INTRODUCTION

Iatrogenic perforation of the right ventricle by pacemaker (PM) or implantable cardioverter defibrillator (ICD) leads is rare, accounting for 0.3%-0.8% of all pacing procedures.\(^1\)\(^,\)\(^2\) It usually occurs <24 hours after device implantation; however, late-onset (>1 month) cardiac perforations have been described.\(^3\) While percutaneous lead removal by simple traction can be uneventfully performed in some cases,\(^1\) far less clear is the proper management of lead migration in the left hemithorax, since no straightforward recommendations are available in this setting.

In this case report, we described the uneventful management of this rare complication. We also endeavored to explore the pathophysiological mechanisms and risk factors associated with this condition.

CASE REPORT

A 78-year-old woman with nonrevascularizable multivessel coronary artery disease (Figure 1A,B) was implanted with a dual-chamber PM (Biotronik Edora 8 DR-T) for symptomatic sick sinus syndrome at our institution. Briefly, after cephalic vein access, the two active fixation leads were placed at the middle portion of the right interventricular septum (Biotronik Solia S 60) and the right atrial appendage (Biotronik Solia S 53), respectively, with excellent pacing parameters and no peri-procedural complications (Figure 2A). Pre-discharge transthoracic echocardiogram showed no signs of structural heart disease.

Two months after discharge, the patient referred to the emergency department for syncopal episodes and unrelenting left chest pain. PM interrogation showed loss of ventricular capture...
and urgent chest X-ray identified the ventricular lead tip at approximately 3.5 cm from the left cardiac margin, abutting the left chest wall (Figure 2B). Similar findings were reported on the thoracic computed tomography (CT) scan, which showed the passage of the left ventricular lead from the interventricular septum to the left ventricular free wall, reaching the left pleural cavity but with no clear signs of left hemothorax (Figure 3).

The subsequent patient's management was thoroughly debated. However, after a thorough research of the available literature (Table 1) and given the potentially life-threatening complications due to transvenous lead removal, the patient was moved to the surgical theater for off-pump lead extraction. The surgical intervention is fully depicted and described in Figure 4A-D. Surgical extraction was uncomplicated, and the patient was discharged home 7 days after the procedure with an uneventful 6-month follow-up.

FIGURE 1 A-B, Coronary angiogram. The left anterior descending and circumflex coronary arteries display a diffuse atherosclerotic disease with multiple focal stenoses (A), and the right coronary artery is slender (B). Of note, poor coronary blood flow is observed on the mid-apical portion of the interventricular septum in this patient (A).

FIGURE 2 A-B, Chest X-rays performed 1 day (A) and 60 days (B) after pacemaker implantation. The day after the procedure, both atrial and ventricular pacemaker leads were properly positioned at the right atrial appendage and septal mid-wall, respectively (A). B, shows the same postero-anterior view of the patient's heart 60 days after the procedure: while the atrial lead is located at the same place as compared with (A), the ventricular lead is well beyond the left cardiac margin and clearly migrated in the left hemithorax (arrow).

FIGURE 3 Thoracic computed tomography scan. The radiological scan clearly shows the ventricular lead course from the right ventricle (1) to the left chest wall (4) in this patient. Perforation of both the interventricular septum (2) and the left ventricular free wall (3) are well evident, posing the non-surgical lead extraction at an exceedingly high procedural risk. Computed tomography scan should therefore be regarded as the gold standard for the strategical management of this complication.

3 | DISCUSSION

Late-onset lead migration beyond the left cardiac margin is a rare event, and, to our knowledge, no clear recommendations
| Author            | Year | Sex | Age (y) | Comorbidity                          | Ventricular lead type | Lead position | Time from implantation to lead complication | Symptoms                  | Pacing parameters | Lead migration                                           | Management                     | New lead position | Follow-up |
|-------------------|------|-----|---------|--------------------------------------|-----------------------|---------------|---------------------------------------------|----------------------------|-------------------|--------------------------------------------------------|-------------------------------|------------------|-----------|
| Selcuk, et al³    | 2006 | F   | 30      | N/A                                  | RV apex               |               | 2 weeks                                     | Chest pain                | N/A               | RV apex, left pleural perforation with no hemothorax | Surgical extraction           | N/A              | Uneventful |
| Migliore, et al⁴  | 2010 | M   | 52      | Brugada Syndrome                     | Active fixation ICD lead | RV apex       | 12 days                                     | None                       | Loss of pacing capture. High pacing impedance | Septum, LV free wall         | Passive fixation ICD lead | Uneventful |
| Bohora et al⁵     | 2010 | M   | 44      | N/A                                  | Active fixation PM lead | RV apex       | 5 days                                      | Chest pain, fatigue, cough, left hemothorax | Loss of pacing capture. Normal pacing impedance | RV apex, left pleura perforation and hemothorax | Surgical extraction | Epicardial pacing lead | Uneventful |
| Kondoh et al⁶     | 2012 | M   | 82      | N/A                                  | Active fixation PM lead | RV septum     | 3 months                                    | Acute severe chest pain   | Loss of pacing capture | Septum, LV free wall | Surgical extraction | Epicardial pacing lead | Uneventful |
| Forleo, et al⁷    | 2013 | F   | 81      | N/A                                  | Active fixation PM lead | RV apex       | 7 months                                    | Third-degree AV block, left hemothorax | Loss of pacing capture. Low ventricular sensing, normal pacing impedance | RV apex, left pleura perforation and hemothorax | Initially conservative, then Surgical extraction | Transvenous active fixation lead on septum | Uneventful |
| Pojar et al⁸      | 2013 | M   | 74      | Dilated cardiomyopathy               | Active fixation PM lead | RV apex       | 3 months                                    | Heart failure and cardiogenic shock | N/A               | RV apex, left pleura perforation and hemothorax | Surgical extraction | Transvenous ICD lead | Uneventful |
| Iribarne, et al⁹  | 2018 | F   | 69      | Asthma on steroids, hypothyroidism   | Active fixation PM lead | RV septum     | 2 weeks                                     | None                       | Loss of pacing capture. Variation in Lead impedences | Septum, free wall, left pleura but with no hemothorax | Surgical extraction | Epicardial pacing lead | Uneventful |
| Satomi et al¹⁰    | 2021 | M   | 84      | Hypertension prior history of stroke | Active fixation PM lead | RV septum     | 2 days                                      | None                       | Loss of pacing capture | Septum, free wall, LV posterior wall, scratching the pleural cavity but with no lung damage | Surgical extraction | Transvenous before cardiac surgery | Uneventful |

Abbreviations: AV, atrio-ventricular; F, female; ICD, implantable cardioverter defibrillator; LV, left ventricular; M, male; N/A, not available; PM, pacemaker; RV, right ventricular.
do exist in this setting. Moreover, the involved pathophysiological mechanisms have not been thoroughly investigated yet.

Table 1 displays lead type, position, migration course, pacing parameters, together with the clinical features, management, and follow-up of all the available clinical cases reported in literature experiencing this troublesome iatrogenic complication.3-10

As previously reported,2 active fixation leads placed on the thin-walled right ventricular apex seem associated with an increased risk of cardiac perforation together with lead migration in the left pleural cavity on account of the close anatomical location of these two anatomical structures. However, as shown in Table 1, left-sided migration of ventricular lead could be also due to double perforation of both the thick-walled interventricular septum and the left ventricular free wall.6,9,10 Although the mechanisms underpinning septal perforation are far from being established, the beat-to-beat twisting motion of the septal musculature together with poor blood supply in this very anatomical region may have played a pivotal role in the reported clinical case. Indeed, in this regard, the ventricular lead was placed at the mid-septum where the coronary angiogram had previously showed poor coronary flow (Figure 1A).

Furthermore, as shown in Table 1, only right ventricular apex perforation seems to be associated with a greater risk of life-threatening hemithorax than septal perforation, potentially due to the iterative, beat-to-beat, thrusting movements of the ventricular lead against the left lung parenchyma and through the pierced right ventricular apex.5,7,8 The reason why double perforation seems associated with less pleural and/or lung parenchymal damage6,9,10 is not clear.

Whatever the mechanism underpinning lead migration in the left hemithorax, as shown in Table 1, off-pump surgical extraction was uneventfully performed in all cases, our patient included. Therefore, chest X-ray and thoracic CT scans are mandatory to assess whether pleural or septal/left ventricular free wall is involved, since these patients, despite the paucity of symptoms, should be promptly taken to the surgical theater for lead extraction. In case of involvement of right ventricular perforation only, transvenous lead extraction can be feasible,4 provided that a surgical back-up is warranted.

4 | CONCLUSIONS

Cardiac perforation and PM migration in the left hemithorax is a rare but potentially deadly complication. Radiological tests are mandatory to diagnose left pleural and/or septal/left ventricular involvement, prompting immediate surgical treatment in this setting. Finally, less traumatic passive-fixation
leads might be used in these high-risk patients with evidence of nonrevascularizable myocardial ischemia and clear indication for PM/ICD implantation.

**CONFLICT OF INTEREST**

Prof. R. De Ponti received lecture fees from Biosense Webster and Biotronik, and his institution received educational grant from Medtronic, Biotronik, Boston Scientific, Biosense Webster, and Abbot.

**AUTHOR CONTRIBUTIONS**

JM conceived the idea, data collection, intellectual process, manuscript drafting, and contributed to the final version of the manuscript. FC contributed to treatment application, manuscript drafting and contributed to the final version of the manuscript. FBMB, TR, MV, and FT contributed to data collection, intellectual process, follow-up, and manuscript writing. AM and CB contributed to treatment application, contributed to data collection, intellectual process, follow-up, and manuscript writing. RDP supervised the project.

**ETHICAL APPROVAL**

Ethical approval is waived for single case reports at our study center.

**DATA AVAILABILITY STATEMENT**

Data used in the current study are available from the corresponding author on reasonable request.

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**REFERENCES**

1. Migliore F, Zorzi A, Bertaglia E, et al. Incidence, management, and prevention of right ventricular perforation by pacemaker and implantable cardioverter defibrillator leads. *Pacing Clin Electrophysiol*. 2014;37:1602-1609.

2. Cano Ó, Andres A, Alonso P, et al. Incidence and predictors of clinically relevant cardiac perforation associated with systematic implantation of active-fixation pacing and defibrillation leads: a single-centre experience with over 3800 implanted leads. *Europace*. 2017;19:96-102.

3. Selcuk H, Selcuk MT, Maden O, et al. Uncomplicated heart and lung perforation by a displaced ventricular pacemaker lead: a case report. *Pacing Clin Electrophysiol*. 2006;29:429-430.

4. Migliore F, Leoni L, Torregrossa G, et al. Asymptomatic right ventricular perforation by an implantable cardioverter defibrillator lead detected by home monitoring system. *J Electrocardiol*. 2010;43:673-675.

5. Bohora S, Unnikrishnan M, Ajit Kumar VK, Nayyar S, Tharakan J. Left hemothorax: a presentation of a late ventricular perforation caused by an active fixation pacing lead. *Int J Cardiol*. 2010;141:e43-e46.

6. Kondoh H, Funatsu T, Taniguchi K. Late left ventricular perforation by active fixation pacemaker lead implanted in the right ventricular septum. *J Card Surg*. 2012;27:530-531.

7. Forleo GB, Zeitani J, Perretta T, et al. Acute left hemothorax as a late complication of an active-fixation pacemaker lead. *Ann Thorac Surg*. 2013;95:1081-1084.

8. Pocu M, Vobornik M, Novy J. Left hemothorax: an unusual complication of delayed right ventricular perforation by a permanent pacemaker lead. *J Card Surg*. 2013;28:325-327.

9. Iribarne A, Sangha RS, Bostock IC, Rothstein ES, McCullough JN. Right ventricular lead perforation through the septum, left ventricle, and pleura, managed by an open surgical approach. *HeartRhythm Case Rep*. 2018;4:397-400.

10. Satomi N, Enta K, Otsuka M, Ishii Y, Asano R, Sawa S. Left ventricular free wall perforation by a right ventricular pacemaker lead: a case report. *Eur Heart J Case Rep*. 2021;5(3):ytab125.