ORIGINAL ARTICLE – ADULT CARDIAC

Total endoscopic ablation of patients with long-standing persistent atrial fibrillation: a randomized controlled study[†]

Espen Fengsrud[a,b,*], Anders Wickbom[c], Henrik Almroth[a,b], Anders Englund[b,d] and Anders Ahlsson[b,c]

[a] Department of Cardiology, Örebro University, Örebro, Sweden
[b] Faculty of Medicine and Health, Örebro University, Örebro, Sweden
[c] Department of Cardiothoracic and Vascular Surgery, Örebro University, Örebro, Sweden
[d] Arrhythmia Centre, South General Hospital, Stockholm, Sweden

* Corresponding author. Department of Cardiology, Örebro University Hospital, 701 85 Örebro, Sweden. Tel: +46-19-6021000; fax: +46-19-6113943;
  e-mail: espen.fengsrud@orebroll.se (E. Fengsrud).

Abstract

OBJECTIVES: Total endoscopic ablation of atrial fibrillation is an alternative to catheter ablation, but its clinical role needs further evaluation. The aim of this study was to compare total endoscopic ablation with rate control in patients with long-standing persistent atrial fibrillation and to examine the effect of endoscopic ablation on heart rhythm, symptoms, physical working capacity and myocardial function during 1 year of follow-up.

METHODS: In a prospective controlled study, 36 patients aged >50 years with symptomatic long-standing persistent atrial fibrillation were randomized to either total endoscopic ablation ($n = 17$, after two drop-outs before ablation $n = 15$) or rate control therapy ($n = 19$). In the ablation group, a box lesion encircling the pulmonary veins was performed, using temperature-controlled radiofrequency energy. Loop recorders were implanted in all patients. Echocardiography and quality-of-life assessment were performed at 6 and 12 months, and physical working capacity assessment at 6 months.

RESULTS: There was no mortality or thromboembolic event. In the control group, all patients were in permanent atrial fibrillation during 12 months of follow-up. In the ablation group, the proportion of patients in sinus rhythm without antiarrhythmic drugs was 12/15 (80%) at 12 months. The median freedom of atrial fibrillation at 3–12 months was 95% in the ablation group and the proportion of patients with an atrial fibrillation burden of <5% at 3–12 months was 8/15 (53%). The left ventricular ejection fraction increased during follow-up in the ablation group compared with the control group (from 53.7 ± 8.6 to 58.8 ± 6.5%, $P = 0.003$), combined with a reduction in the left atrial area (from 29.2 ± 5.5 to 27.2 ± 6.3 cm^2, $P = 0.002$). The physical working capacity increased in the ablation group compared with the control group (from 94 ± 21.4 to 102.9 ± 14.4%, $P = 0.011$). The subjective physical and mental capacity scale also improved during follow-up in the ablation group, but not in the control group ($P = 0.003$ and 0.018, respectively).

CONCLUSIONS: Total endoscopic ablation in patients with long-standing persistent atrial fibrillation significantly reduced atrial fibrillation burden 12 months after intervention compared with controls. The left ventricular function, physical working capacity and subjective physical and mental health were improved. These results need to be confirmed in larger randomized trials.

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Keywords: Atrial fibrillation · Ablation · Endoscopy · Randomized trial · Implantable loop recorder

INTRODUCTION

Atrial fibrillation (AF) is the most common cardiac arrhythmia and is associated with an increased risk of stroke, heart failure and cardiovascular death [1]. The initial treatment of AF is focused on rhythm or rate control and anticoagulation after risk assessment [2].

Catheter ablation is an established treatment option for patients with symptomatic AF refractory to antiarrhythmic medication and is a Class IA indication in patients with paroxysmal AF [2]. In patients with persistent AF, catheter ablation is less effective with long-term freedom from AF in 20–50% of patients [3–5].

Surgical ablation of AF is an alternative after failed catheter ablation or when a surgical approach is preferred [6]. Several studies have reported the rationale behind and results of minimally invasive thoracoscopic ablation [7–10], and some have shown superior results compared with catheter ablation [11, 12]. To further define the role of minimally invasive AF surgery, more data from controlled trials are needed.

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The aim of the present study was to compare total endoscopic ablation of AF with rate control and its effect on heart rhythm, symptoms and physical performance in patients aged >50 years with symptomatic, long-standing persistent AF. In this group of patients, catheter ablation is less frequently used and less effective than in younger patients with paroxysmal AF.

METHODS

Patients

This open-label randomized trial enrolled patients of >50 years of age with symptomatic, long-standing persistent AF, defined as continuous AF of greater than 12 months' duration [6]. Exclusion criteria were left atrial thrombus formation, intolerance to warfarin, a forced expiratory volume of <1.5 l/s (single-lung ventilation required during surgery), a left atrial anteroposterior diameter of >60 mm, body mass index of >35 kg/m^2 and previous thoracic surgery. The study was conducted at Örebro University Hospital, Sweden, and the patients were included from November 2009 to March 2014. The study was approved by the Regional Ethical Committee in Uppsala, Sweden (2009/122) and preregistered in ClinicalTrials.gov with identifier NCT 00940056. Signed informed consent was obtained from each patient. The study report follows the recommendations of the CONSORT statement [13], and an external medical committee was appointed to evaluate adverse events and changes to the protocol.

Eligible patients underwent randomization with sealed opaque envelopes in a blocked randomization scheme, using a computer random number generator with varied block sizes. The randomization process was conducted by an external clinical research support. The patients were randomly assigned to either thoracoscopic ablation or continued rate control. Thirty-six patients were initially randomized, 17 to ablation and 19 to rate control. In the ablation group, 1 patient declined further participation before ablation and in a further patient the surgical procedure was aborted before ablation because of pericardial adhesions. The remaining 34 patients formed the study cohort, divided into the ablation group (*n* = 15) and the control group (*n* = 19) (Fig. 1). This was an open-label study, where both patients and researchers were aware of the treatment group allocation during follow-up.

Definitions

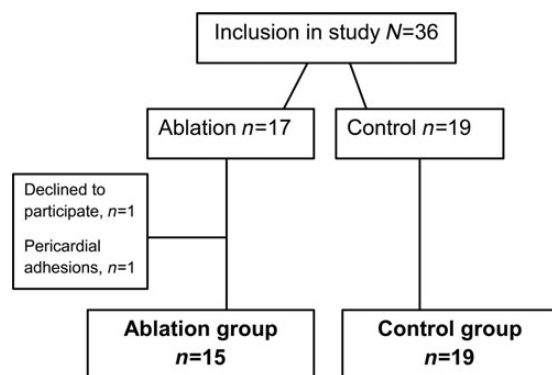Long-standing persistent AF: continuous AF lasting longer than 12 months [6].

Figure 1: Study design.

AF burden: percentage of time in AF in specified time period.

Freedom from AF: percentage of time without AF in specified time period.

Arrhythmia surveillance

After inclusion and randomization, all patients were scheduled for the implantation of a subcutaneous loop recorder (Reveal XT ICM, Medtronic, Minneapolis, MN, USA) within 1 month. The treatment group were ablated 2 months after the Reveal implantation (Fig. 2). The Reveal XT was implanted subcutaneously in a left parasternal position.

The Reveal XT incorporates an algorithm for automatic continuous AF detection. Previous studies have confirmed higher sensitivity and negative predictive value for AF compared with conventional monitoring [14]. On the basis of the Reveal XT detection algorithm, AF recurrence is defined as an AF episode lasting >2 min. The device stores 49.5 min of recorded electrocardiogram (ECG) data as well as the total AF burden, expressed as percentage of time in AF, based on the algorithm. All automatically stored AF episodes were examined by an electrophysiologist (Espen Fengsrud). Any misclassifications of arrhythmia (typically bigeminal rhythm classified as AF) were corrected in the follow-up protocol before the evaluation of results. The Reveal XT data were obtained at 1, 3, 6 and 12 months and if cardioversion was performed. Data were obtained via the CareLink Network monitoring system (Medtronic), which allows for online storage and retrieval of data without the need for an outpatient visit. After ablation, a blanking period of 3 months was allowed, according to the guidelines, before rhythm outcome was analysed.

Heart rhythm outcome is reported in three ways: a 12-lead ECG at 6 and 12 months, a median freedom from AF at 3–12 months postoperatively (median of percentage of time without AF during time period) and the percentage of patients with an AF burden of <5% without antiarrhythmic drugs at 3–12 months postoperatively. Owing to the variable interpretation possibilities of loop recorder data, we have not defined 'success' and 'failure' when reporting the data. Specifically, AF episodes of <30 s are not detected by the loop recorder used in the study. Reporting different categories of outcome data are in accordance with guidelines [6].

Surgical technique

The procedure has been previously described [15]. In brief, three ports were inserted into the right hemithorax during single-lung ventilation (a 10 mm camera port in the fifth intercostal space at the midaxillary line, a 5 mm port in the fourth intercostal space in the anterior axillary line and a 10 mm port in the sixth intercostal space). The intrathoracic pressure was kept between 5 and 8 mmHg by insufflation of CO_2.

The pericardium was incised 2 cm above, and parallel to, the phrenic nerve, from the superior pericardial reflection to the diaphragm. By blunt dissection, the pericardial reflections below the superior and inferior caval veins were opened, giving access to the oblique and transverse sinus. Waterston's groove was dissected and the fat pad removed to enable direct contact between the ablation catheter and the atrial myocardium. Specially designed magnetic-tip guidance catheters (Cobra Magnetic Tip Introducer Set, Estech, Inc., San Ramon, CA, USA) were introduced into the oblique and transverse sinus, connected and retrieved. The
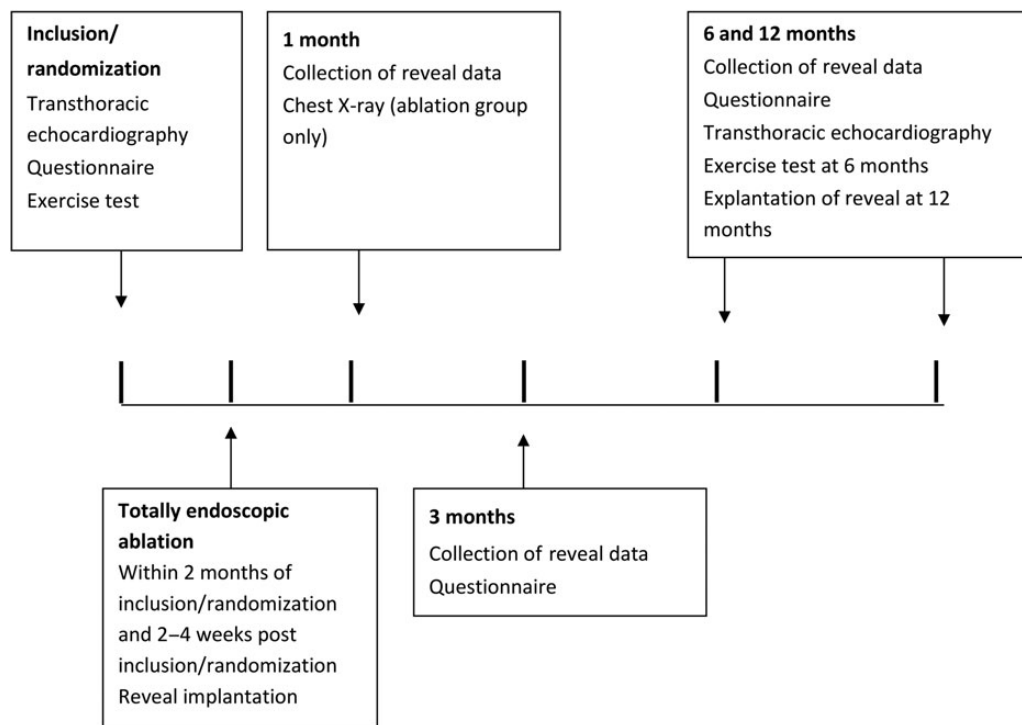
Figure 2: Study flow chart.

position of the guidance catheter in relation to the left atrial appendage was confirmed visually and by transoesophageal echocardiography, as previously described [16]. The guidance catheter was connected to a temperature-controlled radiofrequency ablation catheter (Cobra Adhere XL, Estech, Inc., San Ramon, CA, USA), which was advanced forward into position, and the transoesophageal echocardiography probe retracted. Using a vacuum suction system (600 mmHg), the catheter was attached to the atrial wall. Unipolar temperature-controlled radiofrequency energy was delivered at 60°C in two applications of 120 and 90 s, respectively. The catheter was repositioned during the procedure to create a complete left atrial box lesion. The ablation line was checked visually and where gaps were noted, additional ablation was performed. If the patient was still in AF, two attempts of cardioversion were made. After cardioversion, entrance block was tested by stimulating the right upper pulmonary vein distal to the ablation line using a bipolar pacing probe (AFfirm, Estech, Inc., San Ramon, CA, USA). A third, additional ablation was added (60°C for 120 s) if no exit block was present. After completed ablation, the catheter was withdrawn and a 24 Fr chest tube inserted in the sixth intercostal working port. The patient was extubated and transported to the ward for postoperative care.

Anticoagulation and cardioversion protocol

In the ablation group, subcutaneous dalteparin 50–100 IE/kg was administered twice daily starting 6 h postoperatively. Warfarin medication was reinitiated on the first postoperative day and continued during 12 months of follow-up. In the control group, all patients with CHA_2DS_2-VASc score of ≥ 2 were administered warfarin.

All patients in the ablation group were typically administered amiodarone together with beta-blockers postoperatively. Amiodarone was continued for up to 3 months, or longer if indicated and tolerated by the patient. Cardioversion of AF was attempted as a minimum

at surgery, 3–5 days postoperatively, and at 3 and 6 months if necessary. In the control group, beta-blockers, verapamil or digoxin were administered for rate control therapy.

Physical working capacity and subjective health

The evaluation of physical working capacity (PWC) was performed at inclusion and at 6 months in a sub-maximal cycle ergometer test and expressed as percentage of expected working capacity. Subjective physical and mental health was evaluated using the 36-item short-form health survey (SF-36), which was completed by the patients at 0, 6 and 12 months. The SF-36 scores were transformed to a physical capacity scale (PCS) and a mental capacity scale (MCS) score, as previously described [17].

Echocardiographic assessment

Transthoracic echocardiography was performed at inclusion and at 6 and 12 months. The following measures were analysed: left atrial anteroposterior diameter (mm), left atrial area (cm^2), left ventricular ejection fraction (%), left ventricular end-systolic diameter (mm), left ventricular end-diastolic diameter (mm) and prevalence and Grade (I–IV) of mitral valve insufficiency.

Statistical methods

The sample size was calculated as follows: we estimated the total AF burden (proportions) during 3–12 months to be 50% in the ablation group and 90% in the control group, leading to a standardized difference of 0.87. To obtain a power of 85% and a significance level of 0.05, a minimum of 48 patients was required. To account for drop-outs, the study sample was set to include 60

patients, 30 in each group. At the time of inclusion of patient No. 36, the ablation catheter in use was about to be replaced by a new version with a new energy delivery system and technology. As the difference in AF burden between groups was more pronounced than estimated in the sample size calculation, a decision was made at this point to end the study and report the results after consulting the external medical committee.

The differences in treatment effects between groups were analysed per protocol. To compare the differences in repeated measures of continuous data between the groups, we used repeated measurement analysis of variance. In this, the effect of treatment allocation, time and the interaction between these were analysed. Categorical variables were compared using χ^2 tests or Fisher's exact test, and Mann–Whitney U-test was used to compare variables with non-Normal distribution. Box-plot graphs were constructed to illustrate the results of the health survey. All statistical analyses were performed using SPSS version 22 (IBM Corp, Armonk, NY, USA) or Statistica version 12 (Statsoft, Inc., Tulsa, OK, USA). Probability values of <0.05 were regarded to be statistically significant.

RESULTS

Patient characteristics are given in Table 1. The two groups were fairly well matched, but diabetes mellitus and hypertension were more common conditions in the ablation group and in total,

26/34 patients had a CHA_2DS_2-VASc score of ≥ 2. The median age was 66 years, and most patients were men. The median duration of AF was 4 years, and the predominant symptoms were dyspnoea and fatigue. The mean left atrial diameter and area were 44 mm and 29 cm^2, respectively, and the mean PWC was 94% of expected capacity.

The surgical data for the ablation group are provided in Table 2. The mean time of the surgery was 114 min. There was a slight increase in myocardial enzyme release postoperatively. The majority (11/15) of the patients were in sinus rhythm when leaving the operating theatre. The mean length of stay was 5.6 days and there were no peri- or postoperative complications. There was no postoperative bleeding requiring transfusion or reoperation.

Follow-up

All patients completed the follow-up and there were no missing data. Heart rhythm results are presented in Table 3. In the control group, all patients were in permanent AF during 12 months of follow-up. The proportion of patients in sinus rhythm without antiarrhythmic drugs in the ablation group was 11/15 patients (73%) at 6 months and 12/15 patients (80%) at 12 months. The median freedom from AF at 3–12 months was 95% (first to third quartile interval 78.7–100%) in the ablation group and the proportion of patients with an AF burden of <5% at 3–12 months was 8/15 (53%).

Table 1: Patient characteristics

	Ablation group (n = 15)	Control group (n = 19)
Age (years)	66.6 ± 5.5	65.8 ± 5.0
Gender, M/F	13/2	13/6
BMI (kg/m^2)	29.7 ± 3.5	27.5 ± 3.2
Hypertension, N (%)	10 (67)	4 (21)
Diabetes mellitus, N (%)	5 (33)	2 (10)
Chronic obstructive pulmonary disease, N (%)	2 (13)	1 (5)
Obstructive sleep apnoea syndrome, N (%)	1 (7)	1 (5)
TIA/stroke, N (%)	1 (7)	2 (10)
Previous myocardial infarction, N (%)	2 (13)	0
Congestive heart failure, N (%)	7 (47)	7 (37)
AF duration (years)^a	4 (7)	4 (8)
CHA_2DS_2-VASc score of ≥ 2, N (%)	13 (87)	13 (68)
Left atrial diameter (mm)	47 ± 5	43 ± 5
Left atrial area (cm^2)	29.2 ± 5.5	28.9 ± 4.9
Left ventricular ejection fraction (%)	54 ± 9	55 ± 9
Left ventricular end-systolic diameter (mm)	38 ± 7	34 ± 6
Left ventricular end-diastolic diameter (mm)	50 ± 6	53 ± 6
Mitral valve insufficiency, Grade II/IV	1 (7)	3 (16)
Physical working capacity (% of expected PWC)	94 ± 21	93 ± 13

Data are shown as mean value ± SD or number (%).
AF: atrial fibrillation; BMI: body mass index; F: female; M: male; N: number; PWC: physical working capacity; TIA: transient ischaemic attack; SD: standard deviation.
^{a}Median (interquartile range).

Table 2: Surgical data (ablation group)

Duration of surgery (min)	114 ± 18
Length of stay (days)	5.6 ± 1.3
Postoperative bleeding, median (range) (ml)	150 (0–1100)
Sinus rhythm upon leaving the OR	11/15 (73%)
Entrance block at 10 mV stimulation	3/11 (27%)
CK-MB (µg/l)	18.0 ± 32.6
Troponin I (µg/l)	0.98 ± 0.64

Data are shown as mean ± SD or number/total.
CK-MB: creatinine kinase, muscular band; OR: operating room; SD: standard deviation.

Table 3: Heart rhythm at follow-up

	Ablation group (n = 15)	Control group (n = 19)	P-value
SR at 6 months without AA, N (%)	11 (73)	0	<0.001
SR at 12 months without AA, N (%)	12 (80)	0	<0.001
Median freedom from AF at 3–12 months, % (first to third quartile interval)	95 (78.7–100)	0	<0.001
AF burden <5% at 3–12 months without AA, N (%)	8 (53)	0	0.001
On AA at 6 months, N (%)	4 (27)	0	0.029
On AA at 12 months, N (%)	1 (7)	0	0.441

AA: antiarrhythmic medication; AF: atrial fibrillation; N: number; SR: sinus rhythm.

Table 4: Echocardiography and exercise test results

	Ablation group (*n* = 15)			Control group (*n* = 19)			*P*-value[a]		
	Pre	6 months	12 months	Pre	6 months	12 months	Time	Treatment	Time × treatment
Left ventricular ejection fraction (%)	53.7 ± 8.6	57.9 ± 7.8	58.8 ± 6.5	55.4 ± 8.8	52.8 ± 9.6	52.9 ± 9.0	0.274	0.270	0.003
Left ventricular end-systolic diameter (mm)	38.3 ± 6.8	34.4 ± 7.3	34.8 ± 5.7	34.3 ± 6.5	35.9 ± 7.5	36.3 ± 7.3	0.426	0.912	0.001
Left ventricular end-diastolic diameter (mm)	49.9 ± 6.4	50.2 ± 6.2	49.6 ± 5.4	52.6 ± 6.0	52.3 ± 6.6	52.4 ± 6.5	0.724	0.239	0.903
Left atrial area (cm^2)	29.2 ± 5.5	28.7 ± 6.8	27.2 ± 6.3	26.8 ± 4.3	28.9 ± 4.9	29.6 ± 4.7	0.529	0.977	0.002
Physical working capacity, % of predicted PWC	94.0 ± 21.4	102.9 ± 14.4	–	93.2 ± 12.7	88.5 ± 18.0	–	0.408	0.155	0.011

Pre: at 0 months; PWC: physical working capacity; ANOVA: analysis of variance.
[a]Repeated measurements ANOVA. *P*-values denote effects of time, treatment allocation and interaction of time and treatment.

The left ventricular ejection fraction improved significantly during follow-up in the ablation group compared with the control group (*P* = 0.003), which was mainly due to a decreased left ventricular end-systolic diameter (Table 4; Fig. 3). There was a reduction in the left atrial area in the ablation group compared with the control group during follow-up (from 29.2 ± 5.5 to 27.2 ± 6.3 cm^2 in the ablation group, *P* = 0.002) (Table 4; Fig. 3). In comparison with the control group, the PWC and subjective PCS and MCS scores in the ablation group improved significantly during follow-up (Table 4; Figs 3 and 4).

There was no mortality or thromboembolic episode during the 12-month follow-up. One patient in the ablation group on warfarin therapy suffered spinal bleeding at 7 months with full recovery. No patient required pacemaker implantation postoperatively or suffered from any atypical atrial arrhythmia. The mean number of cardioversions in the ablation group between surgery and follow-up was 2.2 (range 0–9). Between 3 and 12 months, the mean number of cardioversions per patient in the ablation group was 1.2 (range 0–2). No attempts at cardioversion were made in the control group.

DISCUSSION

The major finding in this study is that total endoscopic ablation restores sinus rhythm in the majority of patients and leads to increased working capacity, improved subjective health, improved left ventricular ejection fraction and a reduction in left atrial size. The advantage of the described technique of total endoscopic ablation of AF using three ports in the right hemithorax is a comparably small surgical trauma with a potentially short procedural time. Although this is a small single-centre study, the results are interesting and warrant further investigation.

Long-term freedom from AF in patients with long-standing persistent AF has been reported to be 20–40% after a single catheter ablation procedure and 45–80% after multiple procedures [3–5]. In thoracoscopic ablation procedures, the success rate has been reported to be higher, but also to be associated with more complications [11, 12]. In hybrid procedures combining surgical and catheter ablation, the 1-year freedom from AF in patients with long-standing persistent AF has been reported to be 80–90% [7, 8, 10]. In the present study, 80% of the ablation patients were in sinus rhythm without antiarrhythmic drugs at 1 year, which is in accordance with published results. In addition, the implantable loop recorder (ILR) data showed that the total median freedom from AF

in the ablation group was 95% between 3 and 12 months of follow-up. In other studies using loop recorder registration, freedom from AF after concomitant AF surgery was 68% [18]. Altogether, the described technique seems comparably effective in restoring sinus rhythm in patients with long-standing persistent AF.

The lesion pattern in the ablation group consisted of a left atrial box lesion, performed using temperature-controlled, unipolar radiofrequency energy. The ability to achieve transmural lesions by unipolar radiofrequency in a beating heart has been questioned [19]. Epicardial fat may further decrease the penetration of energy and has to be removed as much as possible, and this constitutes an inherent weakness of the method, as not all epicardial areas are accessible. In fact, we were not able to confirm an entrance block in all patients despite repeated temperature-controlled energy delivery, and testing was not always possible owing to AF rhythm after ablation.

The lesion set was limited to an isolation of the posterior left atrium. The gold standard of AF surgery, the Cox maze III procedure, requires an additional left isthmus line and ablation of the right atrium. Therefore, studies of hybrid procedures have been initiated and show promising results [20], but are still questioned in relation to results for the Cox maze procedure [21]. In the light of the results from the present study, we speculate that the lesion also involves a partial denervation of ganglionic plexi, which are distributed in some of the areas where the ablation probe is placed [22].
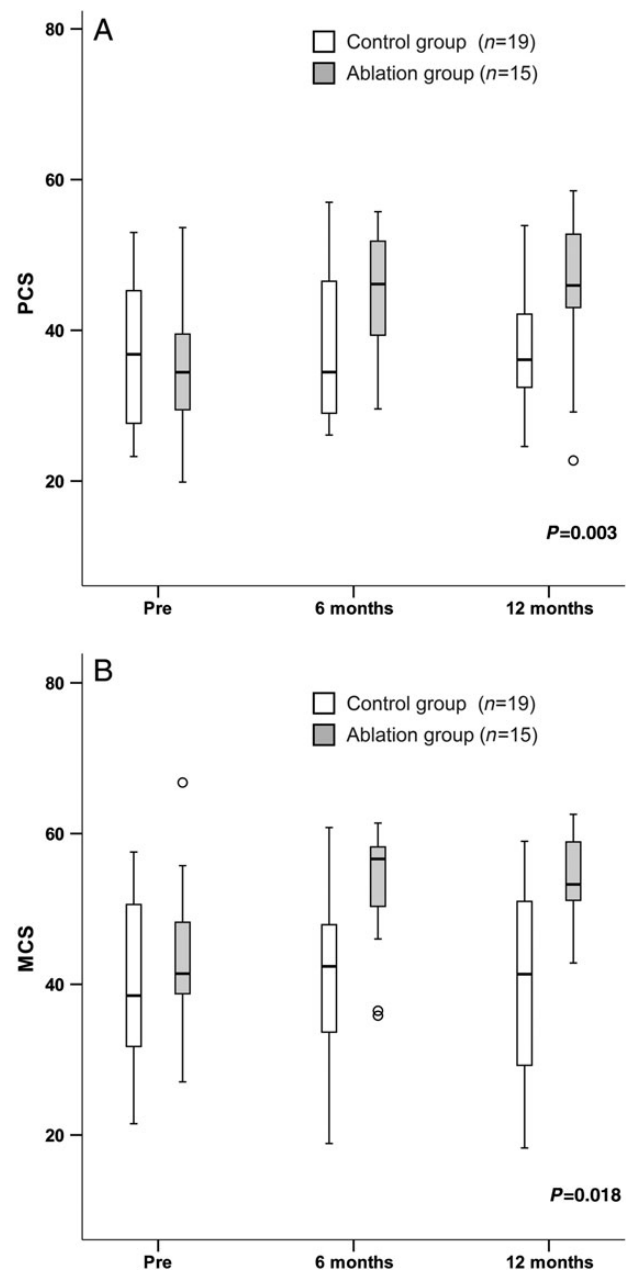
In our study, a unilateral approach was used in order to reduce postoperative pain, whereas the removal of the left atrial appendage requires a bilateral approach. The rationale behind removal of the appendage is to reduce the incidence of future emboli by obliterating the endocardial orifice. Several methods are in use including stapling and removal [23] or closure with a clip [24]. The inability to remove the left atrial appendage is a major drawback of the unilateral technique described. However, the anticipated stroke prevention effect needs to be confirmed in large clinical trials.

The control group were treated using a rate control strategy. It could be argued that the ablation group should be compared with a group undergoing pharmacological rhythm control therapy. While this is a scientifically correct argument, previous studies have shown no benefit of rhythm control over rate control in long-standing persistent AF, and the effect of antiarrhythmic drugs may be deleterious in this group of patients [25]. It was therefore considered unethical to initiate a rhythm control strategy in the
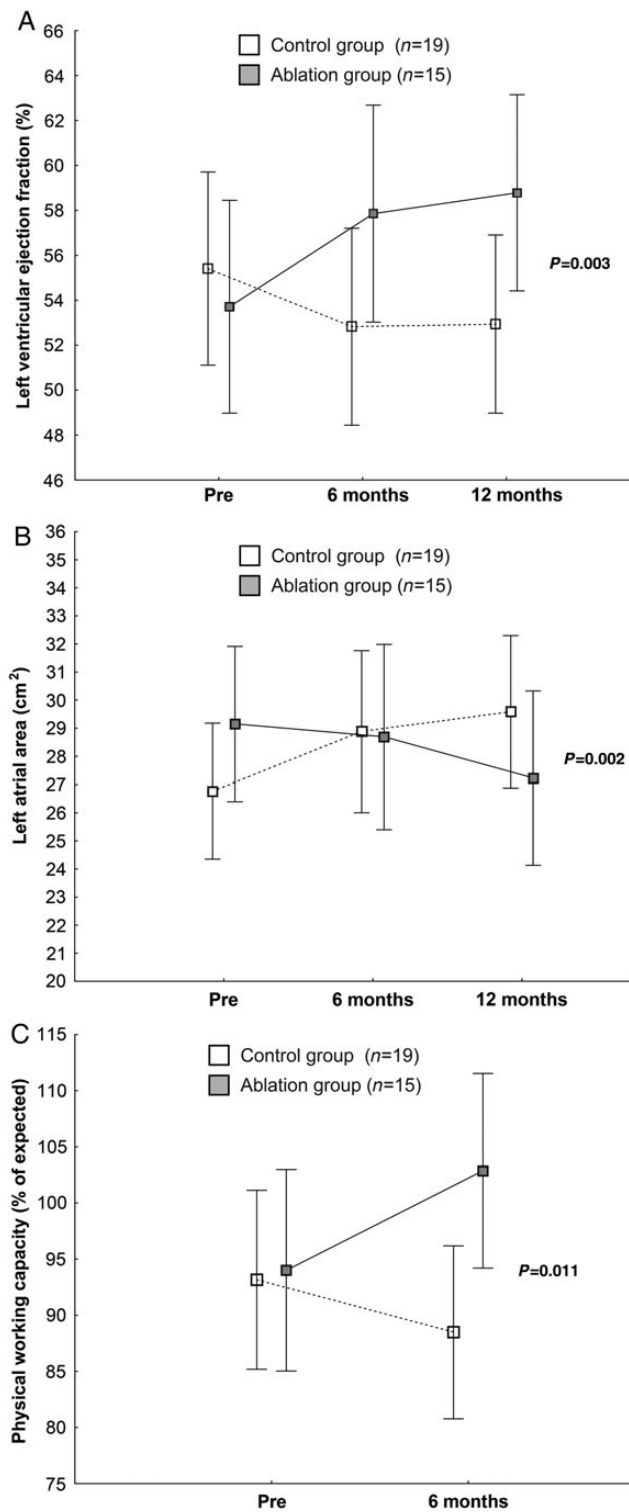
Figure 3: Echocardiographic data and PWC during follow-up. Vertical bars denote ± 95% confidence intervals. The *P*-value denotes significance test of the treatment *X* time interaction in repeated measurements ANOVA. (**A**) Left ventricular ejection fraction; (**B**) left atrial area; (**C**) PWC. PWC: physical working capacity; ANOVA: analysis of variance.

Figure 4: Results of the 36-item health survey (SF-36) and quality-of-life assessment. Box-plot denoting median, interquartile range, minimum–maximum values and outliers. The *P*-value denotes significance test of the treatment *X* time interaction in repeated measurements ANOVA. (**A**) PCS and (**B**) MCS scores. ANOVA: analysis of variance; PCS: physical capacity scale; MCS: mental capacity scale.

Limitations

This is a small prospective randomized study with a limited follow-up. Although the findings are highly significant, they have to be confirmed in larger, multicentre trials with longer follow-up.

Implantable loop recording of heart rhythm has some limitations. The sensitivity, i.e. the ability to detect episodes of AF is high but not 100%. All recordings in the control group showed AF, indicating that the method was very accurate in this study. There is a risk of falsely detected AF in the ablation group since the ILR sometimes records frequent extra systoles as AF. As the recording

control group. Further studies in patients with long-standing persistent AF should probably focus on comparisons between catheter and minimally invasive ablation or combinations of these.

capacity is limited, a regular heart rhythm such as atrial flutter can be misinterpreted as sinus rhythm, and bigeminal rhythm as AF. However, no patient had sustained regular tachycardia episodes during follow-up.

The symptomatic improvement in the ablation group can be the result of a placebo effect. Objective echocardiographic measurements and exercise data are therefore of importance when evaluating the method.

The ablation group were treated with amiodarone, a drug with a sustained half-life. There is therefore a risk that part of the rhythm control effect in the ablation group was due to amiodarone treatment.

In the present study, we chose a unilateral approach to minimize postoperative pain and complications. Removal of the left atrial appendage requires a left-sided approach, and is not possible from the right side with current techniques, which is therefore a limitation of the described technique. The presence of pericardial adhesions may also constitute a problem with the unilateral approach.

CONCLUSION

Total endoscopic ablation in the included patients with long-standing persistent AF significantly reduced AF burden 12 months after intervention, compared with controls. The left ventricular function, PWC and subjective physical and mental health were improved. The results from the present study need to be confirmed in larger randomized trials.

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Conflict of interest: none declared.

REFERENCES

[1] Schnabel RB, Yin X, Gona P, Larson MG, Beiser AS, McManus DD et al. 50 year trends in atrial fibrillation prevalence, incidence, risk factors, and mortality in the Framingham Heart Study: a cohort study. Lancet 2015; 386:154–62.

[2] Camm AJ, Lip GY, De Caterina R, Savelieva I, Atar D, Hohnloser SH et al. 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.

[3] 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.

[4] Verma A, Jiang CY, Betts TR, Chen J, Deisenhofer I, Mantovan R et al. Approaches to catheter ablation for persistent atrial fibrillation. N Engl J Med 2015;372:1812–22.

[5] Tilz RR, Rillig A, Thum AM, Arya A, Wohlmuth P, Metzner A et al. Catheter ablation of long-standing persistent atrial fibrillation: 5-year outcomes of the Hamburg Sequential Ablation Strategy. J Am Coll Cardiol 2012;60:1921–9.

[6] Calkins H, Kuck KH, Cappato R, Brugada J, Camm AJ, Chen SA et al. 2012 HRS/EHRA/ECAS Expert Consensus Statement on Catheter and Surgical Ablation of Atrial Fibrillation: recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design: a report of the Heart Rhythm Society (HRS) task force on catheter and surgical ablation of atrial fibrillation. Europace 2012;14:528–606.

[7] Gelsomino S, Van Breugel HN, Pison L, Parise O, Crijns HJ, Wellens F et al. Hybrid thoracoscopic and transvenous catheter ablation of atrial fibrillation. Eur J Cardiothorac Surg 2014;45:401–7.

[8] Kurfirst V, Mokracek A, Bulava A, Canadyova J, Hanis J, Pesl L. Two-staged hybrid treatment of persistent atrial fibrillation: short-term single-centre results. Interact CardioVasc Thorac Surg 2014;18:451–6.

[9] Metzner A, Wissner E, Schmidt B, Chun J, Hindricks G, Piorkowski C et al. Acute and long-term clinical outcome after endoscopic pulmonary vein isolation: results from the first prospective, multicenter study. J Cardiovasc Electrophysiol 2013;24:7–13.

[10] Muneretto C, Bisleri G, Bontempi L, Curnis A. Durable staged hybrid ablation with thoracoscopic and percutaneous approach for treatment of long-standing atrial fibrillation: a 30-month assessment with continuous monitoring. J Thorac Cardiovasc Surg 2012;144:1460–5; discussion 1465.

[11] Boersma LV, Castella M, van Boven W, Berruezo A, Yilmaz A, Nadal M et al. Atrial fibrillation catheter ablation versus surgical ablation treatment (FAST): a 2-center randomized clinical trial. Circulation 2012;125:23–30.

[12] Pokushalov E, Romanov A, Elesin D, Bogachev-Prokophiev A, Losik D, Bairamova S et al. Catheter versus surgical ablation of atrial fibrillation after a failed initial pulmonary vein isolation procedure: a randomized controlled trial. J Cardiovasc Electrophysiol 2013;24:1338–43.

[13] Schulz KF, Altman DG, Moher D. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. Trials 2010;11:32.

[14] Hindricks G, Pokushalov E, Urban L, Taborsky M, Kuck KH, Lebedev D et al. Performance of a new leadless implantable cardiac monitor in detecting and quantifying atrial fibrillation: results of the XPECT trial. Circ Arrhythm Electrophysiol 2010;3:141–7.

[15] Fengsrud E, Wickbom A, Ahlsson A. Total endoscopic ablation of atrial fibrillation. Multimed Man Cardiothorac Surg 2015; doi:10.1093/mmcts/mmv010.

[16] Ahlsson A, Fengsrud E, Axelsson B. Positioning of the ablation catheter in total endoscopic ablation. Interact CardioVasc Thorac Surg 2014;18:125–7.

[17] Ware JE Jr, Kosinski M, Bayliss MS, McHorney CA, Rogers WH, Raczek A. Comparison of methods for the scoring and statistical analysis of SF-36 health profile and summary measures: summary of results from the Medical Outcomes Study. Med Care 1995;33:As264–79.

[18] Pecha S, Aydin MA, Ahmadzade T, Hartel F, Hoffmann B, Steven D et al. Implantable loop recorder monitoring after concomitant surgical ablation for atrial fibrillation (AF): insights from more than 200 continuously monitored patients. Heart Vessels 2015; doi:10.1007/s00380-015-0735-4.

[19] Ad N. The challenge of defining procedural endpoints for the surgical treatment of atrial fibrillation. Eur J Cardiothorac Surg 2012;41:119–20.

[20] La Meir M, Gelsomino S, Lorusso R, Luca F, Pison L, Parise O et al. The hybrid approach for the surgical treatment of lone atrial fibrillation: one-year results employing a monopolar radiofrequency source. J Cardiothorac Surg 2012;7:71.

[21] Je HG, Shuman DJ, Ad N. A systematic review of minimally invasive surgical treatment for atrial fibrillation: a comparison of the Cox–Maze procedure, beating-heart epicardial ablation, and the hybrid procedure on safety and efficacy. Eur J Cardiothorac Surg 2015;48:531–40.

[22] Sakamoto S, Fujii M, Watanabe Y, Hiromoto A, Ishii Y, Morota T et al. Exploration of theoretical ganglionated plexi ablation technique in atrial fibrillation surgery. Ann Thorac Surg 2014;98:1598–604.

[23] Edgerton JR, Brinkman WT, Weaver T, Prince SL, Culica D, Herbert MA et al. Pulmonary vein isolation and autonomic denervation for the management of paroxysmal atrial fibrillation by a minimally invasive surgical approach. J Thorac Cardiovasc Surg 2010;140:823–8.

[24] La Meir M, Gelsomino S, Luca F, Lorusso R, Gensini GF, Pison L et al. Minimally invasive thoracoscopic hybrid treatment of lone atrial fibrillation: early results of monopolar versus bipolar radiofrequency source. Interact CardioVasc Thorac Surg 2012;14:445–50.

[25] Wyse DG, Waldo AL, DiMarco JP, Domanski MJ, Rosenberg Y, Schron EB et al. A comparison of rate control and rhythm control in patients with atrial fibrillation. N Engl J Med 2002;347:1825–33.