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Transvenous Extraction of Spontaneously Fractured Leads with Migrated Proximal Ends: Techniques and Outcomes

Daniel Fischer[1]*, Laura Meier[1], Thomas Braun[2], Stefan Koch[2], Felix Roth[1]

[1]Department of Translational Clinical Sciences, University of Freiburg, Freiburg, Germany.
[2]Department of Medical Innovation Systems, Karlsruhe Institute of Technology, Karlsruhe, Germany.

Abstract

The extraction of spontaneously fractured pacemaker or defibrillator leads whose proximal segments have migrated into the vascular system has received limited detailed analysis to date. This study was designed to evaluate and compare the efficacy of various extraction techniques and supporting tools for fractured leads with migrated proximal ends. A retrospective review was performed on 72 cases selected from a total database of 3847 transvenous lead extraction (TLE) procedures. The majority of the extracted leads were passive-fixation models, particularly unipolar ones. These procedures were highly complex; nevertheless, the overall success rate remained strong at 93.06% and was not dependent on the exact location of the proximal end during migration. Major complications occurred in 2.78% of cases, a rate that may be linked to the extended implant duration of 152.2 months. Removal of these leads showed no impact on patients' long-term survival. The femoral approach was the most commonly utilized method, applied in 62.50% of cases. Mechanical dissection tools were necessary in 79.16% of the leads. In 66.7% of procedures, the proximal end was tightly adhered to the vessel wall, requiring the creation of a loop for extraction. Additionally, in 15.28% of cases, the lead was coiled around a pigtail catheter using the so-called "spaghetti twisting technique." (1) Spontaneous fracture of a lead with migration of the proximal end into the vascular space is uncommon, accounting for only 1.87% of all TLE procedures. (2) Successful removal of such leads demands a variety of extraction approaches combined with both specialized and standard tools. (3) Although these procedures are highly complex, they achieve good effectiveness with an acceptable incidence of major complications.

Keywords: Transvenous lead extraction, Fractured lead removal, Femoral approach, Methods of fractured lead removal, Extraction of migrated leads

Corresponding author: Daniel Fischer
E-mail: daniel.fischer@outlook.com

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Introduction

Several factors, including overly parasternal venous puncture leading to crush syndrome, inadequate anchoring of severed abandoned leads, and fractures resulting from overly tight ligatures, can cause the proximal portions of leads to migrate into the bloodstream and travel further [1-18]. Leads with migrated proximal ends (LMPE) situated in the subclavian or brachiocephalic vein [1, 7, 8, 10-17] or in the superior vena cava [1, 10, 11-17] frequently develop loops capable of crossing the tricuspid valve and entering the right ventricle, potentially resulting in tricuspid regurgitation [1] or triggering ventricular arrhythmias [8]. When not encased in fibrous tissue, free-floating LMPEs may progress into the pulmonary artery [1, 2, 5, 7] and cause pulmonary embolism [1, 2]. Given the considerable hazards associated with these complications, LMPEs are classified as class 1 or 2b

indications for lead extraction in the Heart Rhythm Society (HRS) guidelines [17, 18]. Descriptions of migrated proximal lead ends appear in multiple case reports [3-11], a limited number of studies [1, 2], and official lead management guidelines [17, 18]. Until now, however, no publication has systematically outlined the extraction techniques or thoroughly assessed their success rates specifically for LMPE removal.

It is worth noting that some authors have advocated a conservative strategy involving no active intervention and only regular patient monitoring [3-5].

This study aimed to assess the effectiveness of various extraction approaches and assistive tools for removing fractured leads with migrated proximal ends (LMPE). In addition, we intended to provide a more detailed description of the specific techniques used across different access routes and with both dedicated and non-dedicated instruments, while considering the position of the proximal end and the degree of fixation provided by surrounding scar tissue.

Materials and Methods

Study population

The institutional database, which included 3847 transvenous lead extraction (TLE) procedures performed from March 2006 to March 2023 at three tertiary, high-volume centers, was screened to identify eligible participants. Patient demographics, cardiac implantable electronic device (CIED) specifications, pacing history, characteristics of the leads targeted for removal, procedural difficulty level, success rates, and outcomes were all retrospectively examined in the electronic registry. For the present analysis, 72 patients were selected in whom the proximal ends of fractured leads had migrated into the vascular compartment. They were no longer reachable from the generator pocket or the original venous insertion point. Attention was limited strictly to this particular subset of cases.

Definitions

Criteria for lead extraction, measures of procedural success, and definitions of complications followed the established lead management consensus documents issued by the Heart Rhythm Society in 2009 and 2017 [17, 18]. Procedural effectiveness was quantified using the rates of both procedural and clinical success [17, 18]. Major complications arising during TLE were classified as any life-threatening event, occurrence causing notable or lasting disability, death, or any situation demanding immediate surgical correction (including emergency cardiac surgery intended to avoid procedure-related fatality or permanent harm) [17, 18].

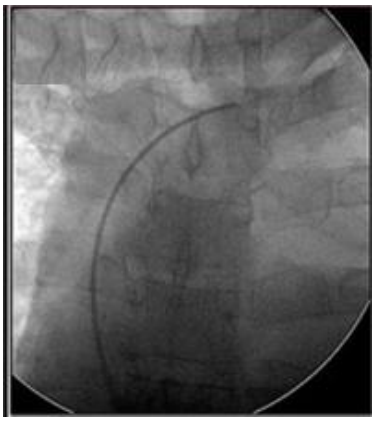
Procedure complexity was evaluated based on overall extraction duration, mean extraction time per individual lead, and the use of second-line or advanced extraction instruments [19, 20]. Another indicator of difficulty was the Complex Indicator of the Difficulty of the TLE (CID-TLE). This score awards 2 points when the extraction of all leads exceeds 20 minutes, 2 points when the average time per lead exceeds 12 minutes, and 1 point each for the use of metal sheaths or Evolution/TightRail devices, the use of an alternative access route, or the necessity of lasso or basket catheters. The accumulated points yield the final CID-TLE value [19].

Unexpected difficulties encountered during the procedure (termed “technical problems”) were unforeseen events that escalated procedural challenges but did not meet the criteria for complications. Examples included obstruction at the venous entry or subclavian area that blocked passage of a polypropylene catheter, collapse or breakage of a Byrd dilator, adhesion between multiple leads, adoption of an alternative access route, loss of a lead fragment (in which the bulk of the lead was freed and extracted while a detached mobile segment remained within the vessels, commonly drifting toward the pulmonary arteries), and unintended displacement of still-active leads [20].

Assessment of procedural difficulty further incorporated the MB score (Mazzone–Bontempi score), which reflects the requirement for advanced tools to complete successful TLE (range 0–5 points) [21], the LED index based on fluoroscopy exposure time as a marker of extraction challenge (range 0–50 points) [22], and the Advanced LE Techniques score designed to anticipate the need for sophisticated extraction methods (range 0–4 points) [23]. In addition, the newly proposed LECOM score — derived from lead dilatation time, reliance on second-line or advanced tools, and use of complex techniques — emerged as the most reliable predictor of unexpected procedural difficulties (UPD) [19].

Leads with their proximal ends migrated into the cardiovascular space—definitions

LMPEs were characterized as leads that fractured for various reasons and via different mechanisms within the implantation veins. Their proximal segments had spontaneously detached and migrated freely into the cardiovascular lumen, advancing from the subclavian vein onward to the superior vena cava, right atrium, right ventricle, pulmonary artery, or, less commonly, into other venous branches. Meanwhile, the distal tips stayed fixed at the original myocardial implantation site **(Figures 1-6)** [1-15].



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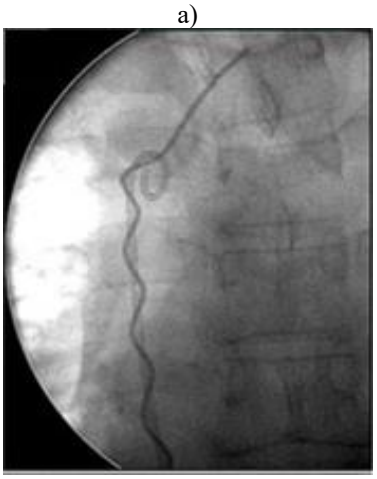

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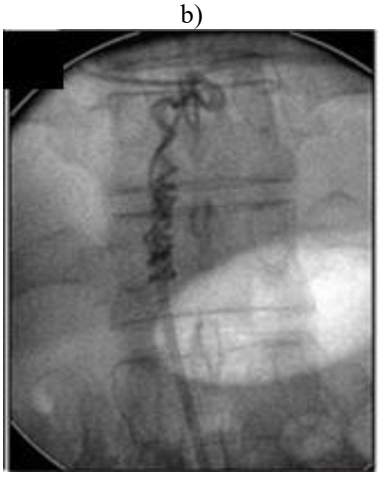

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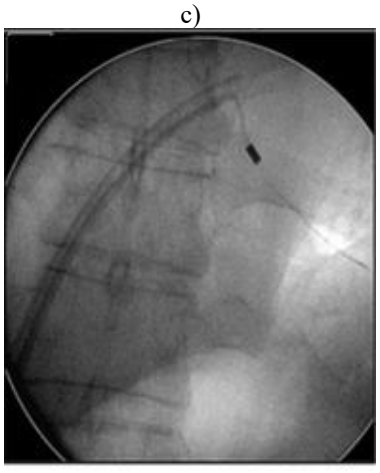

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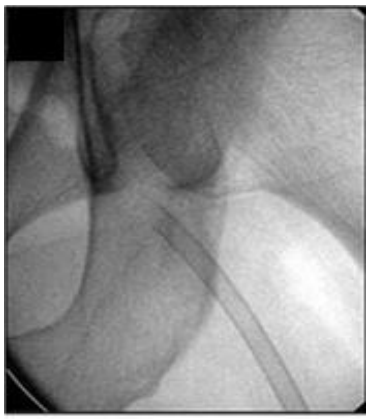

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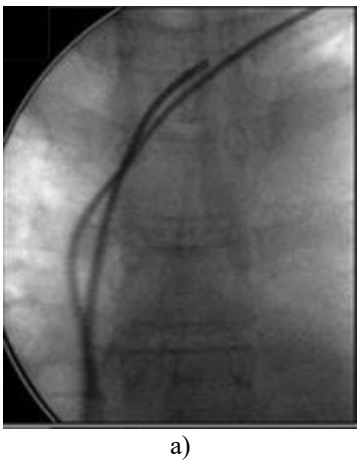
Figure 1. Extraction of the fractured lead through the femoral route employing the "spaghetti twisting technique" to liberate its proximal segment. The fractured bipolar ventricular lead with its proximal end located in the anonymous vein (a), coiling the lead body around the pigtail catheter (b), mild traction applied to the pigtail catheter disengages the proximal end of the lead (c), allowing it to be captured via femoral access and subsequently freed (d), and the successfully extracted lead (e, f). The proximal tip was secured using a basket catheter guided by the bend of the electrophysiological sheath and then separated by rotating a 13F beveled Teflon catheter.



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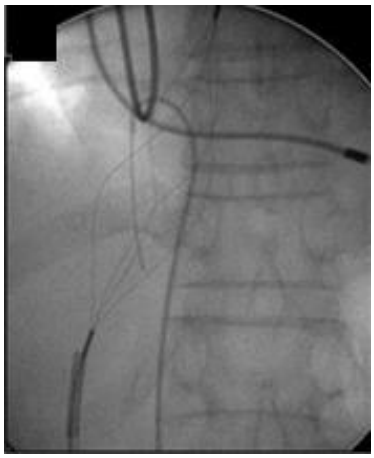

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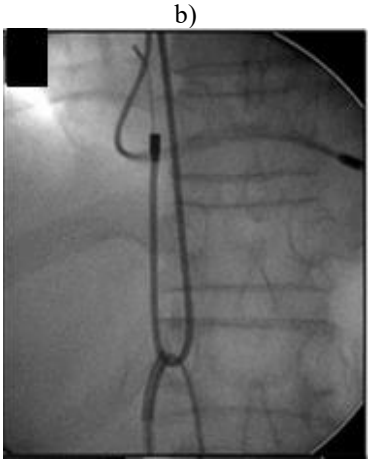

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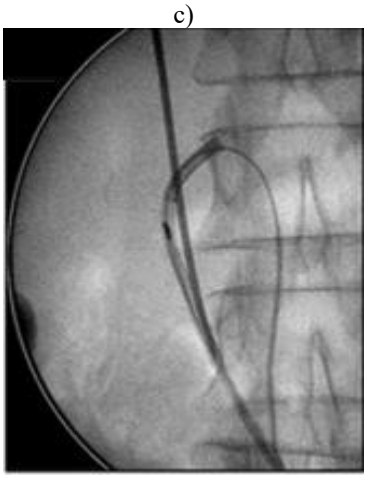

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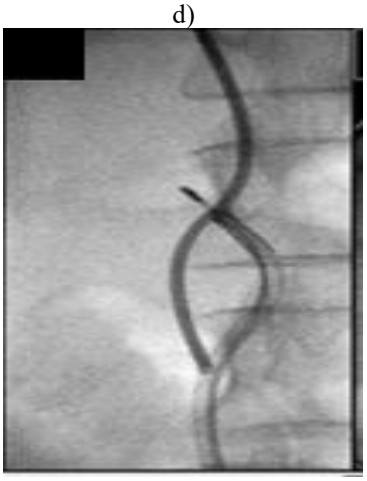

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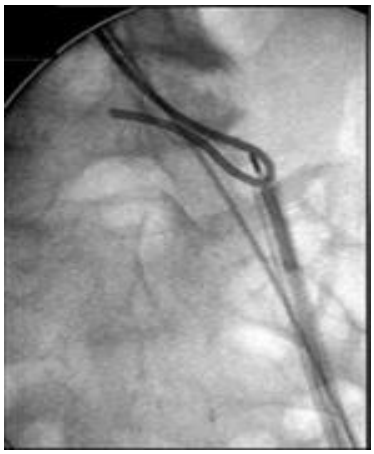

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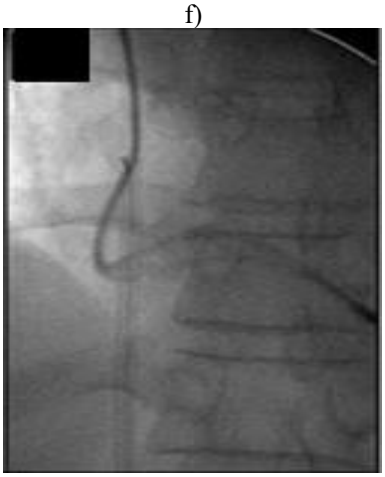
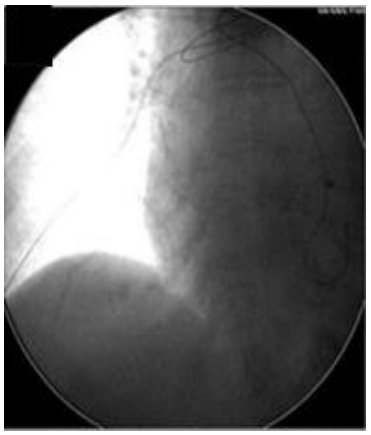


g)

Figure 2. Extraction of the fractured lead through the femoral route employing a loop to liberate its proximal segment. The proximal end of the spontaneously fractured bipolar atrial lead is positioned in the anonymous vein (a), formation of the loop was achieved with a basket catheter, directed by a left ventricular lead delivery catheter, together with an angiographic guidewire (b), downward traction on the loop dislodges the proximal end of the lead and relocates it into the inferior vena cava (c, d), the proximal end was then captured with the basket catheter (e, f), and the lead was successfully freed using an extra-long polypropylene sheath (g).



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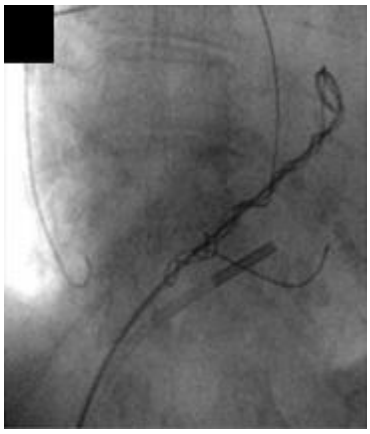

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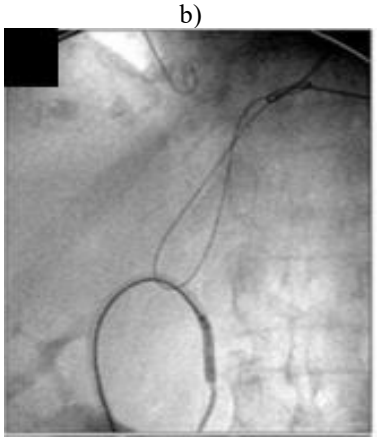

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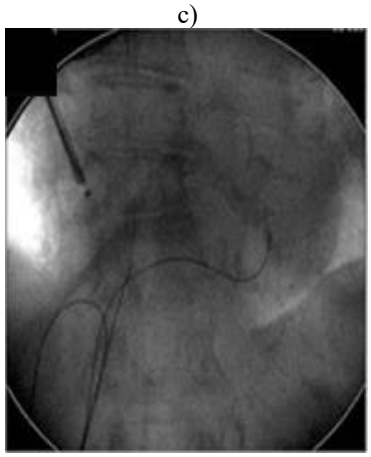

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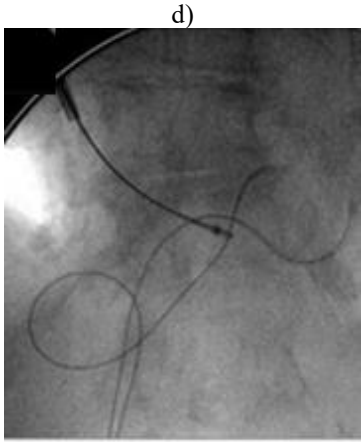

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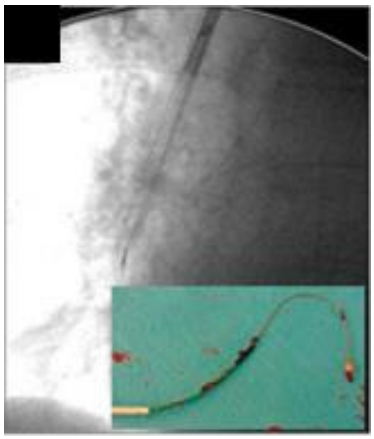

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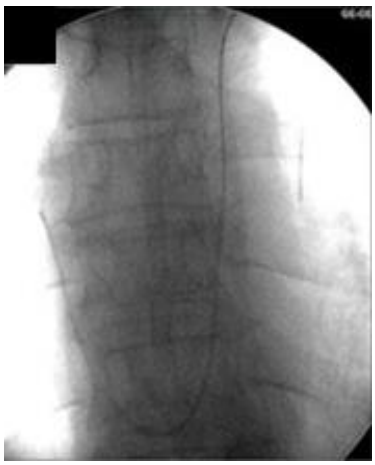
Figure 3. Extraction of the fractured unipolar ventricular lead whose proximal end had lodged in a distal branch of the pulmonary artery. A combined superior and femoral approach was applied, along with the "spaghetti twisting technique" and a loop to dislodge the proximal segment. The fractured unipolar ventricular lead terminated in the distal branch of the right pulmonary artery (a). Partial withdrawal of the proximal lead end from the pulmonary artery proved insufficient. The intervention was technically challenging, requiring simultaneous subclavian and femoral access (with the left ventricular lead delivery catheter functioning as the femoral workstation) (b). Complete lead retrieval from the pulmonary artery was achieved by forming a loop with a lasso catheter and an angiographic guidewire (c, d). The proximal lead end was then captured using a lasso catheter (guided by the left ventricular lead delivery catheter) via the subclavian access (e). Routine lead dissection was subsequently performed with a polypropylene sheath introduced from the subclavian route (f).



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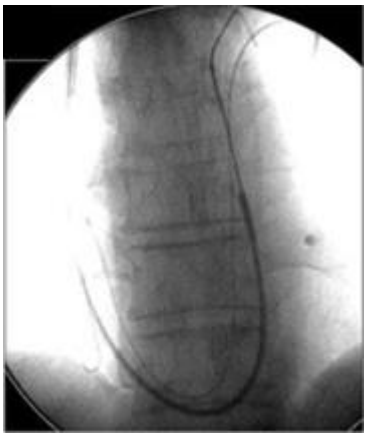

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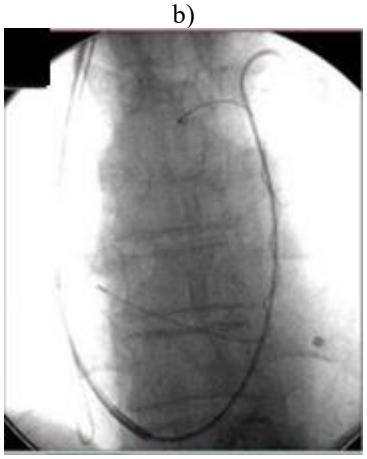

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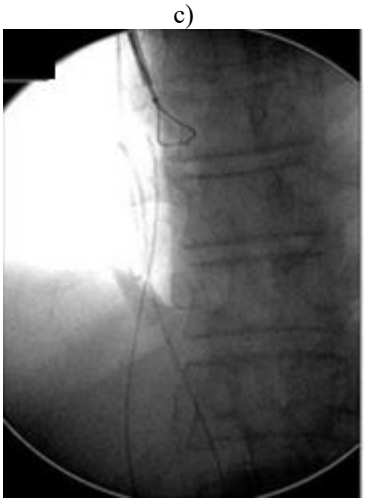

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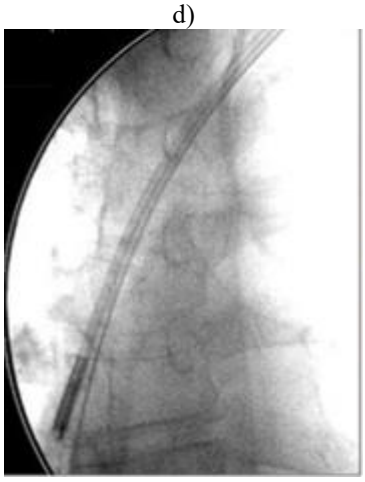

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Figure 4. Extraction of the fractured unipolar atrial lead whose proximal end had lodged in a distal branch of the pulmonary artery was performed entirely from the superior (subclavian) approach with the aid of the "spaghetti twisting technique" to release the proximal segment. The fractured unipolar atrial lead terminated in the distal branch of the left pulmonary artery (a). The lead was engaged inside the pulmonary artery through the "spaghetti twisting technique" (b, c). The catheter designed for left ventricular lead implantation served as a stable workstation to facilitate delivery of the tool into the pulmonary trunk (b, c). Successful withdrawal of the lead from the pulmonary artery was achieved (d). The proximal end was subsequently grasped with a lasso catheter (also directed by the left ventricular lead delivery catheter) from the subclavian access (d, e). Standard lead dissection was followed using a polypropylene sheath advanced from the subclavian route (e, f).

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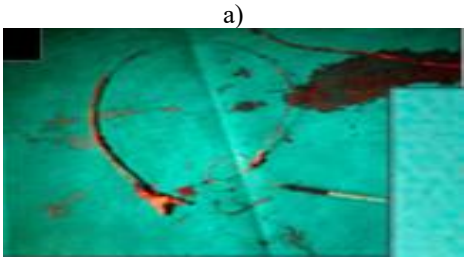

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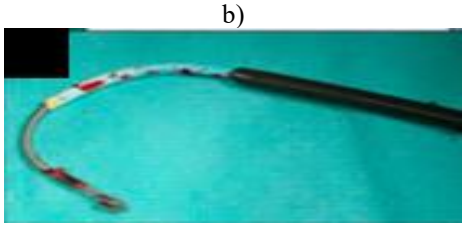

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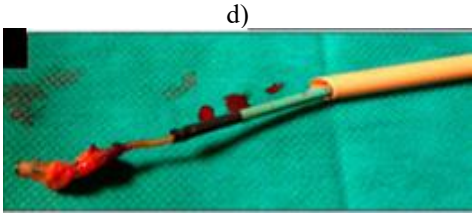

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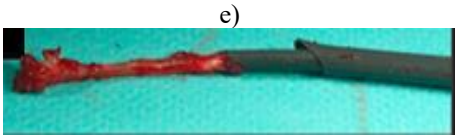

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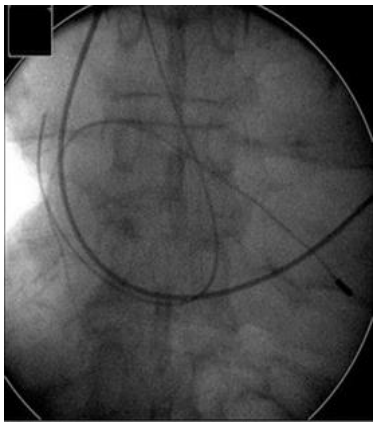
Figure 5. The instruments most often used for removal of spontaneously fractured leads with migrated proximal ends in the cardiovascular space include lasso or basket catheters, directed by a left ventricular lead implantation catheter or by curved electrophysiological catheters. In this setup, the fractured lead, together with the lasso or basket catheter, serves as an extension. At the same time, the outer sheath provides an additional guiding rail for the polypropylene or Teflon catheter. A conventional instrument set is employed, whether the superior or femoral approach is chosen (a). The curved left ventricular lead delivery catheter greatly assists in maneuvering the lasso (b). This same catheter permits ongoing dissection of the distal lead segment from either the superior (jugular or subclavian) or femoral route (c). Several auxiliary surgical tools are applied to stop the grasped lead from slipping out of the lasso (these devices free the operator from continuously holding the lasso closed) (d). The extracted leads are shown alongside the dissection instruments used (e, f).



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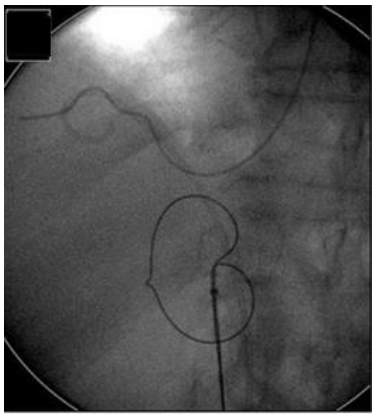

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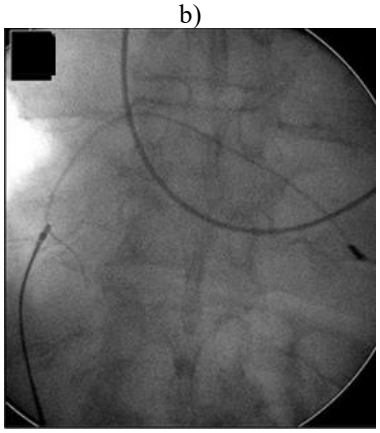

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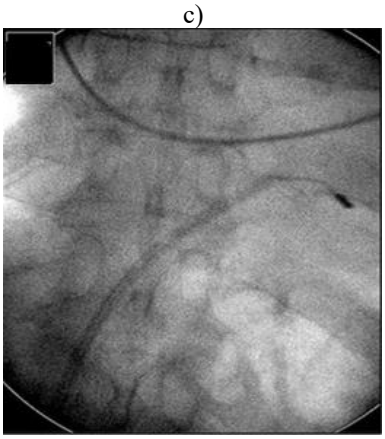

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Figure 6. Extraction of the fractured ventricular lead from the femoral approach employing the "spaghetti twisting technique" to free its proximal end, which was embedded in scar tissue and firmly attached to the right atrial wall. The fractured bipolar ventricular lead had its proximal end deeply fixed within the right atrial wall (a). The lead body was wrapped around the pigtail catheter (b). Traction applied to the pigtail catheter released the proximal end (c), allowing it to be secured with a lasso catheter (b, d). The procedure was then completed by dilating the distal lead segment using an extra-long polypropylene sheath.

Procedure information

All procedures followed a progressive, step-by-step protocol. Standard stylets or locking stylets (Liberator Locking Stylet, Cook Medical Inc., Bloomington, IN,

USA) were applied, with locking stylets reserved primarily for the oldest leads — especially passive-fixation types — that carried a substantial risk of fracture. The initial dissection typically relied on non-powered mechanical telescoping polypropylene sheaths (Byrd Dilator Sheaths, Cook Medical Inc., Bloomington, IN, USA), available in all required sizes and lengths. When blockage occurred within the implantation vein or the proximal subclavian segment, powered mechanical sheath systems (Evolution Mechanical Dilator Sheath, Cook Medical, Bloomington, IN, USA; TightRail Rotating Dilator Sheath, Phillips, Colorado Springs, CO, USA) or metal sheaths were introduced as second-line options. In situations where conventional superior techniques failed (particularly with LMPE or lead rupture), an alternative or combined strategy involving multiple access sites (cervical, subclavian, or femoral) was chosen [1-15].

Extraction of leads with migrated proximal ends into the cardiovascular space

Maximum effort was always directed toward the complete removal of every LMPE. These leads were viewed as non-functional abandoned hardware with the potential to trigger serious problems stemming from migration (thrombosis, venous occlusion, arrhythmias) or from loop formation within the heart (tricuspid valve dysfunction, arrhythmias). A key concern is that progressive fibrous attachment of the looped lead to the venous wall can markedly complicate future extraction should infection arise [1, 2, 11, 13, 16-18]. For this reason, such leads were handled according to the guideline definition of "any lead that, if left in place, may pose an immediate threat to the patient or any lead that, if left in place, may pose a potential threat to the patient in the future" [17, 18].

The retrieval strategy for the proximal end of the fractured and migrated lead depended on its final position. Retrieval was generally attempted with a lasso or basket catheter, most commonly from the femoral vein and less often from the jugular vein. When additional leads were required for extraction, the subclavian access was sometimes re-established after those leads were removed and then used for the migrated segment **(Figures 1-6)** [1-3]. Once the proximal end was securely captured, the lasso or basket catheter effectively extended the lead, permitting controlled dissection and complete removal with polypropylene sheaths or 18F beveled catheters serving as standard polypropylene tools **(Figures 1 and 4)** [1, 2, 12, 13]. Mechanical rotational devices were used infrequently in this cohort, as most cases **(Figures 3 and 4)** predated their commercial availability. The Eye of the Needle Snare© (Cook Medical Inc., Bloomington, IN, USA) was seldom selected because alternative methods consistently proved more reliable. When direct grasping of the proximal end was not possible, it was liberated from encapsulating fibrous tissue by winding the lead body around a pigtail catheter (the "spaghetti twisting technique") **(Figures 1, 3 and 4)** [1, 2, 12, 13] or, with similar frequency, by forming a loop using a guidewire combined with a lasso or basket catheter passed over the target lead and then gently pulled **(Figure 2)** [1, 2, 9, 10, 14, 15] if the spaghetti twisting technique proved insufficient.

No laser sheaths were employed. Over the 17 years, the logistical framework for lead extraction procedures evolved considerably — shifting from interventions performed in the electrophysiology laboratory with intravenous sedation to fully standardized operations conducted exclusively in a hybrid operating room under general anesthesia [24]. In the final 7 years, the core team remained consistent and comprised the same senior lead extractor (now frequently serving as a proctor), an experienced echocardiographer, and a dedicated cardiac surgeon [24].

Dataset and statistical methods

Creation of subgroups for analysis

From the full database, 72 patients were identified for this study. These individuals had been referred for the extraction of leads whose proximal ends had spontaneously migrated into the cardiovascular space. They were no longer accessible from the generator pocket or the original venous entry point. Patient ages ranged from 13 to 88 years, with a mean age of 63.42 years; 27 (37.50%) were female.

Given that the optimal extraction technique is strongly influenced by the precise location of the migrated proximal end, four distinct subgroups were formed: 1. superior vena cava and right atrium (39 patients); 2. subclavian and anonymous vein (13 patients); 3. right ventricle (13 patients); 4. pulmonary artery (7 patients).

Statistics

Continuous data are expressed as mean ± standard deviation. Categorical data are reported as absolute numbers and percentages. Inter-group comparisons were performed using the non-parametric Chi^2 test with Yates' correction or the unpaired Mann–Whitney U test, whichever was more appropriate. Survival curves were compared with the log-rank test. Statistical significance was defined as a P-value < 0.05. All analyses were carried out using Statistica 13.3 (TIBCO Software Inc., Tulsa, OK, USA).

Approval of the bioethics committee

Written informed consent was obtained from every patient for both the transvenous lead extraction procedure and the anonymous utilization of their clinical data. The study received approval from the Bioethics Committee of the

Regional Chamber of Physicians in Lublin (decision no. 288/2018/KB/VII, dated 27 November 2018). All aspects of the research complied with the ethical principles of the 1964 Declaration of Helsinki.

Results and Discussion

Given that the present study centers on the extraction of LMPE and that both the extraction techniques and the challenges involved are strongly influenced by the location of the proximal end, together with the extent of scar tissue surrounding the lead and its migrated segment, the analysis compared four distinct patient groups classified according to the different positions of the migrated proximal ends.

The study groups, categorized by the final position reached by the migrated proximal tip, were largely similar with respect to patient-related risk factors (age at TLE and at initial implantation, gender, cardiac function status, and extraction indications) and system-related risk factors (overall lead burden). The sole clear distinction concerned the formation of lead loops inside the heart. It stands to reason that the more distally the proximal end travels into the cardiovascular space, the greater the probability of loop creation within the cardiac chambers **(Table 1)**.

Table 1. Patient-, system-, and procedure-related risk factors.

Location of the migrated proximal end of a fractured lead within the cardiovascular system					
Risk factors	**Group 1 (SVC and right atrium, n = 39)**	**Group 2 (Subclavian and brachiocephalic Vein, n = 13)**	**Group 3 (Right ventricle, n = 13)**	**Group 4 (pulmonary artery, n = 7)**	**Total (group 5, n = 72)**
	Mean ± SD / n (%)	Mean ± SD / n (%)	Mean ± SD / n (%)	Mean ± SD / n (%)	Mean ± SD / n (%)
P-value vs group 1	—	p (2 vs 1)	p (3 vs 1)	p (4 vs 1)	—
			Patient-related factors		
Variable	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Total**
Age at TLE (years)	64.31 ± 15.97	62.15 ± 20.04 (P = 0.695)	64.54 ± 7.88 (P = 0.960)	58.71 ± 16.50 (P = 0.400)	63.42 ± 15.53
Age at first implantation (years)	51.39 ± 18.42	50.92 ± 17.83 (P = 0.937)	49.62 ± 11.02 (P = 0.684)	46.43 ± 15.70 (P = 0.508)	50.50 ± 16.70
Female sex	15 (38.46%)	5 (38.46%) (P = 0.742)	5 (38.46%) (P = 0.742)	2 (28.57%) (P = 0.941)	27 (37.50%)
LVEF (%)	53.52 ± 13.66	59.54 ± 11.41 (P = 0.345)	48.77 ± 17.17 (P = 0.314)	57.29 ± 14.24 (P = 0.507)	54.22 ± 14.16
Infective indication	9 (23.08%)	5 (38.46%) (P = 0.470)	5 (38.46%) (P = 0.470)	3 (42.86%) (P = 0.529)	22 (30.56%)
			System-related factors		
Variable	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Total**
Number of leads before TLE					
1–2 leads	20 (51.28%)	9 (69.23%) (P = 0.402)	9 (69.23%) (P = 0.402)	3 (42.86%) (P = 1.000)	41 (56.94%)
≥ 3 leads	19 (48.72%)	4 (30.77%) (P = 0.402)	4 (30.77%) (P = 0.402)	4 (57.14%) (P = 1.000)	31 (43.06%)
			Lead loop characteristics		
Variable	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Total**
Long loop affecting the tricuspid valve	16 (41.03)	5 (38.46) P = 0.870	11 (84.62) P = 0.016	7 (100.0) P = 0.014	39 (54.17)
Short loop	23 (58.97)	7 (53.85) P = 1.000	2 (15.38) P = 0.016	0 (0.00) P = 0.014	32 (44.44)
			Predicted procedural complexity		
Score	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Total**

MB score	2.92 ± 1.31	3.23 ± 0.93 (P = 0.436)	3.81 ± 0.95 (P = 0.029)	3.57 ± 0.98 (P = 0.358)	3.11 ± 1.16
LED index	14.26 ± 7.98	13.23 ± 4.09 (P = 0.695)	16.23 ± 5.57 (P = 0.423)	14.86 ± 4.85 (P = 0.848)	14.49 ± 6.71
ALET (Mazzone scale)	2.18 ± 0.91	2.15 ± 0.80 (P = 0.939)	2.23 ± 0.83 (P = 0.875)	2.71 ± 1.11 (P = 0.274)	2.24 ± 0.90
LECOM score	12.92 ± 5.27	12.58 ± 4.51 (P = 0.834)	14.14 ± 5.49 (P = 0.478)	14.55 ± 3.18 (P = 0.435)	13.23 ± 4.97
Interference with the tricuspid valve or pulmonary valve	16 (41.03)	5 (38.46) P = 0.870	11 (84.62) P = 0.016	7 (100.0) P = 0.014	39 (54.17)
			Procedure-related factors		
Variable	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Total**
Extraction of ≥ 3 leads	11 (28.21%)	3 (23.08%) (P = 1.000)	1 (7.69%) (P = 0.254)	4 (57.14%) (P = 0.286)	19 (26.39%)
Removal of abandoned leads	23 (58.97%)	8 (61.54%) (P = 0.870)	10 (76.92%) (P = 0.406)	6 (85.71%) (P = 0.355)	47 (65.28%)
Leads with excessive slack	17 (43.59%)	5 (38.46%) (P = 1.000)	12 (92.31%) (P = 0.006)	7 (100.0%) (P = 0.019)	41 (56.94%)
Oldest lead dwell time (months)	149.1 ± 89.01	138.5 ± 48.92 (P = 0.683)	176.3 ± 67.80 (P = 0.319)	149.2 ± 65.70 (P = 0.998)	152.2 ± 77.03
Mean dwell time (months)	21.43 ± 16.93	18.25 ± 9.94 (P = 0.526)	23.22 ± 12.81 (P = 0.729)	25.94 ± 16.29 (P = 0.518)	21.62 ± 14.99

Abbreviations: CVS = cardiovascular space, N = number, TLE = transvenous lead extraction. MB score (need for advanced tools), LED index (predicted procedure fluoroscopy time), Advanced TL (ALET—need for advanced TLE techniques), LECOM score (predicted procedure complexity).

The pre-procedural scores designed to predict extraction difficulty (which typically overlook the uncommon occurrence of proximal-end migration into the cardiovascular space) showed essentially no meaningful differences between groups, except for the MB score. This finding highlights the restricted usefulness of these scoring systems when applied to cases involving migrated leads.

In the same manner, procedure-related factors linked to extraction complexity revealed no significant inter-group differences, except for a notably higher incidence of abnormal lead loops within the heart when the proximal end had advanced farther into the ventricle or the pulmonary artery **(Table 1)**.

Attention then turned to identifying which lead types and specific models (based on intended function and structural design) were more susceptible to fracture and spontaneous migration into the cardiovascular space **(Table 2)**.

Table 2. Information on fractured and migrated leads.

Location of proximal ends of fractured leads migrated into the cardiovascular system (CVS)					
Fractured lead characteristics	**Group 1 (n = 39)**	**Group 2 (n = 13)**	**Group 3 (n = 13)**	**Group 4 (n = 7)**	**Total (Group 5, n = 72)**
	Mean ± SD/n (%)	Mean ± SD/n (%)	Mean ± SD/n (%)	Mean ± SD/n (%)	Mean ± SD/n (%)
			Fractured lead dwell time (months)		
Duration	141.5 ± 82.41	138.5 ± 48.92 (P = 0.902 vs G1)	175.9 ± 83.04 (P = 0.198 vs G1)	149.0 ± 68.62 (P = 0.844 vs G1)	148.0 ± 76.05
			Location of fractured lead tips		
Right ventricle	20 (51.28)	7 (53.85) (P = 0.873)	9 (69.23) (P = 0.420)	5 (71.43) (P = 0.566)	41 (56.94)
Right atrium	17 (43.59)	5 (38.46) (P = 1.000)	4 (30.77) (P = 0.625)	2 (28.57) (P = 0.743)	28 (38.89)
Other (coronary sinus)	2 (5.13)	1 (7.69) (P = 0.731)	0 (0.00) (P = 1.000)	0 (0.00) (P = 0.694)	3 (4.17)
			Type/Model of fractured lead		

UP passive fixation	12 (30.77)	4 (30.77) (P = 0.729)	11 (84.62) (P = 0.002)	3 (42.86) (P = 0.849)	30 (41.67)
BP passive fixation	25 (64.10)	8 (61.54) (P = 0.868)	1 (7.69) (P = 0.001)	3 (42.86) (P = 0.522)	37 (51.39)
BP active fixation	1 (2.56)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.378)	1 (1.39)
VDD passive fixation	0 (0.00)	0 (0.00) (N/A)	1 (7.69) (P = 0.560)	0 (0.00) (P = 0.378)	1 (1.39)
ICD passive fixation	1 (2.56)	1 (7.69) (P = 1.000)	0 (0.00) (P = 0.560)	1 (14.29) (P = 0.694)	1 (1.39)
ICD active fixation	0 (0.00)	0 (0.00) (NC)	0 (0.00) (NC)	0 (0.00) (NC)	0 (0.00)

Abbreviations: CVS = cardiovascular space, N = number, NC = non-comparable, CS = coronary sinus, UP = unipolar, BP = bipolar, VDD = atrial sensing, ventricular sensing/pacing lead, ICD = implantable cardioverter defibrillator.

Ventricular leads (already marginally more common than atrial leads across the entire database) exhibited a slightly elevated tendency toward fracture and spontaneous migration into the cardiovascular space. However, the results make it evident that passive-fixation leads — above all, unipolar and passive bipolar varieties — are particularly vulnerable to this issue. Other configurations, including bipolar active-fixation leads, VDD leads, and both passive and active ICD leads, seldom experienced fractures and migration. Unipolar leads, being thinner and more supple, showed a stronger inclination to coil inside the ventricle. Bipolar leads, somewhat more rigid, more frequently kept their proximal ends within the venous system or right atrium, or allowed them to advance into the pulmonary artery.

The two tables that follow condense the principal outcomes of this investigation. **Table 3** contrasts procedural difficulty, complexity, complications, and long-term survival among patients whose migrated proximal lead tips occupied different positions within the cardiovascular space. **Table 4** summarizes the vascular access methods, extraction techniques, and instruments used for LMPE removal.

Table 3. Extraction procedure information (difficulty, complexity, complications) and long-term survival.

Location of the proximal end of fractured leads migrated into the cardiovascular system (CVS) – TLE procedure data					
TLE procedure parameters	**Group 1 (n = 39)**	**Group 2 (n = 13)**	**Group 3 (n = 13)**	**Group 4 (n = 7)**	**Total (Group 5, n = 72)**
	Mean ± SD / n (%)	Mean ± SD / n (%)	Mean ± SD / n (%)	Mean ± SD / n (%)	Mean ± SD / n (%)
Techniques used for the removal of migrated lead fragments					
Superior approach	6 (15.39)	3 (23.08) (P = 0.832)	3 (23.08) (P = 0.832)	5 (71.43) (P = 0.007)	17 (23.61)
Combined approach	3 (7.69)	3 (23.08) (P = 0.316)	1 (7.67) (P = 0.548)	1 (14.29) (P = 0.874)	8 (11.11)
Femoral approach	29 (74.36)	7 (53.85) (P = 0.298)	8 (61.54) (P = 0.596)	1 (14.29) (P = 0.001)	45 (62.50)
Extraction during cardiac surgery	1 (2.56)	0 (0.00) (P = 0.560)	1 (7.67) (P = 1.000)	0 (0.00) (NC)	2 (2.78)
Procedure difficulty and complexity					
Mean number of unexpected procedural challenges	1.47 ± 0.84	1.39 ± 0.65 (P = 0.744)	1.55 ± 0.82 (P = 0.777)	2.43 ± 0.79 (P = 0.007)	1.43 ± 0.76
≥ 2 unexpected difficulties	10 (25.64)	4 (30.77) (P = 1.000)	4 (30.77) (P = 1.000)	5 (71.43) (P = 0.052)	18 (25.00)
Average CID-TLE score (1–5)	3.80 ± 0.52	4.08 ± 0.49 (P = 0.094)	3.77 ± 0.73 (P = 0.888)	3.86 ± 0.69 (P = 0.802)	3.85 ± 0.57
CID-TLE score ≥ 4	31 (79.49)	12 (92.31) (P = 0.526)	10 (76.93) (P = 0.845)	5 (71.43) (P = 0.983)	58 (89.56)
Total lead dilatation time	83.54 ± 54.08	61.62 ± 29.43 (P = 0.171)	65.77 ± 19.67 (P = 0.254)	105.7 ± 46.50 (P = 0.003)	78.53 ± 46.14
Dilatation time per lead (min)	48.24 ± 27.82	38.57 ± 18.38 (P = 0.249)	43.08 ± 15.18 (P = 0.528)	43.21 ± 14.05 (P = 0.644)	45.03 ± 23.19
Major complications					
Overall major complications	2 (5.13)	0 (0.00) (P = 1.000)	0 (0.00) (P = 1.000)	0 (0.00) (P = 0.694)	2 (2.78)
Haemopericardium	1 (2.56)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.328)	1 (1.39)
Haemothorax	0 (0.00)	0 (0.00) (NC)	0 (0.00) (NC)	0 (0.00) (NC)	0 (0.00)
Emergency cardiac surgery	1 (2.56)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.694)	1 (1.39)

Outcome of lead remnant extraction					
Successful removal	35 (89.74)	13 (100.0) (P = 0.548)	12 (92.31) (P = 0.786)	7 (100.0) (P = 0.874)	67 (93.06)
Reduction of remnant (< 4 cm)	1 (2.56)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.328)	1 (1.39)
Failed removal attempt	1 (2.56)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.560)	0 (0.00) (P = 0.328)	1 (1.39)
Planned or emergency surgery	2 (5.13)	0 (0.00) (P = 1.000)	1 (7.69) (P = 1.000)	0 (0.00) (P = 0.694)	3 (4.17)
Long-term mortality					
Survivors	22 (56.41)	8 (61.54) (P = 1.000)	8 (61.54) (P = 1.000)	6 (85.71) (P = 0.297)	44 (61.11)
Death within 1 year post-TLE	4 (10.26)	2 (15.39) (P = 1.000)	2 (15.38) (P = 1.000)	1 (14.29) (P = 0.659)	9 (12.50)
Death after > 1 year post-TLE	13 (33.33)	3 (23.08) (P = 0.729)	3 (23.08) (P = 0.729)	0 (0.00) (P = 0.179)	19 (26.39)

Abbreviations: bCVS = cardiovascular space, N = number, TLE = transvenous lead extraction, CID-TLE = Complex Indicator of Difficulty of TLE, and NC = non-comparable.

Table 4. Vascular access, techniques, and tools used for the removal of LMPEs.

Comparison of approaches for the removal of migrated leads and the techniques used			
Superior approach	**N (%)**	**Combined approach**	**N (%)**
Total cases	17 (100.0)	Total cases	8 (100.0)
Lasso/basket within CS sheath + polypropylene or rotational sheath (dilatation)	13 (76.47)	Lasso/basket within CS sheath + polypropylene rotational sheath (dilatation, superior)	8 (100.0)
Lasso/basket within CS sheath (pulling only)	1 (5.88)	Lasso/basket within CS sheath (pulling only, superior)	0 (0.00)
Lasso/basket alone (pulling only)	3 (17.65)	Lasso/basket alone (pulling only, superior)	0 (0.00)
Adjunct tools and techniques			
Total use of adjunct techniques	17 (100.0)	Total use of adjunct techniques	8 (100.0)
Loop technique (pulling, end release)	6 (35.29)	Loop via femoral approach	6 (75.00)
Pigtail + winding and repositioning (superior, end release)	3 (17.65)	Pigtail via femoral approach	1 (12.50)
Pigtail (superior, end positioning)	0 (0.00)	Pigtail + winding and repositioning via femoral approach	1 (12.50)
Not applied	8 (47.06)	Not applied	0 (0.00)
Femoral approach and overall outcomes			
Femoral approach	**N (%)**	**All migrated lead removal procedures**	**N (%)**
Primary/Final technique and tools			
Total cases	45 (100.0)	Total cases	72 (100.0)
Lasso/basket within 13 FWS sheath (dilatation)	31 (68.89)	Lasso/basket within 13 FWS sheath (femoral, dilatation)	31 (43.06)
Lasso/basket within a large polypropylene sheath (dilatation)	5 (11.11)	Lasso/basket within a large sheath (femoral, dilatation)	5 (8.33)
Lasso/basket within transseptal sheath (pulling only)	9 (20.00)	Lasso/basket within transseptal sheath (femoral, pulling)	9 (12.50)
—	—	Lasso/basket within CS sheath + polypropylene rotational sheath (superior, dilatation)	21 (29.17)
—	—	Lasso/basket within CS sheath (superior, pulling only)	1 (1.39)
—	—	Lasso/basket alone (superior, pulling only)	3 (4.17)
—	—	Cardiac surgery	2 (2.28)

Adjunct tools and techniques

Total use of adjunct techniques	45 (100.0)	Total use of adjunct techniques	72 (100.0)
Loop technique via the femoral route (pulling, end release)	35 (77.78)	Loop via femoral approach (pulling, end release)	42 (58.33)
Pigtail + winding and repositioning (femoral, end release)	7 (15.56)	Loop via superior approach (pulling, end release)	6 (8.33)
Pigtail (femoral, end positioning)	3 (6.67)	Pigtail + winding and repositioning (femoral, end release)	8 (11.11)
—	—	Pigtail + winding and repositioning (superior, end release)	3 (4.17)
—	—	Pigtail (femoral, end positioning)	4 (5.56)
—	—	Pigtail (superior, end positioning)	0 (0.00)
—	—	Not applied	9 (12.50)

Surgical intervention among all 72 procedures

Parameter	N (%)
Procedures interrupted due to MC-TLE risk	1 (1.39)
Haemopericardium requiring rescue surgery	1 (1.39)
Total surgical cases	**2 (2.28)**

Abbreviations: N = number, CS = coronary sinus, FWS = femoral workstation, MC = major complication, TLE = transvenous lead extraction.

Evaluation of the three vascular access routes (superior, combined, and femoral) indicated that, exclusively for leads whose proximal ends were situated in the pulmonary artery, the superior route (re-established once the other lead had been extracted) was chosen far more frequently than the femoral route (71.43% vs. 14.29%).

Unexpected procedural challenges occurred more often, and total lead extraction duration was prolonged whenever the proximal lead tip lay within the pulmonary artery. Owing to the low event frequency and limited patient numbers in each subgroup, no significant differences in the occurrence of major complications emerged.

In general, the rates of successful extraction of fractured migrated leads and of markedly shortened residual fragments (< 4 cm) were high and encouraging (93.06% and 1.39%), with no notable variation in complete or partial success rates across the study groups.

The femoral route (45; 62.50%) proved to be the predominant method for extracting leads whose proximal ends had migrated into the vascular system, whereas the superior (subclavian or jugular) route (17; 23.61%) and the combined route (8; 11.11%) were applied less commonly.

Lead dissection employing rotating polypropylene sheaths, 13F curved sheaths, or beveled transseptal catheters was necessary in 36 instances (51.39%) through the femoral route and in 21 instances (29.17%) through the superior route. No dissection was required in nine cases (12.50%) with femoral access and in four cases (5.56%) with superior access. Overall, mechanical dissection was needed in 80.56% of procedures, while simple grasping and traction sufficed in 18.06%.

The crucial step when extracting an encapsulated lead that lacks an accessible end in the subclavian area—meaning the lead has retracted into the cardiovascular space, especially if dissection is involved—is to securely capture its proximal or near-proximal segment. According to the table, only 9 (12.50%) lead ends were free enough to allow effective and stable grasping. In all other patients, additional instruments and modified techniques became necessary. Leads with mildly encapsulated ends pressed against the vessel wall by elastic pressure could typically be dislodged, enabling capture with a pigtail catheter in 4 (5.56%) patients.

In cases where the lead was embedded within fibrous tissue, liberation was achieved by coiling the lead around a pigtail catheter using the "spaghetti twisting technique," then applying downward traction when accessing from the femoral vein (8 patients, 11.11%) or downward pressure when using the superior route (4 patients, 5.56%). This maneuver proved especially beneficial for dislodging leads whose tips were lodged in distal pulmonary arterial branches. Nevertheless, in a substantial number of patients (48/72, 66.67%), the proximal end remained tightly adherent to the vessel wall, rendering the prior techniques ineffective. In such situations, a guidewire loop combined with a lasso or basket catheter was deployed, and the lead was freed by traction applied to the loop.

Leads whose proximal ends have migrated into the cardiovascular space are recognized as increasing the risk of secondary issues, including thrombosis and venous occlusion, pulmonary embolism [1, 2], lead-induced tricuspid valve impairment [1], ventricular arrhythmias [7, 19], infections [1, 2, 13, 15], and even disruption of implantable cardioverter-defibrillator function [11, 16]. Extracting such migrated leads requires methods distinct from standard lead removal via the original implantation vein. Individual case reports [5-15] do not allow for proper evaluation of procedural effectiveness, as they document only successful outcomes.

Results from this study demonstrate that passive-fixation pacing leads—particularly unipolar models—are the types most prone to fracture and subsequent migration into the cardiovascular space, owing to their thinner profile and greater tendency to coil within the ventricle. Procedural difficulty is notably elevated in these patients, above all when migration reaches the pulmonary artery. Even so, the overall extraction success remains high (93.01% complete success and 1.4% partial success) regardless of the position of the proximal end within the cardiovascular space.

Strategies for handling leads with proximal ends located within the cardiovascular space have been outlined in many case reports [5-15], several case series [3], and a limited number of studies [1, 2]. Critical elements include obtaining suitable venous access for tool insertion, releasing the proximal end from surrounding fibrous tissue, achieving a reliable grasp, and finally withdrawing the complete lead via traction, counter-traction, or mechanical separation from fibrous adhesions when needed [1-3].

Published data indicate that the femoral route is the most widely adopted [3, 10, 12-14], while the superior route (subclavian or jugular) is selected somewhat less often [1-3]. Combined access, involving simultaneous use of two entry sites, has been documented only infrequently [1, 11, 14]. In the current analysis, the femoral route was most often used (63.89%), followed by the superior route (23.62%) and the combined route (11.11%). Mechanical dilatation was required for 80.56% of leads regardless of access site. In the remaining 18.06% of procedures, dilatation was unnecessary, and straightforward grasping with traction was adequate.

Due to the extended implantation time, the tip of a broken lead often becomes firmly fixed to the vessel wall. Releasing it from scar tissue then requires advanced methods and additional devices to successfully extract the end. These additional devices consist of a snare loop placed around the lead [1, 2, 12-15] or a pigtail catheter used to coil the lead body ("spaghetti twisting technique") [1, 2, 3, 14]. Insertion of these devices can be performed via either the superior [1, 3, 8] or the femoral route [1, 4].

Within this analysis, fibrous tissue had encased the migrated proximal segment of the spontaneously fractured lead in 66.7% of cases. Consequently, a loop assembled from a guidewire and a lasso or basket catheter was needed to free the end by traction.

In certain situations (10.8% of cases), simply winding the lead around a pigtail catheter ("spaghetti twisting technique") and then applying downward force—either pulling or pushing, depending on the entry site—was adequate to mobilize the end. This approach was notably effective when the lead tip had lodged in a distal pulmonary artery branch. All such maneuvers were performed via either femoral or superior access, guided by each patient's anatomy. Merely 12.5% of the migrated proximal ends from fractured leads remained unattached and permitted reliable, firm grasping.

The investigation revealed no link between the use of specialized instruments or procedures for leads with migrated proximal ends and subsequent long-term mortality rates. As far as we are aware, no earlier work has offered a comprehensive account of the precise techniques, equipment, and outcomes involved in extracting leads whose proximal portions have shifted into the cardiovascular space. It would therefore be beneficial to integrate methods for handling leads with migrated proximal ends (LMPEs) into standard TLE training programs. Successfully dealing with these leads calls for substantial operator skill, ready access to diverse instrumentation, and occasional collaboration with an interventional radiologist.

Conclusion

* Spontaneous fractures of leads causing the proximal end to migrate into the cardiovascular space occur infrequently among individuals sent for transvenous lead extraction (1.87%).
* Extracting these leads demands unconventional access strategies along with both purpose-designed and standard instruments.
* Even though the procedures involve considerable complexity, the success rate stays comparably elevated (93.06% procedural success), and the frequency of serious complications remains within acceptable limits.

Study limitations

Several constraints apply to this work. It draws on experience gathered across three institutions, but every intervention was carried out by the identical lead operator, who currently functions as a proctor. Data collection occurred prospectively, yet evaluation took place retrospectively. Every type of mechanical extraction system was used, except laser-assisted sheaths. One major constraint concerns patient selection, since the group studied does not mirror the entire population of people with fractured leads.

A further minor drawback is that several of the case descriptions referenced in the Discussion had already appeared in publications by researchers at different national institutions. The present series involves a fairly sizable cohort exhibiting a rare pattern of spontaneous lead breakage after unusually prolonged implant times, as reported in most current studies. This stems from our facility having served informally for many years as the national hub for the most complex referrals, which in turn accounts for the noted incidence of major complications and the reduced rate of complete radiographic success.

The insights gained here should be relevant to practitioners who must manage the removal of older passive-fixation leads or address rarer issues arising from long-term cardiac pacing.

Ultimately, these findings stem from the efforts of one highly experienced primary operator and supporting team. They are unlikely to be consistently achieved by operators with only moderate expertise working in lower-volume settings, above all when confronting leads with extended or very extended dwell times and those featuring migrated proximal ends.

Impact on daily practice

Spontaneous lead fracture is an uncommon event that may result in the proximal portion migrating into the vascular compartment, commonly forming loops within the heart. Removing such leads calls for atypical methods and non-routine support devices. This article outlines multiple access options and assesses how well both specialized and general-purpose tools perform during the extraction of fractured leads. According to available information, this represents the initial publication to focus directly on this noteworthy clinical challenge.

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Ethics statement: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Informed consent was obtained from all individual participants included in the study.

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