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Chest Radiographs Are Valuable in Demonstrating Clinically Significant Pacemaker Complications That Require Reoperation

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Abstract

Purpose: To evaluate the utility of chest radiography in demonstrating clinically significant pacemaker complications that required reoperation.
Methods: In this retrospective case-controlled series, we identified 14 consecutive adults who required pacemaker reoperation and who had chest radiographs available for review (6 men, 8 women; mean age, 71 years [range, 43−95 years]). Ten patients had pacemakers implanted at our institution, and 4 were referred for reoperation. Forty-two controls, 3 for each patient, had postoperative chest radiographs and normal device function (25 men, 17 women; mean age 76 years [range, 37−96 years]). All postoperative chest radiographs, including 1-year follow-ups, were blindly reviewed by at least 2 of 4 radiologists for lead perforation and position of right atrial and right ventricular leads. Follow-up radiographs were assessed for lead perforation, lead displacement, and lead fracture. Data were analysed by using the Fisher exact test.
Results: Of the patients, 1.7% (10/581) required reoperation for pacemaker dysfunction (noncapture, oversensing, abnormal atrial and ventricular thresholds, failing impedance), extracardiac stimulation, and lead perforation and/or displacement. There were no lead fractures. Chest radiographs demonstrated pacemaker complications in 57% of patients (8/14) at a median of 2 days (<1−32 days) after implantation and in 5% of the controls (2/42) ($P < .0001$). None of the abnormalities were noted on the official reports. Among subgroups, chest radiographs were abnormal for the following indications: pacemaker dysfunction in 4 of 7 patients versus 0 of 21 controls ($P = .0017$), extracardiac stimulation in 1 of 3 patients vs 0 of 9 controls ($P = .25$), and lead perforation and/or displacement in 3 of 4 patients vs 2 of 12 controls ($P = .06$).
Conclusions: Chest radiographs are useful after pacemaker placement and demonstrate the majority of complications that require reoperation. Familiarity with the expected normal position of the leads, appearances of pacemaker complications, and comparison with prior radiographs is crucial in rendering a correct diagnosis that guides patient management.

Résumé

Objectif: Évaluer l'utilité de la radiographie pulmonaire pour révéler les complications liées à un stimulateur cardiaque qui sont cliniquement significatives et qui nécessitent une réintervention.
Méthodes: Dans cette étude rétrospective de type cas témoins, nous avons identifié une série de 14 patients adultes consécutifs qui ont nécessité une réintervention après l'implantation d'un stimulateur cardiaque et pour qui des radiographies pulmonaires étaient disponibles (6 hommes, 8 femmes; âge moyen de 71 ans [écart, 43 à 95 ans]). Dix patients avaient subi une intervention d'implantation de stimulateur dans notre établissement, tandis que quatre nous ont été adressés pour une réintervention. Les 42 sujets témoins (soit 3 pour chaque patient) avaient subi des radiographies postopératoires et avaient un stimulateur fonctionnant normalement (25 hommes, 17 femmes; âge moyen de 76 ans [écart, 37 à 96 ans]). Toutes les radiographies pulmonaires postopératoires, incluant celles des suivis à un an, ont été révisées à l'aveugle par au moins deux des quatre radiologistes pour dépister une perforation myocardique par une sonde et vérifier la position des sondes auriculaire et ventriculaire droites. Les radiographies de suivi ont été révisées pour détecter la présence de perforations par une sonde, de déplacements et de ruptures de sondes. Les données ont été analysées en utilisant le test exact de probabilité de Fisher.

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Résultats: Une réintervention s'est avérée nécessaire en raison d'un dysfonctionnement du stimulateur cardiaque (non-détection, surdétection, seuils auriculaires et ventriculaires anormaux, impédance insuffisante), d'une stimulation extracardiaque, d'une perforation myocardique et (ou) d'un déplacement de sonde chez 1,7 % des patients (10/581). Aucune rupture de sonde n'a été observée. Les radiographies pulmonaires ont permis de détecter des complications liées au stimulateur cardiaque chez 57 % des patients (8/14) dans un délai médian de deux jours après l'implantation (<1 jour à 32 jours), et chez 5 % des sujets témoins (2/42) ($P < 0{,}0001$). Aucune des anomalies n'était notée dans les rapports officiels. Quant aux sous-groupes, les radiographies pulmonaires étaient anormales dans les indications suivantes : dans les cas de dysfonctionnement du stimulateur, elles étaient anormales chez 4 patients sur 7, comparativement à 0 sujet témoin sur 21 ($P = 0{,}0017$); dans les cas de stimulation extracardiaque, elles étaient anormales pour 1 patient sur 3, comparativement à 0 sujet témoin sur 9 ($P = 0{,}25$); dans les cas de perforation myocardique et (ou) de déplacement de sonde, elles étaient anormales chez 3 patients sur 4, comparativement à 2 sujets témoins sur 12 ($P = 0{,}06$).
Conclusions: La radiographie pulmonaire est utile après l'implantation d'un stimulateur cardiaque, révélant la majorité des complications qui nécessitent une réintervention. Afin de poser un diagnostic exact qui permet de guider la prise en charge du patient, il est essentiel de bien connaître la position normale attendue des sondes ainsi que l'aspect des complications liées aux stimulateurs cardiaques, et d'établir des comparaisons avec les radiographies antérieures.

Key Words: Pacemaker; Chest radiography; Complications

Pacemakers have proven to be effective in the treatment of cardiac arrhythmias, congestive heart failure, and vasodepressor syncope. Postprocedural frontal and lateral chest radiographs are often performed to determine the lead position and integrity after implantation and to identify complications [1]. Early complications after device implantation include lead malpositioning, myocardial perforation, and pneumothorax [1,2]. Suboptimal lead positioning may occur at the time of surgery or may result from lead dislodgement a few days after the procedure [1]. Unsatisfactory lead positioning is not uncommon after surgery and has been reported to occur in 5.5%−14% of patients [3,4]. Clinically manifest acute perforation of the right atrium or right ventricle is extremely rare, occurring in fewer than 1% of patients [3,5]. Pacemaker dysfunction, particularly loss of capture, presents as a delayed complication and is caused by mechanical factors, including lead displacement, myocardial perforation, and lead fracture [1,2]. Lead displacement has an incidence of up to 5%−10% [6,7] and tends to occur early, within weeks of implantation, because the fibrinous adherence that develops between the electrode, and endocardium protects against late displacement [2]. Lead fracture, which has received little attention in the literature, is reported in about 1% of patients and has very subtle imaging findings [3].

The value of routine chest radiography after device implantation remains uncertain and usually plays a secondary role to the clinical scenario, including the sensing and pacing parameters [4]. We conducted the present study to determine whether chest radiography is useful in demonstrating clinically significant device complications that required reoperation.

Materials and Methods

Patients

Our study population comprised 14 consecutive adults who required pacemaker reoperation at our academic medical center between May 2005 and June 2008 and who had chest radiographs available for review after placement of the pacemaker and before reoperation. Ten of the pacemakers were implanted at our institution, and 4 were referred to our institution for reoperation. There were 6 men and 8 women, with a mean age of 71 years (range, 43−95 years). Device complications that required reoperation were divided into 3 categories: pacemaker dysfunction (noncapture, oversensing, abnormal atrial and ventricular thresholds, failing impedance), extracardiac stimulation, and lead perforation and/or displacement. Infection was excluded, because it is known to only rarely be detectable on chest radiography. To optimize the power of this case-control design, we retrospectively identified the 3 controls for each patient [8]. The controls were the 3 consecutive patients who had pacemaker implantation immediately subsequent to each patient and who did not require reoperation. Each control also completed 1 year of follow-up, had normal device function, and had serial chest radiographs available for review on a picture archiving and communication system (PACS). There were 42 controls: 25 men and 17 women, with a mean age of 76 years (range, 37−96 years).

Imaging Assessment of the Pacemaker

The standard protocol at many pacemaker centres consists of immediate assessment of pacemaker lead positioning by using fluoroscopy, followed by postimplantation posteroanterior and lateral or anteroposterior chest radiographs to exclude pneumothorax and confirm lead postioning. Postprocedure posteroanterior and lateral chest radiographs were performed for 6 patients and 31 controls, whereas anteroposterior chest radiographs were performed in 4 patients and 11 controls ($P = .45$).

At least 2 members of a panel composed of 3 board-certified, fellowship-trained cardiothoracic radiologists, and 1 radiology resident, blinded to all clinical information,

retrospectively reviewed the chest radiographs for patients and controls in random order, in consensus. When consensus was not easily achieved, a third member of the panel served as a tie-breaker.

Right ventricular leads placed in the right ventricular apex or septum were considered to be in satisfactory position. On the frontal projection, right ventricular apical leads should curve smoothly along the lateral wall of the right atrium, through the tricuspid valve, with the tip directed anteriorly and inferiorly at the apex, just to the left of the spine (Figure 1A) [2]. On lateral films, apical leads should be directed anteriorly and inferiorly towards the sternum to differentiate from coronary venous positioning (Figure 1B) [1,9]. Septal lead tips should be directed medially and superiorly, just to the left of the spine on frontal radiographs (Figure 2A). On lateral films, right ventricular septal leads should also be directed anteriorly but oriented more superiorly relative to apical leads (Figure 2B). Favorable positioning of atrial leads is typically in the right atrial appendage, although right lateral or septal positions are occasionally selected [10]. Leads are placed in the atrial appendage terminate over the right upper heart border, with lead tips directed cephalad on frontal radiographs (Figure 3A). On lateral films, the lead should follow a smooth anterior curve in the midportion of the heart, with its tip turning cephalad into the appendage (Figure 3B) [11]. Atrial leads that do not curve cephalad but rather curve laterally or medially are in lateral and septal locations, respectively.

Postimplantation radiographs were evaluated for lead type, presence or absence of lead perforation, and the optimal or suboptimal positioning (Table 1) of right atrial and right ventricular leads. Myocardial perforation was diagnosed when the lead tip projected within 3 mm of the fine radiolucent stripe of epicardial fat [12]. Lead fracture manifests as a slight translucency in the conductor of the lead [1]. Follow-up radiographs were examined for the delayed complications of lead displacement, lead perforation, and fracture. The official report of each chest radiograph was also reviewed for findings related to the pacemaker. When chest or abdominal computed tomographies (CTs) were available, they were reviewed.

The study was approved by our institutional review board and was Health Insurance Portability and Accountability Act (HIPAA) compliant. Informed consent was not required.

Statistical Analysis

A comparison between patients and controls was performed by using the Fisher exact test. A P value $<.05$ was considered statistically significant.

Results

Between May 2005 and June 2008, 1.7% of patients (10/581) who had pacemakers implanted required reoperation at our pacemaker centre. Four additional patients were referred for reoperation from outside institutions. Indications for reoperation were pacemaker dysfunction (noncapture, oversensing, failing impedance), extracardiac stimulation, and lead perforation and/or displacement. Pacemaker dysfunction was the most common complication in 7 of 14 patients, followed by perforation and/or displacement in 4 of 14 patients and extracardiac stimulation in 3 of 14 patients. There were no pacemaker lead fractures. Complications occurred at a median of 2 days (range, 0–32 days) after pacemaker implantation.

All the patients had right ventricular leads (1 passive, 13 active). 12 of whom also had right atrial leads (1 passive, 11 active); this did not differ significantly from the controls: all 42 had right ventricular leads (5 passive, 37 active), and 38 also had right atrial leads (2 passive, 36 active).

Chest radiographs demonstrated pacemaker complications in 57% (8/14 patients and 2/42 of controls; $P < .0001$; sensitivity, 57%; specificity, 95%; positive predictive value,

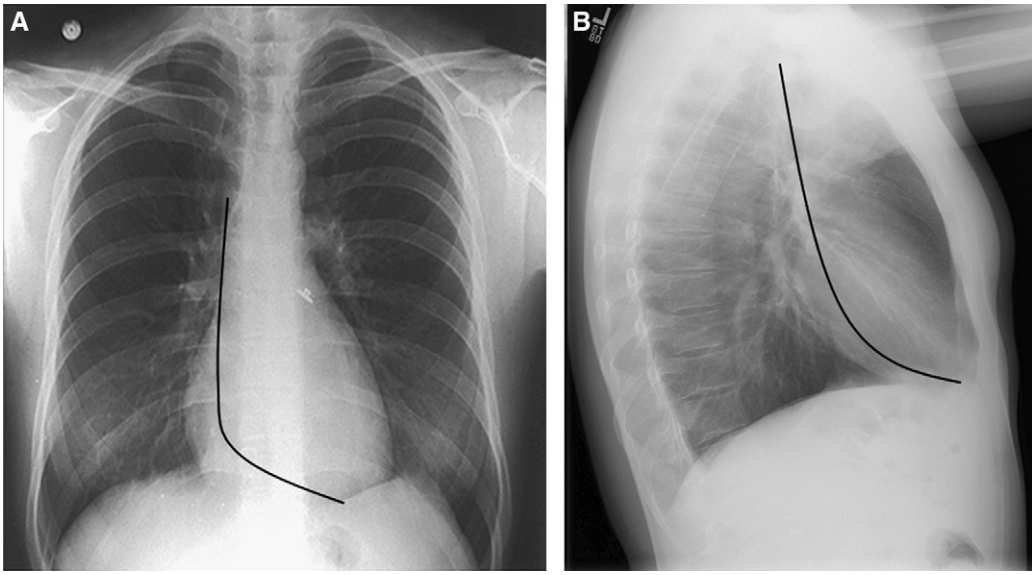

Figure 1. (A, B) Posteroanterior and lateral chest radiographs, with a line that diagrams the expected course of a right ventricular apical pacemaker lead.

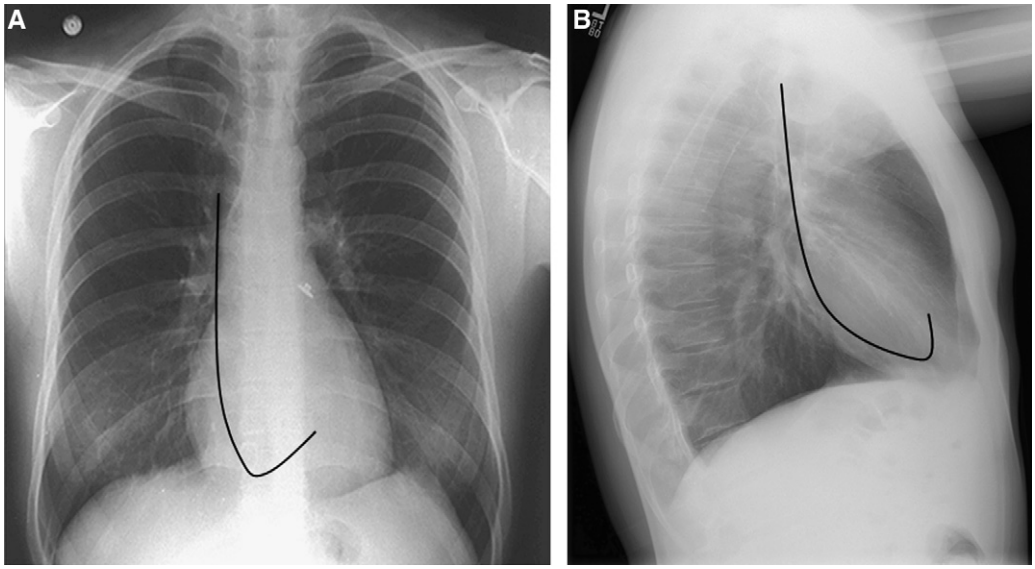

Figure 2. (A, B) Posteroanterior and lateral chest radiographs, with a line that diagrams the expected course of a right ventricular septal pacemaker lead.

80%; negative predictive value, 87%). Subgroup analysis revealed a significant difference between patients and controls for the most common complication, pacemaker dysfunction, with chest radiographs abnormal in 4 of 7 patients and 0 controls ($P = .0017$). One of the 4 patients who required lead repositioning for ventricular noncapture 4 days after implantation. A follow-up chest radiograph performed the day before reoperation was significant for right ventricular lead displacement. Two patients underwent lead repositioning 3 days after implant for high thresholds (Figure 4) and atrial noncapture. Both of their postoperative chest radiographs revealed suboptimal positioning of atrial and ventricular leads. One patient presented with ventricular oversensing the day after implantation but the postoperative chest radiograph revealed atrial lead malpositioning.

Among the 3 patients who required reoperation for extracardiac stimulation, 1 of 3 patients had detectable abnormalities on chest radiography versus 0 of 9 controls ($P = .25$). The 1 patient with a chest radiographic abnormality presented a week and a half after implantation with intercostal muscle stimulation. A chest radiograph performed the same day demonstrated redundancy of the ventricular lead, which required extraction 4 days later.

Among the 4 patients with lead perforation and/or displacement, chest radiographs were abnormal in 3 of 4 patients and 2 of 12 controls ($P = .06$). Two patients required reoperation for lead perforation at 3 days and 1 week after implant. Follow-up chest radiographs obtained the day before each reoperation demonstrated lead displacement and perforation in 1 patient (Figure 5, A and B) and lead

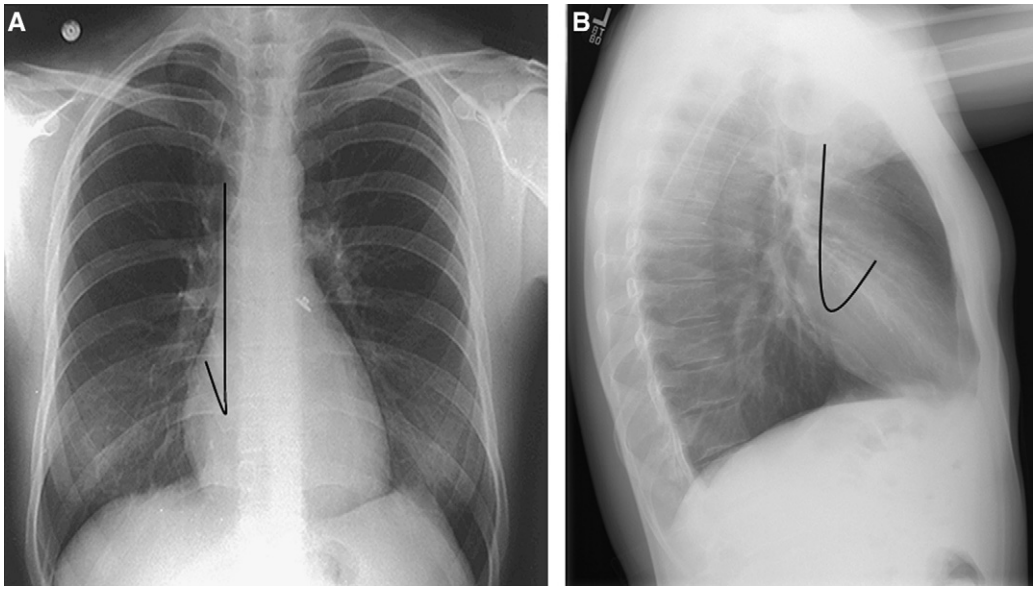

Figure 3. (A, B) Posteroanterior and lateral chest radiographs, with a line that diagrams the expected course of a right atrial appendage pacemaker lead.

Table 1
Expected course of atrial and ventricular pacemaker leads on frontal and lateral chest radiographs

	Frontal projection	Lateral projection
Right atrial lead	Lead tip directed cephalad	Lead should follow a smooth anterior curve in the mid portion of the heart, with its tip turning cephalad into the appendage
Right ventricular lead		
Apical	Leads should curve smoothly along the lateral wall of the right atrium, through the tricuspid valve, with the tip directed anteriorly and inferiorly at the apex, just to the left of the spine	Leads should be directed anteriorly and inferiorly towards the sternum to differentiate from coronary venous positioning
Septal	Lead tips should be directed medially and superiorly, just to the left of the spine	Leads should also be directed anteriorly but oriented more superiorly relative to apical leads

displacement in the other patient. Two patients required reoperation for lead displacement, 1 of whom had radiographically evident displacement, with a right atrial lead displaced into the right ventricle 1 month after pacemaker implantation (Figure 6, A and B). Two controls with normal device function, and who did not require reoperation, demonstrated asymptomatic lead displacement on follow-up chest radiographs. In 1 of these 2 controls, the chest radiograph obtained 4 months after implantation demonstrated a change in the atrial lead's orientation from medial to lateral (Figure 7, A and B). In the other control, a follow-up chest radiograph performed 1 month after implantation revealed a change in course of the right ventricular lead on the lateral projection.

A review of the original postoperative and follow-up radiographic reports was for all chest radiographs in this series. No abnormality was mentioned in the reports for any of the patients. CTs in 2 of 2 patients were unrevealing. Abdominal CT in the 1 control who underwent CT demonstrated an asymptomatic ventricular perforation (Figure 7C).

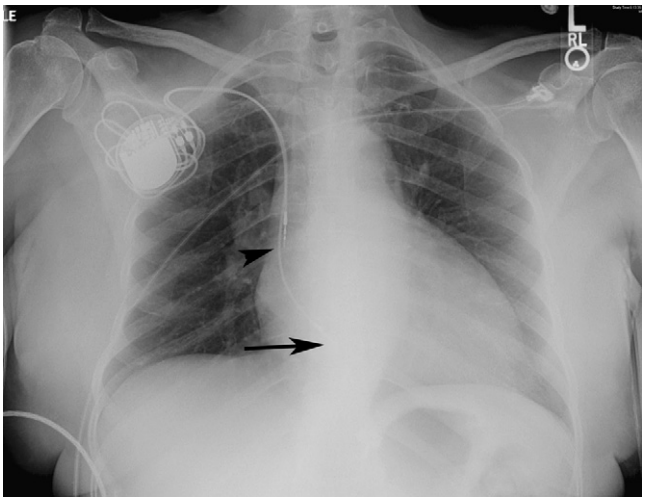

Figure 4. A 64-year-old woman, status post-pacemaker implantation. Anteroposterior portable chest radiograph performed on the day of implantation, showing suboptimal positioning of both leads. The right atrial lead tip is in the region of the superior vena cava (arrowhead) and the j-shape is missing. The right ventricular lead tip (arrow) is in the region of the tricuspid valve. The patient underwent repositioning for high thresholds 3 days later.

Discussion

Pacemaker complications, including suboptimal positioning, lead displacement, myocardial perforation, and lead fracture, which frequently require reoperation, may be evident on chest radiography [1]. Although routine chest radiography after pacemaker implantation remains the current standard, there is debate regarding its necessity [3,4,13].

In the present study, 1.7% of patients required reoperation for pacemaker dysfunction, extracardiac stimulation, and lead perforation and/or displacement over a 3-year period. We chose to study this population because these patients had clinically relevant disease that required treatment. Radiographic abnormalities were detected in the majority of patients, significantly more frequently than in controls, which supported a role for chest radiography in demonstrating clinically relevant pacemaker complications. However, these findings were not described on any of the official reports of the chest radiographs, which highlights the importance, in practice, for radiologists to familiarize themselves with the normal appearance of pacemakers on chest radiography and the appearances of complications. Comparison with prior radiographs is also crucial because a change in device position was present on radiography before reoperation in 4 of 10 of the patients implanted at our institution.

Although CT could more precisely localize the pacemaker leads, only 2 patients and 1 control underwent CT of the chest or abdomen during the follow-up interval. The control showed a clinically silent ventricular perforation, which occurred in 6% of patients in our prior series and does not require treatment [14]. Diagnosing disease that does not require treatment meets the definition of overdiagnosis, which is a common concomitant, along with excess radiation exposure, of imaging, especially for CT. In clinical practice, chest radiography, rather than CT is the imaging mainstay for assessing pacemaker complications.

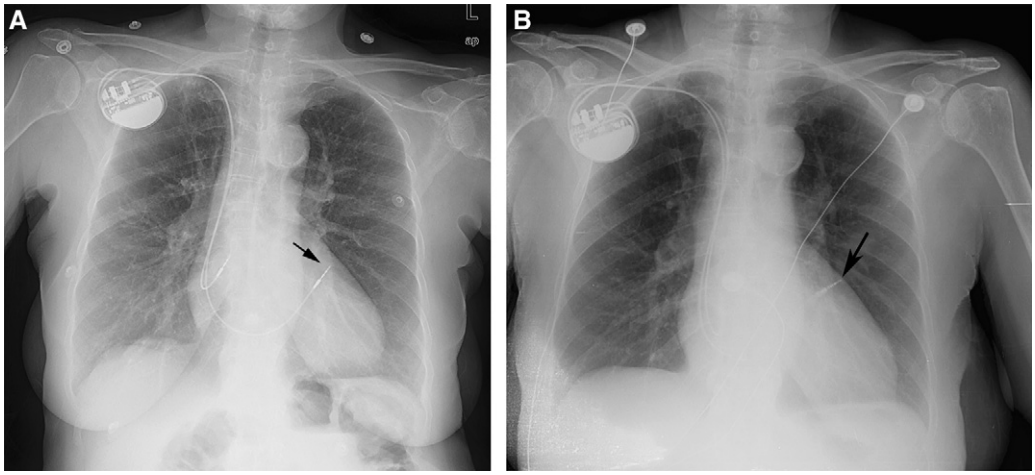

Figure 5. A 74-year-old woman, status post-pacemaker implantation. Three days after implantation, she developed a lead perforation manifest as loss of ventricular capture and a pericardial effusion. (A) Immediate post-implantation posteroanterior chest radiograph, demonstrating the pacemaker leads in the right atrial appendage and right ventricular outflow tract (arrow). (B) Follow-up anteroposterior chest radiograph 1 day after implantation, showing the reorientation of the perforated right ventricular lead tip (arrow), which is within 3 mm of the heart border.

There is a paucity of literature and no consensus regarding the value of routine chest radiography after pacemaker implantation, and this, to our knowledge, is the first case-controlled study. Grier et al [3] retrospectively detected radiographic complications in 21.8% of consecutive patients (131/600) after pacemaker implantation. Similar to our population, only 1.7% of their patients (10/600) required intervention [3]. This suggests that the chest radiographic findings that they described were largely not clinically relevant. In contrast, the present case-controlled series demonstrated significant difference in the chest radiographic findings between patients and controls for a clinically important outcome, device reoperation.

Atrial leads that required reoperation were malpositioned in 3 patients in this series. Lead positioning was assessed by comparing the radiographic appearance of the leads to detailed descriptions from the literature. However, the chest radiographs demonstrated the abnormality in only 1 of the 3 patients and identified a nonclinically significant change in orientation of the atrial lead from medial to lateral in 1 control.

Edwards et al [4] retrospectively analysed post-procedural posteroanterior and lateral chest radiographs for pneumothorax and lead malpositioning in 125 of 126 consecutive patients. Clinical records of the patients who required intervention or subsequent imaging were then examined to determine whether results of chest radiography influenced management. Proper lead positions included the atrial appendage and ventricular apex, which were defined by using the same detailed descriptions that were used in our study. However, in the present series, right lateral and septal positions were also considered to be acceptable for atrial leads as well as the septum for ventricular leads. The ventricular lead position was apical

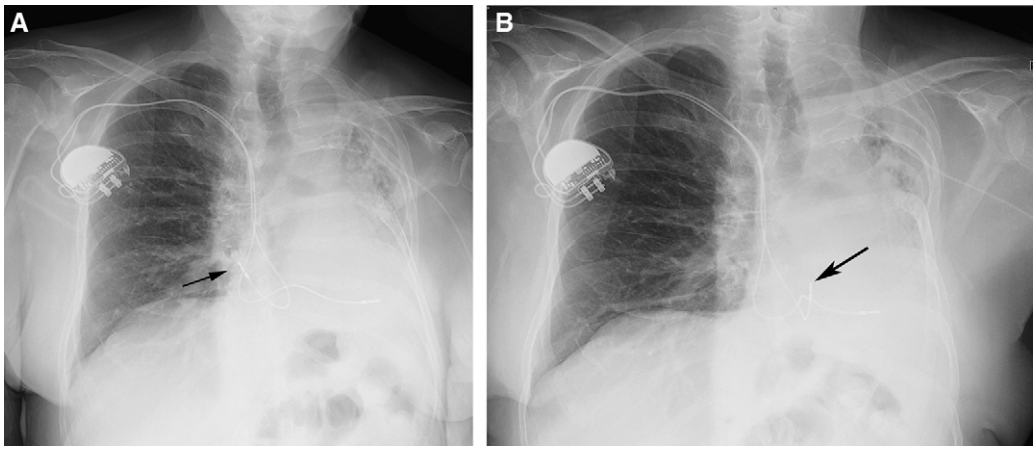

Figure 6. A 70-year-old man with a left fibrothorax underwent pacemaker implantation and required reoperation for atrial lead displacement nearly 2 months later. (A) Anteroposterior chest radiograph 9 days after pacemaker implantation, showing the right atrial lead to be located in the lateral atrium. (B) Follow-up anteroposterior chest radiograph 33 days after implantation, demonstrating displacement of the atrial lead into the right ventricle (arrow).

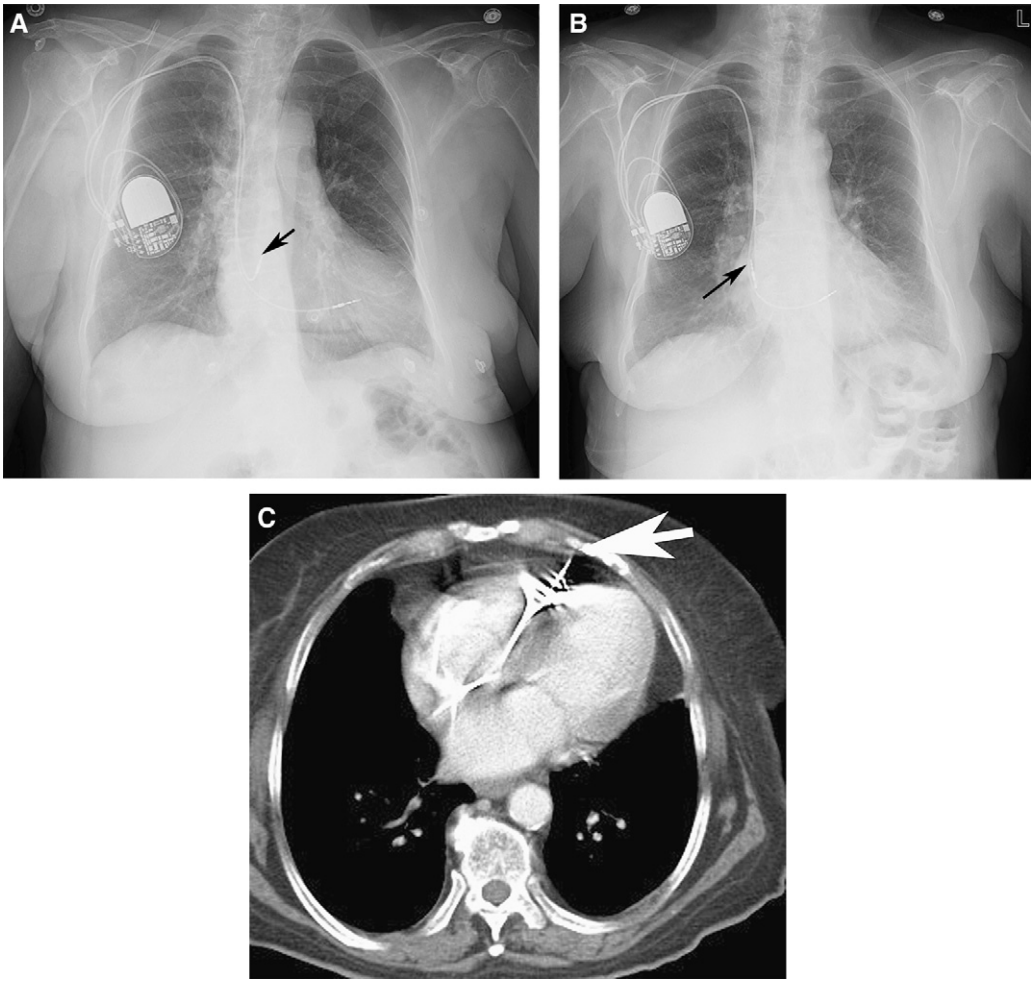

Figure 7. A 76-year-old woman from the control group underwent pacemaker implantation. The pacemaker continued to function well at 1 year. (A) Immediate post-implantation posterolateral chest radiograph, showing the right atrial lead to be oriented medially (arrow) in the atrium; the ventricular lead is apical. (B) Follow-up posteroanterior chest radiograph 4 months after implantation, showing a clinically insignificant change in the orientation of the atrial lead, from a medial to a lateral (arrow) position. (C) Axial image from a contrast-enhanced computed tomography, showing the ventricular lead tip in the epicardial fat superficial to the right ventricle (arrow) consistent with subclinical perforation; there is no pericardial effusion.

in 68% (38/56), septal in 29% (16/56), and suboptimally positioned in the subtricuspid region in 4% (2/56). In contrast, Edwards et al [4] described, suboptimal positioning of either atrial leads, ventricular leads, or both in 14%, double the incidence in the present study (7% for both types of leads), yet none of their patients experienced further complications or needed repeated imaging. All cases of lead malpositioning in the present series required intervention. However, the complications were only evident upon systematic review of the radiographs and were not detailed in the official report.

There were several limitations to this series. We retrospectively identified all adults who required reoperation for pacemaker complications, including device malfunction, displacement and/or perforation, and extracardiac stimulation. We excluded patients with implantable cardioverter defibrillators and resynchronization devices. These devices are less frequently implanted, and, thus, their inclusion would have created heterogeneity in the small study population and would have diminished our ability to achieve meaningful results. We also excluded infection, a common cause of reoperation, which rarely has associated chest radiographic abnormalities. This resulted in a small series of 14 patients over a 3-year period. We chose 3 consecutive controls for each patient to improve the power of the study [8]; this was successful because we demonstrated statistically significant differences between the patients and controls for the population as a whole and also for the subgroup with the most common complication, pacemaker dysfunction. However, the series remains underpowered to demonstrate significance for rare findings. Another limitation of our study was the comparison of device position on radiographs with different projections, because the appearance of lead wires may vary subtly based on projection alone. This reflects the reality of clinical practice, and device complications, nevertheless, were identified in the majority of cases. Lastly, 4 patients were referred to our institution for reoperation, hence, the immediate post-pacemaker implantation chest

radiographs were unavailable for review, which limited our ability to assess for lead displacement in these patients.

In conclusion, postoperative and follow-up chest radiographs are useful after pacemaker placement and demonstrate the majority of complications that require reoperation. Familiarity with the expected normal position of the leads, appearances of pacemaker complications, and comparison with prior radiographs is crucial in rendering a correct diagnosis that guides patient management.

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