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CASE REPORT
Arrhythmias/electrophysiology

Illuminating the Marshall: novel techniques highlighted in an atrial tachycardia case report

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Background Electroanatomic mapping is usually required in order to obtain a precise diagnosis and guide the ablation of atrial tachycardias (ATs) after ablation for atrial fibrillation (AF). However, epicardial connections may limit the interpretation of the endocardial activation sequence as well as the efficacy of endocardial radiofrequency ablation.

Case summary A 53-year-old man with history of AF ablation 2 years ago was admitted for ablation of a recurrent AT (cycle length 275 ms). Ultra-high-density mapping with the Rhythmia™ system revealed a challenging activation map with two focal points of early activation in the left atrium. The use of an advanced mapping software allowed the rapid reanalysis and reannotation of the activation map and suggested epicardial involvement of the Marshall bundle (MB). Subsequent ethanol infusion in the vein of Marshall (VOM) immediately terminated the tachycardia. Six months post-ablation, the patient had no recurrence of arrhythmias.

Discussion This case highlights the role of novel diagnostic and treatment methods in the management of a post-AF ablation AT. By developments in cardiac mapping systems, the rapid editing of a high-density activation map and clarification of the arrhythmia origin can be facilitated overcoming the limitations of conventional techniques. Moreover, ethanol infusion in the VOM was shown to be an effective alternative method in the management of MB-related tachycardias.

Keywords Atrial tachycardia • High-density cardiac mapping • Vein of Marshall • Ethanol infusion • Case report

Learning points

- Developments in cardiac mapping allow detection and rapid reannotation of complex atrial electrograms facilitating the identification of the arrhythmia mechanism and guiding the ablation strategy.
- Ethanol infusion in the vein of Marshall may constitute an alternative treatment for the Marshall bundle-related atrial tachycardias.

Introduction

Atrial tachycardias (ATs) after atrial fibrillation (AF) ablation usually require electroanatomic mapping to obtain a precise diagnosis and guide ablation. However, epicardial connections may impede interpretation of endocardial activation sequence and efficacy of radiofrequency (RF) ablation.[1,2] We present the role of novel techniques in mapping and treatment of a post-AF ablation AT related to the Marshall bundle (MB), an epicardial vestigial myocardial sleeve.

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Timeline

First procedure (June 2017)	Pulmonary vein isolation (wide-area circumferential ablation)
Presentation (July 2019)	Admitted for radiofrequency catheter ablation of atrial tachycardia (AT)
Second procedure (July 2019)	High-density mapping during AT: • Right atrium activation map in favour of a left-sided origin • Left atrium activation map with two focal points of early activation • Reanalysis of the activation map with advanced mapping tools • Reannotation reveals a unique zone of early activation suggesting involvement of the Marshall bundle Ethanol injection in the vein of Marshall with immediate termination of the tachycardia
Follow-up at 6 months (January 2020)	No recurrence of arrhythmias

Case presentation

A 53-year-old man with history of AF ablation 2 years ago was admitted for a recurrent AT (125 b.p.m.) with mild exertional dyspnoea (*Figure 1A*). The medications on admission were apixaban, atorvastatin, and bisoprolol with inadequate rate control. He had neither structural heart disease nor known comorbidities predisposing for atrial myopathy. Physical examination did not reveal signs of heart failure. At the index procedure, only RF pulmonary vein (PV) isolation was performed with wide-area circumferential ablation. A new electrophysiological study was proposed. During an AT with a cycle length (CL) of 275 ms, endocardial mapping was performed using the IntellaMap Orion™ mini-basket mapping catheter and the ultra-high-density Rhythmia™ mapping system (Boston Scientific, Marlborough, MA, USA).

Right atrium map demonstrated passive activation through interatrial septum with collision of wave fronts in the lateral wall indicating the left atrium as the AT origin. Left atrial (LA) map revealed two focal points of early activation followed by centrifugal activation of the remaining atrium. One point was located in the region of the superior ridge and the other inferiorly to the left inferior PV (*Figure 1B*). Activity was accounting for 69% of the CL and coronary sinus (CS) presented a mid-activation preceding proximal and distal activation.

Utilizing the *activation search* and *complex activation* tools of the Rhythmia LUMIPOINT module™ to reanalyse the LA activation map, multiple presystolic fragmented electrograms (EGMs) were highlighted between the previously identified points of earliest precocity (*Figure 2A and B*). These EGMs were characterized by multiphasic, low-voltage potentials (mean amplitude 0.3 mV) of long duration (mean length 95 ms). Unipolar potentials of rS pattern were recorded in the same region. The *group reannotation* tool enabled to reannotate all these potentials at the beginning of the fragmentation revealing a unique larger zone of early activation in the traditional anatomic confluence of the MB (*Figures 2C and 3A*).

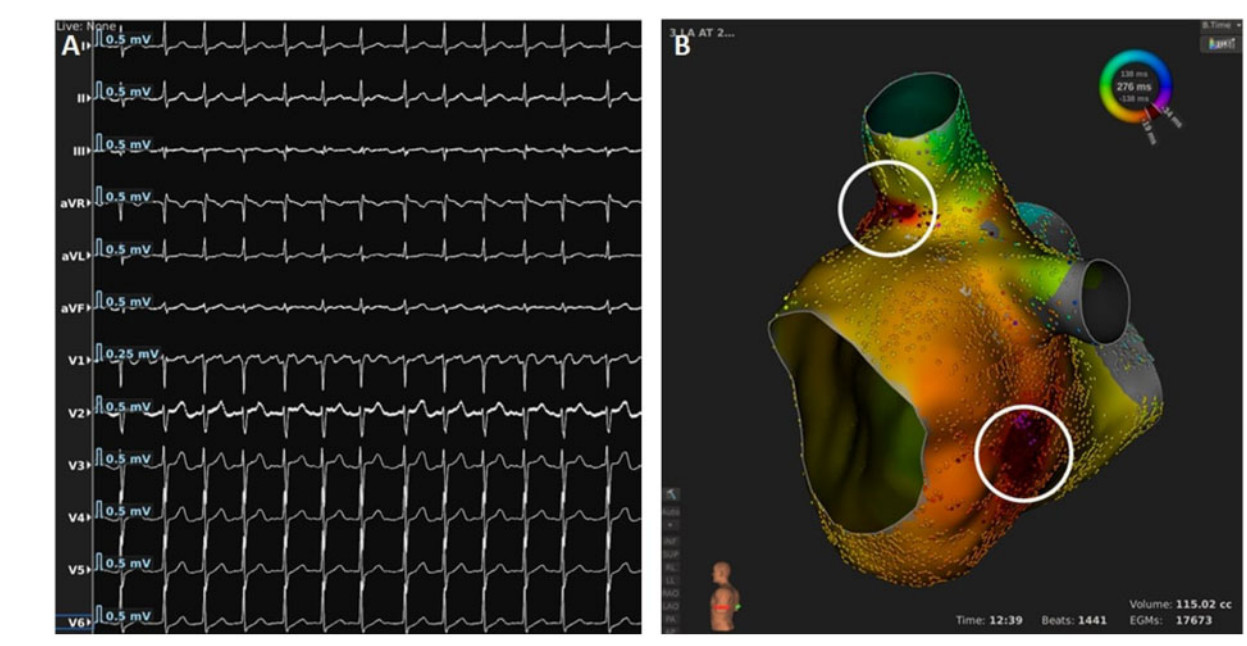

Figure 1 (*A*) 12-lead ECG showed an atrial tachycardia. (*B*) LA 3D activation map showed a centrifugal activation emerging from two points of early precocity (white circles). LA, left atrium; RA, right atrium.

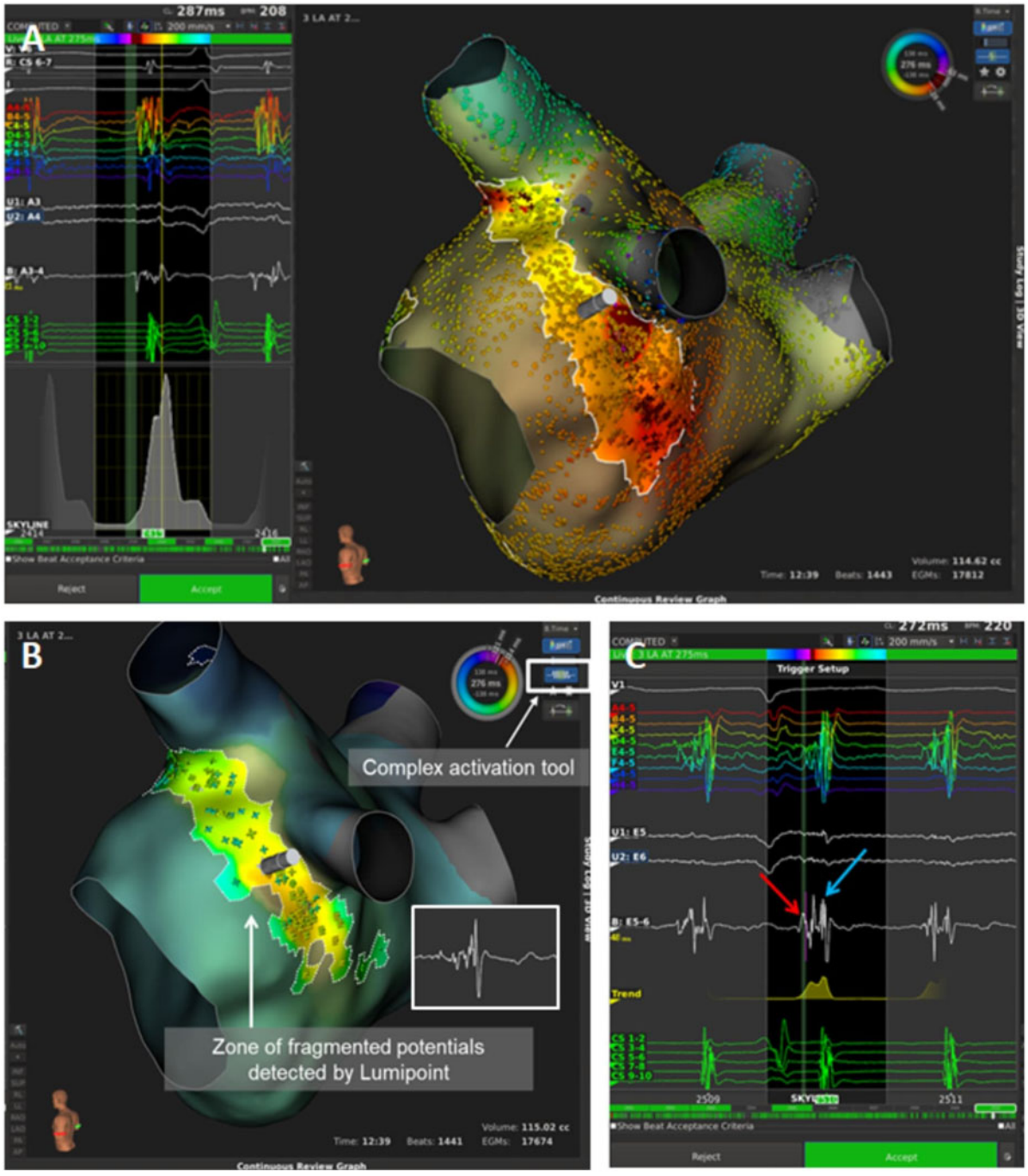

Figure 2 Reanalysis of the LA activation map with the LUMIPOINT software. (*A*) *Activation search* tool with the time window set on the earliest activation (green bar at the histogram of atrial activation) highlighted a region activated in the same period of interest. The grey tag represents one of the highlighted EGMs (line B: A 3-4 at the left panel). This was a fragmented EGM annotated at the maximum amplitude in the middle of fragmentation (yellow line). (*B*) *Complex activation* tool identified this region as a zone of fragmented EGMs. The selected EGM is presented in the window. (*C*) Reannotation of the fragmented EGMs with the *group reannotation* tool. Previously automatic annotation at the component of highest amplitude (blue arrow) was changed to annotation at the beginning of the fragmentation.

Assuming a MB-related AT, ethanol infusion in the vein of Marshall (VOM) was performed as first intention of treatment. Coronary sinus venography permitted to detect and cannulate the VOM and selective injection of 3 mL ethanol 98% was realized with immediate AT termination (*Figure 3B and D*). At the end of the procedure, lack of inducibility was accepted as an indicator of successful ablation. Six months post-ablation, the patient had no arrhythmia recurrence remaining asymptomatic without antiarrhythmic treatment.

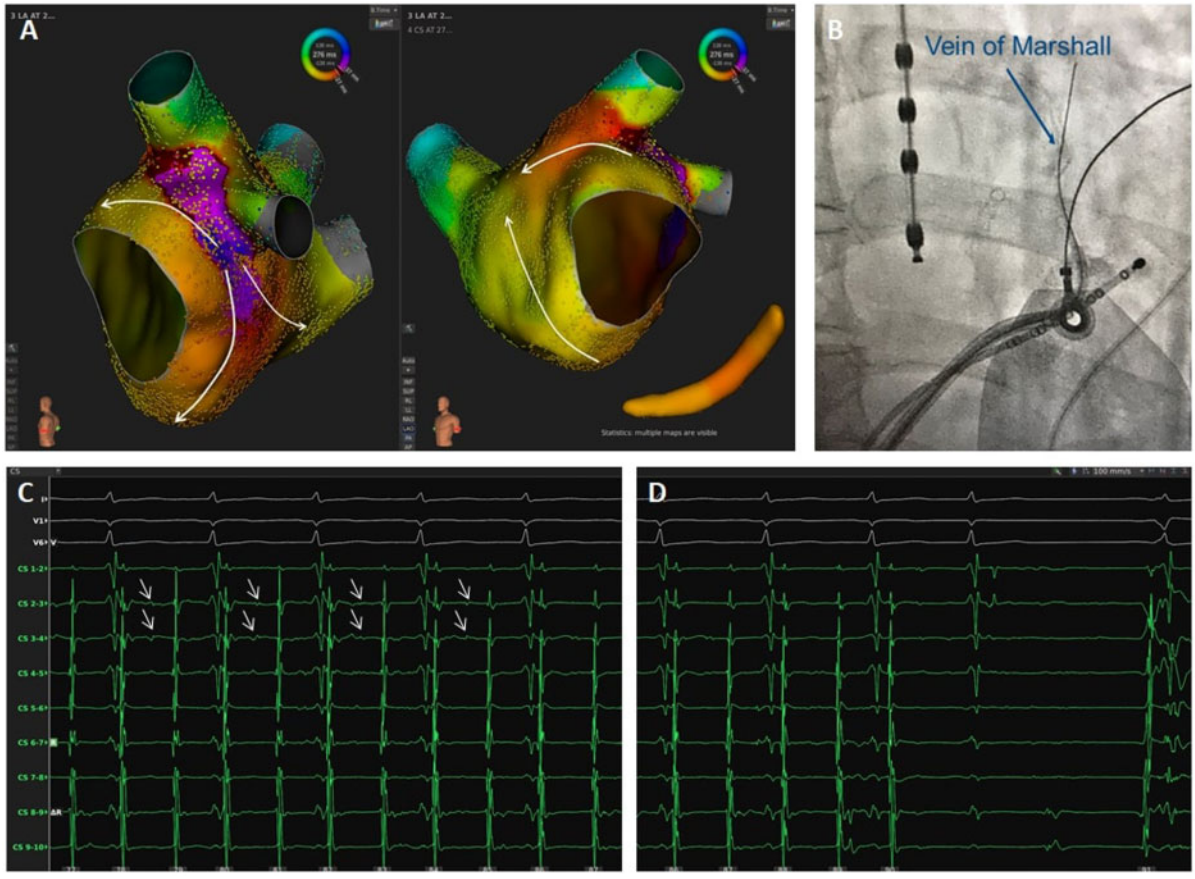

Figure 3 (*A*) Final activation map after reannotations showed a centrifugal activation of the LA (white arrows) from the traditional anatomic region of MB connections. (*B*) Fluoroscopic image in RAO 20° view of VOM cannulation with a LIMA catheter and a guide wire (before ethanol infusion). (*C*) Mid-diastolic potentials appeared during ethanol infusion within the CS in proximity with the origin of VOM (white arrows). These potentials were not recorded previously (*Figure 2A and 2C*). (*D*) Atrial tachycardia termination after ethanol infusion. CS, coronary sinus; LA, left atrium; LIMA, left internal mammary artery; MB, Marshall bundle; RAO, right anterior oblique; VOM, vein of Marshall.

Discussion

The development of high-density mapping systems permits rapid acquisition of activation and substrate maps. Nevertheless, potential pitfalls in endocardial mapping should be taken into consideration when a confusing activation sequence is produced.[1] Far-field signals may interfere with local potentials while fragmented EGMs of long duration may not be precisely annotated. This is especially relevant in areas of low voltage such as heterogeneous zones of scar after previous ablation. Thus, identification and reannotation of these EGMs is essential for the accurate definition of the arrhythmia.

In our case, activation mapping initially demonstrated two focal points of equivalently early activation and a centrifugal LA activation. This finding could indicate a deeper myocardial or epicardial focus or multiple breakthrough sites from a single focus challenging the ablation approach.[1] However, after reanalysis with the LUMIPOINT software, an erroneously annotated region of multiple fragmented potentials was identified. The *activation research* tool selects all the regions containing EGMs that are active within a determined time interval.[3,4] Combining the *complex activation* feature, zones that show high density of multicomponent EGMs activated within the same period are detected.[3] In the present case, by setting a time window that included the previously identified points of early precocity, multiple fragmented potentials were highlighted between them. These potentials were annotated in the middle of fragmentation (site of highest amplitude) and thus, editing of the existing map was required. Although visualization of the EGM associated with each anatomic point is allowed, a manually performed editing may be time-consuming or unachievable. Importantly, another tool of this recent software, named *group reannotation* feature, permits reannotation of a deflection as a reference for the activation time for all the highlighted potentials.[3] This enabled rapid reannotation of all these EGMs defining the time of activation at the beginning of the fragmentation.

After reannotation, atrial activation was arising from the traditional region of the MB terminal end. The MB is a myocardial sleeve contained in the ligament of Marshall along with the VOM and autonomic nerves, located in the epicardial aspect of the left lateral ridge.[5,6] These muscle structures have been shown to be capable of

generating focal automatic activity.[6] Moreover, due to frequently multiple connections with the LA myocardium, MB can be involved in tachycardias of re-entrant mechanism and has been recognized as an anatomical substrate that facilitates AT after AF ablation.[2,6,7]

As activation covered only 69% of the tachycardia CL, and taking into consideration the centrifugal pattern at the endocardial electroanatomic mapping, a non-macroreentrant mechanism was suggested. Fragmented, low voltage, long-duration potentials were recorded in the inferior ridge in proximity to the index ablation line indicating a localized re-entry AT related to the previous lesion.[8] Importantly, only presystolic fragmentation was tracked within the endocardial mapping field (not spanning the entire atrial diastolic phase) suggesting also epicardial involvement. Moreover, rS pattern of unipolar recording was in favour of breakthrough from an epicardial site.[2] These features in this area have been consistently associated with localized re-entry MB-related tachycardias.[2,9] We assume that a part of the diastolic activity could be recorded in the epicardial aspect. Mapping using a 1.5- or 2-Fr catheter into the VOM has been described, but we do not perform this on a regular basis. Mid-diastolic discrete signals can also be recorded within the CS in MB-related ATs with breakout sites close to VOM origin.[9] Interestingly, similar potentials appeared during ethanol infusion and could imply circuit modification before AT termination (*Figure 3C*).

MB-related ATs have been mainly described after extensive substrate ablation while reports after only PV isolation are rare.[2,9] Despite epicardial involvement, they can be usually terminated by endocardial RF ablation that is the preferable approach.[2,9] However, concerns may be raised regarding long-term outcome.[2] Ethanol infusion in the VOM was recently demonstrated to terminate more than half of MB-related ATs without additional RF applications.[10] Importantly, an almost significant tendency of lower recurrences has been shown with this approach.[2] Although RF ablation could probably terminate this AT, we opted for ethanol infusion as first intention of treatment expecting to eliminate epicardial connections and achieve a transmural lesion. Atrial tachycardia was immediately interrupted with a successful long-term outcome. Certainly, further studies are warranted to elucidate whether ethanol infusion has an alternative or complementary role in MB-related tachycardias.

Conclusions

In summary, this case highlights the role of novel diagnostic and treatment methods in the management of a post-AF ablation AT. Through developments in cardiac mapping systems, rapid editing of a high-density activation map and clarification of the arrhythmia origin was facilitated overcoming the limitations of conventional techniques. Moreover, ethanol infusion in the VOM was shown to be effective. Further evidence in feasibility of VOM cannulation and efficacy of ethanol injection, especially regarding long-term outcome, may change the management of MB-related tachycardias.

Lead author biography

Renato Margato, born in 1979, now working at Clinique Pasteur, Toulouse, France (fellow in electrophysiology). He graduated from Instituto Ciências Biomédicas Abel Salazar (University of Porto) in 2003. His specialty is clinical electrophysiology and cardiac devices.

Supplementary material

Supplementary material is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The author/s confirm that written consent for submission and publication of this case report including image(s) and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: none declared.

References

1. Del Carpio Munoz F, Buescher T, Asirvatham SJ. Teaching points with 3-dimensional mapping of cardiac arrhythmias: taking points: activation mapping. *Circ Arrhythm Electrophysiol* 2011;**4**:e22–e25.
2. Vlachos K, Denis A, Takigawa M, Kitamura T, Martin CA, Frontera A et al. The role of Marshall bundle epicardial connections in atrial tachycardias after atrial fibrillation ablation. *Heart Rhythm* 2019;**16**:1341–1347.
3. Martin CA, Takigawa M, Martin R, Maury P, Meyer C, Wong T et al. Use of novel electrogram "Lumipoint" algorithm to detect critical isthmus and abnormal potentials for ablation in ventricular tachycardia. *JACC Clin Electrophysiol* 2019;**5**:470–479.
4. Takigawa M, Martin CA, Derval N, Denis A, Vlachos K, Kitamura T et al. Insights from atrial surface activation throughout atrial tachycardia cycle length: a new mapping tool. *Heart Rhythm* 2019;**16**:1652–1660.
5. Han S, Joung B, Scanavacca M, Sosa E, Chen PS, Hwang C. Electrophysiological characteristics of the Marshall bundle in humans. *Heart Rhythm* 2010;**7**:786–793.
6. Hwang C, Chen PS. Ligament of Marshall: why it is important for atrial fibrillation ablation. *Heart Rhythm* 2009 ;**6**:S35–S40.
7. Kim DT, Lai AC, Hwang C, Fan LT, Karagueuzian HS, Chen PS et al. The ligament of Marshall: a structural analysis in human hearts with implications for atrial arrhythmias. *J Am Coll Cardiol* 2000;**36**:1324–1327.
8. Knecht S, Veenhuyzen G, O'Neill MD, Wright M, Nault I, Weerasooriya R et al. Atrial tachycardias encountered in the context of catheter ablation for atrial fibrillation part II: mapping and ablation. *Pacing Clin Electrophysiol* 2009;**32**:528–538.
9. Chik WW, Chan JK, Ross DL, Wagstaff J, Kizana E, Thiagalingam A et al. Atrial tachycardias utilizing the Ligament of Marshall region following single ring pulmonary vein isolation for atrial fibrillation. *Pacing Clin Electrophysiol* 2014;**37**:1149–1158.
10. Kitamura T, Vlachos K, Denis A, Andre C, Martin R, Pambrun T et al. Ethanol infusion for Marshall bundle epicardial connections in Marshall bundle-related atrial tachycardias following atrial fibrillation ablation: the accessibility and success rate of ethanol infusion by using a femoral approach. *J Cardiovasc Electrophysiol* 2019;**30**:1443–1451.