

# Early experience of thoracoscopic vs. catheter ablation for atrial fibrillation

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## Aims

Video-assisted thoracoscopic surgery (VATS) ablation has been advocated as a treatment option for non-paroxysmal atrial fibrillation (AF) in recent guidelines. Real-life data on its safety and efficacy during a centre's early experience are sparse.

## Methods and results

Thirty patients (28 persistent/longstanding persistent AF) underwent standalone VATS ablation for AF by an experienced thoracoscopic surgeon, with the first 20 cases proctored by external surgeons. Procedural and follow-up outcomes were collected prospectively, and compared with 90 propensity-matched patients undergoing contemporaneous catheter ablation (CA). Six (20.0%) patients undergoing VATS ablation experienced  $\geq 1$  major complication (death  $n=1$ , stroke  $n=2$ , conversion to sternotomy  $n=3$ , and phrenic nerve injury  $n=2$ ). This was significantly higher than the 1.1% major complication rate (tamponade requiring drainage  $n=1$ ) seen with CA ( $P<0.001$ ). Twelve-month single procedure arrhythmia-free survival rates without antiarrhythmic drugs were 56% in the VATS and 57% in the CA cohorts ( $P=0.22$ ), and 78% and 80%, respectively given an additional CA and antiarrhythmic drugs ( $P=0.32$ ).

## Conclusion

During a centre's early experience, VATS ablation may have similar success rates to those from an established CA service, but carry a greater risk of major complications. Those embarking on a programme of VATS AF ablation should be aware that complication and success rates may differ from those reported by selected high-volume centres.

## Keywords

Atrial fibrillation • Catheter ablation • Surgical ablation • Minimally invasive • Thoracoscopic • Complications • Cohort study

## Introduction

Minimally invasive surgical ablation of atrial fibrillation (AF) using video-assisted thoracoscopic surgery (VATS) is growing in popularity. Recent guidelines advocate VATS AF ablation as a viable treatment option,<sup>1,2</sup> with some placing it on a par with catheter ablation (CA) for patients with non-paroxysmal AF.<sup>1</sup> However, a recent meta-analysis<sup>3</sup> showed the reported outcomes from VATS AF ablation are

highly variable, with success rates ranging from 40%<sup>4</sup> to 96%<sup>5</sup> at 12 months. Furthermore, this meta-analysis showed that the definition of complications varies widely between studies. While case series report major complication rates as low as 0% e.g. Ref.<sup>6</sup> prospectively collected data from randomized studies suggests complication rates may be up to 23%.<sup>7</sup> In view of this, concerns have been raised over possible under-reporting of complications, and the latest AF guidelines have highlighted VATS ablation as one of

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### What's new?

- Previous studies have suggested that thoracoscopic ablation for atrial fibrillation is more effective than catheter ablation (CA), but at the cost of a higher complication rate.
- These earlier studies were largely performed using older CA technology, and therefore, may underestimate the efficacy seen if more modern techniques had been used.
- During the institutional learning curve for thoracoscopic ablation, surgical ablation was associated with similar success rates to CA performed using modern technology, but still carried a significantly higher complication rate.

the 'Gaps in Evidence' for which further research needs to be prioritized.<sup>2</sup>

We present our initial experience of VATS ablation for AF, and compare procedural and clinical outcomes with a propensity-matched cohort of patients treated by our well-established CA service. We present our success rates according to consensus guidelines<sup>8</sup> and report our complication rates in full, thereby providing an accurate reflection of what can be expected when starting a programme of VATS ablation.

## Methods

### Patients

Liverpool Heart and Chest Hospital is one of the largest cardiothoracic centres in England with an established high-volume CA programme for AF, survival rates from thoracic surgery significantly better than the national average ([www.scts.org](http://www.scts.org)), and an 'Outstanding' rating from the Care Quality Commission. From late 2013, and as per the National Institute for Health and Care Excellence (NICE) AF guidance,<sup>1</sup> patients with non-paroxysmal AF referred for CA to our centres were offered the choice of undergoing VATS AF ablation instead. Patients were excluded if they had a co-existing indication for cardiac surgery such as severe valvular heart disease. Severe atrial dilatation was not an exclusion criterion. In order to avoid dilution of surgical experience, VATS AF ablation was restricted to a single thoracic surgeon (N.M.) already experienced in VATS techniques. We mandated external proctoring for the first 20 VATS cases by surgeons with extensive experience of VATS AF ablation from other centres.

From December 2013 to May 2017, 35 consecutive patients underwent standalone VATS ablation for AF. Of the first 20 cases, while the first two were performed in December 2013, a hiatus ensued because of funding limitations before the programme recommenced in January 2015. The remaining 18 cases were performed between January 2015 and December 2015. During the same time period, 1032 patients underwent radiofrequency CA for AF. For the purpose of this report, five VATS patients and 105 CA patients were excluded as they had been recruited into research trials reported elsewhere. Propensity matching amongst the remaining CA cohort in a 3:1 ratio identified 90 patients whose outcomes were compared with the 30 VATS patients. An institutional review board-approved electronic patient record was used for prospective data capture for all patients, and the data were collated retrospectively for the catheter cohort after propensity matching had identified the group. Each patient gave written consent for their procedure, and to their data being included in this study.

### Surgical ablation technique

Procedures were performed thoracoscopically under general anaesthesia with sequential single lung ventilation using either a double-lumen tube or bronchial blocker. Patients were positioned supine, with slight reverse Trendelenburg tilt.

The right side was operated on first using three ports in the anterior axillary line after isolation of the ipsilateral lung and carbon dioxide insufflation. The pericardium was opened longitudinally 2 cm anterior and parallel to the phrenic nerve. The inferior edge of the pericardium was retracted with three sutures using the Endo Stitch (Covidien). Dissection between the atrium and pericardium allowed access to the oblique sinus adjacent to the right inferior pulmonary vein (PV). Further dissection along the right superior PV towards the left superior PV exposed the roof of the left atrium. The illuminated Lunitip (AtriCure) dissector facilitated passing the jaws of the bipolar radiofrequency clamp around the right PVs. At least six overlapping ablation lines were created at the antrum of the right PVs. The Isolator Multifunction Pen (AtriCure) was used to create linear ablation lines along the transverse sinus from the right superior PV to the left, with a similar ablation line connecting the right and left inferior PVs. Ganglionic plexi, with specific targeting of the inferior plexi around the coronary sinus, were identified by eliciting a vagal response to rapid stimulation, and ablated until this response was eliminated.

On the left, three ports were positioned in the midaxillary line. The pericardium was opened posterior and parallel to the phrenic nerve. After division of the ligament of Marshall, the tissue between the left superior PV and left pulmonary artery was dissected towards the oblique sinus. The left PVs were isolated with the aid of the Lunitip with at least six overlapping ablation lines. The connecting lines were completed from the left towards the right using the multifunction pen. Electrical block was confirmed by absence of PV signals and on the posterior wall using the pen to sense. Finally the AtriClip (AtriCure) was deployed extrinsically at the base of the left atrial appendage (LAA) under transoesophageal echocardiographic guidance.

### Catheter ablation technique

Our CA technique has been described previously.<sup>9</sup> Procedures were performed under general anaesthesia or conscious sedation. Patients taking warfarin continued uninterrupted anticoagulation, while patients taking non-vitamin K oral anticoagulants had 0–2 doses omitted at the operator's discretion. Patients who had not maintained therapeutic anticoagulation for 4 weeks pre-procedure underwent transoesophageal echocardiography. Ultrasound-guided vascular access was obtained via the right femoral vein.<sup>10</sup> Two trans-septal punctures were performed and unfractionated heparin was used to maintain an activated clotting time of >250 s. A 3.5 mm contact force-sensing irrigated tip ablation catheter (Smarttouch™) was used with the CARTO mapping system (Biosense Webster, Irvine, CA, USA) aiming for contact force of 5–40 g for each lesion. Since December 2014, minimum ablation index values of 550 on the anterior wall and 400 on the posterior wall were targeted.<sup>9</sup> Pulmonary vein isolation (PVI) was mandatory for all patients while additional ablation was performed at operator's discretion. Successful PVI was defined as entrance block confirmed with a 20-pole spiral catheter, and successful linear lesions were defined as bidirectional block. Details of the CA procedure were prospectively captured in a bespoke electronic AF ablation database.

### Definitions

Classification of AF, and procedural success were defined according to ACC/AHA/HRS guidelines,<sup>9</sup> being survival free from any atrial arrhythmias >30 s after a 3-month blanking period. Success was defined on an

intention-to-treat basis including those deceased. All complications that caused prolonged morbidity, increased the duration of planned hospital stay, or prompted readmission were reported and classified according to the Ottawa Thoracic Morbidity and Mortality classification system.<sup>11</sup>

## Follow-up

Patients were followed up at 3 months, 6 months, and 12 months post-procedure with additional clinic visits as required. A 12-lead ECG was recorded at each visit. Additional ambulatory ECG monitoring was performed at physician's discretion depending upon the temporal pattern of symptoms. Records of hospital attendances at referring hospitals were also inspected for evidence of complications or arrhythmia recurrence.

## Statistical analysis

Pre-operative variables were used to develop a propensity score matching patients who had undergone CA to those having undergone VATS ablation using a 3:1 digit greedy matching algorithm based on age, sex, classification of AF, and left atrial diameter.<sup>12</sup> If a match could not be found using a full propensity score, the algorithm then proceeded to the next highest digit of the propensity score (from a seven-digit down to one-digit match) to determine next-best matches. This was performed in a hierarchical sequence until no more matches could be found. Matching was performed without replacement.

Continuous data are presented as mean  $\pm$  standard deviation or median (range) for normally and non-normally distributed data, respectively. The Wilcoxon rank sum and  $\chi^2$  tests were used for univariable comparisons. McNemar and signed rank tests were used as appropriate for matched pairs. The Log-rank test was used to compare survival curves. Statistical analyses were performed using SAS for Windows (Version 9.3, SAS, Cary, NC, USA) and SigmaPlot (Systat Software, CA, USA). Statistical significance was taken as  $P < 0.05$ .

## Results

Propensity matching on age, sex, AF classification, and left atrial diameter yielded groups that were similar with regard to all measured pre-procedural demographics (Table 1). The majority of patients (92%) had persistent or longstanding-persistent AF. The two patients undergoing VATS ablation who had paroxysmal AF had undergone unsuccessful attempts at CA, one having undergone percutaneous closure of an atrial septal defect making trans-septal puncture impossible.

Procedural details and lesions sets can be found in Figure 1 and Table 2. One surgical case was terminated prior to any ablation being performed due to extensive pericardial adhesions; there were no clinical risk factors or features on his pre-procedural CT suggesting adhesions. This patient underwent CA at 4 months and remained free from recurrent atrial arrhythmias until last follow-up at 20 months. The case has been included in the analysis of pre-procedural outcomes but excluded from the analyses of follow-up and freedom from arrhythmia. No CA cases required termination before the PVs had been isolated. The most common reasons for failure to complete the intended surgical lesion set were unfavourable anatomy or procedure termination due to a complication.

At discharge, similar proportions of warfarin vs. non-vitamin K antagonists were used in each group (surgical: warfarin  $n = 17$ , rivaroxaban  $n = 6$ , and apixaban  $n = 5$ ; catheter: warfarin  $n = 47$ , rivaroxaban  $n = 15$ , apixaban  $n = 20$ , and dabigatran  $n = 8$ ).

**Table 1** Demographics

	Surgical (n = 30)	Catheter (n = 90)	P-value
Age (years)	58 $\pm$ 9.9	57.9 $\pm$ 9.8	0.95
Male (%)	86.7%	80.0%	0.41
BMI (kg·m <sup>-2</sup> )	31.7 $\pm$ 4.3	30.5 $\pm$ 4.4	0.19
eGFR	66.7 $\pm$ 12.8	68.7 $\pm$ 17.1	0.60
CHA <sub>2</sub> DS <sub>2</sub> VASc	1.1 $\pm$ 0.9	1.5 $\pm$ 1.3	0.18
EuroSCORE II	0.9% $\pm$ 0.3%	0.8% $\pm$ 0.3%	0.61
PAF (%)	6.7%	8.9%	0.92
PerAF (%)	50.0%	47.8%	0.92
LSperAF (%)	43.3%	43.3%	0.92
AF duration (years)	4.3 $\pm$ 3.7	4.5 $\pm$ 5.3	0.82
DCCV (%)	83.3%	67.8%	0.10
Previous catheter ablation (%)	6.7%	6.7%	1.00
LV ejection fraction (%)	52.3% $\pm$ 6.5%	49.6% $\pm$ 8.3%	0.11
LA diameter (mm)	46.1 $\pm$ 5	46.1 $\pm$ 5.2	0.96
LA volume (mL)	90.8 $\pm$ 18.4	98.1 $\pm$ 32.6	0.46

AF, atrial fibrillation; BMI, body mass index; DCCV, prior direct current cardioversion; eGFR, estimated glomerular filtration rate; LA, left atrial; LSperAF, long-standing persistent atrial fibrillation; LV, left ventricle; PAF, paroxysmal atrial fibrillation; PerAF, persistent atrial fibrillation.

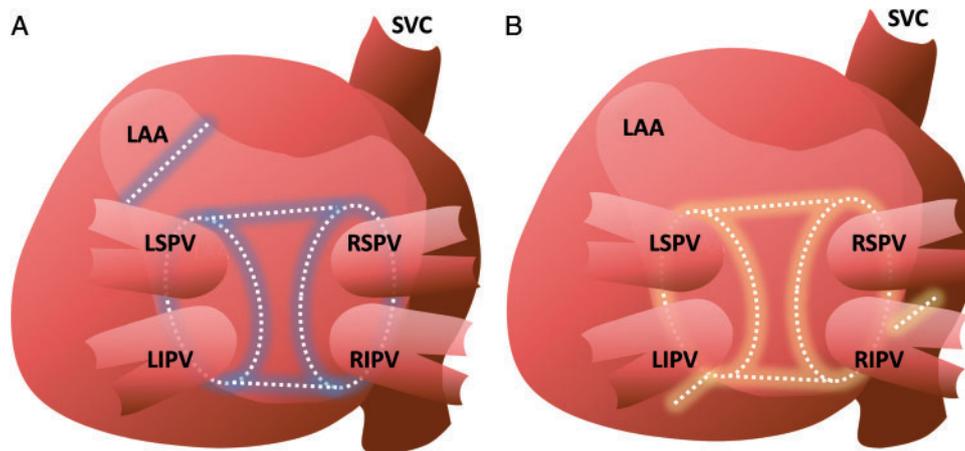
## Follow-up

Duration of follow-up and number of outpatient attendances were similar between groups (surgical 17.7  $\pm$  7.4 months, 4.4  $\pm$  2.0 attendances; catheter 17.9  $\pm$  9.8 months, 3.8  $\pm$  2.6 attendances,  $P = 0.92$ ,  $P = 0.25$ , respectively). Ambulatory monitoring was performed more frequently in the VATS cohort [surgical 23/28 (82%) and catheter 27/90 (30%),  $P < 0.01$ ]. Similar proportions of patients were anticoagulated at last follow-up [surgical 20/29 (69%) and catheter 95/120 (79%),  $P = 0.24$ ].

Post-discharge DC cardioversion was performed in more patients from the VATS cohort [surgical 13/28 (46.4%), of which 6/28 (21.4%) in the post-blanking period; catheter 16/90 (17.8%), of which 4/90 (4.4%) in the post-blanking period;  $P = 0.02$ ,  $P < 0.01$ ]. Additional CA was performed in 5/28 (17.9%) surgical (involving left atrium  $n = 4$ ) and 16/90 (17.8%) catheter patients (involving left atrium  $n = 16$ ),  $P = 0.99$ . Repeat electrophysiological studies showed similar numbers of PV reconnections between groups (surgical 1.0, catheter 1.7,  $P = 0.25$ ). Reconnection of the posterior wall was seen in two out of four surgical patients and three out of five catheter patients in whom this lesion set had been performed.

## Complications

Complications are summarized in Table 3. Six out of 30 (20.0%) patients undergoing VATS ablation experienced one or more major (Ottawa Grade III+) complications. One patient with highly symptomatic persistent AF who suffered from hypertrophic cardiomyopathy and pulmonary fibrosis suffered respiratory failure on post-operative Day 6, a stroke on Day 11, and died on Day 12. Following this case, we no longer offer VATS ablation to patients with pulmonary fibrosis.



**Figure 1** Posterior view of left atrium showing (A) surgical ablation lesion set and (B) catheter ablation lesion set. LAA, left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein; SVC, superior vena cava.

**Table 2** Procedural characteristics

	Surgical (n = 30)	Catheter (n = 90)	P-value
PVI	29 (96.7%)	90 (100%)	0.56
Roof line	26 (86.7%)	37 (41.1%)	<b>&lt;0.01</b>
Floor line	26 (86.7%)	23 (25.6%)	<b>&lt;0.01</b>
Ganglionic plexi	26 (86.7%)	0 (0%)	<b>&lt;0.01</b>
LAA exclusion	24 (80%)	0 (0%)	<b>&lt;0.01</b>
CTI line	0 (0%)	18 (20%)	<b>0.02</b>
MIG line	0 (0%)	5 (5.6%)	0.43
Procedure duration (min)	248 ± 63	176 ± 38	<b>&lt;0.01</b>
Length of hospital stay (days)	7 ± 3	2 ± 0.2	<b>&lt;0.01</b>

CTI, cavo-tricuspid isthmus; LAA, left atrial appendage; MIG, mitral isthmus gauche; PVI, pulmonary vein isolation. Bold text indicates P<0.05.

Three patients experienced cardiac perforations. One patient suffered a perforation at the base of the LAA before the clip had been applied and suffered a stroke on Day 0 leaving him with a homonymous hemianopia. A second patient suffered a perforation of the posterior left atrium during passage of the Lumitip dissector. A third patient suffered a perforation of the right inferior PV during passage of the Lumitip dissector. In each case, the perforation was repaired via midline sternotomy.

One patient suffered a left phrenic nerve transection while dissecting fat from the left hilum. This was re-apposed immediately via thoracotomy. Phrenic nerve function recovered by 6 months. A second patient experienced a right phrenic nerve injury which was identified during readmission for thoracotomy to drain an empyema. The mechanism of this injury is uncertain. Two patients experienced pleural effusions requiring readmission to hospital for percutaneous drainage. A further two patients suffered chest infections causing respiratory failure that required CPAP, and one patient required hospital readmission for a wound infection.

**Table 3** Incidence of complications (non-hierarchical) graded by Ottawa thoracic morbidity and mortality classification

Complications	Surgical (n = 30), n (%)	Catheter (n = 90), n (%)
<b>Major</b>		
Grade V		
Death	1 (3.3)	0 (0.0)
Grade IV		
Stroke	2 (6.7)	0 (0.0)
Grade III		
Atrial tear requiring sternotomy	3 (10)	0 (0.0)
Phrenic nerve injury	2 (6.7)	0 (0.0)
Need for pacemaker	0 (0)	0 (0.0)
Pericardial effusion requiring drainage	0 (0)	1 (1.1)
<b>Minor</b>		
Grade II		
Pleural effusion	4 (13.3)	0 (0.0)
Pneumothorax	0 (0)	0 (0.0)
Pericardial effusion without drainage	0 (0)	1 (1.1)
Respiratory failure requiring CPAP	3 (10)	0 (0.0)
Infection requiring antibiotics	5 (10)	1 (1.1)
Bleeding requiring transfusion	3 (10)	0 (0.0)
Pericarditis	0 (0.0)	2 (2.2)
Oesophageal dysmotility	0 (0.0)	1 (1.1)
Adverse events unrelated to procedure		
Post-discharge mortality	0 (0.0)	1 (1.1)

CPAP, continuous positive airway pressure ventilation.

One out of 90 (1.1%) patients undergoing CA experienced a major complication. This patient suffered a pericardial effusion requiring percutaneous drainage. Another patient was found to have a pericardial effusion without tamponade that was managed conservatively.

Two patients sought medical attention for pericarditis, and one experienced symptoms attributed to oesophageal dysmotility caused by the procedure. No CA patients experienced vascular complications requiring intervention. One patient in the CA group with a pre-existing ischaemic cardiomyopathy suffered a fatal myocardial infarction during follow-up which was not attributable to the procedure.

## Arrhythmia-free survival

Thirteen out of 28 surgical and 32/120 catheter patients experienced recurrent atrial arrhythmias during follow-up. Every patient in whom recurrent arrhythmias were detected on ambulatory monitoring also had evidence of recurrence on a standard 12-lead ECG. Arrhythmia recurrence was more likely to be due to atrial tachycardia or flutter in the VATS cohort [surgical 5/13 (38.5%) and catheter 2/32 (6.2%),  $P < 0.01$ ]. At last follow-up, survival free from any atrial arrhythmias after a single procedure was similar between groups [surgical 15/29 (51.7%) and catheter 53/90 (58.9%),  $P = 0.22$  by log rank, *Figure 2A*]. Arrhythmia-free survival was also similar allowing for an additional CA [surgical 18/29 (62.1%) and catheter 62/90 (68.9%),  $P = 0.32$  by log rank, *Figure 2B*]. At last follow-up, 24/28 (85.7%) surgical and 77/90 (85.6%) catheter patients had discontinued Class I/III antiarrhythmic drugs ( $P = 0.99$ ). Arrhythmia-free survival at specific time points is shown in *Table 4*. A graphical representation of cardiac rhythm post-VATS ablation is shown in *Figure 3*.

## Discussion

Video-assisted thoracoscopic surgery AF ablation is increasing in popularity. However, the published data on VATS AF are highly variable, and the overall 2.8% major complication rate reported by a recent meta-analysis<sup>3</sup> suggested possible publication bias. In particular, few series have involved independent review of outcomes by cardiologists. In this article, involving joint analysis of all outcomes by both

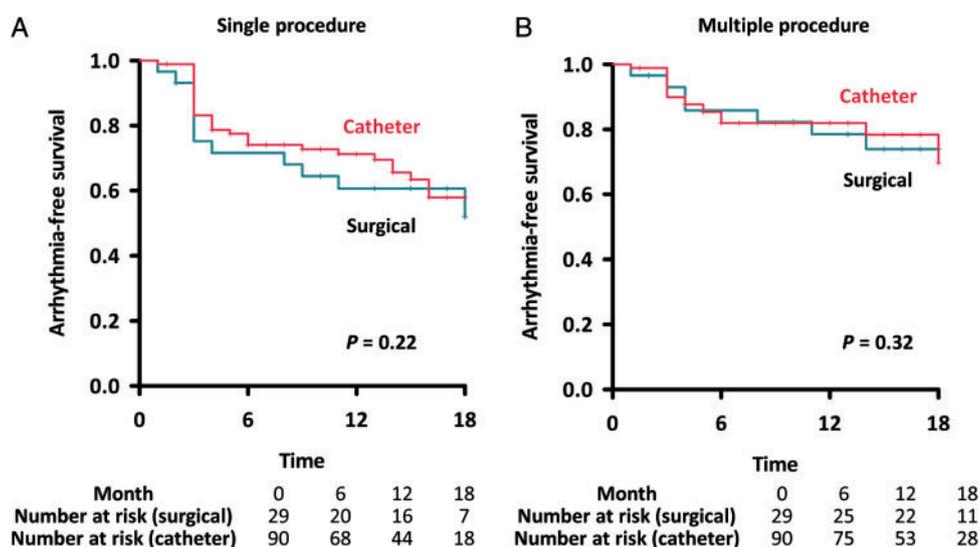
cardiologists and surgeons, we show that while the success rates with VATS AF ablation are encouraging, the procedure carries a significant risk of major complications during a centre's initial experience. Furthermore, a contemporaneous propensity-matched cohort of patients undergoing CA suggested that rates of freedom from arrhythmia may be similar but that CA carries a significantly lower procedural risk.

While one recent randomized trial showed similar efficacy between VATS and CA,<sup>13</sup> four small randomized trials<sup>7,14–16</sup> and three cohort studies<sup>17–19</sup> (*Table 5*) have previously suggested that VATS ablation is associated with greater success than CA. Accordingly, the European Society of Cardiology guidelines on AF (2016)<sup>2</sup> gave a Class IIa indication for standalone VATS AF ablation for non-paroxysmal AF. In contrast with the earlier comparative studies, why has no difference in success rates been found between catheter and VATS ablation by ourselves or by the most recent trialists?

**Table 4** Arrhythmia-free survival

	6 months	12 months	Last follow-up
Surgical			
Off AADs	16/28 (57.1%)	15/27 (55.6%)	13/29 (44.8%)
±AADs	20/28 (71.4%)	16/27 (59.3%)	15/29 (51.7%)
±RFCA and AADs	24/28 (85.7%)	21/27 (77.8%)	18/29 (62.1%)
Catheter			
Off AADs	54/84 (64.3%)	37/65 (56.9%)	50/90 (55.6%)
±AADs	61/84 (72.6%)	44/65 (67.7%)	53/90 (58.9%)
±RFCA and AADs	69/84 (82.1%)	52/65 (80.0%)	62/90 (68.9%)

AADs, Class I/IV antiarrhythmic drugs; RFCA, allowing for a single additional catheter ablation.



**Figure 2** Outcomes. Kaplan–Meier curves of survival free from atrial arrhythmias after 3-month blanking period. (A) Single procedure and (B) Allowing for a single additional catheter ablation.

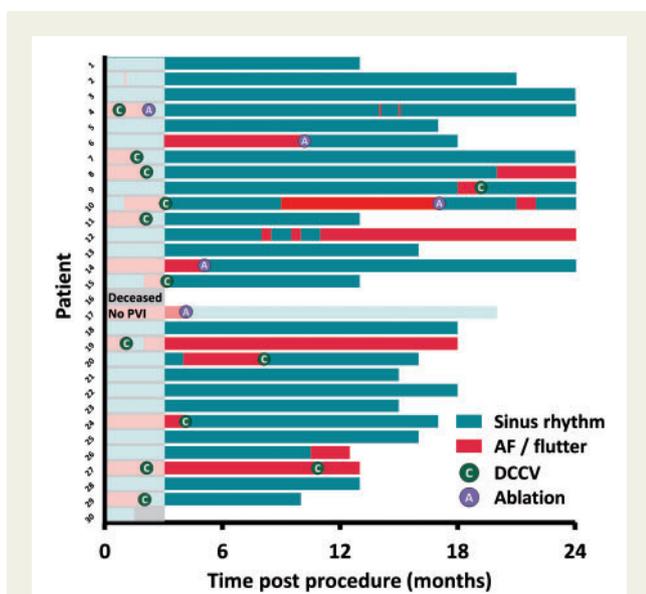
Firstly, it is highly likely that CA has become more effective since the earlier comparative trials shown in *Table 5* were reported. Most studies comparing VATS with CA recruited patients from 2006 to 2011, a period during which CA technology was rapidly evolving, and before contact force-sensing catheters were available. The 12-month success rates from CA in these studies are as low as 30% for paroxysmal<sup>16</sup> and 32% for persistent AF,<sup>19</sup> considerably lower than the 65%<sup>20</sup> reported in a recent meta-analysis of CA for persistent AF. However, the pooled estimates from meta-analyses of CA are similar to the results from CA presented here, suggesting that as CA technology has improved, the previously seen advantages of VATS AF ablation may no longer be as apparent. These rates of freedom from

recurrent arrhythmia seen following CA are similar to those following VATS ablation despite less linear ablation, consistent with studies showing no advantage to lesion sets beyond PVI.<sup>21</sup>

It is possible VATS ablation performed during a centre's early experience might be less effective than procedures performed after more experience has been accrued. As shown in *Table 5*, 12-month success rates ranged from 66% to 90%, similar to a recent meta-analysis reporting a pooled 12-month success of 72%.<sup>3</sup> However, many of these studies recruited a high proportion of patients with paroxysmal AF in whom ablation might be expected to be more successful. Furthermore, definitions of success varied across studies with some using only a point prevalence of sinus rhythm as their primary outcome, a definition which might inflate apparent success. In contrast, we used a guideline-derived definition of success in a cohort of patients with advanced disease. In view of this, our 12-month success rate of 59% in a cohort predominantly comprising non-paroxysmal AF is broadly comparable with the existing literature, suggesting that the impact of the learning curve on success rate has been small. When comparing rates of PV reconnection, the small proportion of patients who underwent repeat CA make comparisons with existing literature difficult. Bearing this in mind, the mean of 1.0 reconnected veins reported here is numerically but not statistically higher than the mean 0.4 veins per patient reported following simultaneous hybrid surgical and CA.<sup>22</sup>

Whilst the relative success rates of VATS and CA reported here differ from those reported elsewhere, our finding that thoracoscopic AF ablation is associated with a higher rate of major complications is consistent with previous work. Our complication rate from VATS ablation of 20% is similar to the 21–35% rate seen in trials in which outcomes have been reported jointly by cardiologists and surgeons (*Table 5*), although markedly higher than the 2.9% described in a recent meta-analysis of the surgical literature.<sup>4</sup> This meta-analysis acknowledged that under-reporting was likely to be present in many of the included case series which did not include a comparator arm.

The incidence of complications is highly variable within the surgical literature, for example the rate of conversion to sternotomy



**Figure 3** Cardiac rhythm following surgical ablation. DCCV, direct current cardioversion.

**Table 5** Comparison with other studies of catheter vs. surgical ablation

Study	n	Percentage of PAF	Recruitment	12-month success off AADs (%)		Major complication rate (%)		
				CA	SA	CA	SA	
Boersma <i>et al.</i> <sup>7</sup>	RCT	124	59%	2007–10	36	66	3	23
Pokushalov <i>et al.</i> <sup>15</sup>	RCT	64	56%	2011	47	81	2	21
Wang <i>et al.</i> <sup>14</sup>	RCT	138	100%	2008–12	75 <sup>a</sup>	89 <sup>a</sup>	–	–
Sugihara <i>et al.</i> <sup>16</sup>	RCT	70	100%	2012–15	30	90	0	35
Adiyaman <i>et al.</i> <sup>13</sup>	RCT	52	74%	Uncertain	56	33	0	22
Wang <i>et al.</i> <sup>17</sup>	Cohort	166	0%	2006–09	59	75	0 <sup>b</sup>	1 <sup>b</sup>
De Maat <i>et al.</i> <sup>18</sup>	Cohort	99	73%	2009–11	42	87	5	21
Haldar <i>et al.</i> <sup>19</sup>	Cohort	51	0%	2011–13	32	73	8	27
This study	Cohort	120	8%	2013–16	66	50	1	20

AADs, Class I/IV antiarrhythmic drugs; CA, catheter ablation; PAF, paroxysmal atrial fibrillation; RCT, randomized controlled trial; SA, surgical ablation.

<sup>a</sup>Point prevalence of sinus rhythm.

<sup>b</sup>Partial complication reporting only.

following bleeding varies from 0% to 10%.<sup>7,13,16,23–25</sup> Comparing composite complication rates is made even more challenging by variable definitions of major and minor complications. While we have used the Ottawa Thoracic Morbidity and Mortality classification system according to which complications requiring operative re-intervention e.g. pacemaker implant or pericardiocentesis are classed as major complications, other large series have described complications such as these as minor,<sup>26</sup> or avoided distinguishing between severities of complication,<sup>25</sup> confounding a direct comparison of headline figures. Higher rates of major complications have been associated with VATS ablation involving ganglionic plexus ablation,<sup>27</sup> but the majority of cases described in this series had already taken place before the AFACT study describing this association had been published.

Our complication rate from CA is slightly lower than reported in other comparative trials, potentially due to our routine use of ultrasound-guided vascular access minimizing the risk of vascular complications.<sup>10</sup>

## Limitations

While the surgeon who performed the thoracoscopic ablation was highly experienced in thoracoscopic surgery, this series of cases fell within his learning curve for VATS AF ablation. To compare surgical results with an established high-volume CA service could be considered unfair. However, 20 of the first 30 VATS cases were proctored by experienced surgeons from other centres. Furthermore, our experience reflects the reality of any new surgical AF service establishing itself in an era when CA AF ablation has become commonplace.

The usage of ambulatory monitoring was lower in the CA cohort, potentially missing AF recurrences and overestimating CA success. However, the incremental benefit of ambulatory monitoring over 12-lead ECGs lies in the detection of asymptomatic paroxysmal AF. The overwhelming majority of patients in both cohorts had symptomatic persistent or longstanding-persistent AF. Given the sustained nature of the arrhythmias experienced by these patients, it is unsurprising that no patient in either cohort had a recurrence of AF detected solely on ambulatory monitoring which was not also documented on 12-lead ECG. Any overestimation of success in the CA cohort caused by a lower use of ambulatory monitoring is therefore likely to be small.

In addition to preventing recurring arrhythmia, the VATS cohort also underwent LAA exclusion with the aim of reducing long-term stroke risk. The outcomes reported here do not take into account this potentially important benefit. Performing routine LAA exclusion and performing a more extensive lesion set in the CA cohort may have led to higher complication rates. It is possible the lesions created by VATS ablation are more durable, and that isolation of the left trial appendage may have reduced long-term risk of stroke, and extended follow-up may therefore have revealed a difference between groups.

The data on the VATS cohort were collected and assessed prospectively, whereas the data from the matched CA cohort were collected prospectively but collated retrospectively (once propensity matching had identified relevant patients). While major complications are likely to have been identified, it is possible that minor complications in the CA group may have been missed. However, it remains unlikely that a potential under-reporting of minor complications in the CA cohort would influence the overall message that the major

complication rate for VATS ablation is significantly higher than those reported by selected high-volume centres. Finally, although every attempt has been made to provide a representative comparator group for the VATS ablation group, the accuracy of propensity matching is reduced when dealing with small cohorts. The demographics of the two cohorts appear well matched, but possible residual differences in unmeasured characteristics cannot be excluded.

## Conclusions

Comparing two groups of patients with advanced AF, we suggest that during a centre's initial experience VATS ablation may be associated with similar success rates to CA, but that VATS ablation may carry a considerably higher complication rate. Cardiothoracic units considering establishing a VATS ablation programme should be aware that initial results may not match the results reported by some established high-volume centres, and that CA may potentially offer equivalent success rates at a lower risk of complications. These findings highlight the need for verification of long-term outcomes using randomized trials comparing VATS ablation with current CA technology.

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