Novel use of 3-dimensional transthoracic echocardiography to guide implantation of a leadless pacemaker system

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Introduction

Leadless cardiac pacing systems were developed to address the limitations of traditional transvenous pacing devices, particularly pocket- and lead-related complications.1,2 Results from the Micra Transcatheter Pacing Study and the Micra Post Approval Registry have demonstrated high implantation success rates and low risk of major adverse events, with a >60% reduction in complications compared to transvenous pacemakers.2–4 For leadless devices, appropriate positioning within the right ventricle (RV) is critical to optimize pacing capabilities and avoid mechanical complications, including cardiac perforation and interactions with the tricuspid valve (TV) and subvalvular apparatus. During the implantation procedure, fluoroscopy with radiographic contrast dye is most often used to guide placement. However, fluoroscopy is limited in its ability to accurately define RV anatomy. Use of contrast may also be undesirable in patients with contrast-related intolerances or poor renal function.

Here we demonstrate the feasibility of 3-dimensional transthoracic echocardiography (3D-TTE) as an imaging modality to guide implantation of leadless pacemakers.

Case report

A 57-year-old woman with an extensive cardiac history including primum atrial septal defect (ASD) and tricuspid regurgitation (TR) with repair of the ASD, TV, and atrioventricular (AV) canal 12 years prior, complicated by pulmonary hypertension and chronic RV failure, presented to the hospital for progressive dyspnea on exertion, palpitations, and lightheadedness. She was found to have dehiscence of the ASD patch. Transesophageal echocardiography showed bidirectional interatrial communication with severe biatrial enlargement, new severe TR, and a severely dilated RV with moderately reduced function. Left ventricular systolic function was preserved. Plans were made for surgical intervention, including ASD repair and TV repair or replacement. During the hospitalization, several episodes of Mobitz II heart block were identified on telemetry. The patient’s baseline electrocardiogram showed sinus rhythm with first-degree AV block and bifascicular block (right bundle branch block with left anterior fascicular block). Owing to evidence of high-grade AV block, electrophysiology was consulted for consideration of preoperative pacemaker placement. An interdisciplinary team including the patient, cardiac surgery, congenital cardiology, and electrophysiology favored placement of a leadless pacemaker device capable of AV

KEY TEACHING POINTS

- Accurate positioning of leadless pacemaker devices within the right ventricle (RV) is critical to reducing the risk of periprocedural complications and optimizing device function.
- Use of 3-dimensional transthoracic echocardiography as an adjunct to fluoroscopy during implantation can improve visualization of the pacemaker device in relation to cardiac structures and reduce or eliminate the need for contrast dye administration.
- Optimal echocardiographic views will vary depending on individual patient anatomy. In this case, an RV modified apical 4-chamber view was the best view to visualize positioning of the device in the apical septum.

KEYWORDS
Transesophageal echocardiography; Micra; Leadless pacemaker; Right ventricular septum; Transcatheter pacing system (Heart Rhythm Case Reports 2022;8:366–369)
synchrony to prevent entrapment and dislodgement of an RV lead during TV repair.

The patient had baseline chronic kidney disease and an allergy of anaphylaxis to iodine-based contrast agents. Hence, administration of contrast during implantation was avoided. Because of the severely dilated RV, accurate fluoroscopic localization was challenging. Therefore, real-time 3D-TTE was used in addition to biplane fluoroscopy for the placement of a leadless Medtronic Micra AV (Medtronic, Minneapolis, MN) device. TTE was performed using a Philips EPIQ ultrasound system (Philips, Amsterdam, Netherlands) and X5-1 transducer with biplane and 3D capabilities. Device unsheathing was carried out under fluoroscopic guidance. TTE was used after unsheathing and during deployment along with fluoroscopy. Deployment was attempted in the apical septal position, away from the TV and papillary muscles. An RV modified apical 4-chamber view with 2D and 3D imaging was used to assess positioning of the Micra device in the RV apex, and biplane imaging confirmed an orientation toward the septum without interaction with the TV and subvalvular apparatus (Figures 1 and 2, Supplemental Video). The RV inflow view and parasternal short-axis view at the level of the apex were also used to confirm position. The device was repositioned 4 times before ultimate placement in the apical septum with satisfactory sensing, impedance, and capture thresholds. A tug test under echocardiographic guidance demonstrated at least 2 tines connecting around RV trabeculae. It was confirmed with Doppler echocardiography that baseline TR had not worsened. The device was successfully deployed. Postdeployment imaging showed stable device position in the apical septum.

The patient recovered well immediately following the procedure and at 3 months from implantation had not experienced any complications of pacemaker placement.

Discussion

We describe the successful use of 3D-TTE along with biplane fluoroscopy to facilitate the appropriate placement of a leadless pacemaker system in a patient with both contraindications to iodine-based contrast and complicated cardiac anatomy, which made accurate, real-time visualization of the device especially critical. Fluoroscopy with radiographic contrast is currently the standard imaging modality used during implantation of leadless pacemaker technology. To the best of our knowledge, this is one of the first reports to demonstrate the feasibility of 3D-TTE in leadless pacemaker implantation. Further studies are needed to evaluate the efficacy of this technique in a broader patient cohort and potential safety advantages over current practices.

Appropriate positioning of leadless pacemaker systems is critical to avoid rare but potentially catastrophic procedural complications and may have important implications for longer-term cardiac function, including the development of TV dysfunction. During implantation, the device must be oriented away from the RV free wall and along the septum, either in a septal-apical or midseptal position, to minimize the risk of free wall perforation. In individuals with abnormal RV anatomy including dilated cardiomyopathy, as was the case in the patient described here, achieving optimal placement is more challenging. As longer-term follow-up data become available, there is also growing evidence to suggest that positioning of the leadless system within the RV has important implications for cardiac and AV valve function. This was demonstrated in a recent study that showed that at 1 year after leadless pacemaker implantation, a more septal rather than apical orientation was associated with greater TV dysfunction owing to mechanical interference of the device with the TV or subvalvular apparatus.5
Echocardiography is an established imaging modality used periprocedurally in both surgical and catheter-based cardiac interventions. Particularly for pacemaker implantation that involves primarily right-sided and therefore more anteriorly oriented structures, TTE represents an attractive adjunct to commonly used imaging modalities, including fluoroscopy. It is noninvasive, widely available, and inexpensive. Cardiac structures can be visualized in real time and in different planes with limited manipulation. Compared to fluoroscopy, 3D imaging capabilities also offer significantly better spatial resolution to visualize orientation of the device relative to other cardiac structures. Finally, use of TTE during pacemaker implantation may reduce the need for contrast dye administration, a consideration that is particularly important in individuals with renal insufficiency or allergies to contrast.

Intracardiac echocardiography (ICE) is another imaging modality that has been used intraoperatively to guide leadless pacing system implantation.6 Three-dimensional TTE was favored over ICE for this procedure for several reasons. ICE is more invasive than TTE, as use of the ICE catheter requires an additional venous sheath, and is associated with additional complications, including bleeding, arrhythmias, vascular complications, and cardiac perforation. It is also more limited in its field of view, particularly for 3D imaging, and catheter manipulation within cardiac chambers is more challenging. Finally, ICE catheters are more expensive than TTE technology.

In this case, an RV modified apical 4-chamber view was the best view to visualize positioning of the device in the apical septum. RV inflow and parasternal short-axis views were also useful for real-time guidance. Optimal echocardiographic views will likely vary depending on individual patient anatomy.

**Conclusion**

We report the novel application of 3D-TTE to guide placement of a leadless pacemaker system in a patient with severe RV dilation and contraindications to contrast dye administration. Use of 3D-TTE as an adjunctive imaging modality to fluoroscopy during leadless pacemaker implantation can facilitate more accurate device placement, which may
improve procedural safety and long-term patient outcomes. Additional study is needed to delineate its utility.

Appendix
Supplementary data
Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2022.02.014.

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