Diagnosis and treatment of the rare procedural complication of malpositioned pacing leads in the left heart: a single center experience

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ABSTRACT

Objectives. This study assessed the management approach and outcome of the pacemaker or implantable cardioverter-defibrillator (ICD) leads malpositioned in the left heart. Malpositioned leads (MPLs) may have deleterious consequences, and appropriate management remains uncertain. Methods. The study population included all patients referred to a single institution for MPL in the left side of the heart after pacemaker or ICD implantation during the period from 2015 to 2021. The approach and outcome of lead management were retrospectively assessed. Results. During the study period, 6887 patients underwent device implantation. MPL was diagnosed in five patients (0.07%). In four cases, the pacing lead was placed in a coronary sinus (CS) branch, while the pacing lead was inside the left ventricle (LV) in one case. Symptoms suggestive of lead malposition were reported by 2 patients (40%). One of the patients presented with recurrent TIAs. Another presented with inappropriate ICD shocks. In one asymptomatic case, an ICD lead changed position from the right ventricle to the CS, suggesting idiopathic lead migration. In 4/5 patients, the leads were removed or repositioned by percutaneous approach, with no major periprocedural complications. Conclusions. In this series of MPL in the left heart, two patients presented with thromboembolic events or inappropriate ICD shocks. These serious complications highlight the critical need for early correct diagnosis and proper management of MPL.

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INTRODUCTION

A malpositioned pacemaker or ICD lead (MPL) in the left side of the heart is an uncommon but serious complication associated with a pacemaker and implantable cardioverter-defibrillator (ICD) implantation. In a large retrospective cohort of 1764 patients, the reported incidence of inadvertent lead malpositioning to the left side of the heart was 0.34% [1]. However, the true prevalence is probably underestimated, given that the diagnosis can be missed in patients with mild or no symptoms.

Patients with MPL (occurring during the implantation procedure or afterward) can present with highly variable symptoms, and many patients remain asymptomatic [2–5]. MPL may be a potential cause of thrombotic events, either systemic thromboembolism [6,7] or coronary sinus (CS) thrombosis [8]. MPL may also result in pacemaker/ICD malfunction due to sensing problems, or diaphragmatic stimulation [9]. The issue of incorrect sensing is particularly important for ICD devices, where sensing problems may result in inappropriate shocks.

Management of patients with MPL remains nonuniform and the optimal approach is uncertain. Cohort studies with a limited number of patients have reported different surgical or percutaneous techniques and outcomes for MPL management. We report a single-center experience of five patients, including a serious ICD sensing problem.

METHODS

This is a single-center retrospective study of all consecutive patients who were diagnosed with MPL in the left side of the heart and referred for lead revision to the Skane University Hospital Lund, Lund University, Sweden from January 2015 to December 2021. The presented patient cohort was part of a larger study that was approved by the Swedish Ethical Review Authority (EPN 2021-05826-01). The requirement for consent was waived by the Ethical Review Authority. All of the data from patients were gathered from the medical records and included in a dedicated dataset in order to perform the final analyses.

MPL in the left heart was defined as inadvertent placement of a permanent active pacemaker or ICD lead inside the left ventricle (LV) [2,10], in the coronary venous system [11] or in the left atrium (LA) [1] after implantation. For each case of MPL, detailed demographic data were recorded, including presenting symptoms, electrocardiogram (ECG),
electrogram (EGM) and diagnostic testing, including chest radiography, transthoracic echocardiography (TTE), and computed tomography (CT).

MPL was suspected when patients presented with the following: 1) TIA after device implantation; 2) EGM showed double counting of P and R waves with/or significantly altered electrical parameters on device interrogation; and 3) evidence of lead malposition/migration on PA and lateral chest x-ray. TTE, transesophageal echocardiography (TEE), chest CT, or 3D imaging was performed as needed to confirm the diagnosis of MPL. Three-dimensional models were created from preoperative CT images using the Segment3DPrint software (Medviso AB, Sweden). The models were 3D-printed as well as digitally visualized in virtual reality.

The MPL revision procedure was performed in either an EP or a hybrid laboratory, with surgical backup support. The method of lead extraction and any associated complications were assessed with reference to the definitions provided by the Heart Rhythm Society consensus document [12]. TTE was systematically performed at the end of the procedure to rule out pericardial effusion and repeated within 24 h afterward. Chest x-ray and device interrogation were performed before hospital discharge. Routine follow-up included a first visit to the outpatient clinic 7–14 days post-discharge and a second visit 1–2 months afterward.

Results

Incidence and patient characteristics

During the study period, 6887 patients underwent device implantation at our institution. Of the 4451 implanted pacemaker devices (65% of all implants), 819 (18%) were single chambers, 3107 (70%) were dual chambers, and 525 (12%) were CRT-P devices. Of the 2436 ICDs (35% of all implants), 587 (24%) were single chambers, 882 (36%) were dual chambers, and 967 (40%) were CRT-D.

During the study period, 5 patients with MPL in the left side of the heart were identified (incidence 0.07%, 60% male, mean age 44.8 ± 31.6 years; range 9–75 years). Characteristics of patients with MPL are summarized in Table 1. The average time from lead implantation to the first diagnosis was 40.6 ± 63.2 months (range 5–153 months). In four cases (patient I, II, IV, V), the lead was placed in a CS branch, while the lead was inside the LV in one case (patient III). Malposition was related to a pacemaker lead in 3 patients (patients III, IV, and V), and an ICD lead in 2 patients (patients I and II).

Diagnosis

Symptoms suggestive of lead malposition were reported by 2 patients (40%, patients I and III). In one patient (patient III), malposition was in the LV via a PFO. This patient presented with recurrent TIAs. In another patient (patient I), an ICD lead malposition was in the main body of the CS. This patient presented with 14 inappropriate ICD shocks (Figure 1). Three patients (II, IV, V) were asymptomatic, in whom lead malposition was discovered incidentally on radiographic imaging.

| Patient number | Sex | Age (years) | Indication | Device type | Heart disease | Position of the lead | Time to diagnosis | Adverse events | Time to chest X-ray | ECG | EGM | TTE/TEE | Chest CT | Lead revision |
|----------------|-----|-------------|------------|-------------|---------------|---------------------|------------------|---------------|-------------------|-----|-----|---------|----------|--------------|
| I              | M   | 64          | VF         | DDD-ICD     | CAD, CABG     | CS                  | 6 months         | ICD shock     | Y                 | Y   | Y   | Y       | Y        | Y            |
| II             | M   | 75          | VF         | DDD-ICD     | DCM           | CS                  | 153 months       | None          | Y                 | Y   | Y   | Y       | Y        | Y            |
| III            | F   | 64          | AVB        | 2/1         | None          | LV                  | 20 months        | None          | Y                 | Y   | Y   | Y       | Y        | Y            |
| IV             | F   | 12          | AVB        | 2/1         | None          | CS                  | 5 months         | None          | Y                 | Y   | Y   | Y       | Y        | Y            |
| V              | M   | 9           | Sinus arrest | DDD-PM    | None          | CS                  | 19 months        | None          | Y                 | Y   | Y   | Y       | Y        | Y            |

AVB: atrio-ventricular block; CAD: coronary artery disease; CF: chronic atrial fibrillation; CS: coronary sinus; CT: computer tomography; DCM: dilated cardiomyopathy; ECG: electrocardiogram; EGM: electrograms; F: female; ICD: implantable cardioverter defibrillator; LV: left ventricle; M: male; PM: pacemaker; PFO: patent foramen ovale; RBBB: right bundle branch block; TIA: transient ischemic attack; TTE: transthoracic echocardiography; TEE: transesophageal echocardiography; Y: yes; -: not relevant.
(Figure 2). One patient had an ICD lead migrate from the right ventricle to the CS sometime between 127 and 153 months after the implantation (patient II, Figure 3), suggesting idiopathic lead migration. There were two children (patients IV and V), where the pacing leads (one right atrial lead and one right ventricular lead) were malpositioned during the primary implant, and ended in the main body of the CS.

Symptoms and findings that support the diagnosis are summarized in Table 1. Chest X-ray lateral view of all patients (Figure 2) showed the ventricular lead further posterior to the usual course, indicating suspicion of the lead being positioned in the left side of the heart. In the PA X-ray view, the leads were more leftward oriented than usual, but this was less obvious than the posterior displacement in the lateral view. The findings were confirmed with either TTE/TEE showing leads inside the LV (Figure 4A) or CS (Figure 4B), or Chest CT (Figure 5) with 3D imaging (Figure 6) clearly showing a lead in the CS.

**Treatment**

In 4/5 patients, the leads were removed or repositioned by percutaneous approach from the left side. In two patients (patients I and IV), the leads were in the CS and removed by manual traction with standard stylets without extraction tools, while in patient V, the lead in the CS was extracted.
by Evolution system (Cook Medical Inc., Bloomington, IN, USA), with no major periprocedural complications. In another (patient III) with TIA attacks and MPL inside the LV, the lead was slowly extracted by traction alone with a regular stylet inside the lead without complications after previous and ongoing dabigatran treatment [13]. In one patient (patient II), the lead was not removed since the device was functioning well, the patient was on chronic warfarin therapy and was completely asymptomatic.

Discussion

We present a case series of 5 patients with leads misplaced to the left side of the heart, with an estimated incidence of 0.07%. Based on this data, we believe that symptomatic MPL to the left side of the heart is a rare complication. Symptoms suggestive of lead malposition were reported by 2 patients (40%), a patient with a left ventricular lead presented with recurrent TIA attacks and the other in the CS with inappropriate ICD shocks, which indicate the MPL in the left heart is a serious complication. These serious complications highlight the critical need for early correct diagnosis and proper management of MPL. There are several learning points to draw from these cases, and in Table 2 we present an overview of underlying conditions, diagnostic findings, potential complications, and treatment options for leads that are inadvertently placed on the left side of the heart.

Causes of misplaced leads

In order for a lead to end up in the left side of the heart, it must either be introduced directly into the arterial circulation or pass from the venous to the arterial side through the atrial or ventricular septum or exit the right atrium into the CS. Risk factors for MPL include abnormal thoracic anatomy, underlying congenital heart disease, and operator inexperience (<100 implants) [1]. With experience, implanters are usually able to distinguish aberrant lead courses on fluoroscopy during the primary implant. Placing the RV lead in the middle cardiac vein is probably not uncommon in patients with a large CS ostium, but can easily be recognized by checking the position using fluoroscopy in a left anterior oblique (LAO) or left lateral projection, and observing the lead movement pattern (absence of tricuspid valve dislocation of the lead). The most common lead course to the inside of the LV is through a PFO or a small ASD. This may be more difficult to diagnose during implant, but again, fluoroscopy in the LAO or left lateral projection will reveal a more posterior leftward-oriented lead location.

How to avoid MPL during implantation

MPL is a preventable complication. It is important for operators performing device implantation to develop techniques that minimize the risk of this complication. Implanters need to make sure they are operating in the venous system [15]. Access through the cephalic vein, where possible, not only ensures venous access but also avoids other complications...
that may be related to axillary or subclavian punctures. Performance of axillary puncture under ultrasound or fluoroscopic guidance reduces the risk of inadvertent arterial puncture. If you are in the venous system, the guidewire and lead should pass down below the diaphragm into the inferior vena cava. If a sheath is inserted into the arterial system, the guidewire or lead will pass toward the left side of the spine, often with buckling at the aortic valve [15]. Prolapsing the ventricular lead through the tricuspid valve into the right ventricle and subsequently advancing the lead into the right ventricular outflow tract or the main pulmonary artery, should prevent inadvertent passage into the CS or middle cardiac vein or through a septal defect. If a hand-shaped curved stylet is used, a slight anterior rotation during advancement over the tricuspid valve minimizes the risk of inadvertent CS cannulation. Usually, ventricular extrasystoles and short ventricular tachycardia bursts are also signs of the lead being inside the right ventricle. Passage of a lead through a patent foramen ovale or a septal defect into the LV may be difficult to recognize on fluoroscopy in the PA.

Figure 4. Echocardiographic image showing a pacing lead (arrows) originating from the RA crossing the atrial septum and mitral valve embedded into the lateral LV wall (A, patient III) and the echocardiographic image showing a pacing lead (arrows) from RA to the coronary sinus (B, patient IV).

Figure 5. Chest CT of patient II (A) and patient IV (B) showed RV lead (arrows) in the coronary sinus.
Patent foramen ovale/C15 predisposing factors Diagnostic findings Potential complications Treatment options

Underlying conditions/Overview of clinical factors and implications with regards to misplaced pacing leads to the left side of the heart.

Table 2. Overview of clinical factors and implications with regards to misplaced pacing leads to the left side of the heart.

| Underlying conditions/ | Diagnostic findings | Potential complications | Treatment options |
|------------------------|---------------------|-------------------------|-------------------|
| Patent foramen ovale   | RBBB pacing config. | Arterial embolization   | Anticoagulant therapy |
| Other atrial septal defects or secundum defect | Posterior or unusually leftward lead course on chest X-ray | Transient Ischemic Attack | Lead extraction |
| Unroofed coronary sinus | No lead found in the RV on echocardiography | Worsened migraine | Reprogramming of ICD detection criteria |
| Ventricular septal defect | Aberrant lead position on cardiac CT or MRI | Inappropriate ICD shocks due to double counting P and R waves | |
| Subclavian artery puncture | | Coronary sinus thrombosis | |
| Inexperienced implanter | | Lead perforation | |

view. However, the use of LAO views will help recognize this complication [15]. Finally, an unusual appearance of the intracardiac electrogram and poor sensing or thresholds should raise the suspicion of MPL.

**Diagnostic findings suggestive of MPL**

An RBBB pattern on a 12-lead surface ECG is a sensitive marker for misplaced pacing leads inside the LV (as was the case in patient III in our study). This phenomenon can also be seen if the lead is placed in the middle cardiac vein or branches of the CS [11]. However, it is not an obligatory finding, and for instance, in patient IV in our series (with a lead in the CS), the ECG did not show an RBBB pattern.

Chest X-ray in the lateral view is the most sensitive marker for a misplaced pacing lead and is often the first reason for suspicion. On the lateral projection, a correctly positioned RV lead shows that the tip of the lead is located anteriorly. In contrast, the tip of a misplaced LV lead is characteristic to the left and further posterior on the lateral view. In the PA chest X-ray projection findings are more subtle, usually showing a more leftward course of the lead, with a soft bend located at the level of the crossing of the atrial or ventricular septum. In all of our five MPL patients, there was a clear sign of MPL suspicion on chest X-ray (Figure 2). Chest CT scans and 3D reconstruction of images will show the lead location accurately and are the gold standard for diagnosing MPL, though these imaging modalities are not used in standard clinical practice for a post-implant check-up.

TTE and TEE can also delineate the course of the lead accurately, although the acoustic shadowing may cause echo drop-outs [16]. With clinical suspicion, TTE and/or TEE can be a very useful tool to distinguish the misplaced pacing lead. TEE can also exclude the presence of any mobile thrombus or fibrous material along MPL.

For leads in the main branch of the CS, double counting P and R waves (and sometimes atrial capture) may be the first presenting sign suggestive of MPL. Leads placed inside the LV cavity usually do not have double counting issues, but may have low-amplitude R-waves and/or higher thresholds, depending on the exact fixation site.

**Potential complications due to MPL**

Complications may arise either during attempts of lead removal or over the time course where the lead is present in the systemic circulation, and/or the device is connected to the misplaced lead. The most dreaded complication is a stroke or other lead-related embolization. In a meta-analysis of cases published until the year 2000, the incidence of thromboembolic complications was 37% [2], and in a more recent study, the incidence was 33% [1]. Symptomatic thromboembolic events primarily occur secondary to an MPL inside the LV [17]. In our patient III, the recurrent TIA/migraine attacks were most likely the result of embolism of microthrombi, either formed around the misplaced pacing lead or coming from the venous circulation and passing through the PFO, which most likely was kept more open by the lead passing through it. However, CS thrombosis (CST) may also occur, which is a rare but life-threatening condition [18–20]. A large diameter lead (especially ICD leads) may increase the risk of partial CS thrombosis. Therefore, anticoagulants should be considered if there is an ICD lead within the CS.

Another complication that can arise is sensing problems, with an RV lead in the CS, which may trigger inappropriate ICD shocks due to double counting P and R waves. This can usually be avoided by adjusting sensitivity to block out atrial signals, but a careful evaluation of electrograms to rule out double counting is very important if there is an ICD lead in the CS, unless it is exchanged for a proper RV lead.

![Figure 6. Three-dimensional (3D) imaging with computed tomography (CT) shows a pacemaker RV lead in the coronary sinus (patient IV). Arrows show the RV lead.](image)
Treatment options

Treatment of patients with MPL in the left side of the heart remains controversial. Treatment will depend on the time from implantation of the misplaced lead, clinical presentation, electrode pathway to the left side, complications, the presence of thrombus on the lead, and the presence of asymptomatic thromboembolic events [21] or electronic dysfunction. If misplacement is diagnosed immediately after implantation, lead removal or adjustment is usually feasible. If timely removal of a malpositioned lead in the left side of the heart is not performed, lifelong oral anticoagulation can be recommended for the prevention of thromboembolic events in asymptomatic patients [2,21]. In symptomatic patients, lead extraction is usually preferred over anticoagulation. However, perioperative prevention of the thromboembolic event is of critical importance. In the four cases in this material (patients I, III, IV, and V), the leads could be removed without complications, and the long-term outcome was uneventful in all cases. Dabigatran treatment pre- and post-operation may have contributed to the successful transvenous lead extraction without complications in patient number III [13]. Concerns about the risk of bleeding associated with dabigatran and the result of a tear in the LV wall highlight the importance of having dabigatran antidote (Idarucizumab) available during the lead extraction for the possibility of a rapid total reversal of anticoagulant effect. If the pacing lead in the LV has been in place for a long time and a mechanical extraction sheath is needed to get into the left side of the heart, we suggest that an arterial cerebral protection system should be used [22–24]. We also recommended using a closure device for treatment of the ASD/PFO that remains after the removal of the lead, to prevent paradoxical embolization in the future.

Limitations

This was a retrospective study on cases that presented either with symptoms or findings suggestive of MPL. Indeed the incidence was significantly lower than in the only other previously presented large series (0.07% vs 0.34%), but we did not systematically screen all implants as the authors did in the study by Ohlow et al. [1], i.e. no screening for MPL in patients who were asymptomatic without findings suggestive of MPL. This may have resulted in an underestimation of the true incidence of MPL. Our institution is a tertiary care centre with high volumes and experienced implanters, and the described incidence may not be representative of smaller centres or less experienced implanters.

Conclusions

Lead misplacement of the left side of the heart is a rare but potentially serious complication to pacemaker and ICD treatment. In this series of five cases of MPL to the coronary sinus or left ventricle, two patients presented with thromboembolic events or inappropriate ICD shock. These serious complications highlight the critical need for early correct diagnosis and proper management of MPL. Percutaneous extraction, repositioning, or replacement of the malpositioned lead was found to be safe and effective management. Anticoagulation should be considered for the prevention of thromboembolic events.

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