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CASE SERIES
Arrhythmias/electrophysiology

Epicardial box lesion using bipolar biparietal radiofrequency and multimodality scar evaluation—a case series

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Background Surgical epicardial atrial fibrillation (AF) ablation can be performed as a stand-alone (thoracoscopic) procedure or concomitant to other cardiac surgery. In hybrid AF ablation thoracoscopic surgical epicardial ablation is combined with a percutaneous endocardial ablation. The Medtronic Gemini-S clamp is a surgical tool that uses irrigated bipolar biparietal radiofrequency (RF) energy applied with two clamp lesions that overlap to create one epicardial box lesion including the posterior left atrial wall and the pulmonary veins.

Case summary We describe three patients with therapy-refractory persistent AF and different stages of atrial remodelling in whom the Medtronic Cardioblate Gemini-S Irrigated RF Surgical Ablation System was used for hybrid AF ablation. Acute endocardial validation at the end of the hybrid ablation revealed a complete box lesion in all three cases. At 2-year follow-up, two out of three patients had recurrence of atrial arrhythmias. Invasive electro-anatomical mapping confirmed the persistence of the box lesion, and the mechanism of arrhythmia recurrence in both patients was unrelated to posterior left atrium or the pulmonary veins. The third patient has been without arrhythmia symptoms since the ablation procedure. A three-dimensional late gadolinium enhancement magnetic resonance imaging illustrates the ablation scar non-invasively in two cases.

Discussion Thoracoscopic biparietal RF AF ablation with the Medtronic Cardioblate Gemini-S Irrigated RF Surgical Ablation System results in permanent transmural scar formation, irrespective of the stage of atrial remodelling, as shown in this small population by means of multimodality scar evaluation.

Keywords Case series • Hybrid atrial fibrillation ablation • Ablation scar evaluation • Cardiac magnetic resonance imaging

ESC Curriculum 2.1 Imaging modalities • 5.3 Atrial fibrillation • 7.5 Cardiac surgery

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Learning points

- Thoracoscopic biparietal radiofrequency (RF) atrial fibrillation (AF) ablation with the Medtronic Cardioblate Gemini-S Irrigated RF Surgical Ablation System results in long-lasting transmural scar formation.
- Arrhythmia recurrence after thoracoscopic biparietal RF AF ablation was due to arrhythmogenic mechanisms unrelated to the isolated posterior box and pulmonary veins in this small population.
- Three-dimensional late gadolinium enhancement magnetic resonance imaging can be an additional tool for the non-invasive evaluation of the ablation scar after hybrid AF ablation. It provides a blueprint of the box lesion, but the technique needs further development to be specific enough to confirm validation of the epicardial lesions.

Introduction

In this case series, we describe three patients with therapy-refractory persistent symptomatic atrial fibrillation (AF) and different stages of atrial remodelling in whom the Medtronic Cardioblate Gemini-S Irrigated radiofrequency (RF) Surgical Ablation System was used for hybrid AF ablation. Hybrid AF ablation combines the strengths of the surgical epicardial approach and the percutaneous endocardial approach, which are the potential to create long-lasting transmural lesions and the ability to address arrhythmogenic substrate for atypical flutter or atrial tachycardia (AT), respectively.[1,2] The Medtronic Gemini-S uses irrigated bipolar biparietal RF energy applied with two clamp lesions that overlap to create one epicardial box lesion to the posterior left atrial (LA) wall and the pulmonary veins (PV). This technique was applied during hybrid AF ablation where thoracoscopic surgical epicardial ablation is combined with an immediate percutaneous endocardial validation of the ablation scar and additional endovascular RF ablation when indicated.

Timeline

Patient	Index treatment	Magnetic resonance imaging	Arrhythmia recurrence		Redo treatment	
	Type of treatment	Time after index treatment	Time after index treatment	Type of arrhythmia	Time after index treatment	Type of treatment
1	Thoracoscopic hybrid pulmonary vein isolation (PVI) with box lesion[a]; isolation of superior caval vein (SCV)[a] left atrial appendage (LAA) exclusion[b]; cavo-tricuspid isthmus (CTI) line	9 months; but not diagnostic due to arrhythmia	9 months	Left-sided re-entry atrial tachycardia at the base of the LAA. Box lesion isolation confirmed.	18 months	Continuous radiofrequency (RF) lesions from the roofline of the box lesion to the base of the LAA + anterior line from base of LAA to mitral valve (MV) annulus
2	Thoracoscopic hybrid PVI with box lesion[a]; isolation of SCV[a] LAA exclusion[b]	7 months	18 months	Atrial fibrillation from continuous activation left atrial (LA) roof and low voltage areas LAA ostium and posterior wall. Box lesion isolation confirmed.	23 months	Radiofrequency ablation of LA roof and low voltage areas + anterior line from base of LAA to MV annulus + additional CTI line.
3	Thoracoscopic hybrid PVI with box lesion[a]; isolation of SCV[a] LAA exclusion[b]; CTI line	7 months	n/a	n/a	n/a	n/a

[a]With the use of a bipolar biparietal RF clamp (Gemini-S clamp, Medtronic Inc., Minneapolis, MN, USA).
[b]With an epicardial clipping device (AtriClip pro2 device, AtriCure Inc., Cincinnati, OH, USA).

Case presentation

Patient 1 is a 66-year-old female who was referred to our centre because of symptomatic, therapy-refractory, persistent AF as well as atypical atrial flutter. Her medical history revealed chronic obstructive pulmonary disease gold II, subtotal strumectomy, and a mild form of Systemic Lupus Erythematosus for which she used Hydroxychloroquine. Family history was unremarkable, but she had a high cardiovascular risk profile with active smoking (45 pack years) and was overweight (body mass index of 28) without sleep apnoea. The first discovery of AF was 1 year prior to the referral. Current anti-arrhythmic drug treatment (AAD) consisted of Sotalol 80 mg three times per day (t.i.d.), previously used AAD were Metoprolol 100 mg once daily (q.d.), Bisoprolol 10 mg q.d., and Digoxin 0.125 mg q.d. Oral anticoagulation (OAC) was used, with a CHA_2DS_2-Vasc score of 3 and HAS-BLED score of 2. Echocardiography showed concentric left ventricular (LV) hypertrophy with good systolic LV function, ejection fraction (EF) 60%, diastolic dysfunction grade III and severe LA dilatation, indexed LA volume (LAVi) 57 mL/m^2. Laboratory evaluation was without abnormalities. Pre-procedural work-up with cardiac computed tomography (CT) scan showed normal PV anatomy and non-obstructive coronary artery disease. Cardiac magnetic resonance imaging (MRI) revealed hypertrophic cardiomyopathy mid-myocardial fibrosis at the place of hypertrophy. The rheumatologist ruled out active systemic disease. In the multidisciplinary heart team, the patient was accepted for hybrid AF ablation. Hybrid ablation was preferred over endovascular catheter ablation alone given the severe LA dilatation and structural remodelling secondary to hypertrophic cardiomyopathy. The hybrid approach has yielded good result in the last decade[1,2] and has a class IIaB indication according to current European Society of Cardiology (ESC) guidelines.[3] The thoracoscopic AF ablation consisted of PV isolation and box lesion and isolation of the superior caval vein (SCV) with the use of a bipolar biparietal RF clamp (Gemini-S clamp, Medtronic Inc., Minneapolis, MN, USA), and finally left atrial appendage (LAA) exclusion with an epicardial clipping device (AtriClip pro2 device, AtriCure Inc., Cincinnati, OH, USA). To our knowledge, this was the first case where epicardial ablation with the Medtronic Gemini-S clamp was acutely evaluated with endocardial bipolar voltage mapping of the LA. The size of the box together with exit and entrance block was confirmed as well as the isolation and bidirectional block of the SCV. The hybrid ablation was completed by an additional cavo-tricuspid isthmus line with successful bidirectional block. The surgery and postoperative course were without complications. At 9 months of follow-up, the patient suffered recurrent palpitations. The electrocardiogram (ECG) revealed a macro re-entry atrial tachycardia (AT) with no recurrence of AF. A redo electrophysiological (EP) procedure 18 months after the initial hybrid ablation was performed with the use of the Advisor^{TM} HD Grid Mapping Catheter Sensor Enabled^{TM} (Abbott Inc., Abbott Park, IL, USA) and EnSite^{TM} NavX^{TM} Precision cardiac mapping system (St Jude Medical Inc., Little Canada, MN, USA). During the redo EP procedure, the box lesion of the initial hybrid procedure showed no reconnection (see *Figure 1*). The electro-anatomical mapping revealed a left-sided re-entry AT at the base of the LAA (see *Video 1*) which was successfully treated with continuous RF lesions from the roofline of the box lesion until the base of the LAA. In addition, an anterior mitral isthmus line from the base of the LAA to the mitral valve (MV) annulus was created with successful bidirectional block to prevent future MV annulus-dependent tachycardias. Since then, the patient had no recurrence of arrhythmias.

Patient 2 is a 69-year-old male with diabetes mellitus type II, hypertension, and prior myocardial inferior infarction percutaneously treated. He experienced symptomatic, therapy-refractory, persistent AF. The first discovery of AF was 5 year prior to the referral after his myocardial infarction but symptomatic recurrences were present for the past year. Current AAD consisted of Metoprolol retard 50 mg q.d. in combination with Digoxin 0.25 mg q.d. with bradycardia preventing uptitration of dosage. Previously used AAD were Amiodarone 200 mg q.d., Sotalol 40 mg twice daily, Verapamil retard 240 mg q.d., and Diltiazem retard 240 mg q.d. Oral anticoagulation was used, with a CHA_2DS_2-Vasc score of 4 and HAS-BLED score of 2. Echocardiography showed inferior wall akinesia and a moderate LV function (EF 45%) during AF with high ventricular rate, as well as severe LA dilatation (LAVi 67 mL/m^2). After pre-procedural work-up with coronary angiography excluding significant stenosis and CT scan revealing a normal PV anatomy, he was scheduled for hybrid AF ablation.

The execution of the hybrid ablation procedure was similar to the one described in Patient 1, including SCV isolation and LAA exclusion. Subsequent endovascular electro-anatomical evaluation showed bidirectional block in the box and the SVC. The surgery and postoperative course were without complications and at 1-year follow-up, there were no arrhythmia recurrences. However, at 18 months of follow-up, Patient 2 had recurrent symptomatic AF. A redo EP procedure was performed 2 years after the initial hybrid ablation with the use of the Advisor^{TM} HD Grid Mapping Catheter Sensor Enabled^{TM} (Abbott Inc., Abbott Park, IL, USA) and EnSite^{TM} NavX^{TM} Precision cardiac mapping system (St Jude Medical Inc., Little Canada, MN, USA). During this redo EP procedure, the complete isolation of the box lesion made by the biparietal bipolar RF clamp and atria was confirmed (see *Figure 2*)—just as in Patient 1. The electro-anatomical mapping during AF revealed continuous activation at the LA roof and low voltage areas anterior from the LAA ostium to the MV annulus, as well as the posterior wall inferior of the right inferior PV. All these areas were isolated with continuous RF lesions. The isolation of these areas was proved during sinus rhythm (SR). Additionally, an anterior line was completed from the base of the LAA to the MV annulus with successful bidirectional block to prevent future MV annulus-dependent tachycardia. Finally, an additional cavo-tricuspid isthmus line was performed since this was not included in the index hybrid procedure.

Patient 3 is a 41-year-old male with psoriasis and symptomatic therapy-refractory persistent AF after the first discovery of the arrhythmia 1 year ago. Current AAD consisted of Sotalol 40 mg q.d. with sinus bradycardia preventing uptitration of this very low dosage. Previously used AAD was Metoprolol retard 50 mg q.d. CHA_2DS_2-Vasc score of 0 and HAS-BLED score was 0, but OAC was used after recent electric cardioversion. Echocardiogram showed a good LV function, no valvular dysfunction, and no LA dilatation (LAVi 21 mL/m^2). The initial ECG showed AF with fine f-waves and adequate rate control. Computed tomography scan

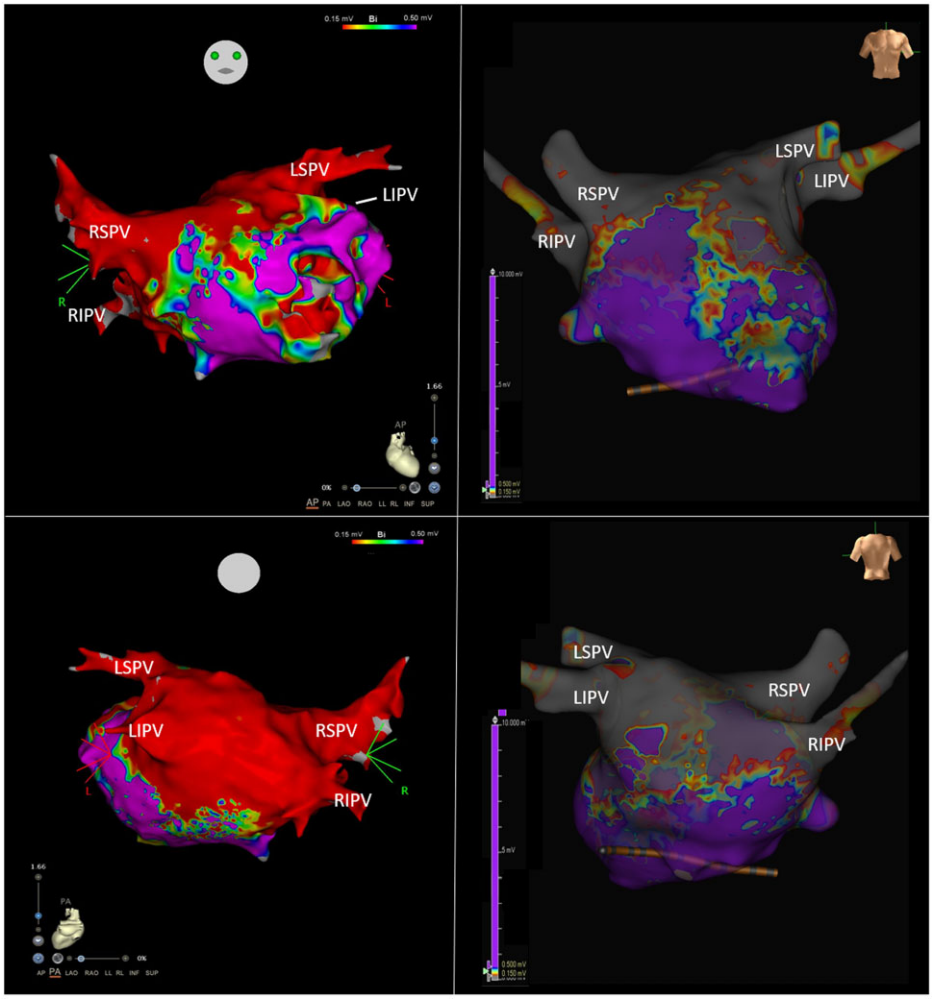
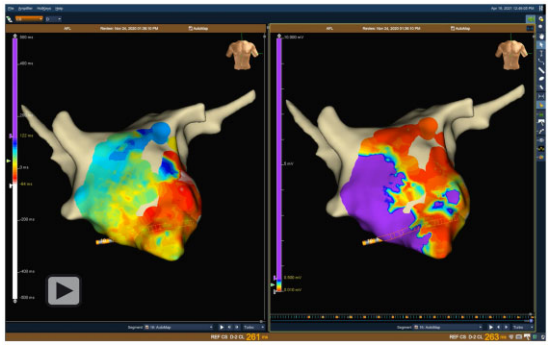


Figure 1 Hybrid ablation results of Patient 1 as visualized with voltage mapping during index hybrid ablation (left panel) and during the redo procedure (right panel) at 18 months of follow-up. Depicted in anterior-posterior view (upper panels) and posterior-anterior view (lower panels). LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.



Video 1 Video of the electrical activation pattern of the macro-re-entrant tachycardia during the redo-procedure of Patient 1. Left panel: activation map, right panel: NavX bipolar voltage map.

showed normal PV anatomy and excluded coronary artery disease, pulmonary function testing was unremarkable. According to the ESC AF guidelines, our patient had a Class IA/B indication for catheter ablation. However, hybrid surgical ablation can also be considered (Class IIaB) in symptomatic persistent AF refractory to antiarrhythmic drug therapy and with risk factors for catheter ablation failure, to maintain long-term SR.[2,3] Since the f-waves suggest advanced atrial electrical and structural remodelling, the chance of obtaining long-term SR might be higher with a hybrid than a catheter alone approach. Our patient could not afford a recurrence of AF due to his occupation, thus he opted for a hybrid approach. The procedure was similar to the one described in detail in Patient 1, including SCV isolation and LAA exclusion, also an additional cavo-tricuspid isthmus line was created. Subsequent endovascular electro-anatomical evaluation showed bidirectional block in the box and the SVC. There were no postoperative complications. The patient was asymptomatic during outpatient clinic

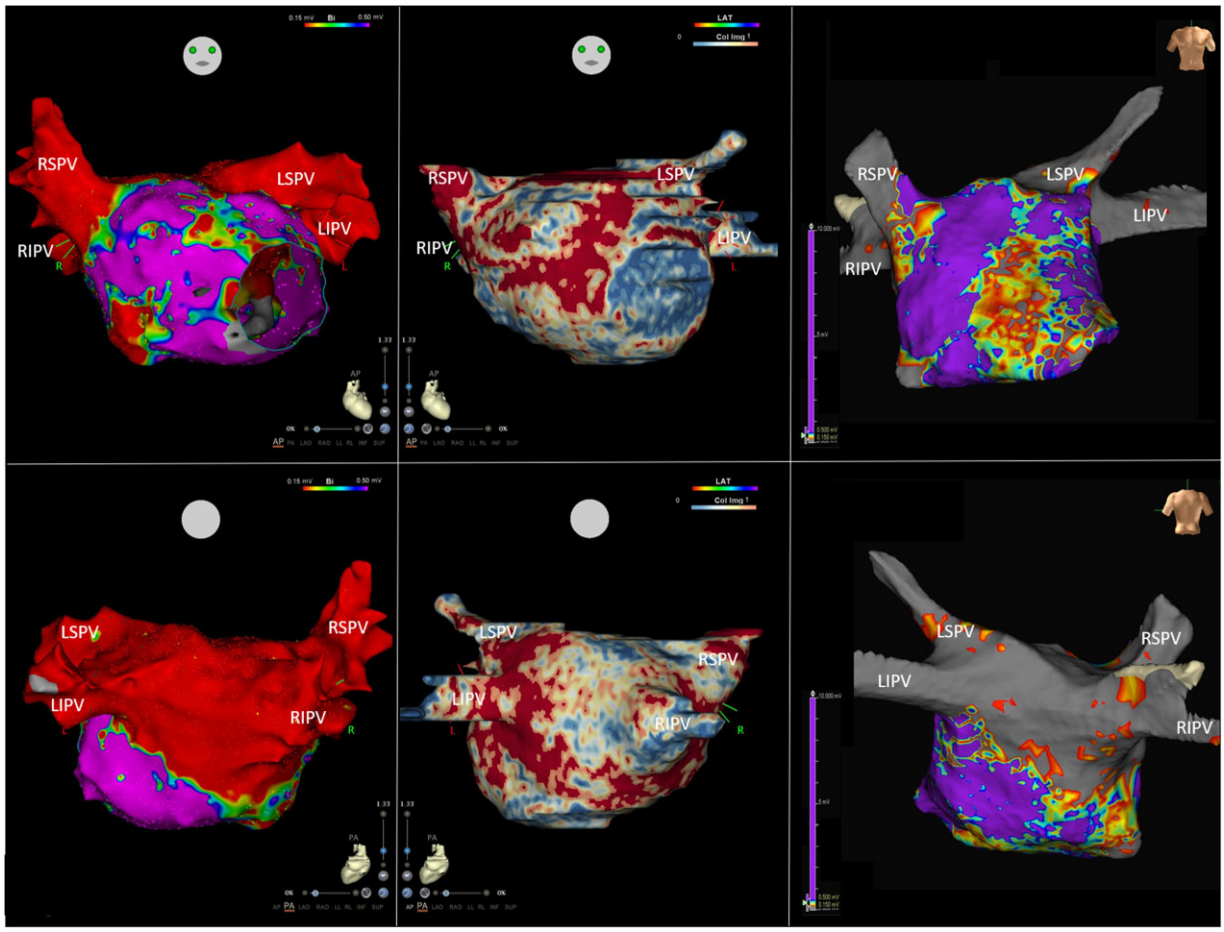


Figure 2 Hybrid ablation results of Patient 2 as visualized with voltage mapping during index hybrid ablation (left panel), during the redo procedure (right panel) at 2-year follow-up and late gadolinium enhancement magnetic resonance imaging (middle panel) at 6 months of follow-up. Depicted in anterior-posterior view (upper panels) and posterior-anterior view (lower panels). On the late gadolinium enhancement magnetic resonance imaging, high signal intensity reflects the scar tissue visualized in red. LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.

visits at 1 year of follow-up and ambulant 24-h Holter evaluation showed no arrhythmia recurrence.

All three patients received a three-dimensional (3D) whole-heart dark-blood late gadolinium enhancement (LGE) MRI[4] of the atria at 6–9 months of follow-up in order to non-invasively investigate the box lesion created by the Medtronic Gemini-S clamp. Unfortunately in Patient 1, the MRI was of inferior quality due to the recurrence of arrhythmia. Post-processing was done with ADAS 3D software (Galgo Medical, S.L., Barcelona, Spain) by an observer blinded to the ablation results. The MRI scans show demarcated areas of high signal intensity indicating scar tissue corresponding to the ablation lines as visualized during the hybrid ablation (see *Figures 2* and *3* and *Video 2*).

Discussion

The concept of a hybrid AF ablation is attacking the substrate both from the epicardium and the endocardium. While it has been demonstrated that epicardial ablation with bipolar biparietal RF clamps results in long-lasting transmural lesions, epicardial validation of these lesions remains challenging due to tissue oedema and pre-existing fibrotic strands in the left atrium. The first gives a false-positive result because validating epicardial pacing devices fail to obtain tissue capture, the latter gives a false-positive result because pre-existing fibrotic tissue is paced. On top of that, most AF patients present with more than 1 atrial arrhythmia. Typical and atypical flutter or AT can be easily addressed from the endocardium but often not from the epicardium when working on the beating heart. As such, combining epicardial efficacy with endocardial high-resolution mapping and substrate ablation is key in complex AF treatment and is the motivation for a hybrid approach. The hybrid approach has yielded good result in the last decade[1,2] and is included in the 2020 European guidelines of cardiologists (ESC) and thoracic surgeons (EACTS) with the advice to consider thoracoscopic AF ablation—including hybrid procedures—in the following clinical situations: (i) should be considered (Class IIaB

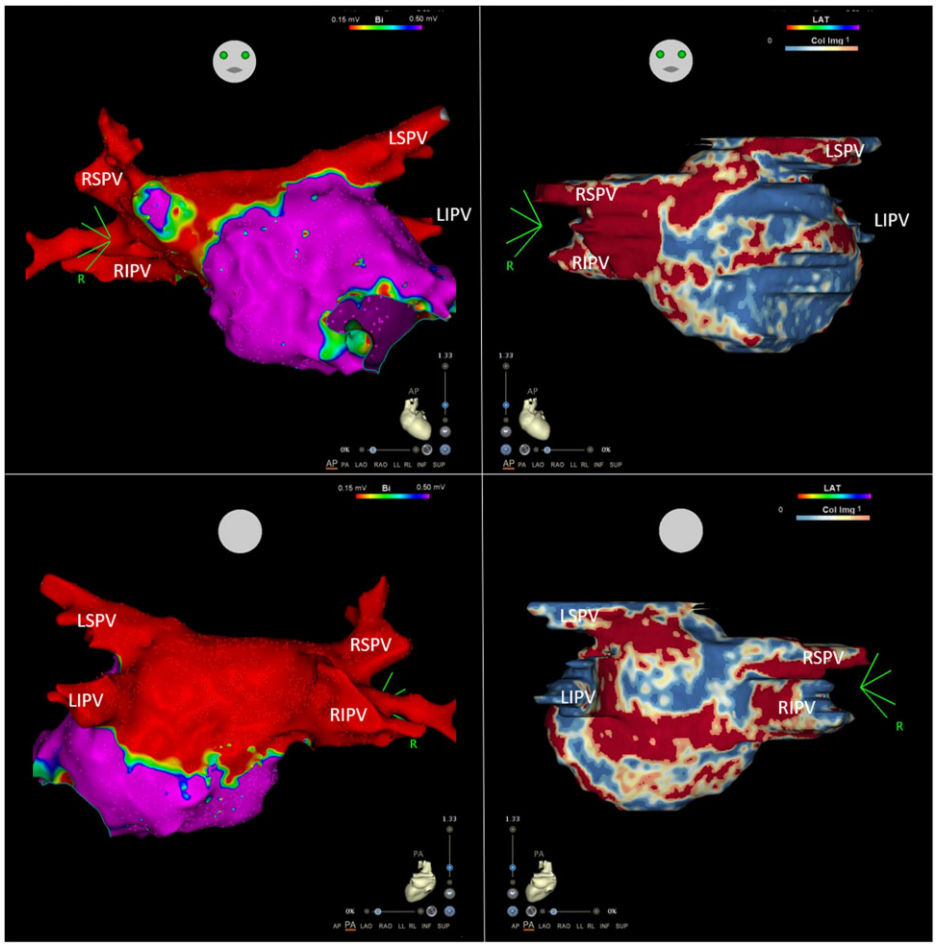
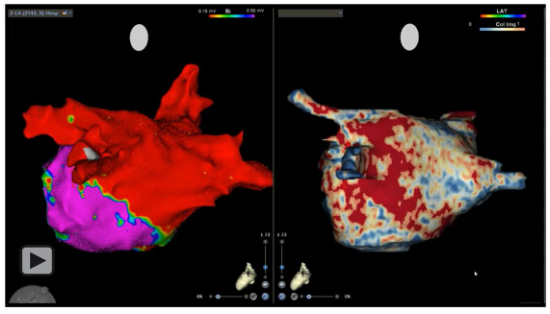


Figure 3 Hybrid ablation results of Patient 3 as visualized with voltage mapping during index hybrid ablation (left panel) and late gadolinium enhancement magnetic resonance imaging (right panel) at 6 months of follow-up. Depicted in anterior-posterior view (upper panels) and posterior-anterior view (lower panels). On the late gadolinium enhancement magnetic resonance imaging high signal intensity reflects the scar tissue visualized in red. LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.



Video 2 Video of 360° image of Patient 3 comparing the NavX bipolar voltage map from the index hybrid procedure (left panel) with the three-dimensional dark-blood whole-heart late gadolinium enhancement magnetic resonance imaging (right panel).

indication) in symptomatic, therapy-resistant, paroxysmal, or persistent AF who have failed percutaneous AF ablation, or with evident risk factors for catheter ablation failure; (ii) may be considered (class IIbC indication) in patients with symptomatic, therapy-resistant, persistent AF with risk factors for recurrence.[3] The success of AF ablation, whether using an endocardial, standalone epicardial, hybrid, or concomitant surgical approach, is determined by the ability to create transmural and continuous scar lesions. The Medtronic Gemini-S clamp is a surgical tool that uses irrigated bipolar biparietal RF energy applied with two clamp lesions that overlap to create one epicardial box lesion including the posterior LA wall and PVs (see *Figure 4*). The proposed strength of this device is the fact that it applies RF energy in a biparietal, bipolar, and irrigated fashion. It utilizes dual electrodes with alternating and overlapping fields to form a continuous transmural lesion. The biparietal bipolar RF energy delivery yields higher transmurality rates in comparison to uniparietal approach.[5]

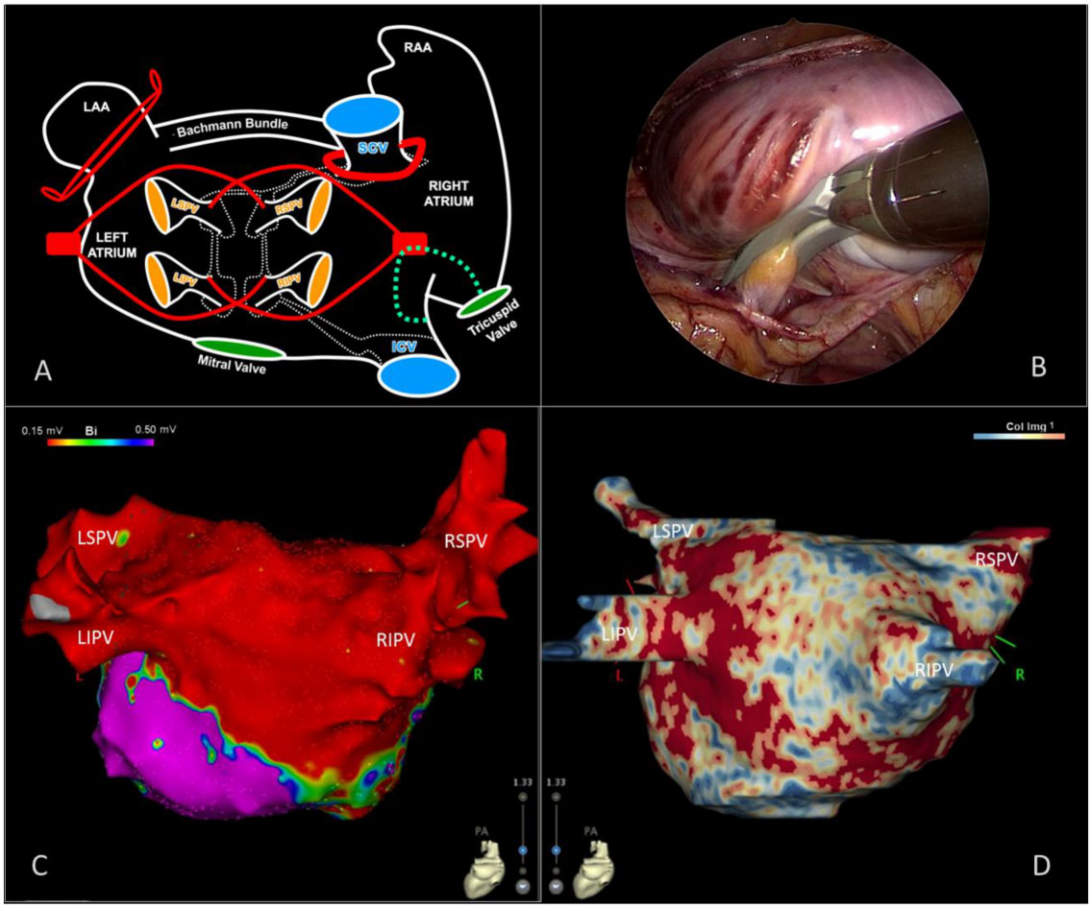


Figure 4 The index hybrid atrial fibrillation ablation visualized above in a schematic view (*A*) and right thoracoscopic view on right pulmonary vein isolation with bipolar radiofrequency clamp (*B*). In *A*, the red lines indicate epicardial ablation lines—resulting in a box lesion and superior caval vein isolation—and a clipping device on the left atrial appendage (Atriclip pro 2, Atricure). The green dashed lines indicate an endocardial cavo-tricuspid isthmus line. Below the electro-anatomical mapping acquired during the index hybrid atrial fibrillation ablation (*C*) and the three-dimensional late gadolinium enhancement magnetic resonance imaging giving a blueprint of the ablation scar acquired >6 months post-procedural (*D*). ICV, inferior caval vein; LAA, left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RAA, right atrial appendage; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein; SCV, superior caval vein.

The use of irrigated bipolar RF energy generates larger and more effective lesions compared with non-irrigated RF ablation.[6] The complete and consistent tissue contact leads to consistent and evenly applied energy delivery resulting in a robust lesion.

To confirm the transmurality and continuity of an ablation scar lesion, the gold standard is endocardial validation during an invasive EP study. In case of a stand-alone epicardial ablation, an epicardial validation of conduction block can be performed, which has been shown to correspond well with endocardial bidirectional conduction block.[7] However, in acute evaluation transient oedema can mimic ablation scar. Moreover, the invasive nature of the gold standard has prompted researchers and clinicians to search for alternative methods. A non-invasive approach to evaluate myocardial scar is LGE MRI. A gadolinium-based contrast agent accumulates in areas with cell membrane disruption (e.g. in case of oedema) or increased extracellular matrix due to coagulative necrosis and fibrotic replacement (e.g. in case of chronic myocardial infarction or ablation scar). Gadolinium contrast changes the focal tissue properties resulting in voxels with high signal intensity on LGE images. Several studies have shown that LGE MRI has great potential in the evaluation of ablation scar in the atria.[8,9] To our knowledge, this is the first case series where this 3D LGE MRI technique is used to visualize the ablation scar created during hybrid AF ablation with the Medtronic Cardioblate Gemini-S Irrigated RF Surgical Ablation System, and illustrate its correspondence to the electro-anatomical mapping during the index procedure. As with any case series, the descriptive approach and small sample size is an important limitation. When the diagnostic value of 3D LGE MRI in this clinical setting would be validated in a cohort study, comparing 3D LGE MRI with endocardial voltage mapping as a gold standard in a larger study population, the clinical impact is potentially large. Especially, for patients undergoing concomitant (two-staged) surgical AF ablation, a 3D LGE MRI showing continuous, transmural scar could dispute the necessity of the second stage invasive EP procedure. Moreover, this case series

illustrates the heterogeneity of the AF population, ranging from Patient 3 with normal LA volume and no comorbidity to Patient 1 with extensive atrial remodelling and hypertrophic cardiomyopathy. The Medtronic Cardioblate Gemini-S Irrigated RF Surgical Ablation System has yielded good results, irrespective of the extent of atrial remodelling. Acute ablation success was shown by the endocardial validation at the end of the hybrid ablation revealing a large and complete ablation box in all cases. At 2-year follow-up, the endurance of this box lesion was confirmed in two out of three cases by invasive electro-anatomical mapping, the 3rd patient has been without symptoms of arrhythmia since the ablation procedure.

Conclusion

This case series illustrates the potential of a multimodality approach towards evaluating the ablation scar after hybrid AF ablation. The clinical value of a non-invasive approach with 3D LGE MRI is potentially large, especially for patients undergoing concomitant surgical AF ablation. In these patients, a 3D LGE MRI showing continuous, transmural scar potentially disputes the necessity of the second stage invasive EP procedure. For this, future scientific studies validating the diagnostic value of LGE MRI in this clinical setting are necessary.

Lead author biography

Geertruida Petronella Bijvoet is an imaging cardiologist working in Maastricht UMC+, the Netherlands, specializing in cardiac MRI. Her research focuses on the role of cardiac MRI in the treatment of cardiac arrhythmia. She is part of the interventional cardiac MRI (iCMR) team currently pioneering in the field of CMR-guided EP procedures. As one of the first centres worldwide to perform CMRguided atrial flutter ablations in patients, this innovative treatment is performed in a transformed diagnostic MRI environment. A third passion, besides research and patient care, is education. She puts this into practice as the educational co-ordinator of the Department of Cardiology.

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: All patients treated in our centre consent to the use of their data under the strict rule that all identifying patient information is removed and complete anonymity is secured. The three patients included in this case series have given additional written consent to the use of their anonymized MRI data for research purposes.

Conflict of interest: J.G.L.M.L. has a Consultancy agreement Medtronic. B.M. is a consultant for Atricure and Medtronic. The other authors have no conflicts of interest relating to this article.

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