JACC: CASE REPORTS VOL. 4, NO. 23, 2022

CASE REPORT

ADVANCED

CLINICAL CASE: TECHNICAL CORNER

A First-in-Human Complete Insertion of Single-Chamber Cardiac Pacemaker Using Ultrasound

Habib Rehman Khan, MBBS, PHD

ABSTRACT

Pacemaker insertion incurs significant costs for fluoroscopy machines and operator-related musculoskeletal injuries from long-term use of radiation protection equipment. Moreover, there are small potential risks to patients from pneumothorax, lead dislodgment, and cardiac perforation. We report a first-in-human case report of successful pacemaker insertion performed entirely with ultrasound. (**Level of Difficulty: Advanced.**) (J Am Coll Cardiol Case Rep 2022;4:101528)
© 2022 The Author. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

An 89-year-old man with a history of dizziness and dyspnea during walking was admitted to the University Hospital (London Health Sciences Center, London, Ontario, Canada) in atrial fibrillation (AF) with a slow ventricular rate response while taking metoprolol, 25 mg twice a day. He described a few months of intermittent, sudden onset lightheadedness and, at other times, having a fast heart rate. He remained stable for 48 hours without needing a temporary pacing wire, vasopressor agents, or chronotropic agents while his metoprolol was stopped. During these 48 hours, he had both bradycardic and tachycardic responses in AF while feeling dizzy, with a heart rate as low as 34 beats/min. Physical examination showed a heart rate of 40 to 50 beats/min with normal jugular venous pressure, irregular heart sounds with a soft ejection systolic murmur, and no added third or fourth heart sound. Chest examination showed normal thorax expansion, equal air entry in both lungs, and no additional sounds. The abdominal examination did not reveal any abnormality, and the results of the neurologic examination were normal.

LEARNING OBJECTIVES

- To illustrate steps of implanting a pacemaker by using ultrasound.
- To show a first-in-human implantation of a pacemaker with ultrasound and potential advantages of using ultrasound for device implantation in the future.

PAST MEDICAL HISTORY

His history included permanent AF treated with appropriate anticoagulation therapy, hypertension, dyslipidemia, osteoarthritis, mild aortic stenosis, mild to moderate mitral regurgitation, a cerebrovascular accident 7 years earlier, and prostate cancer.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis included orthostatic hypotension, medication-related bradycardia, and parasympathetic activation.

From the Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada.
The author attests they are in compliance with human studies committees and animal welfare regulations of the author's institution and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received April 18, 2022; revised manuscript received May 23, 2022, accepted May 26, 2022.

ISSN 2666-0849 https://doi.org/10.1016/j.jaccas.2022.05.034

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

RA = right atrium

RV = right ventricle

INVESTIGATIONS

Laboratory blood investigations showed the following: hemoglobin, 142 g/L; white cell count, 8.3 × 10^9/L; thyroid-stimulating hormone. 1.36 mIU/L; sodium, 140 mmol/L; potassium, 4.1 mmol/L; urea, 8.9 mmol/L; and creatinine, 110 μmol/L.

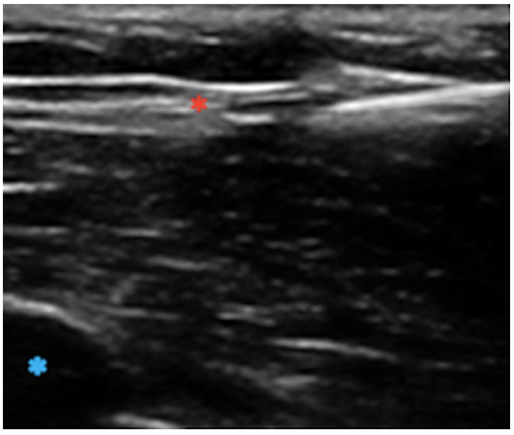
An echocardiogram revealed a sclerotic aortic valve without stenosis, normal biventricular size, biplane left ventricular function of 64%., biatrial dilatation, and mild tricuspid and mitral regurgitation.

MANAGEMENT

A single-chamber permanent pacemaker was chosen to treat the bradycardia and to allow for more medications to prevent tachycardia. Ultrasound-guided pacemaker implantation was selected to reduce risks of pneumothorax and cardiac perforation because the patient had frailty.

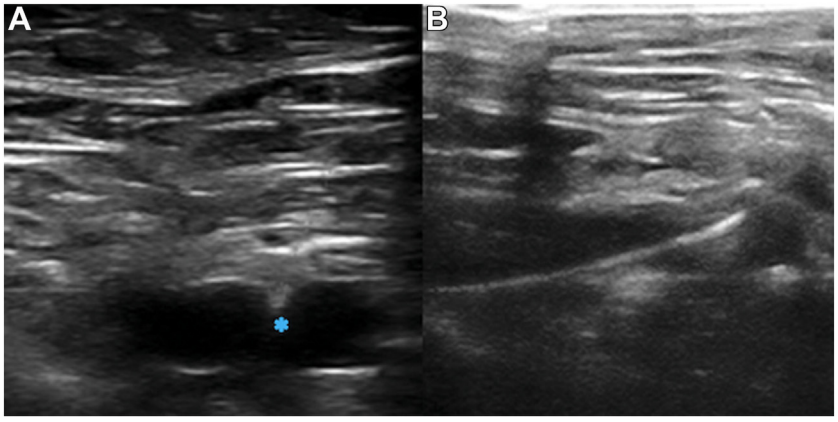
The ultrasound-guided pacemaker insertion steps were as follows: A focused echocardiogram was performed to determine acquisition windows to visualize the right atrium (RA) and right ventricle (RV) clearly. After the skin was cleaned and draped for the procedure, local anesthesia was injected using ultrasound into the layer overlying the prepectoral fascia where the pacemaker generator was placed (Figure 1). The axillary vein was first visualized and confirmed by compression in the short axis and long axis, along with a lack of arterial pulsations. The axillary vein was accessed, and an 0.035-inch guidewire was inserted (Figures 2A and 2B) and passed to the RA by acquiring a subcostal view (Figure 3). The skin incision was made, and a pocket was created for the generator. A 52-cm active fixation pacing lead (Medtronic) was inserted through a peel-away sheath to the RA. The stylet of the lead was shaped with a 60° to 70° curve to allow the lead to be directed toward, and passed through, the tricuspid valve (Figure 4) to the apex of the RV. The pacing lead stylet had a secondary curve added to point the tip of the lead to the septum (Figure 5). The lead was advanced gently until

FIGURE 1 Ultrasound-Guided Local Anesthesia



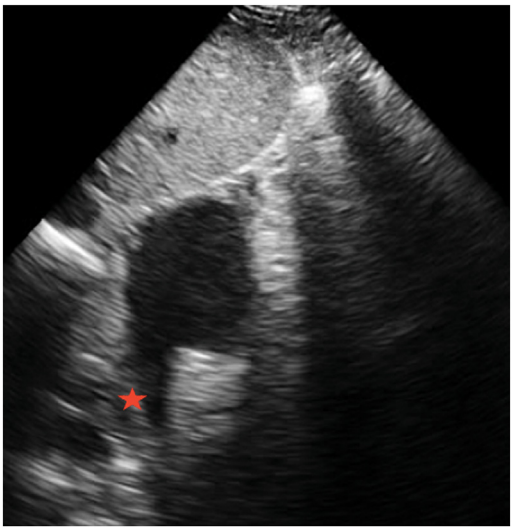
Anesthetic was administered into soft tissue above the prepectoral fascia **(red asterisk)** with the axillary vein view below **(blue asterisk).**

FIGURE 2 Ultrasound-Guided Guidewire Insertion



(A) The needle approaching the axillary vein **(asterisk)** and **(B)** successful confirmation of the guidewire in the lumen.

FIGURE 3 Guidewire Placement Confirmed

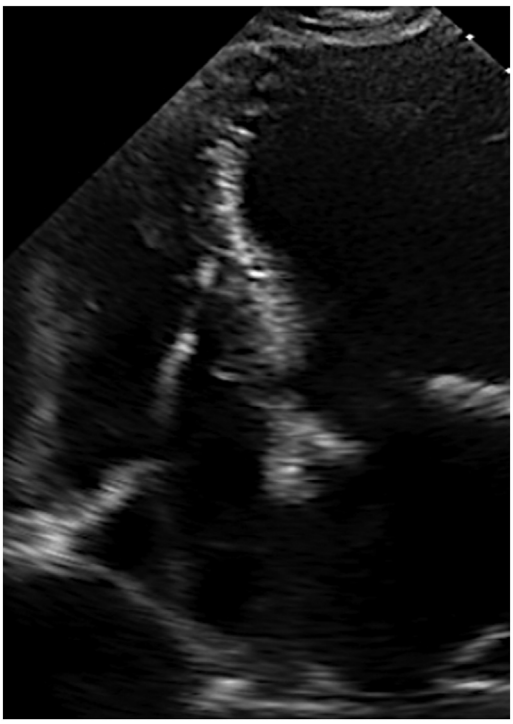


The guidewire is confirmed in the superior vena cava **(asterisk)** entering the right atrium.

mild resistance was felt under direct visualization and was actively fixed with a bipolar electrogram revealing ventricular sensing of 9.1 mV. The threshold was confirmed to be 0.5 V at 0.4 ms pulse width. The lead slack was adjusted by moving the lead from the midatrial position (Figure 6A) to oppose the atrial wall close to the level of the inferior vena cava (Figure 6B). The lead was secured to the prepectoral muscle and connected to a pulse generator, and the wound was closed in layers with absorbable sutures. A chest radiograph confirmed good lead slack and position (Figure 7). The patient was seen 1 week and 1 month after pacemaker implantation, and pacing parameters were shown to be acceptable (Table 1).

FIGURE 4 Subcostal Foreshortened View Showing Pacing Lead Approaching the Tricuspid Valve by Using a Gradual Curved Stylet

FIGURE 5 Pacing Lead Stylet Shaped to Point Toward the Right Ventricular Septum

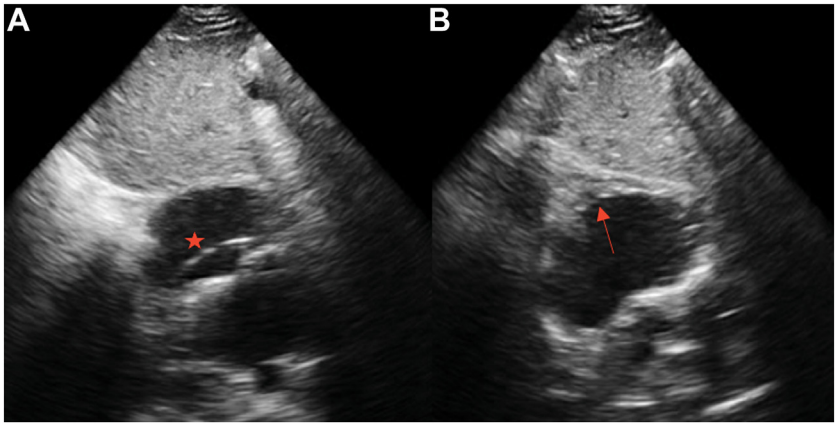


DISCUSSION

Insertion of cardiac implantable electronic devices is commonly performed in most hospitals with cardiovascular services to treat bradycardia. The number of pacemakers implanted in Europe has increased over the last decade, with reports of 600 per million population in 2010 to 702 per million in 2013.[1] Complications arising from pacemakers include pneumothorax (1%-4%), early pocket hematoma or infection (0.5%-7.7%), vascular injury (0.1%-2%), lead dislodgment (4%), and cardiac perforation (1%-3%).[2]

Reduction in vascular complications has been achieved by cephalic vein cut-down or by using ultrasound-guided access to the axillary vein.[3,4] Ultrasound-guided axillary vein access is safe,

FIGURE 6 Lead Slack Adjusted in the Right Atrium



Lead slack adjustment from **(A)** starting **(asterisk)** to **(B)** the final position **(arrow).**

feasible, and quicker than cephalic vein cut-down, with a reduction in pneumothorax.[4] Pneumothorax prolongs length of stay associated with chest drain insertions, particularly in patients >80 years old and those with lung diseases.[5]

Pocket hematoma can be reduced in patients taking anticoagulant agents by direct visualization of the axillary vein, a technique that decreases accidental punctures of the axillary artery during blind fluoroscopic attempts. Tense pocket hematomas have the potential to become infected, with higher hospitalization costs.[6] Lead placement in the heart by using ultrasound has not been reported yet in the literature but can reduce the risk of cardiac perforation by lead placement on the septum rather than the RV anterior wall, as well as reducing damage to the tricuspid valve if ultrasound is used rather than fluoroscopy alone.[7] Visualizing the septum can result in appropriate pacing parameters, including narrower QRS complex duration, although no clinical benefit has yet been shown.[8]

Reducing radiation in procedures is crucial because longer, complex cases require high doses of radiation, between 2 and 5 mSv per year, thus increasing lifetime cancer risk in operators by 0.05% for every 10 mSv in addition to background radiation.[9] Use of ultrasound for just axillary vein access on its own has shown to reduce radiation doses significantly without affecting procedure durations.[9] Radiation protection gear reduces the stochastic effects of radiation;

FIGURE 7 Postprocedure Chest Radiograph Confirming the Good Lead Position

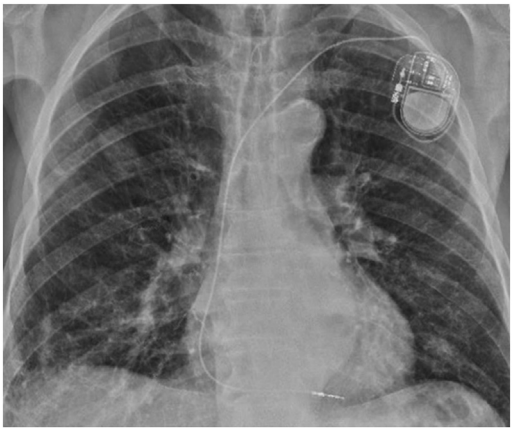


TABLE 1 Pacing Parameters for the Pacemaker at Implantation and Follow-Up

	Implantation	1 wk	1 mo
Sensing, mV	9.0	11.8	14.4
Threshold	0.4 V @ 0.5 ms	0.4 V @ 0.5 ms	0.5 V @ 0.5 ms
Impedance, ohms	545	418	456
Pacing, %	N/A	7.5	24.7
Generator longevity, y	N/A	15.7	15.5
Programming	VVI 50	VVI 50	VVIR 60-110

N/A = not applicable.

however, when this gear is worn for as little as 10 hours per week, it results in musculoskeletal complications for the operators, with subsequent reduced efficiency of health care and additional costs.[10,11] Device implantation without fluoroscopic guidance has been reported using high-definition 3-dimensional (3D) mapping systems; however, ultrasound remains a cheaper, widely available technique with a shorter learning curve than 3D mapping systems.[12]

CONCLUSIONS

We described the first case report of a successful single-chamber pacemaker implanted entirely using ultrasound. This technique has many advantages and warrants further investigation in a study to assess its feasibility.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

This work is funded by the Academic Medical Organization of Southwestern Ontario grant (INN21-013) and startup fund, University of Western Ontario. Dr Khan has received speaker honoraria from the Canadian Heart Rhythm Society.

ADDRESS FOR CORRESPONDENCE: Dr Habib Khan, Department of Cardiovascular Medicine, London Health Sciences Center, Western University, Room C6-114, 339 Windermere Road, London, Ontario N6G5A5, Canada. E-mail: habib.khan@lhsc.on.ca. Twitter: @Dr_Habib_Khan.

REFERENCES

1. Raatikainen MJ, Arnar DO, Zeppenfeld K, et al. Statistics on the use of cardiac electronic devices and electrophysiological procedures in the European Society of Cardiology countries: 2014 report from the European Heart Rhythm Association. *Europace*. 2015;17(suppl 1):i1–i75.

2. Kirkfeldt RE, Johansen JB, Nohr EA, Jorgensen OD, Nielsen JC. Complications after cardiac implantable electronic device implantations: an analysis of a complete, nationwide cohort in Denmark. *Eur Heart J*. 2014;35:1186–1194.

3. Khan HR, Shah N, Parviz Y. Cephalic vein access - a feasible, safe and effective method for device implantation. *J Ayub Med Coll Abbottabad*. 2017;29:514–515.

4. Tagliari AP, Kochi AN, Mastella B, et al. Axillary vein puncture guided by ultrasound vs cephalic vein dissection in pacemaker and defibrillator implant: a multicenter randomized clinical trial. *Heart Rhythm*. 2020;17:1554–1560.

5. Thomas GR, Kumar SK, Turner S, Moussa F, Singh SM. The natural history and treatment of cardiac implantable electronic device associated pneumothorax-a 10-year single-centre experience. *CJC Open*. 2021;3:176–181.

6. Malagu M, Trevisan F, Scalone A, Marcantoni L, Sammarco G, Bertini M. Frequency of "pocket" hematoma in patients receiving vitamin K antagonist and antiplatelet therapy at the time of pacemaker or cardioverter defibrillator implantation (from the POCKET study). *Am J Cardiol*. 2017;119:1036–1040.

7. Vamos M, Erath JW, Benz AP, Bari Z, Duray GZ, Hohnloser SH. Incidence of cardiac perforation with conventional and with leadless pacemaker systems: a systematic review and meta-analysis. *J Cardiovasc Electrophysiol*. 2017;28:336–346.

8. Gupta A, Parakh N, Bansal R, et al. Correlation of pacing site in right ventricle with paced QRS complex duration. *Indian Pacing Electrophysiol J*. 2018;18:210–216.

9. Migliore F, Fais L, Vio R, et al. Axillary vein access for permanent pacemaker and implantable cardioverter defibrillator implantation: fluoroscopy compared to ultrasound. *Pacing Clin Electrophysiol*. 2020;43:566–572.

10. Andrew S, Abdelmonem MR, Kohli S, Dabke H. Evaluation of back pain and lead apron use among staff at a district general hospital. *Cureus*. 2021;13:e18859.

11. Monaco MGL, Carta A, Tamhid T, Porru S. Anti-X Apron wearing and musculoskeletal problems among healthcare workers: a systematic scoping review. *Int J Environ Res Public Health*. 2020;17(16):5877.

12. Gianni C, Della Rocca DG, Natale A, Horton RP. Fluoroless 3D mapping-guided pacemaker implant in a pregnant patient. *Pacing Clin Electrophysiol*. 2021;44:1641–1645.

KEY WORDS cardiac pacemaker, echocardiography, ultrasound