patients with syncope or palpitations as indications for ILR implantation needed to result in an additional invasive interventional therapy, such as ICD or pacemaker implant, was 7.5 and 8.5, respectively.

An ILR provides the opportunity for longer-term monitoring in patients with symptoms or conditions presumed to be of an arrhythmic origin. ILR implantation has been reviewed and evaluated in a variety of clinical situations, including unexplained syncope, palpitations, and other presentations that could suggest an arrhythmic cause.[2–4] Prior data have suggested that early rather than late implantation of ILR in patients undergoing evaluation for syncope helps in the reduction of hospitalization and morbidity (53% vs 75%, $P$ value < 0.001).[5]

The age distribution of patients evaluated in this study was lower compared to patients evaluated in the PICTURE registry as well as the EaSyAs,[1] EGSYS2,[6] and ISSUE 2[7] syncope studies. In addition, our group also had fewer comorbidities. The device implantation characteristics mirror the change in technology of ILRs over a period of time as evidenced by the near equal distribution of Reveal XT and Reveal Linq devices implanted. All cases of premature device extraction occurred in the Reveal XT cohort, likely due to the size of the device compared to the smaller Reveal Linq device. Although the contribution of infection to the removal of device was high (9.5%) compared to available evidence,[8,9] this should be considered with caution as only 63 patients (20.2%) had devices removed during a relatively short follow-up period.

### 4.1 | Potential for a change in management

Diagnostic tests are valuable to either rule in or rule out a possible diagnosis of specific symptoms. In our study, 146 (47%) patients had a change in management attributable to ILR monitoring correlating

**TABLE 3** Regression analysis of variables predictive of a change in management post-ILR monitoring

| Change in management (Categorical—Nominal) | UVA | MVA |
|---|---|---|
| | OR (95%CI) | OR (95%CI) |
| | *P* Value | *P* Value |
| Age > 55 Years | 1.37 (0.87-2.18) | Not included |
| | 0.12 | |
| Gender | 1.97 (1.24-3.15) | 2.14 (1.33-3.49) |
| | **0.004** | **0.002** |
| DM | 1.46 (0.72-3) | Not included |
| | 0.29 | |
| HT | 1.17 (0.74-1.86) | Not included |
| | 0.51 | |
| CAD | 1.49 (0.83-2.72) | Not included |
| | 0.19 | |
| CLD | 0.99 (0.12-8.36) | Not included |
| | 0.99 | |
| CKD | 1.66 (0.74-3.91) | Not included |
| | 0.22 | |
| Stroke | 0.99 (0.45-2.18) | Not included |
| | 0.98 | |
| Arrhythmias | 1.77 (0.69-4.87) | Not included |
| | 0.24 | |
| Conduction block | | |
| Prior AF | 0.93 (0.45-1.92) | Not included |
| | 0.84 | |
| CHADS2VaSc score > 1 | 0.99 (0.6-1.61) | Not included |
| | 0.96 | |
| Palpitations | 0.43 (0.22-0.82) | 0.63 (0.3-1.29) |
| | **0.01** | 0.21 |
| Syncope | 2.18 (1.32-3.64) | 2.06 (1.17-3.67) |
| | **0.002** | **0.01** |

AF = atrial fibrillation; CAD = coronary artery disease; CI = confidence interval; CKD = chronic kidney disease; CLD = chronic lung disease; DM = diabetes mellitus; HT = hypertension; IRL = implantable loop recorder; MVA = multivariate analysis; OR = odds ratio; UVA = univariate analysis. The bold values are the P values and indicate significance.

to a number needed to treat of 2.1, a majority of whom (62, 42.5%) had a change in cardiac management. When limited to syncope alone, 77 (39%) patients had a change in management after ILR implantation, correlating to a number needed to treat of 2.5. When limited to palpitations alone, 32 (63%) patients had a change in management after ILR implantation, correlating to a number needed to treat of 1.6. After failing a battery of conventional tests to effect management, 47% patients had a directed change in management with ILR. In a multivariate analysis, the preimplantation indication of syncope (odds ratio [OR] = 2.06; confidence intervals [CI] = 1.17-3.67; *P* value = 0.01) and male gender (OR = 2.14; CI = 1.33-3.49; *P* value = 0.002) were associated with a significant impact on the possibility of change in management post-ILR monitoring (Table 3).

## 4.2 | Role in cryptogenic stroke

When limited to cryptogenic stroke, nearly 20% of patients had an AF diagnosis. This was similar to the findings seen in the study by Gladstone et al.[10] Ziegler et al in their review of the de-identified Medtronic Discovery Link database also detected AF at a median duration of 112 days in 21% of patients postcryptogenic stroke with better results seen using continuous monitoring over intermittent monitoring.[11] Brachmann et al concluded that the longer the time over which continuous monitoring was performed, the higher the yield of diagnosing AF in the CRYSTAL–AF study.[13] Ziegler reproduced the same results in a real-world cohort.[14] A total of 26 % of all our patients underwent monitoring for > 12 months before the absence of AF was concluded. Cessation of monitoring was determined by a combination of factors including patient preference, physician decision, and results of continued follow-up. The CHADS2VaSc scores of those with cryptogenic stroke receiving ILR in our population was similar to that seen in the CRYSTAL-AF study.[15]

## 4.3 | Symptom-rhythm correlation

Therapy was changed based on ILR monitoring in most patients who reported symptoms during monitoring. Our results showed more frequent changes in management than in the PICTURE registry but similar to the study by Krahn et al. [16] The predictive accuracy of the device to rule out cardiac causes in symptomatic patients was similarly high (24%). In the subgroup of patients with syncope, an arrhythmia to symptom correlation was documented in 54 % patients, which likely represents the heterogeneous nature of the etiology of syncope in this group. In the subgroup with unexplained palpitations, symptoms correlated with an arrhythmic etiology in 90% of patients indicating the utility of ILR monitoring for diagnosis and symptom correlation in this subgroup.

De novo detection of potentially high-risk arrhythmias (atrial arrhythmias including AF and ventricular arrhythmias needing ICD) was seen in 44 patients, of whom three patients received ICDs for prevention of sudden cardiac death from ventricular arrhythmias. This finding reinforces the findings of Solomon et al who similarly concluded that 48-h monitoring alone does not identifies all potential high-risk arrhythmias.[17] One limitation of our study is how one defines the duration of AF needed to be regarded as "clinically significant." While robust evidence is present for the significance of AF > 24 h,[18] it is unclear how shorter episodes contribute to strokes.[19–23]

## 4.4 | Limitations

Our study has several limitations. This is a single-center retrospective design with no randomization and no comparison group. The findings may be unique to our center and reflect institutional practice patterns. Our study did not address cost and did not allow us to characterize which of the subgroups would benefit most from ILR monitoring in a cost-effective manner due to varying insurers and levels of payment. However, this has been studied in a microcosting study by Edvardsson et al who concluded that avoiding repetition and early prescription

of testing (such as ambulatory monitoring) were important considerations in choosing when to implant an ILR when attempting to reduce costs.[24] They recommended a standard structured testing format prior to implantation to maximize cost efficacy of long-term monitoring. We were unable to evaluate this in our study.

## 5 | CONCLUSIONS

In a large cohort of patients, ILR implantation provided diagnostic and therapeutic guidance in 48% and 47% of patients, respectively. Nearly one out of every two patients with a change of management had a cardiac-specific therapy implemented due to ILR monitoring. These findings confirm the utility of ILR in patients with single or multiple symptoms of a possible arrhythmic etiology.

### CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

### ORCID

*Peter A. Noseworthy MD* http://orcid.org/0000-0002-4308-0456
*Paul A. Friedman MD* http://orcid.org/0000-0001-5052-2948
*Suraj Kapa MD* http://orcid.org/0000-0003-2283-4340

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### SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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