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Managing superior vena cava syndrome in patients with cardiac implantable electronic device leads: Strategies and considerations

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ABSTRACT

BACKGROUND Data on transvenous (TV) lead–associated superior vena cava (SVC) syndrome are limited. The management of this problem might require a multidisciplinary approach, often involving transvenous lead extraction (TLE) followed by angioplasty and stenting.

OBJECTIVE The purpose of this study was to describe the management and outcome of TV lead–associated SVC syndrome.

METHODS We retrospectively identified patients with a diagnosis of SVC syndrome and TV leads at Emory Healthcare between 2015 and 2023.

RESULTS Fifteen patients with lead-related SVC syndrome were identified. The cohort average age was 50 years. Symptoms included swelling of the face, neck, and upper extremities (67%); shortness of breath (53%); and lightheadedness (40%). Patients had an average of 2 ± 0.7 leads crossing the SVC, with a lead dwell time of 9.8 ± 7.5 years. Thirteen patients were managed with TLE, followed by SVC stenting and angioplasty in 10 and angioplasty alone in 2; 1 patient had no intervention after TLE. One patient was managed with anticoagulation, and another had angioplasty and stenting with lead jailing. One patient experienced SVC perforation and cardiac tamponade during SVC stenting, which was managed successfully with a covered stent and pericardiocentesis. Among the 12 patients with TLE and angioplasty ± stenting, 7 underwent reimplantation of a transvenous lead. Two of those patients had symptoms recurrence, and none of the 5 patients without lead reimplantation had recurrence of symptoms.

CONCLUSION Lead-related SVC syndrome management requires a multidisciplinary approach often including TLE followed by angioplasty and stenting. Avoiding TV lead reimplantation might help reduce symptoms recurrence.

KEYWORDS Superior vena cava; Superior vena cava syndrome; Pacemaker lead; Implantable cardioverter-defibrillator lead; Transvenous lead extraction; Superior vena cava stenting; Superior vena cava balloon angioplasty

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Introduction

Cardiac implantable electronic device (CIED) lead–related venous stenosis is a common complication after pacemaker (PM) and implantable cardioverter-defibrillator (ICD) insertion.[1] If severe stenosis occurs at the level of the superior vena cava (SVC), patients can present with symptoms of SVC syndrome, which includes edema of the face, neck, and upper extremities; facial flushing; dizziness; and headaches.[2] Although >25% of patients who undergo PM or ICD insertion develop some degree of venous stenosis,[3] SVC stenosis and subsequent SVC syndrome is a rare condition occurring in up to 1.5% of CIED patients.[4] Hence, limited data on the management of SVC syndrome in patients with PM or ICD leads are available. This practice has shifted from conservative treatment with anticoagulation and thrombolytics to a procedural approach that requires "heart team"–based interventions including transvenous lead extraction (TLE), SVC balloon angioplasty, and stenting.[5]

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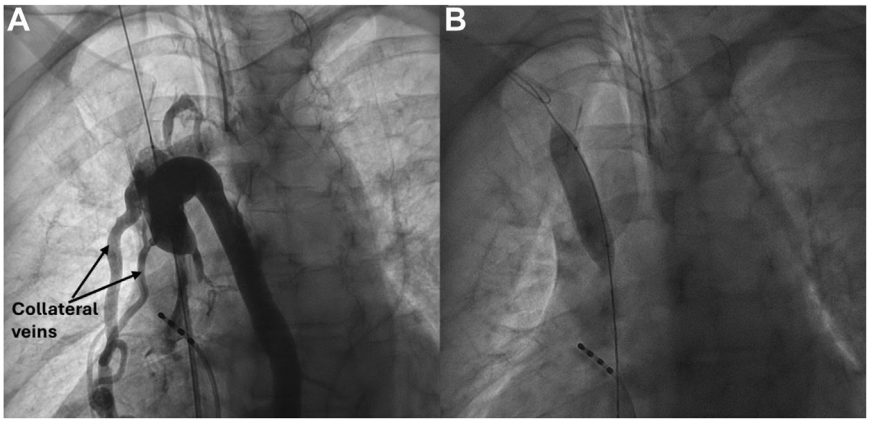

Figure 1
A: Venous angiogram showing complete superior vena cava (SVC) stenosis with contrast flowing through collateral venous circulation. **B:** Balloon angioplasty of the SVC.

Methods

This study was approved by the Emory University Institutional Review Board and adhered to the Helsinki Declaration as revised in 2013. We retrospectively identified all patients with a diagnosis of SVC syndrome who received care at Emory Healthcare between 2015 and 2023. We screened the patients to include only patients with CIED leads. SVC syndrome was diagnosed when a combination of symptoms (including but not limited to swelling of the face, neck, and upper extremities; headache; flushing; and dizziness) and radiological evidence of venous stenosis (venous angiogram or computed tomographic angiogram showing >90% stenosis in the SVC) (Figure 1A) were encountered.

Patient demographic data, past medical history, and SVC syndrome symptoms were identified by review of electronic medical records. We reported the outcomes of TLE, SVC balloon angioplasty (Figure 1B), stenting (Figure 2), and any procedure-related complications. Patients were categorized according to their management plan.

We also compared the outcome of TLE in patients with SVC syndrome to the outcome of TLE in all patients who have undergone this procedure at our institution and during the same period.

TLE was defined according to the Heart Rhythm Society consensus statement[6]: Lead removal procedure in which at least 1 lead removal required the assistance of equipment not typically used during lead implantation or at least 1 lead was implanted for >1 year. The TLE procedures were performed by experienced electrophysiologists. Before TLE, a temporary PM was inserted via femoral venous access in PM-dependent patients, and arterial and femoral venous access were obtained routinely for hemodynamic monitoring and to provide large-bore venous access for hemodynamic support and also to have the ability to go on arteriovenous bypass in case of an emergent need for rescue sternotomy. TLE was performed per our institutional standards, in a hybrid electrophysiology/catheterization laboratory or operating room with a cardiac surgeon and a surgical team on standby. Leads were prepared for extraction using a locking stylet and a suture on the outer insulation. Leads that were not removed with simple traction were extracted using an excimer laser or a rotating mechanical sheath (Philips, Amsterdam, The Netherlands).

SVC angioplasty and stenting procedures were performed by experienced interventional cardiologists or interventional radiologists. The procedures were performed in the same procedural room as the TLE. During extraction, the electrophysiologist attempted to leave a wire across the SVC stenosis. When this failed, the interventional cardiologist or interventional radiologist crossed the lesion using the femoral approach. The stenosed SVC area was dilated using a balloon or predilated in preparation for stent deployment. The decision for stent insertion was left to the operator discretion. A stent was deployed if needed (Supplemental Table 1). A final venogram was performed to check for contrast flow across the SVC and to assess for any residual stenosis (Figure 2).

Abbreviations

CIED: cardiac implantable electronic device

ICD: implantable cardioverter-defibrillator

PM: pacemaker

SVC: superior vena cava

TLE: transvenous lead extraction

Statistical analysis

Statistics included frequency distribution for categorical variables and mean ± SD for continuous variables. Differences between the SVC syndrome group and control group were assessed using the Student *t* test and χ^2 where appropriate. All analyses were performed using IBM SPSS Version 29.0 (IBM SPSS Statistics, Armonk, NY).

Results

Between 2015 and 2023, 73 patients were diagnosed with SVC syndrome, of whom 15 had CIED leads crossing the SVC. This cohort consisted of almost equal numbers of males and females (8 vs 7), with an average age of 50 years. Congenital heart disease was present in 53% of patients, and 47% had previous cardiac surgery (Table 1). Patients presented mostly

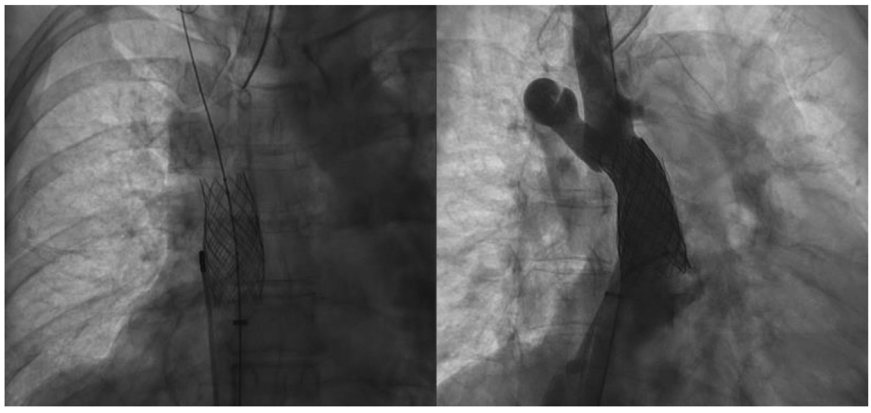

Figure 2
Contrast flowing through the superior vena cava after the stent was deployed

with swelling of the face, neck, and upper extremities (67%); shortness of breath (53%); and lightheadedness (40%) (Table 2). Median [interquartile range Q1–Q3] time from onset of symptoms to diagnosis was 2 months [0.5–4 months]. Two patients had a delayed diagnosis of SVC syndrome, occurring >2 years after initial symptoms presentation. Patients had an average of 2 ± 0.7 leads implanted with a dwell time of 9.8 ± 7.5 years. Lead extraction was attempted in 13 patients (87%). Powered tools were used in 11 of 13 patients to achieve 69% procedural success and 100% clinical success (Table 3).

In this study involving 15 patients (Figure 3), 13 underwent TLE; the remaining 2 were managed with either anticoagulation with rivaroxaban or SVC balloon angioplasty and stenting (which involved jailing the CIED lead). Both patients had symptoms resolution.

Among the 13 patients who underwent TLE, 1 had the procedure performed for lead revision, so no targeted intervention for SVC stenosis was performed because the patient was minimally symptomatic. Two patients underwent TLE and SVC balloon angioplasty without stenting. The operating interventional cardiologist elected not to deploy a stent because of the tortuosity of the SVC in one patient and because of the large diameter of the SVC in the other patient. Given their lack of underlying bradyarrhythmia requiring pacing, no device reimplantation was necessary.

The majority of our cohort (10 patients) underwent TLE followed by SVC angioplasty and stenting with or without subsequent device reimplantation (Figure 4). TLE procedures were uneventful; however, complications arose in 2 patients during SVC balloon angioplasty and stenting. One patient experienced vasodilatory shock and required temporary use of pressors. A transvenous device was not reimplanted in this patient. Complete symptom resolution was noted afterward. In the other patient, SVC perforation and cardiac tamponade occurred during SVC angioplasty, which were managed by deploying a covered stent in the SVC and pericardiocentesis. A device was reimplanted the following day, anticoagulation with coumadin was initiated on discharge, and the patient's symptoms improved at follow-up (Figure 5). Among the remaining 8 patients who underwent TLE, SVC balloon angioplasty, and SVC stenting, 2 did not undergo transvenous device reimplantation, and their symptoms improved over the follow-up period. Of the 6 patients who had a transvenous device reimplanted, 4 experienced symptoms improvement, whereas 2 had symptoms recurrence of the same severity and manifestation as before the intervention. Repeat TLE, SVC angioplasty, and stenting were performed in these 2 cases, but symptoms recurred afterward.

During the duration of the study, 1706 patients underwent TLE. We compared the characteristics and outcome of

Table 1 Baseline patients characteristics (N = 15)

Male	8 (53)
Age (y)	50.1 ± 12.7
BMI (kg/m^2)	28.4 ± 6.5
Atrial fibrillation	9 (60)
Congenital heart disease	8 (53)
History of cardiac surgery	7 (47)
Heart failure	4 (27)
Ejection fraction (%)	54 ± 14
End-stage renal disease	2 (13)
Hypertension	2 (13)
Coronary artery disease	1 (7)
Diabetes	1 (7)
On anticoagulation	5 (33)
Follow-up duration (y)	1.4 ± 1.1

Values are given as n (%) or mean ± SD.
BMI = body mass index.

Table 2 Presenting symptoms of patients with SVC syndrome and CIED leads

Symptoms occurrence	
Edema in face, neck	10 (67)
Shortness of breath	8 (53)
Lightheadedness	6 (40)
Limited dialysis access	1 (7)
Asymptomatic	1 (7)

Values are given as n (%)
CIED = cardiac implantable electronic device; SVC = superior vena cava.

Table 3 Characteristics and outcomes of TLE in patients with and without SVC syndrome

Transvenous leads management	SVC syndrome (N = 15)	Control group (N = 1706)	*P* value
Age (y)	50.1 ± 12.7	64.7 ± 15.1	<.001
Male	8 (53)	1049 (61.5)	.5
BMI (kg/m^2)	28.4 ± 6.5	30.1 ± 12.5	.3
Hypertension	2 (13)	490 (28.7)	.19
Coronary artery disease	1 (7)	415 (24.3)	.1
Diabetes	1 (7)	271 (15.9)	.1
End-stage renal disease	2 (13)	99 (5.8)	.22
Leads crossing the SVC	2 ± 0.7	1.67 ± 0.8	.2
Pacing leads	1.6 ± 0.9	1.08 ± 0.9	.1
Defibrillator leads	0.4 ± 0.5	0.6 ± 0.6	.2
Lead age (years)	9.8 ± 7.5	5.6 ± 5.3	<.001
TLE	N = 13	N = 1706	*P* value
Age (y)	49 ± 9.8	64.7 ± 15.1	<.001
Male	7 (53.8)	1049 (61.5)	.57
BMI (kg/m^2)	27.5 ± 5.9	30.2 ± 12.5	.26
Lead age (y)	10.5 ± 8.2	5.6 ± 5.3 years	<.001
Use of powered tools	11 (85)	841 (49.3)	.047
Complete procedural success	9 (69)	1600 (93.8)	<.001
Complete clinical success	13 (100)	1644 (96.4)	.48
TLE-related complications	0 (0)	23 (1.3)	.67

BMI = body mass index; TLE = transvenous lead extraction; SVC = superior vena cava.

extraction in patients with SVC syndrome to those without (Table 3). Patients with SVC syndrome were younger (49 vs 64.7 years; *P* <.001) and had longer lead dwell time (10.5 vs 5.6 years; *P* <.001). Procedural success was lower in the SVC syndrome group (69% vs 93.6%; *P* <.001), but clinical success was similar (100% vs 96.4%; *P* = .48).

The 4 patients with procedural failure were as follows. In 1 patient with congenital heart disease, two 29-year-old pacing leads fractured during extraction. The remaining retained small fragments were abandoned. In another patient, a 19-year-old Fineline pacing lead was fractured during extraction, and a small remaining part was also abandoned. In the remaining 2 patients with procedural failure, the lead tip of an 8-year-old passive fixation right ventricular lead remained embedded in the myocardium in 1 patient, while in the other patient, the lead tip of a 13-year-old pacing lead remained embedded in the SVC area after it separated from the rest of the lead during TLE.

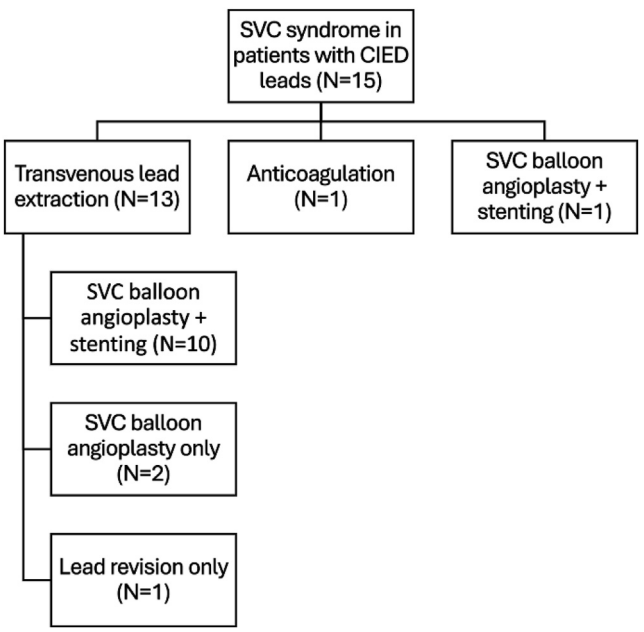

Figure 3
Management of patients with cardiac implantable electronic device (CIED) leads and superior vena cava (SVC) syndrome.

Discussion

With the introduction of powered tools for lead extraction and SVC percutaneous interventions (venoplasty and stenting), the management of SVC syndrome in patients with transvenous leads has shifted from a conservative approach[5] to a vascular/percutaneous approach. According to the Heart Rhythm Society expert consensus, lead extraction is recommended for patients with symptomatic SVC stenosis.[6] Most of our patients underwent TLE followed by SVC interventions. Despite a 2.3% risk of major complications and a 0.9% risk of death associated with TLE,[7] none of the patients in our cohort experienced a TLE-related complication. However, SVC angioplasty and stenting were not without risks. One of the 13 patients (7.7%) had a life-threatening complication after balloon inflation, and another patient (7.7%) had a minor complication.

SVC angioplasty and stenting without lead extraction were effective in treating 1 patient in our cohort. However, jailing the CIED lead carries a significant risk, particularly in patients who are PM-dependent or at high risk for infections.[8] The entrapped lead may malfunction or dislodge when the stent is deployed. In addition, it would be challenging to extract the lead in the event of a CIED infection.

Only 1 patient in our cohort was managed conservatively with anticoagulation, and the patient's symptoms resolved. Historical data show that anticoagulation is sometimes effective in treating lead-related SVC syndrome, with an approximate 21% recurrence rate.[5] In a study by Arora and Carrillo,[9] 17 patients with SVC syndrome were treated: 13 with an extraction followed by balloon angioplasty, 1 patient required surgical reconstruction, and 3 received balloon angioplasty without TLE. In their study, venoplasty alone was effective in treating lead-associated SVC syndrome without recurrence after 1-year follow-up. However, other studies have shown limited long-term efficacy of venoplasty or anticoagulation as standalone therapies for lead-induced SVC syndrome.[5] Histological data indicate that only a minority of cases of lead-related SVC syndrome arise from lead thrombosis, with the predominant cause being fibrosis occurring between the blood vessels and the CIED leads.[10] This hypothesis is further supported by the manifestation

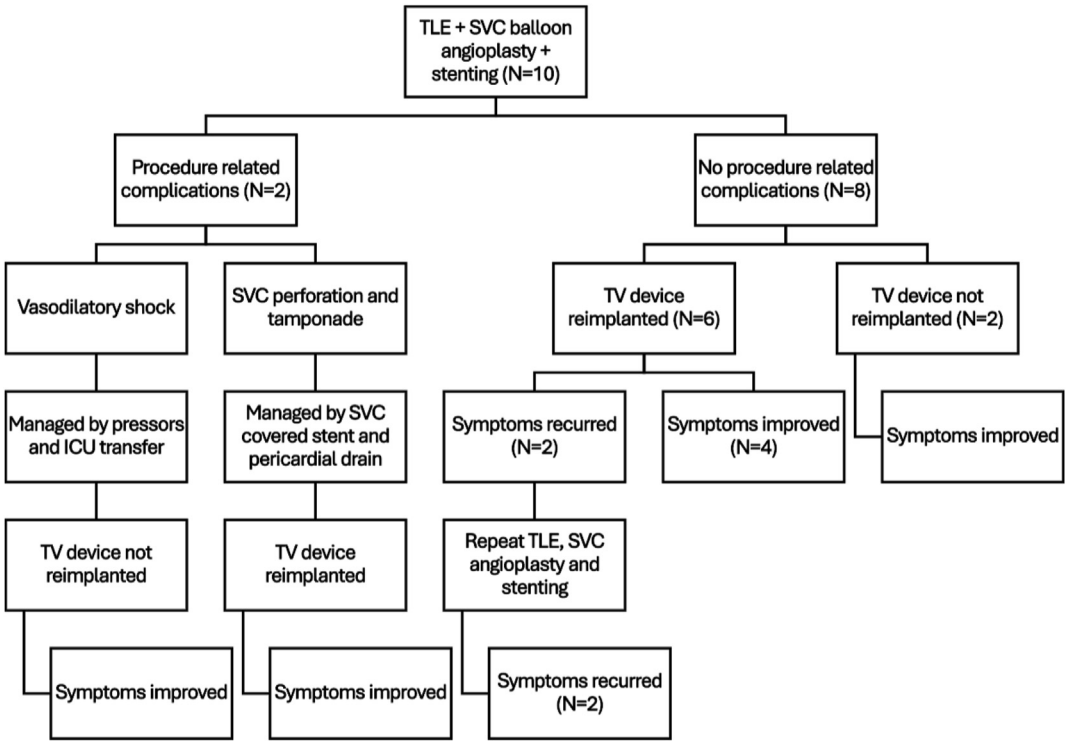

Figure 4
Outcomes of 10 patients managed with transvenous lead extraction (TLE) and subsequent superior vena cava (SVC) balloon angioplasty and stenting. ICU = intensive care unit; TV = transvenous.

of the disease long after lead implantation, implying a progressive nature of fibrotic vein narrowing.

In a study by Gabriel et al,[11] 16 patients with SVC syndrome and CIED were evaluated. Half of the patients had undergone SVC balloon angioplasty with recurrence of symptoms and were referred for further management. Fifteen patients had successful TLE, but 1 patient had an SVC tear that required surgical repair. Six patients received an SVC stent, and 3 had a brachiocephalic stent. Five patients did not receive any intervention because of inability to cross the SVC stenosis. Over 5 years of follow-up 25% of patients had recurrence of symptoms.

We also note that although the clinical success of TLE was excellent in our cohort, the procedural success was lower than expected (69% vs 94% in the non-SVC syndrome cohort). This could be related to patient characteristics. The mean age of our patients was 49 years, and TLE is more challenging in younger patients,[12] probably because of their tendency for more fibrosis. In addition, 53% of patients had congenital heart disease and leads with a long-dwell time (up to 30 years).

For most of our cohort, SVC syndrome management was complex. It involved TLE, SVC angioplasty, and stenting with or without subsequent device reimplantation. With these procedures come inherent risks of complications. This should be considered when weighing the pros and cons of conservative vs interventional treatment. One of the complications of SVC angioplasty was SVC perforation and cardiac tamponade. This complication responded to pericardiocentesis and the deployment of a covered stent. Our data further indicate that among the patients who underwent TLE, SVC balloon angioplasty, and stenting without device reimplantation, had permanent symptoms resolution without recurrence. In contrast, among the remaining patients who had a transvenous device reimplanted, 2 of 7 patients experienced symptoms recurrence despite repeat TLE, SVC angioplasty, and stenting. This suggests that the presence of a transvenous lead contributes to the recurrence of stenosis, even after interventions targeting the venous stenosis.

It is important to carefully weigh the decision to reimplant a transvenous device in patients with SVC syndrome even after percutaneous treatment. Device reimplantation may be necessary in some cases, but our results suggest that it may lead to recurrent stenosis. In these cases, leadless PMs or non-transvenous ICDs should be considered as an alternative to traditional transvenous systems.

Study limitations

This was a retrospective single-center study with a small sample size. Also, our center is a tertiary care center with experience in TLE and venous angioplasty and stenting, so our results may not be generalized to smaller centers with less expertise. Finally, the follow-up duration was not long enough to account for long term in-stent restenosis.

Conclusion

The management of SVC syndrome in patients with CIED lead–related venous stenosis requires a multidisciplinary

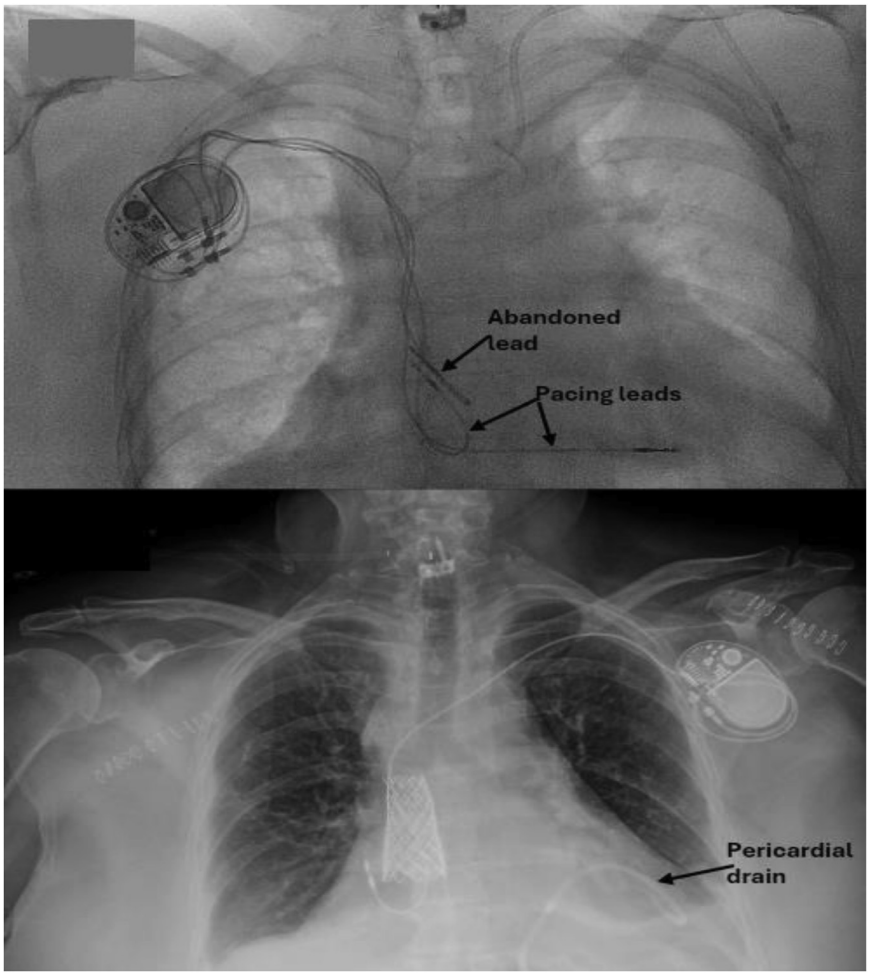

Figure 5
Chest radiographs of a patient who underwent right-sided device extraction, superior vena cava (SVC) angioplasty, and stenting followed by left-sided device implantation. A pericardial drain was placed for treatment of pericardial tamponade caused by SVC angioplasty.

"heart team" approach. Although interventions such as TLE, SVC angioplasty, and stenting alleviate symptoms, they also entail a risk of complications. The decision to reimplant a device should be carefully weighed against the risk of restenosis. Leadless PMs and subcutaneous or extravascular ICDs may offer safer alternatives to transvenous devices in this setting. Individualized treatment plans, considering patient-specific factors, are crucial for optimizing outcomes

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrthm.2024.06.060.

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