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CASE REPORT
Electrophysiology

Single catheter ablation of atrioventricular node in a patient with dextrocardia and permanent atrial fibrillation via peripheral vascular access using remote magnetic navigation: a case report

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Background Cardiac interventions may be challenging in patients with congenital cardiac abnormalities. This case reports cardiac resynchronization therapy pacemaker (CRT-P) implantation and single catheter ablation of atrioventricular node (AVN) with remote magnetic navigation (RMN) via peripheral vascular access in a patient with Kartagener's syndrome and permanent atrial fibrillation (AF).

Case summary A 74-year-old male with situs inversus presented for treatment of permanent AF and severe heart failure. In echocardiography, left ventricular ejection fraction was 30%, and there was severe dyskinesia due to a left bundle branch block. After successful CRT-P implantation, we performed AVN ablation because biventricular (BiV) pacing was <75% despite maximal rate control medication. The ablation catheter was inserted from the right basilic vein, and no other catheters were used. Despite peripheral vascular access, manipulation of the ablation catheter with RMN was easy, and the ablation was successful. After the ablation, BiV pacing instantly increased to 100%, and left ventricular function and symptomatic status improved gradually.

Conclusions Cardiac resynchronization therapy pacemaker implantation and RMN-guided single catheter ablation of the AVN in a patient with dextrocardia via peripheral vascular access was effective and safe. The use of RMN and peripheral vascular access may offer important advantages also in other patient groups.

Keywords Case report • Dextrocardia • Permanent atrial fibrillation • Atrioventricular node ablation • Remote magnetic navigation

ESC curriculum 5.3 Atrial fibrillation • 5.11 Cardiac resynchronization therapy devices • 9.7 Adult congenital heart disease

Learning points

- Invasive cardiac procedures are challenging in patients with congenital anatomical abnormalities such as dextrocardia and in those with limited vascular access.
- Remote magnetic navigation allows catheter ablation to be performed safely and effectively via peripheral vascular access ('arm approach') also in these patients.
- The arm approach has potential cost-saving implications as early mobilization reduces the risk of adverse events and shortens the recovery time.

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Introduction

Kartagener's syndrome is an autosomal recessive genetic ciliary disorder comprising the triad of situs inversus with dextrocardia, chronic sinusitis, and bronchiectasis.[1] In dextrocardia, the heart is situated in the right side of the thoracic cavity with the apex pointing to the right. It has an estimated incidence of 1 per 12 000 live births.[2] According to the current guidelines, cardiac resynchronization therapy (CRT) combined with ablation of the atrioventricular node (AVN) is recommended for heart failure patients with inadequate biventricular (BiV) pacing due to rapid atrial fibrillation (AF).[3,4] However, in dextrocardia, pacemaker implantation and catheter ablation are technically challenging due to the complex anatomy and altered fluoroscopic orientation.[5]

Computer-controlled remote magnetic navigation (RMN) system incorporates two permanent magnets (0.08–0.1 T) with a motorized catheter advancement and retraction unit and a novel software to remotely orient and steer the ablation catheter and other RMN-compatible devices such as guidewires freely in the 3D space.[6] Remote magnetic navigation enables the physician to remotely navigate the ablation catheter extremely precisely using a conventional computer mouse (or joystick) to the designated target site inside patient's heart. Remote magnetic navigation offers several advantages over conventional ablation techniques particularly in patients with congenital cardiac abnormalities or limited vascular access.[7–9] Besides shorter learning curve and better catheter manoeuvrability and safety compared to conventional ablation methods, RMN has been shown to reduce radiation doses and to improve ergonomics for the operator.[10] Moreover, Ernst *et al.*[11] recently demonstrated that the unique design of the soft RMN catheter enables ablation even via peripheral vascular access.

We present a patient with dextrocardia, permanent AF, left bundle branch block (LBBB) and congestive heart failure, who underwent BiV pacemaker implantation and single catheter ablation of the AVN via peripheral vascular access using RMN. To our knowledge, this is the first report of successful ablation of the AVN via peripheral vascular access in a patient with dextrocardia.

Summary figure

Case presentation

A 74-year-old gentleman with Kartagener's syndrome presented to us for treatment of permanent AF and severe heart failure. Atrial fibrillation started as paroxysmal in 2008 and progressed to permanent AF in 2021. His underlying diseases included ischaemic cardiomyopathy, type 2 diabetes mellitus, and dyslipidaemia. Right and left anterior descending coronary artery stenoses were treated successfully with percutaneous coronary intervention in 2017, and rectum cancer was treated with surgery and adjuvant radiation therapy in 2021. According to the CHA_2DS_2-VASc (a total of 5 points from age, diabetes, vascular disease, and heart failure) and the HAS-BLED score (a total of 2 points from age and cancer), the current risk of stroke was markedly elevated, and the risk of bleeding was modest, respectively.

Heart failure symptoms exacerbated gradually despite optimal medication including bisoprolol, sacubitril-valsartan, spironolactone, dapagliflozin, furosemide, and warfarin. In a recent echocardiography, left ventricular ejection fraction (LVEF) had reduced to 30%, and there was severe dyssynchrony due to LBBB. The New York Heart Association (NYHA) functional class was III. Therefore, we decided to implant CRT pacemaker (CRT-P). The procedure was performed under uninterrupted warfarin therapy. A conventional bipolar lead was placed on right septal surface, and a quadripolar LV lead was positioned into the posterolateral branch of the coronary sinus (CS) via right axillary vein under fluoroscopic control (*Figure 1A*). To overcome the technical challenges related to the unfamiliar anatomy, we flipped the fluoroscopic image projection 180° from right to left to create a 'normal' angiographic view.

The QRS duration was shorter during BiV pacing than at baseline (*Figure 1*). However, in remote monitoring, the percentage of BiV pacing remained less than 75% despite maximal rate control medication (bisoprolol and digoxin), and the patient remained symptomatic with no improvement in the NYHA class. Hence, we decided to ablate the AVN to ensure adequate BiV pacing. Pulmonary vein isolation was not considered suitable due to the long history of permanent AF and frailty stage of the patient. As the patient had severe dyspnoea and continuous coughing due to the heart failure and severe bronchiectasis, we chose to use RMN and single catheter approach via peripheral venous access to minimize the duration of bed rest and to reduce the risk of

15 years prior	Diagnosis of paroxysmal AF and start of oral anticoagulation therapy
5 years prior	Diagnosis of symptomatic coronary artery disease and percutaneous coronary intervention for right and left anterior descending coronary artery
17 months prior	Permanent atrial fibrillation
5 months prior	CRT-P implantation due to worsening of heart failure and LBBB LVEF 30% and NYHA functional class III
1–3 months prior	Low BiV pacing (<75%) in remote monitoring of the device despite rate-controlling medication NYHA functional class III
Day 1	Admission to hospital for ablation of the AVN Ablation of the AVN via peripheral vascular access with RMN
Day 2	Discharge with continuing remote monitoring of the device
9 months	Clinical control visit at outpatient clinic LVEF 50% and NYHA functional class II
15 months	No low BiV pacing alarms in remote monitoring

CRT-P, cardiac resynchronisation therapy pacemaker; LBBB, left bundle branch block; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association functional class; RMN, remote magnetic navigation.

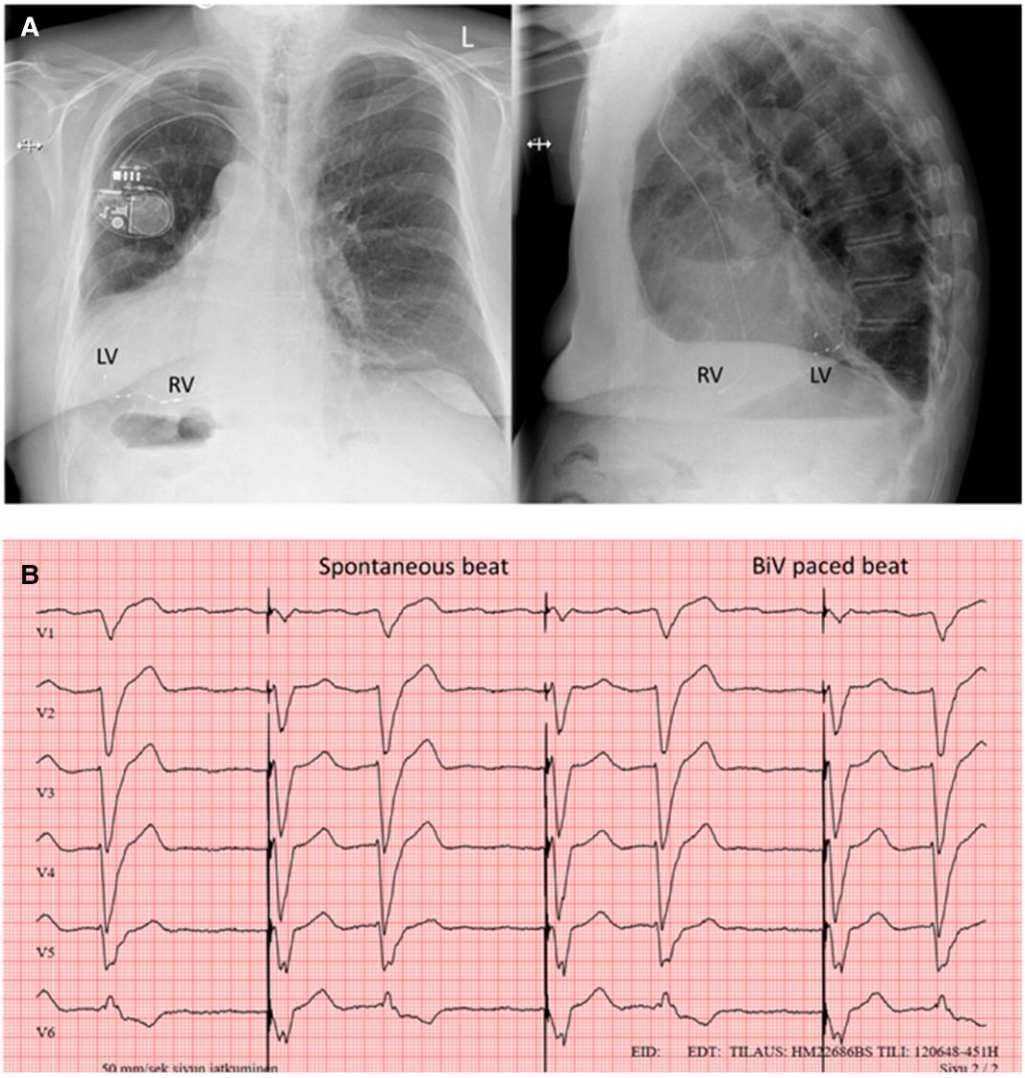

Figure 1 Chest radiography showing the right ventricular lead at septal position and the left ventricular lead in a lateral branch of the coronary sinus (*A*) in posteroanterior and lateral view. In the electrocardiogram before atrioventricular node ablation (chest leads 50 mm/s), the duration of the QRS complex was shorter during biventricular pacing than during spontaneous rhythm (*B*), but the biventricular pacing percentage was low. In order to provide a 'true' electrocardiogram presentation despite the dextrocardia, the precordial electrocardiogram leads were placed in a mirror-image position on the right side of the chest, and the right and left arm electrodes were reversed.

complications related to central venous puncture. Like the pacemaker implantation, AVN ablation was performed under uninterrupted oral anticoagulant therapy, and no bridging with low-molecular-weight heparin (LMWH) was used.

An 8 F sheath was introduced in the right basilic vein over a long guidewire under ultrasound control, and an open-irrigated Navistar RMT catheter (Biosense Webster, Diamond Bar, CA, USA) was advanced into the heart under fluoroscopic control (*Figure 2*). No preoperative venography was performed, because there were no problems in advancing the long guidewire into the heart. The right atrium and tricuspid annulus were mapped using Genesis RMN system (Stereotaxis, St. Louis, MO, USA) integrated with CARTO RMT electroanatomical mapping system (Biosense Webster) without any interference with the pacing leads. Typical signal of the conduction system (His potential) was easily identified (*Figure 3*), and upon radiofrequency ablation (40 W/17 mL/min/90 s), AVN conduction terminated rapidly and did not recover during the 20-min waiting period. The introducer sheath was removed in the catheterization laboratory, and a pressure bandage was applied to the puncture site to stop bleeding. The patient was mobilized immediately with no restrictions to physical activity. Total duration of the procedure was 45 min, and the fluoroscopy time was 2.1 min.

The patient stayed overnight on telemetry monitoring and was discharged on the following morning. Digoxin was stopped, and the daily dose of bisoprolol was reduced from 20 to 10 mg before discharge, while the other heart failure medications and oral anticoagulation with warfarin were not changed. At discharge, there were no signs of vascular complications, and LVEF had improved to 53%. In remote monitoring, BiV pacing has been 100%, and at 9-month follow-up visit, the patient was feeling well (NYHA functional class II).

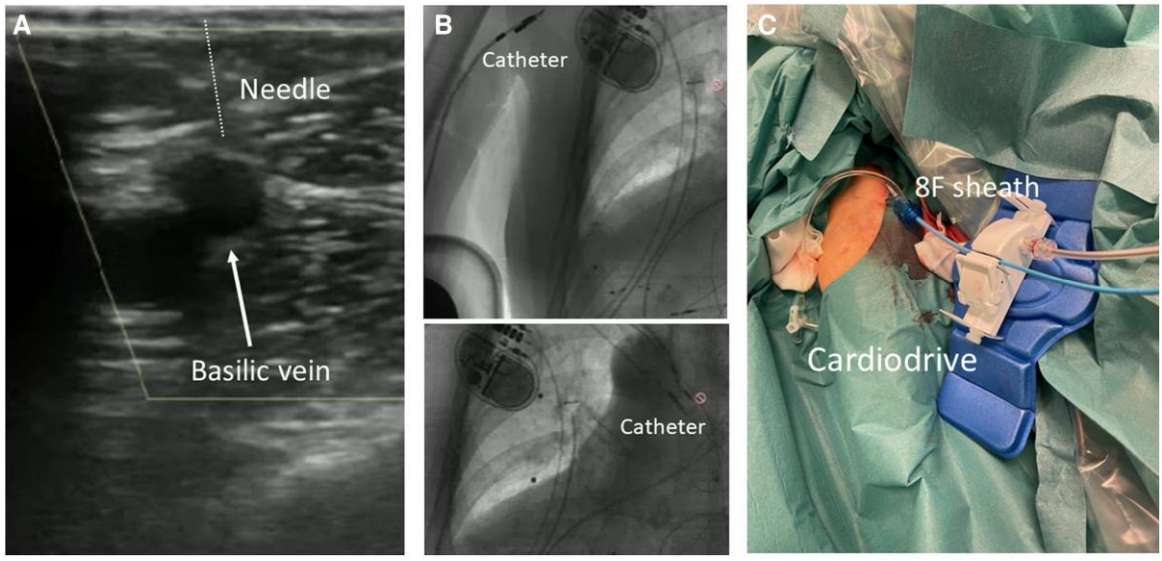

Figure 2 Ultrasound-guided puncture of the right basilic vein at the antecubital fossa. The vein was identified by slight compression, and the needle was advanced under real-time ultrasound control inside the vein. The needle shadow is marked with a dotted line in the ultrasound image (*A*). A conventional 8 F vascular introducer was inserted into the vein over a long guidewire, whereafter the soft ablation catheter was advanced easily from the arm into the heart under fluoroscopic guidance in posteroanterior projection (*B*) and connected to the QuickCAS CardioDrive™ (Stereotaxis Inc. St Louis, MO, USA) for mapping and ablation (*C*).

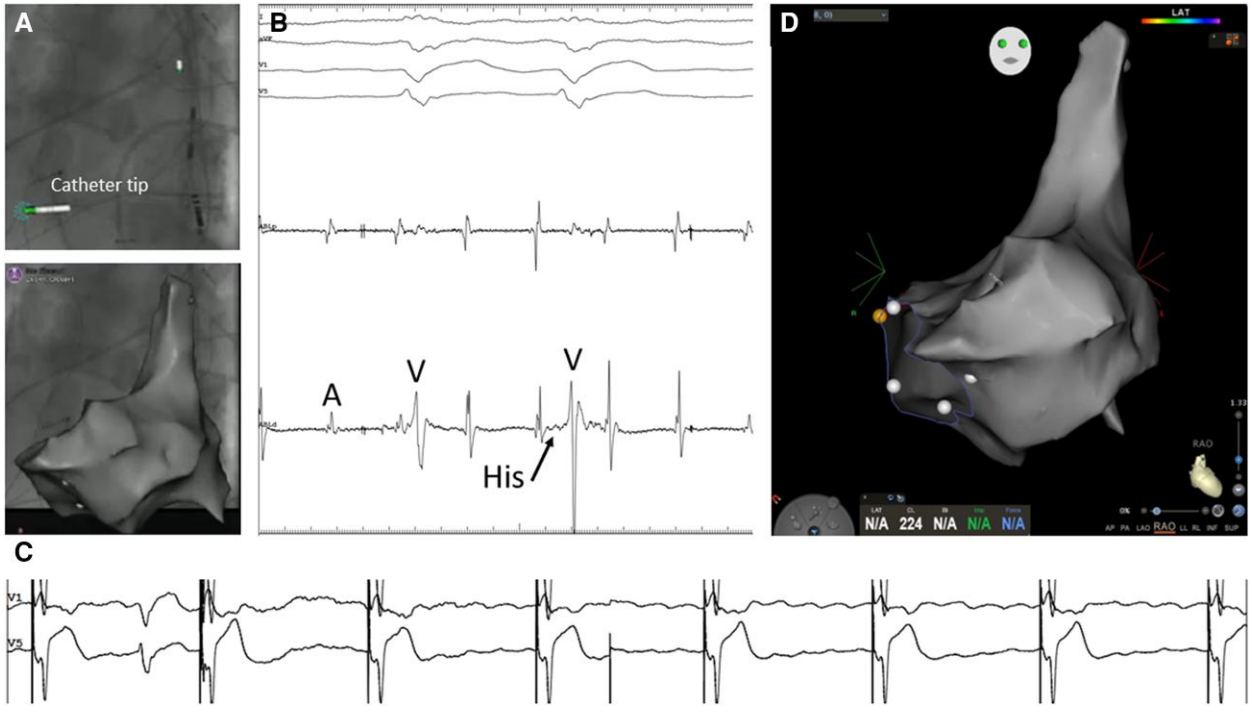

Figure 3 The ablation catheter was manipulated remotely using the Genesis remote magnetic navigation system (Stereotaxis Inc.). The Navigant™ software integrates the fluoroscopic (*A*) and the 3D electroanatomic mapping information (*D*) allowing non-fluoroscopic visualization of the ablation catheter in real time. The atrial, ventricular, and typical conduction system (His potential) signals were easily identified (*B*), and atrioventricular nodal conduction terminated rapidly upon ablation at this site (*C*). After the ablation while waiting if the atrioventricular nodal conduction recovers, we completed the right atrial map without using any fluoroscopy despite the unusual anatomy (*D*). Note that due to the dextrocardia the tricuspid annulus (the line connecting the white dots in the Carto™ image) is best visualized in right anterior oblique projection.

Discussion

To our knowledge, this is the first report of successful single catheter ablation of the AVN via peripheral vascular accesses ('arm approach') in a patient with dextrocardia. Stereotaxis RMN system has been available for more than two decades,[6] and its efficacy and safety in the treatment of various atrial and ventricular tachyarrhythmias have been proven in randomized clinical trials and meta-analyses.[7,12,13] For example, in pulmonary vein isolation, the efficacy of RMN is similar to manual ablation, while complication rate and total radiation exposure are lower.[12] The atraumatic design of the RMN catheter allows for versatile and safe high-precision computer-guided catheter movements through multiple curves even via peripheral vascular access.[11] The advantages of the arm approach over the traditional femoral or subclavian/jugular access site are obvious. With peripheral access, the risk of bleeding is minimal, and there is no risk of iatrogenic pneumothorax or haemothorax. Early mobilization and short recovery time have positive impact on patient-reported outcomes and reduce the length of hospital stay. In addition, the procedural cost can be reduced by limiting the number of diagnostic catheters. However, single catheter ablation is justified only for treatment of arrhythmias in which the ablation target (e.g. the AVN, manifest accessory pathway, or the origin of frequent ventricular premature complexes) can be identified without using additional diagnostic catheters or pacing manoeuvres.

Dextrocardia is a rare condition in which interpretation of the fluoroscopic anatomic landmarks and manipulation of leads and catheters are demanding and may result in prolonged procedure times, increased radiation doses, and worse outcomes. Like Steinbert *et al.*,[14] we felt that flipping of the fluoroscopic image facilitated CS cannulation and positioning of the pacing leads, although this resulted in the guiding catheter and the lead moving in 'opposite' direction when manipulated. On the other hand, altered eye–hand coordination related to dextrocardia is not an issue when steering the ablation catheter remotely with RMN, and thus, no image flipping was applied during the AVN ablation.

Despite the safety and the potential cost-saving implications of peripheral vascular access, endocardial catheter ablations are still almost exclusively performed via femoral veins. In contrast, the use of femoral access is becoming increasingly rare in interventional cardiology. For example, in our hospital, over 95% of coronary interventions are carried out via radial artery. The RMN-guided arm approach initially described by Ernst *et al.*[11] is a promising alternative to the current ablation techniques. Our case provides further support for the arm approach and suggests that electrophysiologists should consider moving out from central vascular access sites to the peripheral ones like the interventional cardiologist have already done.

In conclusion, RMN-guided single catheter ablation via peripheral vascular access is feasible, safe and cost-saving. Hence, in the future, the arm approach should be considered not only in those with anatomic abnormalities or blocked femoral vascular access but also in the 'normal' cases.

Lead author biography

Dr Raatikainen is working as Head Physician and Director of Cardiac Electrophysiology and Pacing at the Heart and Lung Center, Helsinki University Hospital. He has more than 15 years of experience in using remote magnetic navigation for catheter ablation on complex tachyarrhythmias.

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Consent: The authors confirm that written informed consent for submission and publication of this case report has been obtained from the patient in line with COPE guidelines.

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Data availability

The data underlying this case report cannot be shared publicly due to the privacy of the patient. The data will be shared on reasonable request to the corresponding author.

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