Clinical outcomes after catheter ablation of atrial arrhythmias guided by ultra-high density mapping system in heart failure patients

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Abstract

Introduction: Catheter ablation of atrial fibrillation (AF) and/or atrial tachycardia (AT) in heart failure (HF) patients provides improvement in symptoms cardiac function and survival. However, these procedures remain challenging with higher recurrence and complication rates compared to patients with normal cardiac function. We aimed to compare outcomes of AF/AT ablations guided by an ultra-high density mapping system between HF patients and controls. **Methods and results:** Primary endpoint was the one-year recurrence rate of AF/AT. We retrospectively examined all Rhythmia-guided procedures performed in Caen and Toulouse University Hospitals between 2015 and 2018 for AF/AT. Patients with reduced left ventricular ejection fraction (LVEF) (i.e. <50%), or with preserved LVEF and signs/symptoms of HF were constituted the HF group and were subsequently classified in two subgroups of HF patients with preserved (HFpEF) or reduced/mildly reduced (HFrEF) LVEF. 246 patients were included, 135 in the HF group. At one-year, 71 patients had experienced AF/AT recurrences, with no difference between HF group versus non-HF group (31.9 vs 25.2% respectively, p=0.262). AF/AT recurrence rates were not different between HFpEF and HFrEF subgroups (37.1 vs 26.4% respectively, p=0.196). In multivariate analysis, patients with mitral regurgitation (p=0.011), hypertrophic cardiomyopathy (p=0.011) and persistent AF (p=0.02) were at higher risk of recurrence. AF/AT recurrence was not significantly associated with HF hospitalization (p=0.078) but HF status was the only independent predictive factor of HF hospitalization (p=0.002). Patients in the HF group showed significant improvement in both their NYHA class and LVEF than non-HF patients. After ablation procedures, while patients with HFrEF and HFpEF showed similar NYHA class improvement, LVEF only improved in HFrEF patients. The rate of complications were comparable in both groups. **Conclusion:** Clinical outcomes of AF/AT ablations guided by UHD mapping system appear similar in HF and non-HF patients. During the follow-up period, patients with HF exhibit improvement of NYHA status and LVEF.

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Conclusion: Clinical outcomes of AF/AT ablations guided by UHD mapping system appear similar in HF and non-HF patients. During the follow-up period, patients with HF exhibit improvement of NYHA status and LVEF.

Key Words: atrial arrhythmia, heart failure, catheter ablation, clinical outcomes, electroanatomic mapping system

INTRODUCTION

Congestive heart failure (HF) and atrial fibrillation (AF), two major cardiovascular conditions, often coexist. Patients with HF usually have chronically elevated filling pressures, that favour left atrial enlargement and atrial arrhythmias, either AF or atrial tachycardia (AT) occurrence. Besides, AF worsens their functional capacity and increases mortality, regardless of whether they have preserved or reduced left ventricular ejection fraction (LVEF).[1,2] Catheter ablation (CA) of AF in a setting of HF with reduced LVEF is safe, and has proven effectiveness in improving functional status, quality of life, LVEF,[3–5] and mortality.[6] Data regarding CA for AF in case of HF with preserved LVEF (HFpEF) are limited but encouraging. [7,8] AF and AT often coexist as they shared risk factors and underlying substrate, especially in HF. Nevertheless, these procedures can be challenging in HF patients, who are likely to experience more recurrences, and repeated ablations than patients with normal cardiac function, despite the use of three-dimensional electroanatomic (3D) mapping systems.[7,9] The novel ultra-high-density (UHD) mapping system (Rhythmia, Boston Scientific,

Inc., Marlborough, MA, USA) using a dedicated 64-pole mini-basket catheter (IntellaMap Orion, Boston Scientific) has been now widely used, enabling rapid and accurate mapping with low signal/noise ratio and limited need for additional manual editing. Several studies have reported the ability of this system to elucidate complex arrhythmias. [10,11] However, data about clinical use of this UHD mapping system in HF patients are scarce, and whether this UHD system could improve CA results, with no clear data on safety in this particular population is unknown. The aim of our study was to assess clinical outcomes after Rhythmia-guided ablation procedures of complex atrial arrhythmias in patients with clinical HF with and without reduced LVEF, compared to patients normal LVEF and no HF.

METHODS

Study population

We conducted a retrospective study including every consecutive ablation procedure of AF or atrial tachycardia (AT) using the Rhythmia system at both University Hospitals of Caen and Toulouse from August 2015 to April 2018. We considered de novo and redo procedures, paroxysmal and persistent AF and AT. AT was defined as organized atrial activity on 12 lead ECG and electrophysiological study demonstrating macro/micro reentrant or focal mechanism. We excluded AT displaying ECG pattern of typical cavotricuspid dependant atrial flutter.: Patients with reduced left ventricular ejection fraction (LVEF) (i.e. <50%), or with preserved LVEF and signs/symptoms of HF and evidence for cardiac structural of functional abnormalities (elevated filling pressures, natriuretic peptides) were designated the HF group, and the remaining patients constituted the non-HF group.[12] HF patients were divided into subgroups based on LVEF : reduced or mildly reduced LVEF (HFrEF) if LVEF<50%, and HFpEF if LVEF[?]50%.

Radiofrequency ablation procedure

All procedures were performed according to standard of care and current guidelines. Patients were under efficient stable oral anticoagulation for at least four weeks with no interruption prior to ablation. Contrast cardiac computed tomography or transesophageal echocardiography was performed the day before the procedure to rule out intracardiac thrombus. All patients underwent ablation under mild or deep assisted sedation or general anaesthesia. After venous femoral access, intravenous heparin was infused targeting an activated clotting time (ACT) >300 s. ACT was tested every 30 min, and additional heparin was applied if necessary. Trans-septal puncture was performed by standard technique under fluoroscopy and transoesophageal echocardiography guidance when needed. Electroanatomic mapping was completed using IntellaMap Orion. Radiofrequency (RF) ablation was performed with standard 4-mm-tip irrigated catheter (Celsius Thermocool, Biosense Webster; Blazer OI, Boston Scientific), magnetic irrigated catheters (IntellaNav OI, Boston Scientific) or with contact force sensing irrigated catheters (Tacticath, St. Jude Medical). PVI was achieved using a wide circular antral linear lesion. Additional lesion sets including linear lesions and ablation of complex fractionated atrial electrograms for persistent AF procedures were performed at the physician's discretion. For AT, ablation targeted the critical isthmus or the area of focal origin.Pulmonary veins entrance and exit blocks, as well as bidirectional blocks for linear lesions were confirmed by conventional pacing and/or activation mapping. After procedure completion, the patient was monitored in the recovery unit then discharged 24 to 48 hours later after clinical examination, ECG and transthoracic echocardiography. .

Follow-up and data collection

All patients were scheduled for follow-up visit three months after the procedure and every six months with clinical examination, AF/AT recurrences were documented either by electrocardiogram or Holter recordings. Patients with recurrences after the blanking period of three months after procedure were considered for repeated ablation. We collected clinical, electrocardiographic, echocardiographic, and procedural data from medical files, or from patients' cardiologist if they were no longer followed in our centers.

Clinical endpoints

The primary endpoint was one-year recurrence of AF/AT. Secondary endpoints were hospitalizations for HF at one year, death of any cause, cardiovascular death, NYHA class and LVEF improvements.

Statistical analysis

Categorical variables were expressed as numbers and percentages and compared using the Pearson Chi square test or Fisher's exact test as suitable. Continuous variables were expressed as mean +- standard deviation if normally distributed otherwise as median (1^{st} and 3^{rd} quartiles) and compared using Student's t-test or non-parametric Mann-Whitney test as needed. Association between baseline characteristics and the occurrence of clinical event was evaluated by univariate analysis. Variables with p value [?]0.20 in the univariate analysis were introduced in the multivariate analysis using a binary logistic regression model with Wald's step-by-step method. Statistical significance was set at a two-tailed probability level of <0.05. All analyses were performed using IBM SPSS Statistics for Windows version 23.0 (released 2015, IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA).

Ethics

This retrospective study based on previous collected data complied with the Declaration of Helsinki and French ethics guidelines. This study was approved by the regional ethics committee and the French committee of informatics and civil liberties (CNIL, conformity agreement ndeg2204611). All patients provided written informed consent for intervention and received a non-opposition letter, as requested by French authorities for retrospective studies.

RESULTS

Baseline characteristics and procedural data

During the study period, 644 patients underwent AF/AT ablation procedures in our two centres, and 253 of them were performed with the Rhythmia system. Seven patients were lost to follow-up. Finally, 246 patients were included, 135 of them (54.9%) constituted the HF group (Figure 1). In the HF group, 62 patients had preserved LVEF (46.3%), and 72 (53.7%) had reduced LVEF. One patient was excluded from subgroup analysis due to missing LVEF data.

The procedures were performed mostly in men (71.5%) with a median age of 64 years old (56-69). The clinical characteristics are detailed in Table 1. As expected, patients in the HF group had more comorbidities and were more symptomatic. Arrhythmias were also unequally distributed between the groups; AT and persistent AF were more frequent in the HF group, whereas 20% of the patients in the non-HF group had paroxysmal AF (p=0.005). The majority of the patients had already undergone a previous CA (59.3%) with no difference between groups. Patients with HF had more frequent history of non-PVI and non cavo-tricuspid isthmus ablation (p=0.04).

Procedures in the HF group were longer (p=0.01), with longer fluoroscopy duration (p<0.001), higher fluoroscopy dose (p<0.001), more maps (p=0.017), and longer mapping time (p<0.001), compared to procedures in the non-HF group. Conversely, the number of recorded electrograms (p=0.714), the RF duration (p=0.118), and the volume of infused serum (p=0.623) did not differ between the groups. A total of 285 ATs were analysed, including those occurring during ablation of persistent AF. Most of them were macro-reentries (58.9%) while the mechanism of 33 ATs remained undetermined (12.3%), with no difference between groups.

Primary endpoint

At one-year, 71 patients had experienced AF/AT recurrences after one or more procedures, with no difference between the groups: 43/135 HF patients relapsed (31.9%) versus 28/111 control patients (25.2%), p=0.262. The average rate of repeated ablation was 17.1% with a trend toward a greater number of procedures performed in the HF group (1.2+-0.5 procedures vs 1.1+-0.4 respectively, p=0.065). Nevertheless, there was also no difference in recurrence rates between HF and non-HF groups after the index procedure (44.4% vs 36% respectively, p=0.196). In multivariate analysis using Cox regression, the cumulative risk of AF/AT recurrence was significantly higher in case of mitral regurgitation (Hazard ratio [HR]=2.38, 95% confidence interval [CI] 1.22 to 4.69, p=0.011), hypertrophic cardiomyopathy (HR= 2.35, 95% CI 1.21 to 4.57, p=0.011) and persistent AF (HR=1.89, 95% CI 1.11 to 3.22, p=0.02). AF/AT recurrence rates were not significantly

different, considering the type of ablation catheter used (36% with contact force catheter versus 47% with other catheter, p=0.277). About a quarter of the patients (62/246) had interrupted their antiarrhythmic drug therapy at one-year regardless of HF status. One-year survival without AF/AT recurrence was not modified by antiarrhythmic drug regimen, in both groups. Survival curves are represented by the Kaplan Meier method in Figure 2. Primary and secondary outcomes are detailed in Table 2.

Secondary outcomes

Mortality

Three patients died during follow-up, all in the HF group. There was only one cardiovascular death resulting from cardiogenic shock during pulmonary sepsis. The two remaining patients died from a biliary tract cancer and from haemorrhagic complications of liver cirrhosis. Therefore one-year survival was 98.8% with no difference between groups (p=0.254).

Heart failure hospitalization

As expected, more HF patients (19/135, 14.1%) were hospitalized for worsening of HF during follow-up than controls (2/111, 1.8%), p<0.001 (Figure 2). If AF/AT recurrence tended only to increase the risk of HF hospitalization (HR=2.71, 95% CI 0.90 to 8.20, p=0.078), HF status was the only independent predictive factor in multivariate analysis (HR=10.2, 95% CI 2.29 to 10.43, p=0.002). Conversely, patients referred for redux procedure were significantly less hospitalized for HF worsening, than patients with index procedure (HR=0.32, 95% CI 0.12 to 0.82, p=0.018). Among HF patients, we did not find predictive factor associated with hospitalization.

Functional status

At the end of follow-up, 69/135 HF patients experienced an improvement by one or more NYHA class (51.9%) compared to 36 non-HF patients (34%), p=0.006. Among HF patients, AF/AT recurrence was negatively associated with NYHA improvement (HR=0.42, 95% CI 0.19 to 0.91, p=0.028).

Cardiac function

At one-year after the index procedure, we observed an improvement in LVEF, by 5% or more, in 46.4% of the HF patients and in 5.7% of the control patients (p<0.001). HF patients who experienced AF/AT recurrence were less likely to improve their LVEF, but with no statistical difference (35.7% vs 51.8% respectively, p=0.126). HF patients with paroxysmal AF were less likely to improve their LVEF (HR=0.08, 95% CI 0.01 to 0.79, p=0.030) than HF patients with AT or persistent AF.

HF Subgroup analysis

Patients with HFpEF and HFrEF were comparable in their baseline characteristics, comorbidities, symptoms, previous ablations, medications, and echocardiography findings except LVEF. Baseline characteristics of patients of the subgroup analysis are detailed in Table 3. AF/AT recurrence rates were not different whether HF patients had preserved (37.1%) or reduced (26.4%) LVEF, p=0.196. However, patients in HFpEF subgroup (35.6%) had more antiarrhythmic drug therapy discontinuation than HFrEF patients (15.9%), p=0.014. At one-year, there was a greater proportion of LVEF improvement among patients with HFrEF (40/72, 55.6%) compared to patients with HFpEF (18/62, 29%, p=0.002), whereas NYHA improvement was not different between the subgroups (47.2% versus 54.8% respectively, p=0.49).

Complications

Fourteen complications occurred in 13 procedures with no difference between the groups: 8 procedures (5.3%) in the HF group had complications versus 5 in the non-HF group (4.8%) (p=1.000), with no difference whether LVEF was preserved or reduced. The types of complications were equally distributed between groups: two tamponades in each group; three groin bleedings, two of them in the HF group; two other vascular complications in each group, either femoral arteriovenous fistula or pseudoaneurysms; and three strokes, all in the HF group (p=0.231). One HF patient experienced both femoral pseudoaneurysm and a

stroke. There was no hemodynamic complication or congestive heart failure but patients of the HFrEF group were more likely to need diuretics increase after ablation (p=0.013).

DISCUSSION

Our present study is the first to evaluate long-term clinical outcomes after AF/AT ablation procedures guided by UHD mapping system, in patients with clinical HF, with either preserved or reduced LVEF. We showed that recurrence rates after complex ablations were not lower in HF patients than in non-HF patients. There was no difference in the mortality rates, whereas HF patients were more likely hospitalized for HF worsening during follow-up. Nevertheless, as expected, CA was associated with greater NYHA and LVEF improvements in HF patients compared to controls.

CA of complex atrial arrhythmias has been shown to be safe and able to improve prognosis of patients with HF, particularly in cases with HFrEF. Nevertheless, those patients are at high risk of recurrence, and reported rates varied from 27-73% after one procedure to 23-34% after repeated ablation on or off antiarrhythmic drug therapy.[4,7–9,13,14]. Data are more limited in HFpEF patients, but they also seem to benefit from CA, despite high recurrence rates.[7,8,15] HF has been identified as an independent risk factor for AF/AT recurrence in several reports that compared CA outcomes in patients with or without HF.[7,9,14] These lower success rates in HF could be related to different mechanisms: atrial enlargement and structural remodelling, due to chronic high filling-pressures and/or mitral regurgitation, that favours perpetuation of AF and a higher proportion of persistent AF; ischemia or the cardiomyopathy itself that can also alter atrial myocardium; but also patients' frailty, that can prevent from long-lasting procedures' completion. There were only few studies that directly compared outcomes of CA of AF between HF and control patients. Chen et al reported a 27% rate of AF recurrence in patients with systolic dysfunction after PVI achieved without 3D mapping, whereas patients with normal cardiac function had only 13% of recurrence (p=0.03).[9] Using a standard 3D mapping system, Cha et al reported respectively 38%, 25% and 16% one-year recurrence in patients, whether they had systolic dysfunction, diastolic dysfunction, or normal cardiac function.[7] Furthermore, success rates of AF ablation were previously reported lower in patients with LVEF<50% compared to patients with LVEF>50%.[13]Black-Maier et al. recently published outcomes of CA of AF in both HFrEF and HFpEF patients with respectively 32.6% and 33.9% of recurrence (p=NS), but lower rates of repeated ablations than in our study.[15] Our present one-year recurrence rates were consistent with previous reports. Moreover, HF status was not a predictive factor of AF/AT recurrence, as well as the alteration of LVEF among HF patients. Yang et al. reported that patients with previous CA of AF would rather have AT than AF recurrence, depending on the degree of atrial remodelling. Patients with more dilated atria and lower left atrial bipolar voltage were likely to have AF recurrence suggesting that HF patients should preferably relapse in AF.[16] It is important to note that ATs were the most frequent arrhythmia in our study population in both groups. AF and AT share the same precipitants and are often studied as interchangeable diagnosis, even an important proportion of patients with AF would not experience AT and vice-versa. In the particular setting of HF patients, the overlap between AF and AT is important and should justify to study these atrial arrhythmias together.[17] In our study, the high proportion of AT was consistent with the high proportion of repeated procedures as previous ablation can lead to additional atrial scar and subsequent complex ATs. In our study, the type of arrhythmia was not predictive of recurrence. The UHD mapping system we used was already reported to be able to improve comprehension and ablation success of complex post-AF ablation ATs.[18,19]

In our study, we identified mitral regurgitation, hypertrophic cardiomyopathy and persistent AF as predictive factors of recurrences. A multicentre registry also highlighted higher recurrence rates in HF patients with persistent AF compared to controls, whereas the results of CA for paroxysmal AF were not different between HF patients and controls.[14] Data about CA in this setting are scarce, but a systematic review has already reported higher recurrence rates in patients with hypertrophic cardiomyopathy compared to controls and with mitral regurgitation that amplifies and aggravates the atrial remodelling.[20]

The other important result of our present work is the beneficial effect of CA on both NYHA class and LVEF in patients with HF. In patients with HFrEF, CA of persistent AF, using a 3D mapping system, was already reported to improve LVEF, peak oxygen consumption, and Minnesota living with HF questionnaire score.[4]

Another study reported better improvement in 6 minutes walking distance, Minnesota score and LVEF, after PVI compared to atrioventricular node ablation combined with cardiac resynchronization.[3] Moreover, the CASTLE-AF trial, reported a decrease in a composite endpoint of mortality and hospitalization for HF in the CA group compared to control group, in patients with HFrEF.[6] Another study conducted in patients with HFpEF, showed that only patients who maintained sinus rhythm had improvement in echographic parameters.[8] We also reported here, that AF/AT recurrence was associated with lower improvement in functional status and LVEF. Black-Maier et al reported similar effect of CA on AF recurrence and NYHA improvement in both HFrEF and HFpEF groups, as we did, but they did not include AT in their analysis. They also showed a trend towards a greater improvement in NYHA class in patients with HFpEF that nearly reached statistical significance.[15] Likewise, our patients with HFrEF did not improve their NYHA class more than HFpEF patients, despite a significant larger increase in LVEF.

Despite longer procedures with longer mapping duration in the HF group, there was no difference in fluid intake and no acute HF, even in patients with reduced LVEF. Our present complications rates were similar with those previously reported in HF patients or with this particular mapping system. The TRUE-HD study, the largest prospective study assessing outcomes of this novel UHD mapping system, reported a 4% complications rate. [21] We acknowledge that our patients did not present severely depressed LVEF, as the median LVEF was 45% in the HF group. Nevertheless, they had associated comorbidities and were more fragile than the non-HF patients. Acute HF events were not rare in patients with HFpEF (3.8%) and HFrEF (6.2%) after CA of AF in a previous report using the same LVEF cut-off values.[15]

Limitations

Our study was retrospective, leading to possible confusion bias. Nevertheless, we included all consecutive procedures in each group over the same period of time. The choice of the Rhythmia system to guide ablation procedure was not randomized, and one could assume that our study population should be slightly different if all procedures were considered, regardless of the mapping system used. LVEF was not determined by a core-lab but was retrieved from medical files. We did not use a standardized arrhythmia recurrence diagnostic protocol and patients with HFrEF had more implanted device allowing asymptomatic recurrence documentation. Therefore, it would be important to address these biases and confirm our results in a prospective manner. Conversely, our study population is probably representative of the real-life ablation landscape in a setting of HF, with repeated ablations and recurrent ATs.

CONCLUSION

CA of complex atrial arrhythmias performed in patients with HF, either with preserved or reduced LVEF and guided by an UHD system is associated with similar rates of AF/AT recurrence, and achieved greater improvement in both NYHA class and LVEF, compared to non-HF patients. Outcomes of CA were similar in HF patients with preserved or reduced LVEF. Larger studies should be conducted to address the potential benefit of this novel mapping system in complex arrhythmias management in case of HF and the relative benefit of CA and in the particular population of HFpEF patients.

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REFERENCES

1. Kirchhof P, Benussi S, Kotecha D, et al. 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS.*Eur Heart J* . 2016;37(38):2893-2962. doi:10.1093/eurheartj/ehw210

2. Wang TJ, Larson MG, Levy D, et al. Temporal relations of atrial fibrillation and congestive heart failure and their joint influence on mortality: the Framingham Heart Study. *Circulation* . 2003;107(23):2920-2925. doi:10.1161/01.CIR.0000072767.89944.6E

3. Khan MN, Jais P, Cummings J, et al. Pulmonary-vein isolation for atrial fibrillation in patients with heart failure. *N Engl J Med* . 2008;359(17):1778-1785. doi:10.1056/NEJMoa0708234

4. Hunter RJ, Berriman TJ, Diab I, et al. A randomized controlled trial of catheter ablation versus medical treatment of atrial fibrillation in heart failure (the CAMTAF trial). *Circ Arrhythm Electrophysiol* . 2014;7(1):31-38. doi:10.1161/CIRCEP.113.000806

5. Di Biase L, Mohanty P, Mohanty S, et al. Ablation Versus Amiodarone for Treatment of Persistent Atrial Fibrillation in Patients With Congestive Heart Failure and an Implanted Device: Results From the AATAC Multicenter Randomized Trial. *Circulation* . 2016;133(17):1637-1644. doi:10.1161/CIRCULATIONAHA.115.019406

6. Marrouche NF, Brachmann J, Andresen D, et al. Catheter Ablation for Atrial Fibrillation with Heart Failure. *N Engl J Med* . 2018;378(5):417-427. doi:10.1056/NEJMoa1707855

7. Cha YM, Wokhlu A, Asirvatham SJ, et al. Success of ablation for atrial fibrillation in isolated left ventricular diastolic dysfunction: a comparison to systolic dysfunction and normal ventricular function. *Circ Arrhythm Electrophysiol* . 2011;4(5):724-732. doi:10.1161/CIRCEP.110.960690

8. Machino-Ohtsuka T, Seo Y, Ishizu T, et al. Efficacy, safety, and outcomes of catheter ablation of atrial fibrillation in patients with heart failure with preserved ejection fraction. *J Am Coll Cardiol* . 2013;62(20):1857-1865. doi:10.1016/j.jacc.2013.07.020

9. Chen MS, Marrouche NF, Khaykin Y, et al. Pulmonary vein isolation for the treatment of atrial fibrillation in patients with impaired systolic function. *J Am Coll Cardiol* . 2004;43(6):1004-1009. doi:10.1016/j.jacc.2003.09.056

10. Sohns C, Saguner AM, Lemes C, et al. First clinical experience using a novel high-resolution electroanatomical mapping system for left atrial ablation procedures. *Clin Res Cardiol* . 2016;105(12):992-1002. doi:10.1007/s00392-016-1008-7

11. Schaeffer B, Hoffmann BA, Meyer C, et al. Characterization, Mapping, and Ablation of Complex Atrial Tachycardia: Initial Experience With a Novel Method of Ultra High-Density 3D Mapping. *J Cardiovasc Electrophysiol* . 2016;27(10):1139-1150. doi:10.1111/jce.13035

12. Hindricks G, Potpara T, Dagres N, et al. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC) Developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. *Eur Heart J* . 2021;42(5):373-498. doi:10.1093/eurheartj/ehaa612

13. Lutomsky BA, Rostock T, Koops A, et al. Catheter ablation of paroxysmal atrial fibrillation improves cardiac function: a prospective study on the impact of atrial fibrillation ablation on left ventricular function assessed by magnetic resonance imaging. *Europace* . 2008;10(5):593-599. doi:10.1093/europace/eun076

14. Ullah W, Ling LH, Prabhu S, et al. Catheter ablation of atrial fibrillation in patients with heart failure: impact of maintaining sinus rhythm on heart failure status and long-term rates of stroke and death. *Europace* . 2016;18(5):679-686. doi:10.1093/europace/euv440

15. Black-Maier E, Ren X, Steinberg BA, et al. Catheter ablation of atrial fibrillation in patients with heart failure and preserved ejection fraction. *Heart Rhythm* . 2018;15(5):651-657. doi:10.1016/j.hrthm.2017.12.001

16. Yang PS, Park YA, Kim TH, et al. Which patients recur as atrial tachycardia rather than atrial fibrillation after catheter ablation of atrial fibrillation? *PLoS ONE* . 2017;12(11):e0188326. doi:10.1371/journal.pone.0188326

17. Diamant MJ, Andrade JG, Virani SA, Jhund PS, Petrie MC, Hawkins NM. Heart failure and atrial flutter: a systematic review of current knowledge and practices. *ESC Heart Fail* . 2021;8(6):4484-4496.

doi:10.1002/ehf2.13526

18. Takigawa M, Derval N, Frontera A, et al. Revisiting anatomic macroreentrant tachycardia after atrial fibrillation ablation using ultrahigh-resolution mapping: Implications for ablation. *Heart Rhythm* . 2018;15(3):326-333. doi:10.1016/j.hrthm.2017.10.029

19. Kitamura T, Martin R, Denis A, et al. Characteristics of Single-Loop Macroreentrant Biatrial Tachycardia Diagnosed by Ultrahigh-Resolution Mapping System. *Circ Arrhythm Electrophysiol* . 2018;11(2):e005558. doi:10.1161/CIRCEP.117.005558

20. Providencia R, Elliott P, Patel K, et al. Catheter ablation for atrial fibrillation in hypertrophic cardiomyopathy: a systematic review and meta-analysis. *Heart* . 2016;102(19):1533-1543. doi:10.1136/heartjnl-2016-309406

21. Hindricks G, Weiner S, McElderry T, et al. Acute safety, effectiveness, and real-world clinical usage of ultra-high density mapping for ablation of cardiac arrhythmias: results of the TRUE HD study. *Europace* . 2019;21(4):655-661. doi:10.1093/europace/euy191

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