

# Surgical vs. transcatheter pulmonary vein isolation as first invasive treatment in patients with atrial fibrillation: a matched group comparison

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## Aims

Pulmonary vein isolation (PVI) can be considered for treatment of symptomatic atrial fibrillation (AF). Nowadays, in addition to transcatheter ablation, thoracoscopic surgical PVI is available. The aim of this study is to compare clinical outcome of surgical with transcatheter PVI as first invasive treatment strategy of AF.

## Methods and results

From June 2009 to November 2011, 33 patients underwent minimally invasive surgical PVI, and were matched (1:2 fashion) retrospectively according to age, sex, and AF type, with 66 patients who underwent transcatheter PVI. Success was defined as freedom from atrial arrhythmias on 24 h Holter monitoring without use of anti-arrhythmic drugs (AADs) at 1 year. Mean age was  $52 \pm 10$  years, 82% were male. Paroxysmal AF was present in 76 patients (77%), persistent AF in 23 (23%) patients. None underwent prior ablations, and failed on  $1.2 \pm 0.6$  AADs. At 12 months, complete freedom from atrial arrhythmias without AADs in the surgical PVI group was 88% compared with 41% in the transcatheter PVI group ( $P < 0.001$ ). Freedom from atrial arrhythmias with AADs was 91 vs. 62%, in the surgical vs. transcatheter PVI group, respectively ( $P = 0.002$ ). Complications occurred in seven (21%) surgical PVI patients, and three (5%) transcatheter PVI patients ( $P = 0.015$ ).

## Conclusion

In present matched study comparing a surgical with transcatheter PVI treatment strategy in symptomatic AF patients failed on AADs, but without prior ablations, a surgical PVI strategy was more effective to prevent recurrence of atrial arrhythmias, than a transcatheter PVI treatment strategy. However, complications were more frequent with surgical PVI.

## Keywords

Atrial fibrillation • Ablation • Pulmonary vein isolation • Surgical • Treatment

## Introduction

Atrial fibrillation (AF) has a major impact on health care in the Western population and is associated with poor prognosis.<sup>1,2</sup> Atrial fibrillation is associated with impaired quality of life (QoL), and two-third of the AF patients are symptomatic.<sup>3</sup> According to the European Society of Cardiology (ESC) guidelines, pharmacological rhythm-control therapy is recommended for symptomatic AF patients. However, antiarrhythmic drugs (AADs) are only moderately effective maintaining sinus rhythm and have known adverse effects.<sup>4,5</sup> Non-pharmacological therapies have been introduced in the last decade to improve rhythm-control therapy.<sup>6</sup> Transcatheter

pulmonary vein isolation (PVI) is a widespread and well-established technique to prevent recurrence of AF.<sup>1,2</sup> Transcatheter PVI is reported to be effective in 61–89% of patients, with a complication rate of 6%.<sup>7</sup> In approximately one-third of the patients multiple transcatheter ablations are necessary.<sup>7</sup> Surgical treatment for AF was first described by Cox *et al.*<sup>8</sup> Long-term results of the Maze-III operation are excellent, with freedom from symptomatic AF up to 90% at 10 years.<sup>9,10</sup> However, this invasive procedure proved technically demanding which limited the popularity and applicability. Therefore, minimally invasive surgical PVI, using bipolar radiofrequency (RF) and other energy sources has been developed and is applicable through video-assisted thoracoscopic (VATS) approach,<sup>11–13</sup> 65–82%

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## What's new?

- This study compares surgical and transcatheter pulmonary vein isolation (PVI) as first invasive therapy for symptomatic atrial fibrillation.
- A surgical PVI treatment strategy was more effective to prevent recurrence of atrial arrhythmias, than a transcatheter PVI treatment strategy, in patients with symptomatic atrial fibrillation.
- Complications were more frequent with surgical PVI, than transcatheter PVI, in patients with symptomatic atrial fibrillation.

freedom from AF without AADs has been reported in small series.<sup>14–17</sup> Surgical PVI has a class IIb recommendation in current ESC AF guidelines for patients with a failed transcatheter PVI.<sup>18</sup> In the recently published 'Atrial Fibrillation: Ablation or Surgical Treatment (FAST)' study, surgical PVI was superior to transcatheter PVI with regard to freedom from AF in patients who failed on at least one AAD and the majority had undergone a prior transcatheter PVI, although a higher complication rate of surgical PVI was reported.<sup>19</sup> The aim of this study was to compare the efficacy and safety of surgical and transcatheter PVI as first invasive treatment strategy for AF.

## Methods

We compared a surgical PVI and a transcatheter PVI treatment strategy in patients with paroxysmal or short-lasting persistent AF, who failed on at least one AAD, but without prior ablation. Potential PVI candidates were seen at the outpatient department by a cardiothoracic surgeon and an electrophysiologist, and were good candidates for either procedure. After informing the patient, and after reading the addition patient information of both procedures, the final decision was led to the discretion of the patient. The surgical PVI group consisted of 33 consecutive patients, operated between June 2009 and November 2011. The thoracic surgeon (M.M.) who performed the surgical PVIs, had performed > 50 surgical PVI procedures. Patients treated with surgical PVI were matched retrospectively 1:2 according to age, sex, and duration of AF, with patients who underwent transcatheter PVI in the same calendar period. In total, 66 patients treated with transcatheter PVI, were selected from the University Medical Center Groningen PVI database. Both electrophysiologists (A.C.P.W., E.S.T.) who performed the transvenous PVIs were experienced and had performed > 500 PVI procedures. Exclusion criteria for surgical PVI were left atrial (LA) size > 55 mm (parasternal view), prior transcatheter PVI, prior heart or lung surgery, significant coronary disease or previous myocardial infarction, left ventricle hypertrophy > 12 mm, previous hospitalization for heart failure, left ventricular dysfunction (ejection fraction < 50%), moderate or severe mitral- or aortic valve disease, or lung disease (prior tuberculosis or chronic obstructive pulmonary disease Gold class III-IV). All patients were eligible for the transcatheter PVI according to the ESC AF guidelines.<sup>18</sup>

Patients were admitted to the hospital 2 days prior to surgical or transcatheter PVI. Oral anticoagulation was discontinued 2 days before the procedure and replaced by full-dose low-molecular-weight heparin. At admission, a trans-oesophageal echocardiography was performed to

exclude atrial thrombi and computed tomographic (CT) scan was performed to document the anatomy of the pulmonary veins and left atrium.

The surgical PVI consisted of a minimal invasive off-pump bilateral VATS, which was performed under general anaesthesia and selective lung ventilation. First, the right pulmonary veins were accessed from the right side, through two 5 mm ports and one 10 mm port in a diamond-shape configuration, according to patient's body size and shape. After right lung deflation, the pericardium was opened and blunt dissection was used to surround the right pulmonary veins. A bipolar clamp (AtriCure, Inc.) using RF, was used to achieve three to five linear ablation lesions.<sup>12</sup> To confirm PVI, in all patients direct pacing (120 bpm, 18 mV output, 200 Hz) was applied on the pulmonary veins (exit blocks). Then, from the left side, the left pulmonary veins were targeted in the same manner. Whenever active ganglionic plexi were found these were additionally ablated using the monopolar Isolator Pen (Atricure).<sup>20,21</sup> Ganglionic plexi were tested for inducibility by high-rate pacing and ablated. Successful ablation was confirmed by the absence of a vagal response after ablation. No additional linear ablation lines were applied on the atria and the LA appendage was not amputated.

The transcatheter, wide circumferential PVI was performed as described by Pappone under local anesthesia using the Seldinger technique through the right femoral vein and subsequently through the atrial septum by puncture.<sup>22</sup> A bidirectional steerable sheath (Agilis<sup>®</sup>; St. Jude Medical Inc.) was employed. One decapolar catheter (Cordis-Webster) with 5 mm electrodes and 2 mm inter-electrode spacing was placed in the coronary sinus. A bolus of unfractionated heparin was administered after the first transeptal puncture and subsequently, an additional bolus of heparin after 2 h. The left atrium and the pulmonary veins were mapped and reconstructed using CARTO FAM 3D electro-anatomic maps (Biosense-Webster, Diamond Bar). Then the CARTO<sup>®</sup> left atrium map was aligned to the CT scan reconstruction of the left atrium. Point-by-point ablation lines were created, circumferating each pulmonary vein using RF pulses in unipolar mode via the distal catheter electrode (EZ-steer Biosense Webster).<sup>23</sup> Radiofrequency energy was delivered at a temperature setting of 60°C, with a power limit of 40 W during 40 s, except for the posterior atrium where a maximum of 30 W was delivered during 30 s. In case of an impedance rise, cough, burning pain, or severe bradycardia, RF delivery was stopped. After deployment of the contiguous focal lesions, measurement of the effective electrical disconnection was performed only by pacing within the pulmonary veins (exit block), no fixed diameter steerable decapolar circumferential catheter (Lasso, Biosense Webster) was employed. If patients were in AF before measurement, a cardioversion was performed. During the first procedure, no additional linear ablation lines or CAFE ablations were performed. If AF recurred or flutter occurred, 3 months after the first transcatheter PVI, the completing of the lines around the pulmonary veins was checked, and if necessary, lines were completed. Additional lines ablation was performed at the discretion of the treating electrophysiologist, or in case of a typical atrial flutter a cavo-tricuspid isthmus ablation was performed.

After the PVI procedure patients were treated with full-dose low-molecular-weight heparin. In the surgical group, oral anticoagulation was restarted 1 month after procedure (to prevent bleeding), and low-molecular-weight heparin was stopped when International normalized ratio (INR) > 2.0 was reached. In the transcatheter group oral anticoagulation was immediately post-procedure restarted, and low-molecular-weight heparin was stopped when INR > 2.0 was reached. Oral anticoagulation treatment was determined based on the CHADS<sub>2</sub>VA<sub>2</sub>Sc score for stroke.<sup>1,2</sup> Antiarrhythmic drugs were continued during the first 3 months.<sup>24</sup> Patients treated with surgical PVI were seen at 1 week, 1, 3, 6, and 12 months post-PVI. In the transcatheter group, patients were first seen at 3 months after ablation, and at 6 and

12 months. To assess the occurrence of (a)symptomatic atrial arrhythmias, at 6 months 96 h Holter monitoring and at 12 months 24 h Holter monitoring was performed. At each visit a routine 12 lead electrocardiogram was performed, and when atrial arrhythmia was detected, a 12 lead rhythm strip (>30 s) was produced. The indication for a re-PVI procedure was based on the presence of symptomatic atrial arrhythmias, patient preference, and led to the discretion of the treating physician. Echocardiography was performed at all visits except at 6 months, when a cardiac CT scan was performed to document possible potential pulmonary vein stenosis. In addition to standard echocardiographic measurements, we measured atrial dimensions and total atrial conduction time. LA volume was calculated and corrected for body surface area (BSA) with the following formula:

$$\frac{((0.523 \times \text{LA parasternal} \times \text{LA length} \times \text{LA width})/\text{BSA})}{1000}$$

Total atrial conduction time (TACT) is the time between initiation of the electrocardiographic P wave and the peak velocity of the LA free wall measured with tissue velocity imaging, and is a measure for atrial conduction.<sup>24</sup> Pre-ablation and at 12 months QoL was assessed using the validated Dutch SF-36 questionnaire.<sup>25</sup>

Primary efficacy endpoint was freedom of atrial arrhythmias after one or more PVI procedures, i.e. no evidence of AF, atrial flutter, or other atrial arrhythmias with a duration >30 s, without use of AADs at 12 months, or at the end of follow-up. This in accordance with the definitions as described in the 2012 expert consensus statement on AF ablation.<sup>26</sup> Secondary efficacy endpoints were freedom from atrial arrhythmias with the use of AADs, QoL, and atrial diameters, total atrial conduction time and volume. Recurrences of AF were censored within the first 3 months (blinking period) to prevent unjustified classification of failure.<sup>27</sup>

Primary safety end point was the occurrence of procedural and post-procedural complications. Complications were defined as an event that resulted in death or permanent injury, in temporarily injury that required intervention or specific treatment, or (prolonged) hospitalization >48 h (e.g. stroke, transient ischemic attack, major bleeding requiring surgery or blood transfusion or >2.0 points hemoglobin decrease, cardiac tamponade and/or perforation, significant/symptomatic PV stenosis >70%, pericarditis and/or pericardial effusion, acute coronary syndrome, myocardial infarction, fluid retention, nervus phrenicus lesion, pneumothorax, wound infections, empyema, pneumonia, peri-procedural conversion to thoracotomy, and other not pre-defined events).

Baseline descriptive statistics are presented as mean  $\pm$  standard deviation or median (range) for continuous variables, depending on the normality of the data, and counts with percentages for categorical variables. Differences between both groups (surgical vs. transcatheter PVI), at baseline, during follow-up, and end of study were evaluated by Student's *t*-test or the Mann–Whitney *U* test, depending on normality of the data, for continuous data. Fisher's exact test was used for comparison of categorical variables. Kaplan–Meier analysis was used to assess freedom from atrial arrhythmias. Data were censored for patients with recurrence of atrial arrhythmias, completed follow-up duration or reached the last date of follow-up, whichever came first. Statistical significance was considered at the level of  $P < 0.05$ . The statistical software package IBM SPSS Statistics 20 was used for the analyses.

## Results

Of the 99 patients included in this study, 33 consecutive patients were treated with surgical PVI, the other 66 patients were treated with transcatheter PVI (Table 1). Mean age was  $52 \pm 10$  years; 81 (82%) patients were male. Atrial fibrillation was paroxysmal in 76 (77%)

patients and persistent in 23 (23%) patients. Median time from first AF to ablation was 50 months (range 5–344) and patients had failed on  $1.2 \pm 0.6$  AADs. At baseline, there were no significant differences between both groups, except for diastolic blood pressure, which was lower in the surgical group (74 vs. 80 mmHg,  $P = 0.003$ ) and oral anticoagulation use, which was higher in the transcatheter group (48 vs. 79%,  $P = 0.002$ ).

Mean intervention time of the surgical PVI was  $155 \pm 33$  min compared with  $199 \pm 54$  min of the transcatheter PVI ( $P < 0.001$ ). In all surgical PVI procedures, acute success was reached and confirmed by acute exit blocks, whereas after first transcatheter PVI, in 14 patients conduction block was doubtful and in two patients conduction block was not achieved. Further, in two transcatheter PVI patients it was not possible to isolate the right pulmonary veins. During the surgical PVI, ganglionated plexi were found and additionally ablated in 25 (76%) patients, which was not performed in the transcatheter PVI group. Following surgical PVI, hospitalization was  $8.4 \pm 4$  days, compared with  $2.4 \pm 2$  days in the transcatheter group ( $P < 0.001$ ).

Mean follow-up was  $12.6 \pm 2$  months. Two patients in the surgical group, and two in the transcatheter group did not complete the 12 months follow-up. Last follow-up in those patients was the 6 months visit. Three (9%) surgical PVI patients underwent an additional transcatheter ablation, and 1 (3%) patient underwent two additional transcatheter ablations. In three patients the combination of surgical and transcatheter PVI led to freedom from atrial arrhythmias. In the transcatheter group, 25 (38%) patients underwent a second PVI procedure, and 1 (1%) patient underwent a third procedure. At 12 months, seven (11%) transcatheter PVI patients were awaiting a second ablation and seven (11%) patients were awaiting a third ablation. In the surgical group, no patients were awaiting additional ablative procedures.

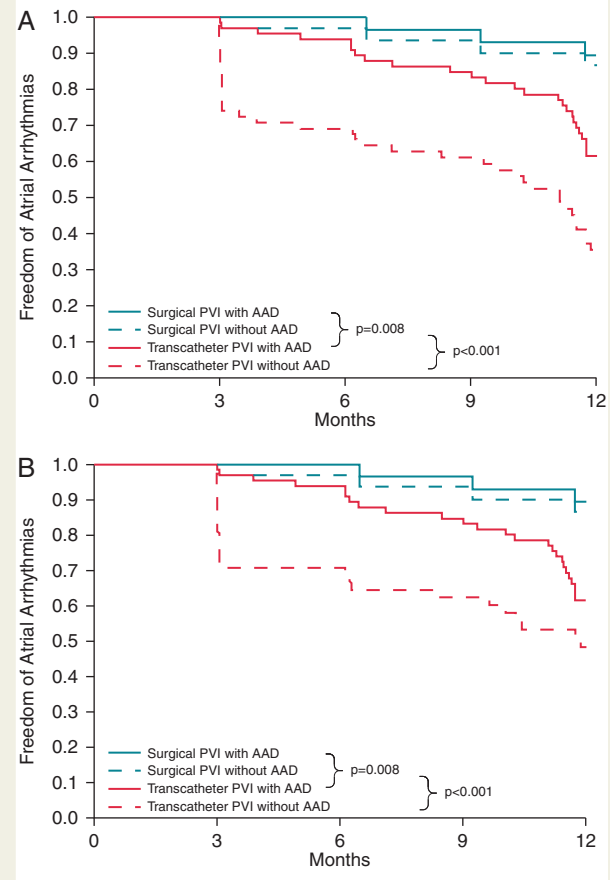
Freedom from atrial arrhythmia without AADs occurred in 27 (87%) patients in the surgical and in 27 (42%) patients in the transcatheter group ( $P < 0.001$ ). Freedom from atrial arrhythmia with AADs occurred in 28 patients (90%) in the surgical and in 4 (63%) patients in the transcatheter group ( $P = 0.007$ ). Kaplan–Meier curves are depicted in Figure 1A. In Figure 1B, we show the Kaplan–Meier curves, excluding the patients awaiting an additional ablation procedure ( $n = 14$  in the transcatheter PVI group).

In the surgical PVI group, seven (21%) patients developed a major complication in the post-operative phase, compared with three (5%) patients in the transcatheter group ( $P = 0.015$ ). In the surgical group two patients required intervention by VATS for evacuation of a tamponade, one during hospital admission, the other patient was re-admitted 5 days after surgery. Another patient with pericardial effusion was re-admitted, but did not require treatment and recovered completely. One patient had a hemoglobin decrease of 2.3 mg/dL, although only 300 mL periprocedural blood loss was recorded, and blood transfusion was not required. One patient developed a peri-operative cerebrovascular accident with partial recovery. A transient unilateral paralysis of the diaphragm was also recorded, and a prolonged hospitalization for fluid retention requiring diuretics. In the transcatheter group, one patient suffered from a peri-procedural tamponade which required immediate drainage, another patient had a bleeding from the groin, requiring surgical intervention. Furthermore, one patient had a prolonged hospitalization due to a peri-procedural allergic reaction on local anesthetic drug.

**Table 1** Baseline characteristics of patients undergoing surgical or transcatheter PVI

	Surgical PVI group (n = 33)	Transcatheter PVI group (n = 66)	P value
Age (years)	51 ± 10	53 ± 9	0.53
Male	27 (82%)	54 (82%)	1.00
Type of AF			0.21
Paroxysmal	28 (85%)	48 (73%)	
Persistent	5 (15%)	18 (27%)	
Total duration AF (months)	41 (5–203)	58 (8–344)	0.16
Hypertension	10 (30%)	28 (44%)	0.28
Diabetes mellitus	–	4 (6%)	0.30
Coronary artery disease	–	3 (5%)	0.55
Chronic obstructive pulmonary disease	1 (3%)	4 (6%)	0.66
Complaints AF			
Palpitations	22 (67%)	53 (80%)	0.15
Dyspnea	9 (27%)	13 (20%)	0.45
Fatigue	6 (18%)	15 (23%)	0.80
Chest pain	4 (12%)	4 (6%)	0.44
Previous class I AAD	23 (70%)	39 (59%)	0.38
Previous class III AAD	14 (42%)	41 (62%)	0.09
Body Mass Index (kg/m <sup>2</sup> )	28 ± 3	28 ± 4	0.93
Body surface area (m <sup>2</sup> )	2.2 ± 0.2	2.2 ± 0.2	0.53
Systolic blood pressure (mmHg)	126 ± 20	128 ± 18	0.66
Diastolic blood pressure (mmHg)	74 ± 9	80 ± 9	0.008
Echocardiographic measurements			
LA volume (mL)	29.5 ± 9.1	28.3 ± 8.6	0.56
Parasternal LA diameter (mm)	41.7 ± 5.4	40.8 ± 5.4	0.46
LVEDD (mm)	51.0 ± 4.4	51.2 ± 6.1	0.88
LVESD (mm)	33.2 ± 5.8	34.0 ± 6.8	0.57
Medication at baseline			
Oral anticoagulation	16 (48%)	52 (78%)	0.003
Beta blocker	18 (55%)	33 (50%)	0.83
Verapamil	7 (21%)	10 (15%)	0.57
Digoxin	1 (3%)	3 (5%)	0.10
ACE-I	4 (12%)	20 (30%)	0.051
ARB	5 (15%)	14 (21%)	0.59
Antiarrhythmic drugs			
Flecainide	17 (52%)	24 (36%)	0.20
Sotalol	7 (21%)	13 (20%)	1.00
Amiodarone	3 (9%)	13 (20%)	0.25
Total atrial conduction time (ms)	127 ± 22	128 ± 23	0.87

AADs, anti arrhythmic drugs; ACE-I, angiotensin converting enzyme inhibitor; AF, atrial fibrillation; ARB, angiotensin receptor blocker; LA, left atrium; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; PVI, pulmonary vein isolation.



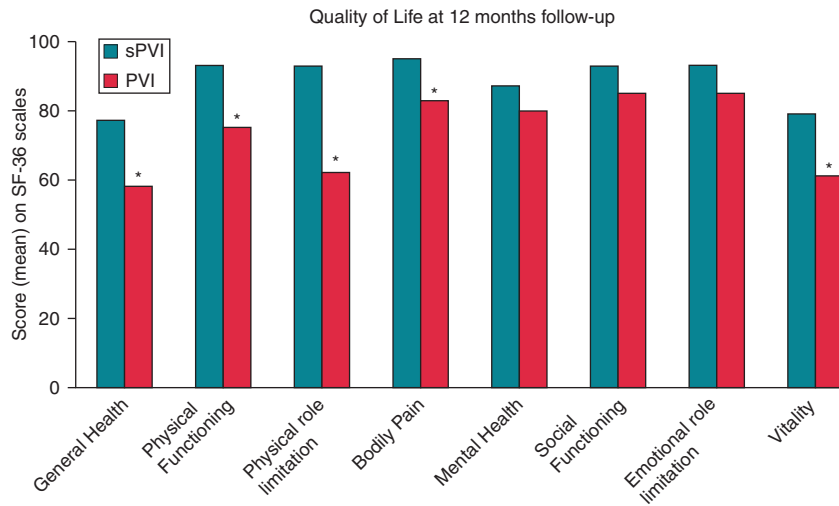
**Figure 1** Kaplan–Meier curve of arrhythmia free survival after surgical vs. transcatheter PVI, with and without AAD. In (A) all 99 patients were included, in (B) those awaiting an additional ablation were excluded (n = 14, all in the transcatheter group).

All transcatheter patients recovered completely. During 12 months follow-up, no other cardiovascular events, i.e. stroke, major bleeding, myocardial infarction, heart failure hospitalization, or death occurred in both treatment strategies.

Quality of life questionnaires were obtained from 19 (58%) patients in surgical PVI group and 30 (45%) patients in transcatheter PVI group. At baseline, there were no significant differences between both groups. After 12 months follow-up, five domains of the SF-36 questionnaire were statistically significant different between both groups, in favour of the surgical PVI group (Figure 2). At 12 months, surgical PVI group showed significant increase in QoL in six of eight domain, whereas transcatheter PVI group showed no significant increase in QoL, except for the domain of social functioning.

Baseline and follow-up echocardiographic data were available in 33 (100%) patients in surgical PVI group and 57 (86%) patients in transcatheter PVI group (Table 2). No change in LA diameter and volume was observed between baseline and end of follow-up. Since sinus rhythm (and adequate P wave detection) is mandatory for TACT-measurement, data are only available in a subset of patients with sinus rhythm at baseline and at follow-up (both baseline and follow-up TACT measurements were available in 18 (55%) patients of the





**Figure 2** Results of SF-36 quality of life questionnaire at 12 months follow-up comparing surgical vs. transcatheter PVI. \* $P < 0.05$ , difference between groups. PVI, transcatheter pulmonary vein isolation; sPVI, surgical pulmonary vein isolation.

**Table 2** Echocardiographic measurements at end of follow-up

	Surgical PVI group (n = 33)	Transcatheter PVI group (n = 57)	P value
LA volume (mL)	26.9 ± 7.7	27.0 ± 8.7	0.98
Parasternal LA diameter (mm)	42.3 ± 5.5	40.2 ± 5.7	0.13
Total atrial conduction time (ms)	116 ± 16	139 ± 27	0.001

LA, left atrial; PVI, pulmonary veins isolation.

surgical group and 19 (29%) of the transcatheter group). No significant change in total atrial conduction time was observed in both groups between baseline and 12 months, TACT was significantly longer (139 ms) in the transcatheter group compared with the surgical group (116 ms) at 12 months ( $P = 0.001$ ).

## Discussion

In this matched study comparing a surgical with transcatheter PVI treatment strategy in symptomatic patients failed on antiarrhythmics, but without prior PVI ablations, a surgical PVI strategy is more effective than a transcatheter PVI strategy. However, the incidence of complications was higher with surgical PVI.

Freedom from AF after surgical PVI is reported in 65–92% of paroxysmal AF patients, and 67–80% in persistent AF patients.<sup>28</sup> A systematic review of 752 patients after surgical PVI (with and without additional ablation lines) showed a single procedure success rate of 69% without AADs in patients with paroxysmal or persistent AF.<sup>29</sup> In our study, surgical PVI showed 88% success at 12 months follow-up.

In the transcatheter group freedom of atrial arrhythmias, without AADs, was 42%, and when excluding those waiting for an additional ablation, freedom of atrial arrhythmias without AADs was 52%. The efficacy of transcatheter PVI has been investigated extensively and compared with pharmacological therapy in multiple randomized clinical trials. For example, Wilber *et al.*<sup>30</sup> randomized a comparable population of 167 patients with paroxysmal AF to ablation or pharmacologic therapy. At 12 months follow-up, the catheter ablation resulted in 66% freedom of AF. These results are better than achieved in our population. This may be due to the fact that in our transcatheter population 27% of the patients had persistent AF, at 1 year seven (11%) patients were awaiting a second PVI and seven (11%) patients were awaiting a third procedure, and we measured the acute effectiveness of electrical disconnection only by pacing within the pulmonary veins (exit block), and no steerable decapolar circumferential catheter was employed, which may have negatively influenced our efficacy results.

Recently, in the randomized FAST trial, a direct comparison of surgical PVI with transcatheter PVI was performed. The authors found 66% freedom from AF after surgical PVI, and 37% after transcatheter PVI (both without AADs).<sup>19</sup> However, in that study patients had more progression of AF. The majority of patients had failed on a prior transcatheter PVI, the others had enlarged left atria. This in contrast to the surgical PVI patients in our study, where none of the patients had a prior ablation, enlarged atria (LA > 55 mm), and AF was present for a shorter period of time and persistent AF was less frequent (15% compared with 26% in the FAST study). There are various possibilities to explain the better outcome of surgical compared with transcatheter PVI. Firstly, surgical PVI with bipolar RF entails continuous ablation lines, compared with the point-by-point ablation line created with transcatheter RF ablation. Secondly, with transcatheter PVI the achievement of transmural lesions and permanent electrical conduction block is difficult. This is because of variations in LA wall thickness, fibrosis, and anatomical location of the

pulmonary veins. Furthermore, after acute conduction block is achieved by transcatheter PVI, electrical reconduction has been described.<sup>31</sup> Data regarding electrical reconduction with surgical PVI are unavailable yet. Thirdly, with surgical PVI we performed the additional treatment of active ganglionic plexi.<sup>21</sup> The benefit of active ganglionic plexi ablation remains controversial since the potential beneficial effect has never been investigated in a randomized clinical trial and the long-term results (possible pro-arrhythmic effect) remain to be studied.<sup>32</sup> But it may potentially have increased the outcome of the surgical PVI procedure.<sup>20</sup> Finally, the higher success rate of surgical ablation may have also been influenced by the fact that surgical patients seemed to have less comorbidities, although this was not statistically significant.

Furthermore, although we had only limited QoL data and our study was not blinded, QoL was significantly improved and better in patients treated with surgical PVI, than in those with transcatheter PVI. Furthermore, echocardiographically measured LA size was not different between the surgical and transcatheter PVI groups. The TACT, measured by tissue Doppler imaging in a subset of patients who were in sinus rhythm at the time of echocardiography, was comparable at baseline but significantly shorter in the surgical PVI group at 12 months. Although the limited number of TACT measurements precludes any definite conclusions, reduced TACT without change of LA size may indicate less conduction delay, i.e. reduction of the atrial remodelling process in the surgical PVI group.

The complication rate was higher with surgical PVI. The complication rate of surgical PVI in this study was comparable to the 23% observed in the randomized FAST trial. Also, the complication rate in the transcatheter PVI group in our study was comparable to prior reports.<sup>33</sup> This difference is not completely unexpected since surgery is a more invasive procedure than transcatheter PVI. Comparison of complications between both procedures is difficult because of the differences in approach and invasiveness. Of the surgical PVI patients with a post-operative complication, six of seven patients recovered completely, and in two of seven patients (transient unilateral paralysis of the diaphragm and periprocedural hemoglobin decrease of 2.3 points) no intervention was required. Hence, comparing surgical to transcatheter PVI, higher efficacy combined with a higher risk of complications of the surgical PVI has to be weighed against the less effective but also less invasive procedure of the transcatheter PVI. Large randomized clinical trials are warranted to study the outcome, both freedom for atrial arrhythmias, but even more important freedom of AF-associated cardiovascular morbidity and mortality of both PVI strategies. While awaiting the results of randomized PVI trials, our results may assist physicians to select the most appropriate patient-tailored therapy.

The extensive and consistent follow-up represents important strengths. However, our study has limitations that merit consideration. This study was a retrospective matched group comparison, patients were not randomly assigned to a treatment strategy, and any possible referral bias cannot be excluded. Furthermore, only a relatively small number of patients were included. Lastly, we may have overlooked asymptomatic atrial arrhythmias, although we performed multiple 24–96 h Holter monitoring in addition to electrocardiogram and rhythm strips.

A minimal invasive surgical PVI treatment strategy was more effective in preventing recurrence of atrial arrhythmias during 12 months

follow-up, compared with a transcatheter PVI treatment strategy. However, the incidence of complications was higher with surgical PVI.

**Conflicts of interest:** none declared.

## References

1. Camm AJ, Kirchhof P, Lip GY, Schotten U, Saveliev I, Ernst S et al. Guidelines for the management of atrial fibrillation: the Task Force for the Management of Atrial Fibrillation of the European Society of Cardiology (ESC). *Europace* 2010;**10**:1360–420.
2. Camm AJ, Lip GY, De Caterina R, Saveliev I, Atar D, Hohnloser SH et al. 2012 focused update of the 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. Nieuwlaar R, Capucci A, Camm AJ, Olsson SB, Andresen D, Davies DW et al. Atrial fibrillation management: a prospective survey in ESC member countries: the Euro Heart Survey on Atrial Fibrillation. *Eur Heart J* 2005;**22**:2422–34.
4. Van Gelder IC, Hagens VE, Bosker HA, Kingma JH, Kamp O, Kingma T et al. A comparison of rate control and rhythm control in patients with recurrent persistent atrial fibrillation. *N Engl J Med* 2002;**23**:1834–40.
5. 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;**23**:1825–33.
6. Haissaguerre M, Jais P, Shah DC, Takahashi A, Hocini M, Quiniou G et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. *N Engl J Med* 1998;**10**:659–66.
7. 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;**2**:160–6.
8. Cox JL, Schuessler RB, D'Agostino HJ Jr, Stone CM, Chang BC, Cain ME et al. The surgical treatment of atrial fibrillation. III. Development of a definitive surgical procedure. *J Thorac Cardiovasc Surg* 1991;**4**:569–83.
9. Prasad SM, Maniar HS, Camillo CJ, Schuessler RB, Boineau JP, Sundt TM 3rd et al. The Cox maze III procedure for atrial fibrillation: long-term efficacy in patients undergoing lone versus concomitant procedures. *J Thorac Cardiovasc Surg* 2003;**6**:1822–8.
10. Hemels ME, Gu YL, Tuinenburg AE, Boonstra PW, Wiesfeld AC, van den Berg MP et al. Favorable long-term outcome of Maze surgery in patients with lone atrial fibrillation. *Ann Thorac Surg* 2006;**5**:1773–9.
11. Wolf RK, Schneeberger EW, Osterday R, Miller D, Merrill W, Flege JB Jr et al. Video-assisted bilateral pulmonary vein isolation and left atrial appendage exclusion for atrial fibrillation. *J Thorac Cardiovasc Surg* 2005;**3**:797–802.
12. Yilmaz A, Van Putte BP, Van Boven WJ. Completely thoracoscopic bilateral pulmonary vein isolation and left atrial appendage exclusion for atrial fibrillation. *J Thorac Cardiovasc Surg* 2008;**2**:521–2.
13. Klinkenberg TJ, Ahmed S, Ten Hagen A, Wiesfeld AC, Tan ES, Zijlstra F et al. Feasibility and outcome of epicardial pulmonary vein isolation for lone atrial fibrillation using minimal invasive surgery and high intensity focused ultrasound. *Europace* 2009;**12**:1624–31.
14. Santini M, Loiaconi V, Tocco MP, Mele F, Pandozi C. Feasibility and efficacy of minimally invasive stand-alone surgical ablation of atrial fibrillation. A single-center experience. *J Interv Card Electrophysiol* 2012;**1**:79–87.
15. Han FT, Kasirajan V, Kowalski M, Kiser R, Wolfe L, Kalahasty G et al. Results of a minimally invasive surgical pulmonary vein isolation and ganglionic plexi ablation for atrial fibrillation: single-center experience with 12-month follow-up. *Circ Arrhythm Electrophysiol* 2009;**4**:370–7.
16. 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;**4**:823–8.
17. Yilmaz A, Geuzebroek GS, Van Putte BP, Boersma LV, Sonker U, De Bakker JM et al. Completely thoracoscopic pulmonary vein isolation with ganglionic plexus ablation and left atrial appendage amputation for treatment of atrial fibrillation. *Eur J Cardiothorac Surg* 2010;**3**:356–60.
18. European Heart Rhythm Association, Heart Rhythm Society, Fuster V, Ryden LE, Cannom DS, Crijns HJ, Curtis AB, Ellebogen KA et al. ACC/AHA/ESC 2006 guidelines for the management of patients with atrial fibrillation—executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines. *J Am Coll Cardiol* 2006;**4**:854–906.
19. Boersma LV, Castella M, van Boven W, Berrueto A, Yilmaz A, Nadal M et al. Atrial fibrillation catheter ablation versus surgical ablation treatment (FAST): a 2-center randomized clinical trial. *Circulation* 2012;**1**:23–30.
20. Doll N, Pritzwald-Stegmann P, Czesla M, Kempfert J, Stenzel MA, Borger MA et al. Ablation of ganglionic plexi during combined surgery for atrial fibrillation. *Ann Thorac Surg* 2008;**5**:1659–63.

21. Lu Z, Scherlag BJ, Lin J, Yu L, Guo JH, Niu G *et al.* Autonomic mechanism for initiation of rapid firing from atria and pulmonary veins: evidence by ablation of ganglionated plexi. *Cardiovasc Res* 2009;**2**:245–52.
22. Pappone C, Santinelli V. How to perform encircling ablation of the left atrium. *Heart Rhythm* 2006;**9**:1105–9.
23. Pappone C, Rosanio S, Oreto G, Tocchi M, Gugliotta F, Vicedomini G *et al.* Circumferential radiofrequency ablation of pulmonary vein ostia: a new anatomic approach for curing atrial fibrillation. *Circulation* 2000;**21**:2619–28.
24. Buck S, Rienstra M, Maass AH, Nieuwland W, Van Veldhuisen DJ, Van Gelder IC. Cardiac resynchronization therapy in patients with heart failure and atrial fibrillation: importance of new-onset atrial fibrillation and total atrial conduction time. *Europace* 2008;**5**:558–65.
25. Aaronson NK, Muller M, Cohen PD, Essink-Bot ML, Fekkes M, Sanderman R *et al.* Translation, validation, and norming of the Dutch language version of the SF-36 Health Survey in community and chronic disease populations. *J Clin Epidemiol* 1998;**11**:1055–68.
26. 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;**4**:528–606.
27. Joshi S, Choi AD, Kamath GS, Raiszadeh F, Marrero D, Badheka A *et al.* Prevalence, predictors, and prognosis of atrial fibrillation early after pulmonary vein isolation: findings from 3 months of continuous automatic ECG loop recordings. *J Cardiovasc Electrophysiol* 2009;**10**:1089–94.
28. La Meir M, Gelsomino S, Luca F, Pison L, Colella A, Lorusso R *et al.* Minimal invasive surgery for atrial fibrillation: an updated review. *Europace* 2012;**2**:170–82.
29. Krul SP, Driessen AH, Zwinderman AH, van Boven WJ, Wilde AA, de Bakker JM *et al.* Navigating the mini-maze: systematic review of the first results and progress of minimally-invasive surgery in the treatment of atrial fibrillation. *Int J Cardiol* 2013;**166**:132–40.
30. Wilber DJ, Pappone C, Neuzil P, De Paola A, Marchlinski F, Natale A *et al.* Comparison of antiarrhythmic drug therapy and radiofrequency catheter ablation in patients with paroxysmal atrial fibrillation: a randomized controlled trial. *JAMA* 2010;**4**:333–40.
31. Nanthakumar K, Plumb VJ, Epstein AE, Veenhuizen GD, Link D, Kay GN. Resumption of electrical conduction in previously isolated pulmonary veins: rationale for a different strategy? *Circulation* 2004;**10**:1226–9.
32. Oh S, Zhang Y, Bibevski S, Marrouche NF, Natale A, Mazgalev TN. Vagal denervation and atrial fibrillation inducibility: epicardial fat pad ablation does not have long-term effects. *Heart Rhythm* 2006;**6**:701–8.
33. Cappato R, Calkins H, Chen SA, Davies W, Iesaka Y, Kalman J *et al.* Updated worldwide survey on the methods, efficacy, and safety of catheter ablation for human atrial fibrillation. *Circ Arrhythm Electrophysiol* 2010;**1**:32–8.

## IMAGES IN ELECTROPHYSIOLOGY

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### Giant coronary arteriovenous fistula between left superior pulmonary vein and left atrial appendage

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A 71-year-old male patient had symptomatic paroxysmal atrial fibrillation. Computed tomography detected that coronary arteriovenous fistula originated from the coronary left circumflex artery to the coronary sinus, which extended superiorly and traversed between the left superior pulmonary vein (LSPV) and the left atrial appendage (LAA). This fistula could be injured by catheter ablation to the LSPV. Hence, we performed extensive encircling pulmonary veins isolation on the right side and individual isolation for the left inferior pulmonary vein only but did not try our hands on the LSPV. There was no recurrence of atrial fibrillation with carvedilol over 10 months. Prior understanding of anatomical feature is warranted.

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