

Catheter ablation of atrial fibrillation in patients with diabetes mellitus: a systematic review and meta-analysis

Matteo Anselmino¹, Mario Matta¹, Fabrizio D'ascenzo¹, Carlo Pappone², Vincenzo Santinelli², T. Jared Bunch³, Thomas Neumann⁴, Richard J. Schilling⁵, Ross J. Hunter⁵, Georg Noelker⁶, Martin Fiala⁷, Antonio Frontera⁸, Glyn Thomas⁸, Demosthenes Katritsis⁹, Pierre Jais¹⁰, Rukshen Weerasooriya^{10,11}, Jonathan M. Kalman¹², and Fiorenzo Gaita^{1*}

¹Division of Cardiology, Department of Medical Sciences, Città Della Salute e Della Scienza Hospital, University of Turin, Corso Dogliotti 24, Torino 10126, Italy; ²Department of Arrhythmology, Maria Cecilia Hospital, GVM Care & Research, Cotignola, Italy; ³Intermountain Heart Institute, Intermountain Medical Center, Murray, UT, USA; ⁴Department of Cardiology, Kerckhoff Heart and Thorax Center, Bad Nauheim, Germany; ⁵Cardiovascular Biomedical Research Unit, St. Bartholomew's Hospital, Barts Health NHS Trust, London, UK; ⁶Department of Cardiology, Heart and Diabetes Center North Rhine-Westphalia, Ruhr University Bochum, Bad Oeynhausen, Germany; ⁷Department of Cardiology, Heart Centre, Hospital Podlesi as, Trinec, Czech Republic; ⁸Department of Cardiology, Bristol Heart Institute, University Hospital Bristol NHS Trust, Bristol, UK; ⁹Department of Cardiology, Athens Euroclinic, Athens, Greece; ¹⁰Department of Cardiac Electrophysiology, Hopital Cardiologique du Haut-Leveque, Bordeaux-Pessac, France; ¹¹University of Western Australia, Crawley, Western Australia, Australia; and ¹²Department of Cardiology, The Royal Melbourne Hospital, Melbourne, Australia

Received 26 February 2015; accepted after revision 22 May 2015

Aims

Diabetes mellitus (DM) and atrial fibrillation (AF) share pathophysiological links, as supported by the high prevalence of AF within DM patients. Catheter ablation of AF (AFCA) is an established therapeutic option for rhythm control in drug resistant symptomatic patients. Its efficacy and safety among patients with DM is based on small populations, and long-term outcome is unknown. The present systematic review and meta-analysis aims to assess safety and long-term outcome of AFCA in DM patients, focusing on predictors of recurrence.

Methods and results

A systematic review was conducted in MEDLINE/PubMed and Cochrane Library. Randomized controlled trials, clinical trials, and observational studies including patients with DM undergoing AFCA were screened and included if matching inclusion and exclusion criteria. Fifteen studies were included, adding up to 1464 patients. Mean follow-up was 27 (20–33) months. Overall complication rate was 3.5 (1.5–5.0)%. Efficacy in maintaining sinus rhythm at follow-up end was 66 (58–73)%. Meta-regression analysis revealed that advanced age ($P < 0.001$), higher body mass index ($P < 0.001$), and higher basal glycated haemoglobin level ($P < 0.001$) related to higher incidence of arrhythmic recurrences. Performing AFCA lead to a reduction of patients requiring treatment with antiarrhythmic drugs (AADs) from 55 (46–74)% at baseline to 29 (17–41)% ($P < 0.001$) at follow-up end.

Conclusions

Catheter ablation of AF safety and efficacy in DM patients is similar to general population, especially when performed in younger patients with satisfactory glycemic control. Catheter ablation of AF reduces the amount of patients requiring AADs, an additional benefit in this population commonly exposed to adverse effects of AF pharmacological treatments.

Keywords

Atrial fibrillation • Catheter ablation • Diabetes mellitus • Meta-analysis • Rhythm control

Introduction

The risk of atrial fibrillation (AF) in patients affected by diabetes mellitus (DM) is increased and likely multifactorial.^{1,2} Diabetes mellitus, both type 1 and type 2, impacts coronary micro- and macrovasculature and as such results in left ventricular diastolic dysfunction and,

consequently, atrial structural remodelling.³ In addition, patients with DM have higher levels of systemic inflammatory markers, particularly in the setting of poor glycemic control.⁴ Chronic systemic inflammation can locally result in higher levels of atrial myocyte breakdown and fibrosis,⁵ and as a consequence provides sources of AF initiation

* Corresponding author. Tel: +39 011 6335570; fax: +39 011 6966015. E-mail address: fiorenzo.gaita@unito.it

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2015. For permissions please email: journals.permissions@oup.com.

and maintenance. Finally, diabetic autonomic neuropathy can increase the risk of AF occurrence,⁶ in particular incidence of asymptomatic AF, and potentially raises the risk of thrombo-embolic events.⁷

Catheter ablation of AF (AFCA) is a well-established treatment option for patients with symptomatic AF refractory to antiarrhythmic drugs (AADs).^{8,9} Despite a relatively high incidence of late recurrences, long-term efficacy in maintaining sinus rhythm (SR) is encouragingly high, especially if compared with the long-term efficacy and tolerance of pharmacologic approaches.¹⁰ Diabetes mellitus patients are often included among patients undergoing AFCA, and although this procedure has been reported more effective in achieving rhythm control compared with AADs in general,¹¹ data concerning this subset population are limited to small, short-term studies and may not be specifically generalized. Therefore, the present systematic review and meta-analysis aims to investigate the long-term outcome of AFCA in patients with DM, focusing on procedural safety, long-term efficacy in achieving rhythm control, and predictors of recurrence, to improve knowledge in search of predictors of recurrence that could improve candidates' choice, or direct towards treatment of patients' reversible factors that may negatively impact the outcome of the procedure.

Methods

The present study was conducted in accordance to current guidelines, including the recent Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) amendment to the Quality of Reporting of Meta-analyses (QUOROM) statement, as well as recommendations from The Cochrane Collaboration and Meta-analysis Of Observational Studies in Epidemiology (MOOSE).^{12,13}

Search strategy and study selection

MEDLINE/PubMed and Cochrane database were searched for pertinent articles published in English from 2002 until October 2013, according to published recommendations.¹⁴ The following terms: 'atrial fibrillation' AND 'catheter ablation' AND ('diabetes mellitus' OR 'diabetic patients') were used to identify all the published articles referring to this specific population. A second search was then performed using the following terms: 'atrial fibrillation' AND 'catheter ablation' AND ('long-term outcome' OR 'long-term results'), to retrieve published articles referring to long-term results of this procedure among the general population; among them, all the studies presenting a mean follow-up of at least 2 years were selected, and the corresponding author was contacted for quantitative details on DM patients (established diagnosis or the use of glucose-lowering drugs and/or insulin), offering coauthorship in this work. Each included study was approved by an institutional review committee and all subjects gave informed consent.

Data extraction

Retrieved citations were first screened independently by two unblinded reviewers (authors: M.A. and M.M.) with divergences resolved after consensus. If the citations were deemed potentially pertinent, they were then appraised as complete reports according to the following explicit selection criteria: (i) human studies, (ii) published between 2002 and October 2013, (iii) investigating patients affected by type 1 or type 2 DM, or (iv) studies with unselected patients undergoing AFCA with a mean follow-up of at least 2 years. Exclusion criteria were (one enough for exclusion): (i) non-human setting, (ii) duplicate reporting (in which case the manuscript reporting the largest sample of patients was selected), (iii) studies including patients undergoing surgical or hybrid AF ablation, or (iv) studies without comprehensive follow-up description,

including duration and AF recurrence rates. Diabetes mellitus was defined as current treatment with glucose-lowering drugs or previous diagnosis of DM according to current recommendations.¹⁵

Statistical analysis

Continuous variables were reported as mean (standard deviation) or median (range), and categorical variables as *n* (%), weighted for sample size of each study and according to standard error by logarithmic transformation. Funnel plot analysis was used to evaluate potential publication bias, and Cochran Q2 tests and I2 to investigate heterogeneity. Using rates of event as dependent variables, a meta-regression analysis was performed to test whether an interaction between baseline clinical features [age, body mass index (BMI), paroxysmal AF, and basal glycated haemoglobin level], and incidence of AF recurrences was present. Owing to the observational design of most of the included studies, random effect was performed for all analysis. Statistical analyses were performed with Comprehensive Meta-analysis (Trial Version) and Review Manager.

Results

Search results

As highlighted in *Figure 1* and Representative Figure, the first search identified 85 abstracts referring to AFCA in DM patients; among this group, 74 were excluded following application of the inclusion and exclusion criteria; 11 of them were selected and full text was read by two authors; 7 were excluded because of incomplete baseline or follow-up characteristics. Four trials were finally included^{11,16–18} meeting all the pre-specified inclusion criteria.

The second search identified 681 abstracts referring to long-term results of AFCA; among them, 646 were excluded following application of the inclusion and the exclusion criteria. Thirty-five of them were selected and full text was read by two authors; 11 were excluded because of incomplete baseline or follow-up characteristics, 4 because reporting duplicate data and one because DM patients were not included. Following this selection approach, 19 trials were identified, and the corresponding author contacted, offering co-authorship in return for data concerning DM patients. Besides 8 authors which could not participate, due to the fact that the required data were not easily or promptly available from their dataset, 11 provided requested data regarding DM patients.^{19–29}

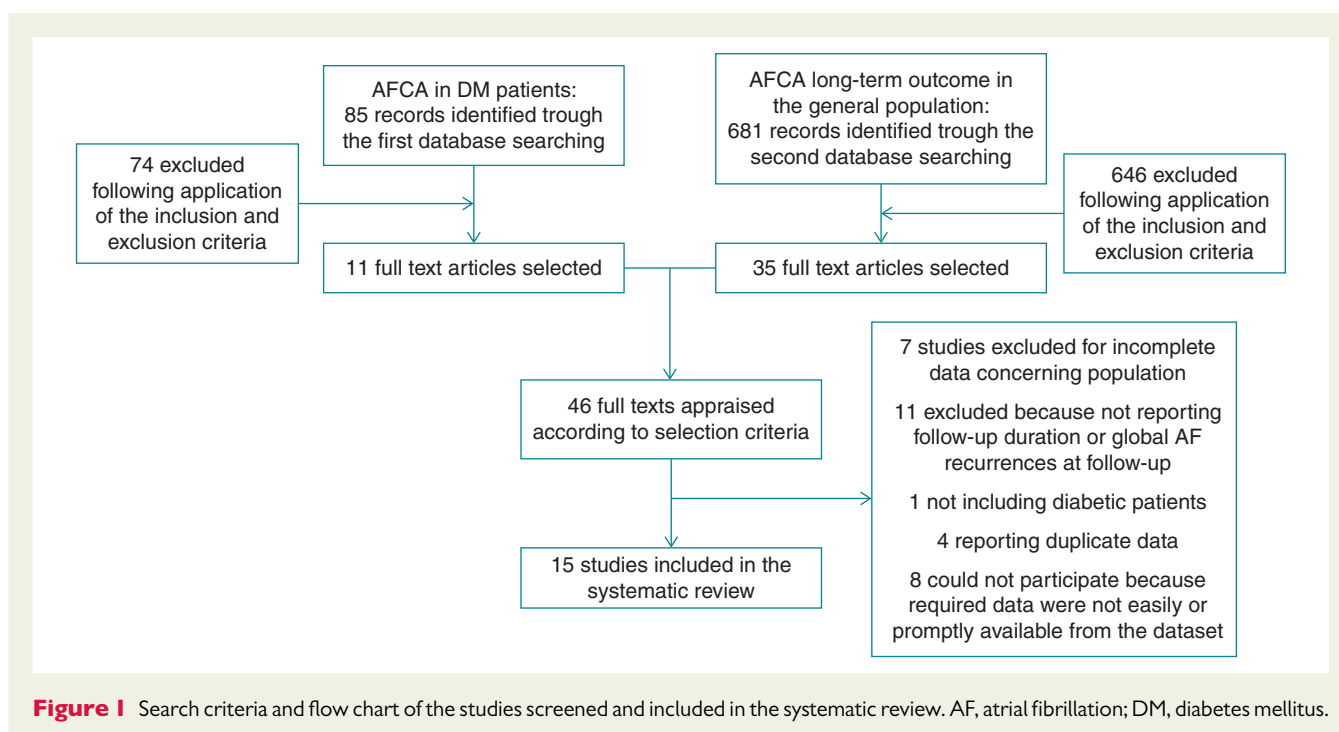
First author, study design, publication date, and main characteristics of each included study are reported in *Table 1*.

Baseline patients characteristics

A total of 1464 patients with DM were finally included from 15 studies. Based on the nine studies reporting this detail, 97.8% were type 2 and 2.2% type 1 DM patients. Baseline characteristics are shown in *Table 2*. Mean age from each study ranged from 55 to 65 years, and 33% were women. Paroxysmal AF accounted for 65% of the population. Concerning pharmacological therapy, 55% of the patients were treated with AADs at the time of ablation, and 85% were on oral anticoagulants. The majority of patients received oral glucose-lowering drugs, and 15% were on insulin treatment.

Catheter ablation protocol and complications

Catheter ablation of AF procedural features are reported in *Table 3*. Major procedural complication rates ranged from 1.5 to 5.0% (mean



3.5%). The most frequent complications were related to the access site and to cerebral thrombo-embolic events. Redo procedures were performed in 37 (27–43)% of the cases.

Follow-up and recurrences

The mean follow-up was 27 months, ranging from 20 to 33 months. Recurrences were defined, consistently within all the studies, as episodes of AF or atrial tachycardia or atypical atrial flutter lasting at least 30 s detected during follow-up, with a blanking period of 3 months after ablation (Table 1). Overall long-term efficacy in SR maintenance after AFCA was 66 (58–73)% (Figure 2). Freedom from AF after a single procedure ranged, instead, from 41 to 56%. As illustrated in Figure 3, the number of patients receiving AADs significantly decreased during follow-up from 55 (46–74)% to 29 (17–41)% ($P < 0.001$).

A meta-regression analysis (Figure 4) was performed to assess whether an interaction between relevant baseline clinical features, and incidence of AF recurrence was present: advanced age (β 0.12 [0.09–0.15], $P < 0.001$), higher basal glycated haemoglobin levels (β 0.5 [0.1–0.9], $P < 0.001$), and higher BMI (β 0.08 [0.01–0.15], $P < 0.001$) related to a higher AF recurrence rate. Paroxysmal vs. persistent AF (β 0.001 [–0.002 to 0.13], $P = 0.81$), instead, did not relate to AF recurrences.

Discussion

Current evidences regarding the safety and efficacy of AFCA in DM patients are based on small trials or observational studies enrolling up to 150 patients. The real world safety and efficacy of AFCA in subset populations requires multicentre experiences. By not including available literature only but directly contacting each corresponding author of published long-term AFCA experiences, the present

collaborative multicentre meta-analysis is the first study, to the best of our knowledge, to include a relevant number of patients with DM. These data are clinically significant because, as previously discussed, DM patients are prone to develop AF, often present more comorbid disease states, and are at higher risk for AF complications such as stroke⁸ and heart failure.⁵ Effective treatment by AFCA may therefore warrant significant benefits not only in terms of symptoms control but also in reducing the risk of complications related to AF and/or to its pharmacological treatment in patients with DM.

Based on the present analysis, AFCA in patients with DM reports an overall complication rate of 3.5 (1.5–5.0)%. This incidence is similar to that reported among the general AFCA populations¹⁰ and, although a direct comparison between DM and non-DM patients was not performed, these results provide indirect evidence that the procedure does not relate to disproportionate procedural risks.

Similar to safety, the long-term SR maintenance rates were favourable, compared with available data concerning efficacy of AADs therapy in the general population. In this multicentre analysis, approximately half of the patients were free from AF following the first procedure. With the inclusion of redo procedures, the long-term SR maintenance rate improved to 66%: this result is comparable with long-term outcomes reported in general AFCA populations, which typically include patients with both their first and redo ablations.^{10,30,31} The relatively large proportion (37%) of patients requiring more than one procedure to achieve effective long-term SR maintenance may be explained by the aforementioned complexity of the electrical and anatomical atrial substrate and metabolic alterations of DM patients.^{4,5} Furthermore, the frequent need for redo procedures in this large population did not result in a linear increase in procedural complications. The included studies cover a

Table 1 First author, publication date, population, and main characteristics of the included studies

| First author, country, year of publication | Study design | Number of patients | Follow-up (months) | AF recurrence monitoring | Paroxysmal AF (%) | Age (years) | Baseline AADs use (%) | SR at follow-up end (%) |
|--|---|--------------------|--------------------|---|-------------------|-------------|-----------------------|-------------------------|
| Forleo, Italy, 2009 ¹¹ | Randomized, multicentre | 35 | 12 | ECG and 24-h Holter ECG at 1, 3, and every 3 months | 46 | 63 | – | 80 |
| Tang, China, 2006 ¹⁶ | Prospective, single-centre | 31 | 13 | ECG and 24-h Holter ECG at 1, 3, 6, and 12 months | 81 | 62 | – | 68 |
| Chao, Taiwan, 2010 ¹⁷ | Retrospective, single-centre | 65 | 19 | ECG and 24-h Holter ECG at 2 weeks and every 1–3 months | – | 56 | 35 | 81 |
| Gu, China, 2011 ¹⁸ | Prospective, single-centre | 150 | 23 | ECG and 24-h Holter ECG at 2 weeks, 1, 3, 6, 9, 12, and every 6 months | – | 59 | 55 | 76 |
| Pappone, Italy, 2003 ¹⁹ | Prospective controlled trial, single-centre | 589 | 46 | ECG and 24-h Holter ECG at 1, 3, 6, 12, and every 6 months | 69 | 61 | 67 | 69 |
| Gaita, Italy, 2008 ²⁰ | Randomized controlled trial, single-centre | 43 | 21 | ECG and 24-h Holter ECG at 1, 3, 6, 12, 18, and 24 months | 49 | 62 | 76 | 61 |
| Katritsis, Greece, 2008 ²¹ | Prospective, single-centre | 5 | 43 | ECG and 24-h Holter ECG at 6 weeks and every 3 months | 100 | 65 | – | 60 |
| Pappone, Italy, 2011 ²² | Randomized controlled trial, single-centre | 5 | 48 | ECG and 48-h Holter ECG at 3, 6, and 12 months | 100 | 60 | – | 60 |
| Medi, Australia, 2011 ²³ | Retrospective, single-centre | 2 | 31 | ECG and 24-h Holter ECG at 3, 6, 12, and every 6 months | 100 | 59 | 50 | 0 |
| Weerasooriya, France, 2011 ²⁴ | Prospective, single-centre | 3 | 56 | ECG and 24-h Holter ECG at 1, 3, 6, 12, and every 12 months | 100 | 58 | 100 | 33 |
| Bunch, USA, 2011 ²⁵ | Retrospective, single-centre | 342 | 58 | ECG and visit at 3, 6, 12 and every 12 months | 48 | 68 | 54 | 47 |
| Hunter, UK, 2012 ²⁶ | Retrospective, multi center | 60 | 42 | ECG and 24-h Holter ECG at 3, 6, 12, and every 12 months | 42 | 62 | – | 72 |
| Neumann, Germany, 2013 ²⁷ | Prospective, single-centre | 63 | 33 | ECG and 7-day Holter ECG at 3, 6, 9, 12, and every 12 months | 52 | 61 | 63 | 60 |
| Vogt, Germany, 2013 ²⁸ | Prospective, single-centre | 44 | 18 | ECG and 7-day Holter ECG at 3, 6, 9, and 12 months; ECG every 6 months later | 95 | 63 | 74 | 61 |
| Fiala, Czech Republic, 2014 ²⁹ | Prospective, single-centre | 27 | 37 | ECG and 24-h Holter ECG at 3, 6, 12, and every 6 months; tele-ECG for 3 weeks | 0 | 63 | 26 | 63 |

AF, atrial fibrillation; AADs, antiarrhythmic drugs; SR, sinus rhythm; ECG, electrocardiogram.

Table 2 Baseline characteristics of the study population (1464 patients)

| | Mean value (lower–upper 95% CI) |
|---|------------------------------------|
| Age (years) | 62 (55–65) |
| Female gender (%) | 33 (24–48) |
| BMI (kg/m ²) | 30 (27–32) |
| Mean follow-up (months) | 27 (20–33) |
| Basal glycated haemoglobin (%) | 6.8 (5.5–8.1) |
| Type of AF | |
| Paroxysmal (%) | 65 (54–67) |
| Persistent (%) | 21 (19–26) |
| Long-standing persistent (%) | 14 (10–19) |
| Duration of AF (months) | 42 (34–49) |
| EHRA class | |
| I (%) | 18 (17–27) |
| II (%) | 21 (16–29) |
| III or IV (%) | 41 (35–48) |
| Hypertension (%) | 80 (75–91) |
| Prior stroke or TIA (%) | 6.0 (4.0–11.5) |
| Cardiomyopathy | |
| Ischaemic (%) | 17 (14–31) |
| Hypertensive (%) | 12 (8–19) |
| Valvular heart disease (%) | 1.5 (0.5–5.0) |
| Idiopathic (%) | 5.0 (3.0–7.0) |
| QRS duration (ms) | 94 (85–100) |
| Previous electrical cardioversion (%) | 67 (56–71) |
| Impaired renal function (eGFR < 60 mL/min) (%) | 9.0 (4.0–13.0) |
| Thyroid disease | |
| Hyperthyroidism (%) | 4.5 (3.2–9.5) |
| Hypothyroidism (%) | 14 (6–21) |
| Dyslipidaemia (%) | 41 (35–56) |
| LDL levels (mg/dL) | 117 (90–125) |
| HDL levels (mg/dL) | 50 (43–63) |
| Triglycerides levels (mg/dL) | 180 (145–210) |
| Chronic lung disease (%) | 7.5 (6.0–9.0) |
| Obstructive sleep apnoea (%) | 7.0 (5.0–12.0) |
| Baseline medical therapy (%) | |
| Antiarrhythmic drugs (%) | 55 (46–74) |
| Beta blockers (%) | 78 (67–81) |
| Oral anticoagulants (%) | 85 (80–89) |
| Aspirin (%) | 15 (11–15) |
| Oral glucose-lowering drugs use (%) | 85 (77–91) |
| Biguanides (%) | 61 (50–65) |
| Thiazolidinediones (%) | 5.0 (3.0–8.0) |
| Dipeptidyl peptidase-4 inhibitors (%) | 5.0 (2.0–8.5) |
| Sulfonylureas (%) | 44 (27–51) |
| Insulin use (%) | 15 (12–21) |
| LV ejection fraction (%) | 56 (50–61) |
| LV diastolic dysfunction (%) | 67 (61–74) |
| Left atrium area (cm ²) | 27 (22–29) |

CI, confidence interval; BMI, body mass index; AF, atrial fibrillation; TIA, transient ischaemic attack; LV, left ventricular.

Table 3 Catheter ablation procedural features and long-term rates of SR maintenance of the study population (1464 patients)

| | Mean value (lower–upper 95% CI) |
|--|------------------------------------|
| First ablation procedure | |
| PV isolation (%) | 100 (100–100) |
| PV isolation alone (%) | 72 (56–81) |
| Left isthmus line (%) | 21 (16–34) |
| Roof line (%) | 17 (11–20) |
| CFAE (%) | 7.0 (3.0–11.0) |
| Fluoroscopy time (min) | 26 (15–34) |
| Procedural time (h) | 3.1 (1.5–3.3) |
| Post procedural cardioversion (%) | 21 (17–34) |
| Overall complications (%) | 3.5 (1.5–5.0) |
| Access site complications (%) | 1.5 (0.5–3.0) |
| Stroke/TIA (%) | 1.0 (0.5–2.0) |
| Cardiac tamponade (%) | 1.0 (0.5–1.5) |
| Others (%) | 0.5 (0.5–1.0) |
| Redo procedure, performed in 37 (27–43)% of the patients | |
| Time after first procedure (months) | 12 (7–21) |
| PV isolation (%) | 97 (90–100) |
| PV isolation alone (%) | 44 (29–55) |
| Left isthmus line (%) | 50 (45–53) |
| Roof line (%) | 30 (20–37) |
| CFAE (%) | 15 (11–19) |
| Overall complications (%) | 3.0 (0–6.0) |
| Access site complications (%) | 1.5 (0–3.0) |
| Stroke/TIA (%) | 1.5 (0–3.0) |
| Cardiac tamponade (%) | 0 |
| First procedure efficacy (%) | 50 (41–56) |
| Final efficacy (%) | 66 (58–73) |

CI, confidence interval; PV, pulmonary veins; CFAE, complex fractionated atrial electrograms; TIA, transient ischaemic attack.

wide temporal interval, however, this did not influence: baseline characteristics and AF ablation outcome did not differ among patients included in the earliest¹⁹ compared with latest^{26,27} studies. Of note, follow-up monitoring included periodic Holter electrocardiogram (ECG) assessments in almost all studies, except Bunch et al.²⁵ that were driven by clinical symptoms and ECG only, while Vogt et al.²⁸ and Neumann et al.²⁷ required 7-day Holter recordings. Despite these discrepancies study design also did not significantly influence incidence of recurrences. The only notable difference that emerges, instead, relates to follow-up durations: longer follow-up studies²⁵ report higher recurrence rates compared with shorter follow-up studies.

Diabetes mellitus patients with AF carry a worse prognosis than those in SR.³² Therefore, safe and effective rhythm control treatments that prove to be able to maintain SR long-term may reduce or negate the long-term negative impact of AF in DM patients, turning into prognostic positive effects. Other AF treatment options

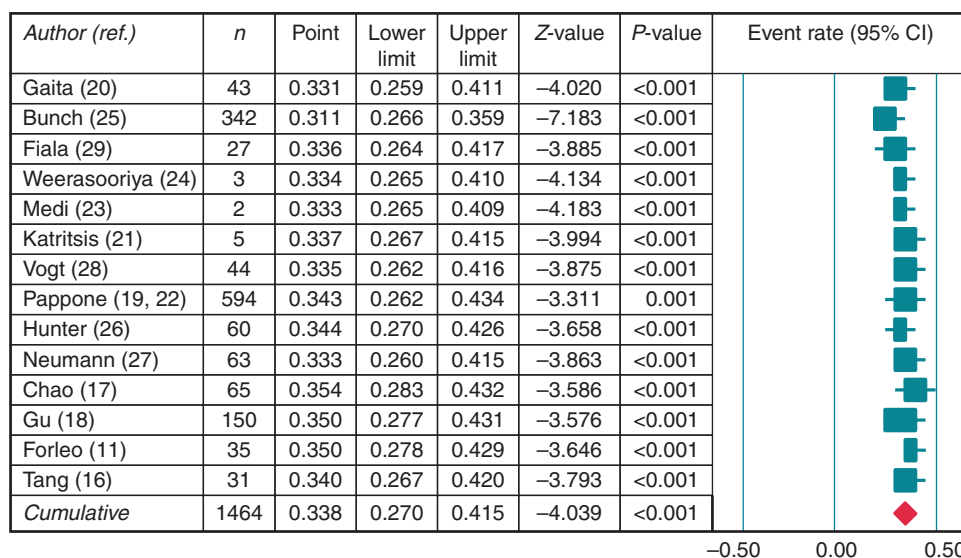


Figure 2 Forest plot of the included studies concerning AF recurrence rate at follow-up end, highlighting the statistic relevance of the results from each single study. CI, confidence interval.

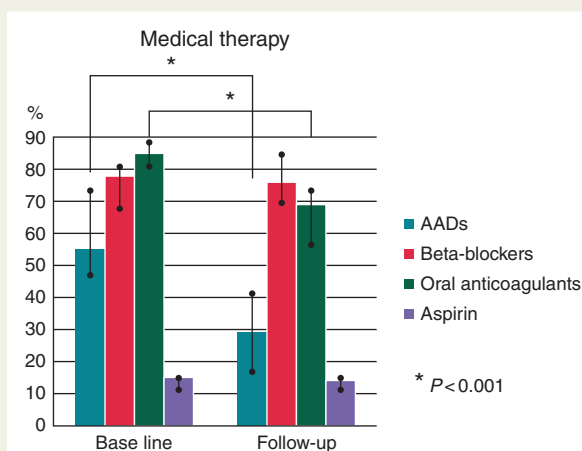


Figure 3 Medical therapy at baseline and follow-up end (1464 patients), showing significant reduction in AADs ($P < 0.001$) and oral anticoagulants ($P < 0.001$) use during follow-up. AADs, anti-arrhythmic drugs.

present, in fact, several limitations. Previous studies have reported higher recurrence rates after AF electrical cardioversion for patients with DM compared with those without DM,³³ and lower efficacy of AADs in animal studies.³⁴ In addition, DM patients may be more exposed to the frequent and potentially harmful adverse effects of AADs treatment, due to the large prevalence of silent ischaemic heart disease and heart failure.³² For these reasons the finding that AFCA may, at least, reduce the proportion of patients requiring pharmacological treatment with AADs during follow-up is, indeed, clinically relevant.

Based on the present meta-regression analysis, advanced age, high BMI, and higher basal glycated haemoglobin levels relate to higher AF recurrence rates, suggesting a role for DM-related metabolic alterations in promoting arrhythmic recurrences. The role of the electroanatomical atrial myocytes alterations described in patients with DM, magnified by the concomitant presence of obesity (one of the markers of the metabolic syndrome)^{4,5} emerges, in fact, more evidently than AF duration (paroxysmal or persistent AF) and other 'classical' recurrence predictors.³⁵ This finding, deviant from what is documented in the general population, is also sustained by the need, despite inclusion of a majority of paroxysmal AF patients (65%), for frequent redo procedures and wide substrate modification (linear lesions and/or CFAE ablation in the left atrium) to achieve effective long-term rhythm control. Optimal glyco-metabolic control and weight reduction may, therefore, be crucial to optimize AF management^{36–38} and enhance ablation outcomes.³⁹ In fact, a one point increase in basal glycated haemoglobin raised by 0.5 the odds ratio of AF relapse during the long-term follow-up, suggesting that even small changes in DM control can impact outcomes. Finally, an interaction between left atrial enlargement and AFCA outcome was not identified: this surprising finding may most probably be explained by the very large prevalence of patients with enlarged left atrium (over 80%) included in the analysis.

Limitations

This study presents the following limitations. First, AFCA is a relatively recent and developing procedure, with different centres using different protocols and tools. Catheter ablation of AF procedural characteristics may grow heterogeneity; however, in this study safety and efficacy outcomes did not present time-related trends. This limitation therefore serves also as strength, as these data provide a real world understanding of AFCA outcomes and as such are more likely to replicate individual practices. Secondly, DM is a

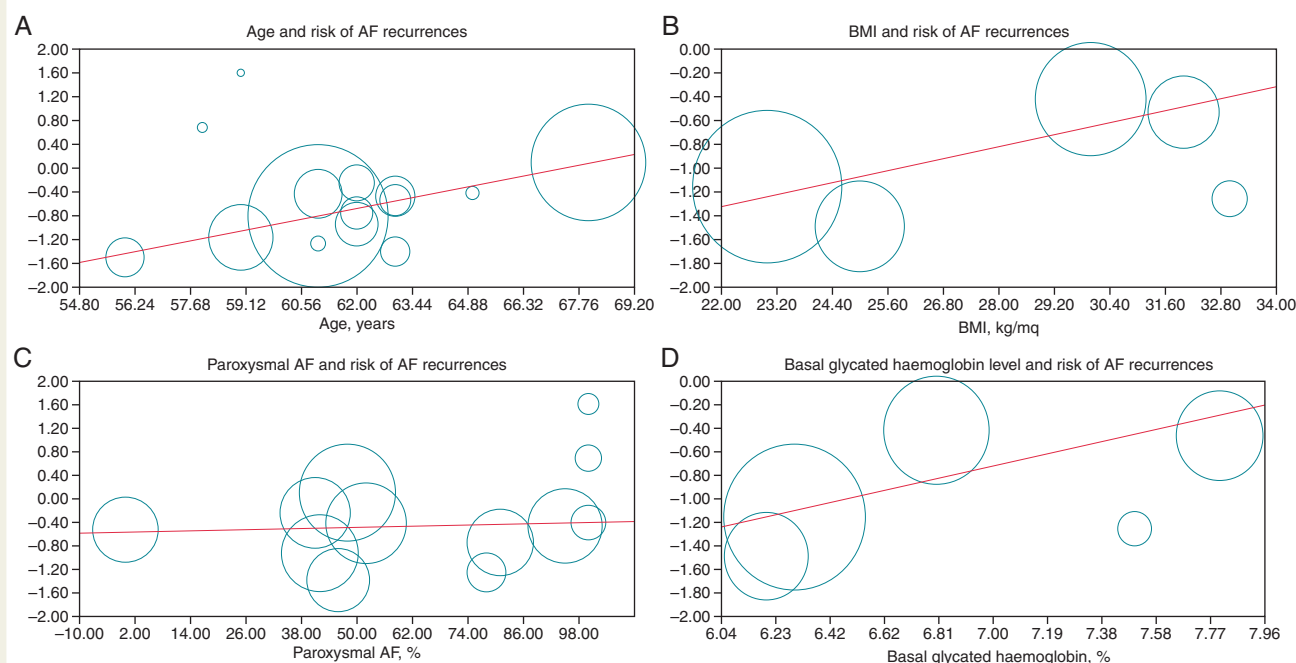


Figure 4 Meta-regression analysis assessing the impact of age (A, β 0.12 [0.09–0.15], $P < 0.001$), BMI (B, β 0.08 [0.01–0.15], $P < 0.001$), paroxysmal AF (C, β 0.001 [–0.002 to 0.13], $P = 0.81$), and basal glycated haemoglobin level (D, β 0.5 [0.1–0.9], $P < 0.001$) on long-term incidence of AF recurrences. AF, atrial fibrillation; BMI: body mass index.

progressive disease, even in case of optimal glycemic control, and the heterogeneity among DM patients, with its variable progression over follow-up, may affect atrial substrate properties and consequently AFCA outcome. Additionally, being type 1 DM patients scarcely represented (<3%), results cannot be generalized specifically to this subset of patients. Thirdly, the low prevalence of patients with obstructive sleep apnoea syndrome, impaired renal function, and on insulin treatment (compared with oral glucose-lowering drugs) may reflect a selection, in each individual study, of patients with less severe DM and lower comorbidities/complications, limiting generalization of the results to this setting of patients. Fourthly, although heterogeneity was appraised by random effect, this meta-analysis, in order to include the largest amount of data available from current literature, combines randomized controlled trials with observational studies. The enrolled population may therefore be affected by selection bias of single centres' experience and preference in referring patients to AFCA. Finally, meta-regression analysis does not allow clinicians to drive causative inferences, but only speculative. The absence of a control population, although data are indirectly compared with previously published meta-analyses performed on the general population, may limit the strength of the results. The focus of the present work, however, is to detect predictors of outcome intrinsic to DM patients, useful to improve candidates' choice, or direct towards treatment of patients' reversible factors that may negatively impact outcome. Large prospective multicentre clinical trials are, however, warranted to precisely define AFCA safety and efficacy in this group of patients.

Conclusion

Catheter ablation of AF complications rate and long-term SR maintenance in patients with DM are comparable with those reported among the general population, although with a relatively frequent need of redo procedures. Performing the procedure among younger patients with an optimal glycol-metabolic control may be crucial to improve outcome. Eventually, AFCA is related to a subsequent reduced need of AADs, limiting the risk of their frequent adverse effects.

Authors' contribution

M.A. conceived the design of this work. M.A. and M.M. reviewed the literature, performed the selection of the studies, and wrote the manuscript. F.D.A. performed the statistical analyses and contributed to write the manuscript. C.P., V.S., T.J.B., T.N., R.J.S., R.J.H., G.N., M.F., A.F., G.T., D.K., P.J., R.W., and J.M.K. retrieved the required data from their centres' population and revised the manuscript. F.G. revised and approved the final version of the manuscript.

Acknowledgements

We thank all contacted centres for the professionalism demonstrated by promptly collaborating and sharing data with the only aim to improve current medical knowledge.

Conflicts of interest: none declared.

References

- Huxley RR, Filion KB, Konety S, Alonso A. Meta-analysis of cohort and case-control studies of type 2 diabetes mellitus and risk of atrial fibrillation. *Am J Cardiol* 2011; **108**:56–62.
- Anselmino M, Gohlke H, Mellbin L, Rydén L. Cardiovascular prevention in patients with diabetes and prediabetes. *Herz* 2008; **33**:170–7.
- Andersson C, Gislason GH, Weeke P, Hoffmann S, Hansen PR, Torp-Pedersen C et al. Diabetes is associated with impaired myocardial performance in patients without significant coronary artery disease. *Cardiovasc Diabetol* 2010; **9**:3.
- Raposeiras-Roubín S, Rodiño-Janeiro BK, Grigorian-Shamagian L, Seoane-Blanco A, Moure-González M, Varela-Román A et al. Evidence for a role of advanced glycation end products in atrial fibrillation. *Int J Cardiol* 2012; **157**:397–402.
- Saunders J, Mathewkutty S, Drazner MH, McGuire DK. Cardiomyopathy in type 2 diabetes: update on pathophysiological mechanisms. *Herz* 2008; **33**:184–90.
- Anselmino M, Ohrvik J, Rydén L, Euro Heart Survey Investigators. Resting heart rate in patients with stable coronary artery disease and diabetes: a report from the Euro Heart Survey on diabetes and the heart. *Eur Heart J* 2010; **31**:3040–5.
- Potpara TS, Polovina MM, Marinkovic JM, Lip GY. A comparison of clinical characteristics and long-term prognosis in asymptomatic and symptomatic patients with first-diagnosed atrial fibrillation: the Belgrade Atrial Fibrillation Study. *Int J Cardiol* 2013; **168**:4744–9.
- Camm AJ, Lip GY, De Caterina R, Savelieva I, Atar D, Hohnloser SH et al., ESC Committee for Practice Guidelines (CPG). 2012 focused update of the ESC Guidelines for the management of atrial fibrillation: an update of the 2010 ESC Guidelines for the management of atrial fibrillation. Developed with the special contribution of the European Heart Rhythm Association. *Europace* 2012; **14**:1385–413.
- Anselmino M, D'Ascenzo F, Amoroso G, Ferraris F, Gaita F. History of transcatheter atrial fibrillation ablation. *J Cardiovasc Med* 2012; **13**:1–8.
- Ganesan AN, Shipp NJ, Brooks AG, Kuklik P, Lau DH, Lim HS et al. Long-term outcomes of catheter ablation of atrial fibrillation: a systematic review and meta-analysis. *J Am Heart Assoc* 2013; **2**:e004549.
- Forleo GB, Mantica M, De Luca L, Leo R, Santini L, Panigada S et al. Catheter ablation of atrial fibrillation in patients with diabetes mellitus type 2: results from a randomized study comparing pulmonary vein isolation versus antiarrhythmic drug therapy. *J Cardiovasc Electrophysiol* 2009; **20**:22–8.
- Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009; **339**:b2535.
- Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D et al. Meta-analysis of observational studies in epidemiology: proposal for reporting. Meta-analysis of observational studies in epidemiology (MOOSE) group. *JAMA* 2000; **283**:2008–12.
- Wilczynski NL, Haynes RB, for the Hedges Team. Developing optimal search strategies for detecting clinically sound prognostic studies in MEDLINE: an analytic survey. *BMC Med* 2004; **2**:23.
- American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2013; **36**(Suppl. 1):S67–74. doi: 10.2337/dc13-S067.
- Tang RB, Dong JZ, Liu XP, Fang DP, Long de Y, Liu XH et al. Safety and efficacy of catheter ablation of atrial fibrillation in patients with diabetes mellitus—single center experience. *J Interv Card Electrophysiol* 2006; **17**:41–6.
- Chao TF, Suenari K, Chang SL, Lin YJ, Lo LW, Hu YF et al. Atrial substrate properties and outcome of catheter ablation in patients with paroxysmal atrial fibrillation associated with diabetes mellitus or impaired fasting glucose. *Am J Cardiol* 2010; **106**:1615–20.
- Gu J, Liu X, Wang X, Shi H, Tan H, Zhou L et al. Beneficial effect of pioglitazone on the outcome of catheter ablation in patients with paroxysmal atrial fibrillation and type 2 diabetes mellitus. *Europace* 2011; **13**:1256–61.
- Pappone C, Rosanio S, Augello G, Gallus G, Vicedomini G, Mazzone P et al. Mortality, morbidity, and quality of life after circumferential pulmonary vein ablation for atrial fibrillation: outcomes from a controlled nonrandomized long-term study. *J Am Coll Cardiol* 2003; **42**:185–97.
- Gaita F, Caponi D, Scaglione M, Montefusco A, Corleto A, Di Monte F et al. Long-term clinical results of 2 different ablation strategies in patients with paroxysmal and persistent atrial fibrillation. *Circ Arrhythm Electrophysiol* 2008; **1**:269–75.
- Katritsis D, Wood MA, Giazitzoglou E, Shepard RK, Kourlaba G, Ellenbogen KA. Long-term follow-up after radiofrequency catheter ablation for atrial fibrillation. *Europace* 2008; **10**:419–24.
- Pappone C, Vicedomini G, Augello G, Manguso F, Saviano M, Baldi M et al. Radio-frequency catheter ablation and antiarrhythmic drug therapy: a prospective, randomized, 4-year follow-up trial: the APAF study. *Circ Arrhythm Electrophysiol* 2011; **4**:808–14.
- Medi C, Sparks PB, Morton JB, Kistler PM, Halloran K, Rosso R et al. Pulmonary vein antral isolation for paroxysmal atrial fibrillation: results from long-term follow-up. *J Cardiovasc Electrophysiol* 2011; **22**:137–41.
- Weerasooriya R, Khairy P, Litalien J, Macle L, Hocini M, Sacher F et al. Catheter ablation for atrial fibrillation: are results maintained at 5 years of follow-up? *J Am Coll Cardiol* 2011; **57**:160–6.
- Bunch TJ, Crandall BG, Weiss JP, May HT, Bair TL, Osborn JS et al. Patients treated with catheter ablation for atrial fibrillation have long-term rates of death, stroke, and dementia similar to patients without atrial fibrillation. *J Cardiovasc Electrophysiol* 2011; **22**:839–45.
- Hunter RJ, McCready J, Diab I, Page SP, Finlay M, Richmond L et al. Maintenance of sinus rhythm with an ablation strategy in patients with atrial fibrillation is associated with a lower risk of stroke and death. *Heart* 2012; **98**:48–53.
- Neumann T, Wójcik M, Berkowitsch A, Erkapic D, Zaltsberg S, Greiss H et al. Cryoballoon ablation of paroxysmal atrial fibrillation: 5-year outcome after single procedure and predictors of success. *Europace* 2013; **15**:1143–9.
- Vogt J, Heintze J, Gutleben KJ, Muntean B, Horstkotte D, Nölker G. Long-term outcomes after cryoballoon pulmonary vein isolation: results from a prospective study in 605 patients. *J Am Coll Cardiol* 2013; **61**:1707–12.
- Fiala M, Wichterle D, Bulková V, Sknouril L, Nevralová R, Toman O et al. A prospective evaluation of haemodynamics, functional status, and quality of life after radiofrequency catheter ablation of long-standing persistent atrial fibrillation. *Europace* 2014; **16**:15–25.
- Arbello E, Brugada J, Hindricks G, Maggioni AP, Tavazzi L, Vardas P et al., Atrial Fibrillation Ablation Pilot Study Investigators. The Atrial Fibrillation Ablation Pilot Study: an European Survey on Methodology and Results of Catheter Ablation for Atrial Fibrillation: conducted by the European Heart Rhythm Association. *Eur Heart J* 2014; **35**:1466–78.
- Arbello E, Brugada J, Hindricks G, Maggioni A, Tavazzi L, Vardas P et al. ESC-EURObservational Research Programme: the Atrial Fibrillation Ablation Pilot Study, conducted by the European Heart Rhythm Association. *Europace* 2012; **14**:1094–103.
- Du X, Ninomiya T, de Galan B, Abadir E, Chalmers J, Pillai A et al., ADVANCE Collaborative Group. Risks of cardiovascular events and effects of routine blood pressure lowering among patients with type 2 diabetes and atrial fibrillation: results of the ADVANCE study. *Eur Heart J* 2009; **30**:1128–35.
- Soran H, Younis N, Currie P, Silas J, Jones IR, Gill G. Influence of diabetes on the maintenance of sinus rhythm after a successful direct current cardioversion in patients with atrial fibrillation. *QJM* 2008; **101**:181–7.
- Ito I, Hayashi Y, Kawai Y, Iwasaki M, Takada K, Kamibayashi T et al. Diabetes mellitus reduces the antiarrhythmic effect of ion channel blockers. *Anesth Analg* 2006; **103**:545–50.
- D'Ascenzo F, Corleto A, Biondi-Zoccai G, Anselmino M, Ferraris F, di Biase L et al. Which are the most reliable predictors of recurrence of atrial fibrillation after transcatheter ablation?: a meta-analysis. *Int J Cardiol* 2013; **167**:1984–9.
- Anselmino M, Malmberg K, Mellbin L, Rydén L. Overview of the importance of glycaemic control for cardiovascular events in the in-and out-patient setting. *Rev Endocr Metab Disord* 2010; **11**:87–94.
- Abed HS, Wittert GA, Leong DP, Shirazi MG, Bahrami B, Middeldorp ME et al. Effect of weight reduction and cardiometabolic risk factor management on symptom burden and severity in patients with atrial fibrillation: a randomized clinical trial. *JAMA* 2013; **310**:2050–60.
- Pathak RK, Middeldorp ME, Meredith M, Mehta AB, Mahajan R, Wong CX et al. Long-term effect of goal directed weight management in an atrial fibrillation cohort: a Long-term Follow-Up Study (LEGACY Study). *J Am Coll Cardiol* 2015. doi: 10.1016/j.jacc.2015.03.002.
- Pathak RK, Middeldorp ME, Lau DH, Mehta AB, Mahajan R, Twomey D et al. Aggressive risk factor reduction study for atrial fibrillation and implications for the outcome of ablation: the ARREST-AF cohort study. *J Am Coll Cardiol* 2014; **64**:2222–31.