To retrieve, or not to retrieve: System revisions with the Micra transcatheter pacemaker

Eric Grubman, MD, FHRS,* Philippe Ritter, MD,† Christopher R. Ellis, MD, FHRS,‡ Michael Giocondo, MD,§ Ralph Augustoniti, MD, FHRS,¶ Petr Neuzil, MD,† Bipin Ravindran, MD,¶ Anshul M. Patel, MD, FHRS,** Pamela Omdahl, MBA,†† Karen Pieper, BS,††† Kurt Stromberg, MS,†† J. Harrison Hudnall, BS,†† Dwight Reynolds, MD, FHRS,‡‡ for the Micra Transcatheter Pacing Study Group

From the *Section of Cardiovascular Medicine, Yale University School of Medicine, New Haven, Connecticut, †Hôpital Cardiologique du Haut-Lévêque, CHU Bordeaux, Université Bordeaux, IHU LIRYC, Bordeaux, France, §Vanderbilt University Medical Center, Nashville, Tennessee, ¶St. Luke’s Mid-American Heart Institute, Kansas City, Missouri, ‡The Ohio State University Wexner Medical Center, Columbus, Ohio, ††Na Homolce Hospital, Prague, Czech Republic, **Michigan Heart, Ypsilanti, Michigan, §§Emory University Hospital, Atlanta, Georgia, †††Medtronic, plc, Mounds View, Minnesota, and ‡‡Cardiovascular Section, University of Oklahoma Health Sciences Center, OU Medical Center, Oklahoma City, Oklahoma.

BACKGROUND Early experience with leadless pacemakers has shown a low rate of complications. However, little is known about system revision in patients with these devices.

OBJECTIVE The purpose of this study was to describe the system revision experience with the Micra Transcatheter Pacing System (TPS).

METHODS Patients with implants from the Pre-market Micra Transcatheter Pacing Study and the Micra Transcatheter Pacing System Continued Access Study (N = 989) were analyzed and compared with 2667 patients with transvenous pacemakers (TVPs). Revisions included TPS retrieval/explant, repositioning, replacement, or electrical deactivation (with or without prior attempt at retrieval, generally followed by TVP implant) for any reason. Kaplan-Meier revision rates were calculated to account for varying follow-up duration and were compared using a Fine-Gray competing risk model.

RESULTS The actuarial rate for revision at 24 months postimplant was 1.4% for the TPS group (11 revisions in 10 patients), 75% (95% confidence interval 53%–87%; P < .001) lower than the 5.3% for the TVP group (123 revisions in 117 patients). TPS revisions occurred 5–430 days postimplant for elevated pacing thresholds, need for alternate therapy, pacemaker syndrome, and prosthetic valve endocarditis; none were due to device dislodgment or device-related infection. TPS was disabled and left in situ in 7 cases, 3 were retrieved percutaneously (range 9–406 days postimplant), and 1 was surgically removed during aortic valve surgery.

CONCLUSION The overall system revision rate for patients with TPS at 24 months was 1.4%, 75% lower than that for patients with TVPs. TPS was disabled and left in situ in 64% of revisions, and percutaneous retrieval was successful as late as 14 months postimplant.

KEYWORDS Leadless pacemaker; Pacemaker; Pacemaker revision; Retrievals; Transcatheter pacemaker

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Introduction

Complications associated with conventional transvenous pacing systems occur early at or near the time of device implantation and late, months to years after device implantation. Early device complications may be due to issues involving the pulse generator or lead and can include acute dislodgment of the leads, lead/connector issues, system infection, or pacemaker syndrome. Late system complications are more likely the result of lead failure, infection involving the pocket and/or leads, premature battery depletion, or device malfunction. Regardless of the timing, revision of the pacing system is often deemed necessary. Revision of the pacing system may also be needed to upgrade the pacing system (ie, addition of leads and therapies). In the FOLLOWPACE study, transvenous pacing system revisions occurred at a rate of 4.22% within 2 months of implant and at 4.02% during long-term follow-up.†
Transcatheter Pacing System (TPS) were developed, in part, to minimize or eliminate many of the complications associated with transvenous pacemaker systems. As currently available, Micra TPS (Medtronic) is a self-contained VVIR pacemaker that is inserted directly into the right ventricle via the femoral vein, eliminating the need for either a lead or a subcutaneous pocket. Its functionality and features are similar to those of conventional VVIR pacemakers and can be programmed via a standard programmer. At the end of the service, the TPS can be electronically disabled and left in place. In addition, the device has a feature that allows for percutaneous snare retrieval and removal. All these factors should greatly reduce the need for system revision with transcatheter pacemakers as compared with transvenous pacemaker systems.

The need for system revision and the success in revising transcatheter systems has not yet been characterized. We sought to review the experience with Micra to determine the clinical frequency, reason for system revision, and success of system revision with this TPS.

Methods
Study design and oversight
Patients were included from the Pre-market Micra Transcatheter Pacing Study (ClinicalTrials.gov identifier: NCT02004873) and from the Micra Transcatheter Pacing System Continued Access Study (CA; ClinicalTrials.gov identifier: NCT02488681). The design, details, and results of the Micra Transcatheter Pacing Study have been previously described. Briefly, the prospective nonrandomized trial, which had a historical comparison cohort of transvenously implanted pacemakers, evaluated the short-term and long-term safety of the Micra transcatheter pacemaker in a large cohort of patients around the world. The Micra CA study was conducted to allow for continued access of the Micra transcatheter pacemaker in the United States while the device was pending Food and Drug Administration approval. Patients were enrolled in the same centers as the original study.

In both the initial and CA studies, enrolled patients met class I or II guideline recommendations for ventricular pacing and there were no comorbidity restrictions. Both studies were sponsored by the manufacturer Medtronic plc (Mounds View, MN). The protocols were approved by the ethics committee at each of the centers, and all patients provided written informed consent. Adverse events were adjudicated by the same Clinical Events Committees that comprised independent physicians.

Study device and system modification procedure
The Micra TPS is a single-chamber, self-contained, miniaturized ventricular pacemaker (0.8 cm³, 2.0 g) and is 90% smaller than a traditional pacemaker. The Micra device is implanted through a femoral vein by advancing a delivery catheter into the right ventricle,8 positioning proximal to the retrieval feature, and complete encapsulation is expected. Micra has a programmable Device Off mode that permanently deactivates pacing and sensing (OOO) in the event of an electrical reset (“power on reset”) or upon reaching the end of the service. Thus, the device may be programmed to Device Off (OOO) mode and remain in the body indefinitely. Alternatively, the Micra device was designed with a retrieval feature at the proximal end. The Micra delivery tool may be used for retrieval. The lumen allows for a compatible off-the-shelf snare, which once inserted is advanced to the right ventricle, positioned proximal to the retrieval feature, snared, and pulled back into the device cup (Figure 1).

Objective
The objective of this analysis was to describe the system revision experience with the Micra TPS. In addition, the Micra TPS system revision rate will be compared with the system revision rate of conventional transvenous pacemakers using a predefined historical control data set. Revisions included TPS retrieval/explant, repositioning, replacement, or electrical deactivation (with or without prior attempt at retrieval, generally followed by transvenous pacemaker implantation) for any reason.

Statistical analysis
TPS patient data from the initial and CA studies were pooled. To compare TPS system revisions with conventional pacemaker system revisions, an individual patient level data set of 2667 de novo patients with pacemaker from 6 recent Medtronic trials of dual-chamber pacing with transvenous leads was assembled. In order to approximate the rate of system revisions for a single-chamber data set, system revision events involving only the right atrial lead were excluded. The Fine-Gray competing risk model was used to compare the system revision rate through 24 months postimplant between the TPS and historical control groups. For this model, the event of interest was system revision for any reason and the competing event was death unrelated to system revision. In addition, this same comparison was repeated with a 1:1 propensity-matched subgroup of control patients with transvenous pacemakers to adjust for differences in patient characteristics (see Supplemental Appendix for details). All analyses were conducted with SAS version 9.4 (SAS Institute, Glastonbury, Connecticut) or the R statistical package (R Project for Statistical Computing, Vienna, Austria).

Results
A total of 989 patients underwent successful TPS implantation, including 720 in the initial trial and 269 in the continued access study. The mean follow-up duration was 12.6 ± 7.6 months (16.4 ± 4.9 months in the initial trial and 2.4 ± 2.4 months in the continued access study). There were a total of 11 system revisions in 10 patients, representing a 1.4% (95% confidence interval [CI] 0.7%–2.6%) actuarial rate through 24 months of follow-up (Figure 2). Of the 10 patients requiring TPS system revision, 4 were women and the mean age was 71.1 ± 14.6 years (range 43–92 years) (Table 1).
Details of the individual cases requiring revision are presented in Table 2. In summary, TPS was disabled and left in situ in 7 of 11 of revisions (range 5–296 days postimplant); in 5 patients, there was no retrieval attempt, 1 retrieval attempt was aborted because of fluoroscopy failure, and 1 retrieval attempt was unsuccessful because of inability to dislodge device. Remaining revisions included 3 percutaneous retrievals (range 9–406 days postimplant) and 1 retrieval during surgical valve replacement (430 days postimplant). There were no complications associated with the attempted removal of these systems. When a transvenous system was implanted in the presence of an abandoned deactivated TPS, there were no reported interactions between the 2 systems, either at the time of implantation or in subsequent follow-up.

Early revision cases (5–104 days postimplant)

Five patients required system revision within the first 6 months of device implantation. These early revisions were due to elevated pacing capture threshold in 3 patients, the development of worsening heart failure in 1 patient, and the development of pacemaker syndrome in 1 patient.

Retrieval was attempted in 2 patients requiring early revision and was successful in both cases. In 1 case, the leadless pacemaker was successfully snared using the proximal retrieval feature of the device. In the other instance, it was retrieved using a conventional snare, which was able to engage the fixation tines of the device. Both these patients underwent successful reimplantation of a TPS.

![Figure 1](image1.png)

**Figure 1** Micra retrieval using a delivery catheter and snare. A: Micra delivery system cup being advanced toward the proximal end of the delivery system. B: The snare has captured the proximal retrieval feature, and the snare sheath has been advanced to close the loop around the neck of the retrieval feature. C: Recapture cone is extended past the end of the device cup. D: Recapture cone is axially aligned and mated with the proximal end of the device to allow centering of the device to pull inside the cup.

![Figure 2](image2.png)

**Figure 2** System revision rate for Micra vs transvenous control cohort. Subdistributional HR derived from data through 24 months postimplant for each cohort by comparing the cumulative incidence (rate) of system revision using the Fine-Gray competing risk model in the presence of competing risk of death for any reason. The inset shows the same data on an enlarged y-axis. For the 1:1 propensity-matched subset, the HR was 0.27 (95% CI 0.14–0.54; P < .001). CI = confidence interval; HR = hazard ratio.
these patients, the second TPS developed an elevated pacing capture threshold and the device was programmed Off and left in situ without attempting retrieval. A transvenous pacing system was then implanted.

Retrieval was not attempted in the remaining 3 patients requiring early revision. In these patients, the device was programmed to Device Off mode (2 patients) or VVI40 (1 patient) and a transvenous system was implanted.

Late revision cases (229–430 days postimplant)
Five patients required system revision more than 6 months after device implantation. These late revisions were due to worsening heart failure in 2 patients, pacemaker syndrome in 1 patient, prosthetic valve endocarditis in 1 patient (430 day post pacemaker implantation), and battery depletion in 1 patient (406 days post pacemaker implantation). The patient with a battery-depleted device had an elevated threshold at

### Table 1 Baseline characteristics of patients with Micra revision

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Summary*</th>
</tr>
</thead>
<tbody>
<tr>
<td>First revision day†</td>
<td>5</td>
<td>16</td>
<td>32</td>
<td>44</td>
<td>104</td>
<td>229</td>
<td>259</td>
<td>296</td>
<td>296</td>
<td>406</td>
<td>430</td>
</tr>
<tr>
<td>Age (y)</td>
<td>67</td>
<td>61</td>
<td>92</td>
<td>88</td>
<td>77</td>
<td>43</td>
<td>62</td>
<td>83</td>
<td>65</td>
<td>73</td>
<td>71.1 ± 14.6</td>
</tr>
<tr>
<td>Sex: female</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>40% (4/10)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>30% (3/10)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>20% (2/10)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>60% (6/10)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>40% (4/10)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>90% (9/10)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10% (1/10)</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>30% (3/10)</td>
</tr>
<tr>
<td>Left bundle branch block</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0% (0/10)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20% (2/10)</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>60</td>
<td>60</td>
<td>55</td>
<td>55</td>
<td>58</td>
<td>64</td>
<td>45</td>
<td>55</td>
<td>NA</td>
<td>55</td>
<td>56.3 ± 5.3</td>
</tr>
</tbody>
</table>

*LVEF = left ventricular ejection fraction; NA = not applicable.
*Mean ± SD values are displayed for continuous variables.
†First revision day relative to the initial Micra implant date.

### Table 2 System revisions

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Reason for revision</th>
<th>Days postimplant</th>
<th>Micra removal attempt</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Elevated pacing capture threshold</td>
<td>5</td>
<td>Percutaneous</td>
<td>Elevated thresholds: Micra removed. New Micra implanted.</td>
</tr>
<tr>
<td></td>
<td>Elevated pacing capture threshold</td>
<td>9*</td>
<td>None</td>
<td>Micra turned off. Transvenous pacing system implanted.</td>
</tr>
<tr>
<td>2</td>
<td>Elevated pacing capture threshold, device dislocation</td>
<td>16</td>
<td>Percutaneous</td>
<td>Micra removed. New Micra implanted.</td>
</tr>
<tr>
<td>3</td>
<td>Elevated pacing capture threshold</td>
<td>32</td>
<td>None</td>
<td>Micra programmed to Device Off. Transvenous pacing system implanted.</td>
</tr>
<tr>
<td>4</td>
<td>Pacemaker syndrome</td>
<td>44</td>
<td>None</td>
<td>Micra programmed to VVI 40 beats/min. Transvenous BiV pacing system implanted.</td>
</tr>
<tr>
<td>5</td>
<td>Need for BiV therapy</td>
<td>104</td>
<td>None</td>
<td>Micra programmed to Device Off. Transvenous BiV system implanted.</td>
</tr>
<tr>
<td>6</td>
<td>Pacemaker syndrome</td>
<td>229</td>
<td>Percutaneous</td>
<td>Micra unable to be removed, turned to Device Off mode. Transvenous pacing system implanted.</td>
</tr>
<tr>
<td>7</td>
<td>Need for BiV therapy—cardiac failure</td>
<td>259</td>
<td>Percutaneous</td>
<td>Micra device snared but unable to be removed after fluoroscopy malfunction. Abandoned retrieval and turned to Device Off mode. Transvenous BiV system implanted.</td>
</tr>
<tr>
<td>8</td>
<td>Cardiac failure</td>
<td>296</td>
<td>None</td>
<td>Micra programmed to Device Off. BiV device implanted.</td>
</tr>
<tr>
<td>9</td>
<td>Expected battery depletion due to elevated Micra threshold</td>
<td>406</td>
<td>Percutaneous</td>
<td>Micra removed. Transvenous system implanted.</td>
</tr>
<tr>
<td>10</td>
<td>Prosthetic valve endocarditis</td>
<td>430</td>
<td>Surgical</td>
<td>Micra surgically removed, along with porcine aortic valve. Patient died.</td>
</tr>
</tbody>
</table>

BiV = biventricular.
*System revision occurred 9 d after the replacement Micra was implanted (14 d postindex procedure).
the time of device implantation and was programmed to a pacing output of 5.0 V at 1.0 ms before hospital discharge.

Percutaneous retrieval was attempted in 3 patients requiring late revision and was successful in 1 patient. In the successful retrieval, the device was percutaneously snared via the proximal retrieval feature of the device and removed. In the second patient, the device was snared but attempts at removal were not successful. In the third patient, the device was snared but retrieval was aborted because of fluoroscopy equipment failure. These retained devices were turned to Device Off mode and left in place. Transvenous systems were implanted in all 3 patients.

Retrieval was not attempted in 2 patients requiring late revision. One patient developed fulminant endocarditis and sepsis because of an infected prosthetic valve more than 1 year after TPS implantation. The device was surgically removed at the time of urgent aortic valve replacement. This patient died within 24 hours of the valve replacement procedure; however, this was deemed to be not related to the Micra removal, but rather related to the combination of infection and surgical removal of the valve. In the second patient, no retrieval attempt was made, the device was programmed Off and left in place, and a biventricular transvenous system was implanted.

Comparison to historical control

In the historical control population, there were 123 revisions in 117 patients through 24 months of follow-up (actuarial rate 5.3%; 95% CI 4.4%–6.4%) (Figure 2), with 107 (87.0%) occurring within 12 months. The risk of system revision through 24 months postimplant was 75% lower for patients with Micra relative to control patients with transvenous pacemakers (hazard ratio 0.25; 95% CI 0.13–0.47; P < .001) (Figure 2). To account for differences in age, sex, and comorbidities between patients with Micra and patients with transvenous pacemakers, propensity score matching was performed (see Supplemental Table 1 for details). After matching, a similar reduction in system revisions was observed with Micra (hazard ratio 0.27; 95% CI 0.14–0.54; P < .001). The majority of transvenous pacemaker system revisions occurring within 24 months of implant were lead related (93 [75.6%]), and the remainder were related to therapy (16 [13.0%]), the pocket (9 [7.3%]), the lead and pocket (2 [1.6%]), or unknown (3 [2.4%]). Most common lead-related revisions were due to lead dislodgment (46/93, 49%), elevated thresholds (29/93, 31%), and perforation/effusion (7/93, 7%). Heart failure (12/123, 10%) and infections (7/123, 6%) also led to system revisions. The rest were accounted for by various types of events (see Supplemental Table 2 for complete list).

Discussion

Pacemaker system revision is a significant cause of morbidity and cost in patients with implantable pacemakers. Transcatheter pacemakers are designed to mitigate complications associated with the lead and subcutaneous pocket, common sources of transvenous system malfunction and infection. The devices are small, lack a conventional lead, do not require a pocket, and can quickly become encapsulated. These factors should significantly decrease the risk of complications requiring system revision. We have demonstrated a low incidence of system revision in this study of 989 patients with TPS, and there were no subsequent complications related to the Micra modification. The overall actuarial rate of complications necessitating system revision was only 1.4% through 2 years after implant as compared with a 5.3% revision rate in patients undergoing transvenous pacemaker implantation.

Despite these technological advances, some patients still require TPS system revision because of either battery deple-


tion, need for system upgrade (such as a biventricular device), or complications related to the device. We have demonstrated that the Micra TPS device can be percutaneously removed in some patients more than 1 year after implantation. It is expected that the Micra TPS will become encapsulated over time; however, because of the small number of patients with retrieval attempts, we cannot yet determine when percutaneous retrieval will become unlikely to be successful. In addition, the TPS can be permanently deactivated and left in place, which is likely the preferred alternative, given its small size. For those devices left in place, there was no interaction, electrical or mechanical, with subsequently implanted pacing systems, including both transvenous pacemakers and TPS devices. Although there were no cases in the present data set, multiple deactivated TPS devices can potentially be left in place.

The substantially lower rate of system revisions with Micra compared with transvenous pacemakers can largely be accredited to the lack of dislodgment, low rate of threshold elevation, and absence of infections. These data from the transvenous pacemaker cohort confirm that most complications leading to system revision are due to the lead and pocket. Micra eliminates these risks because of the absence of a lead and pocket, but the strong safety profile may also be attributed to the novel fixation method. Micra has 4 flexible nitinol tines designed to provide secure holding force with the cardiac tissue. These tines are separate from the pacing electrode, isolating the cardiac tissue injury and allowing for stable electrical performance.

Study limitations

Our study has several limitations. TPS is a relatively new device, and the length of follow-up is limited to 1 year in the majority of patients with some follow-up to 2 years. However, a significant proportion of transvenous system revisions occur within the first year and our results are likely quite meaningful. We assume that device longevity for TPS will be comparable to transvenous systems. TPS battery longevity is projected to be excellent, but this is still being clinically evaluated. Rates of TPS retrieval success are reflective of the experience of the current cohort and should not be broadly interpreted as the general success rates that may emerge as clinical experience accumulates. The historical control comprises dual-chamber
events and may overestimate the rate of system revisions; however, to account for this, we have excluded events related to the right atrial lead.

**Conclusion**

In this study of patients undergoing leadless pacemaker implantation, the need for system revision was extremely low and was 75% lower than the rate for patients with transvenous pacemakers. In those patients requiring revision, the device could safely be either disabled and left in place or removed, as late as 14 months after implantation.

**Acknowledgments**

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**Appendix**

**Supplementary data**

Supplementary data associated with this article can be found in the online version at [http://dx.doi.org/10.1016/j.hrthm.2017.07.015](http://dx.doi.org/10.1016/j.hrthm.2017.07.015).

**References**