Stand-alone minimally invasive surgical bipolar radiofrequency ablation for atrial fibrillation

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July 2011
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Summary

- Cardiac ablation is an established treatment which is often curative in atrial fibrillation. It is usually carried out in addition to other cardiac surgery such as valve replacement. Stand-alone surgical ablation permits the use of minimally invasive surgical techniques.

- There is a large volume of generally low quality evidence specifically for stand-alone minimally invasive surgical bipolar radio-frequency ablation of AF. In addition, there is also more general evidence for certain aspects of the technique. The evidence demonstrates high rates of treatment success which may correlate to the underlying AF diagnosis (e.g. paroxysmal vs. persistent vs. permanent). The evidence is confounded by considerable variation in the technique and procedure undertaken.

- The safety of the intervention is not easy to ascertain from the available evidence. Serious complications occur in about 5% to 10% of cases but reporting is inconsistent and irregular. Many patients still require anti-arrhythmic drugs or go on to have further treatments for atrial fibrillation.

- A single intervention is estimated to cost between £13,000 and £14,000. This does not include any allowance for surgical complications. Considerable off-set costs exist especially in relation to catheter ablation, where costs can sometimes escalate due to repeated procedures.

- The intervention has been positively appraised by NICE based on a reduced volume of evidence. The surgical team to which the application relates already provide the intervention to non- NHS North East patients. No additional equipment or training costs are envisaged.

- The intervention may be targeted at patients for whom catheter ablation is considered unsuitable or contra-indicated, for example:
  - Patients at high risk of stroke
  - Patients who are highly anxious of a higher risk of stroke associated with catheter ablation
  - Patients unsuitable for anticoagulation
  - Technical or anatomical difficulties which preclude catheter ablation
Introduction

Ablation of cardiac tissue is an established surgical technique which is used to control the pattern of electrical signals travelling over the heart and thus control the contraction of cardiac muscle. In this way it is possible to cure conditions such as atrial fibrillation and other cardiac arrhythmias. 1-7

There are several methods used to surgically ablate cardiac tissue including the creation of surgical scar tissue, cryotherapy (freeze burns), and thermal coagulation of tissue by application of energy sources such as microwaves and high-frequency radio waves. The use of bipolar radiofrequency ablation requires the insertion of probes into the heart in a clamp-like fashion between which the high-frequency radio waves can be applied. As the waves travel from one probe to the other through the cardiac tissue (the heart wall) the tissue coagulates and leaves behind a small scar. This scar is unable to conduct the electrical impulses which pass over the heart tissue and in this way the pattern and path of electrical impulses and hence heart contraction can be controlled depending on the position of the scars. The advantage of the bipolar clamp technique as opposed to a unipolar surface-application is a better penetration and more complete coagulation of cardiac tissue. 1-7

There are ‘standard’ patterns of scar lesions and variants thereof which are used to control electrical conduction across the heart. One of the most commonly used is an extensive set of lesions known as the Cox-Maze procedure. Another commonly used technique is to isolate the pulmonary veins which exit the atria as these are believed to be a common site for the initiation of unwanted electrical impulses. More recent additions to lesion sets have sought to isolate particular nerve centres known as ganglionic plexi which are also thought to be common sites for the propagation of unwanted electrical impulses in cardiac tissue. Along with the ablation of cardiac tissue in this way, patients will often at the same time have their left atrial appendage excluded either through complete excision or surgical closure. 1-7

Atrial fibrillation may be described as paroxysmal, persistent or permanent. Paroxysmal AF is an intermittent arrhythmia occurring for up to seven days at a time. Persistent AF is also an intermittent arrhythmia although each incidence will persist for longer periods of time and for at least seven days. Persistent AF can be converted (terminated) with drugs or electrical cardioversion. Permanent AF is an established and essentially continuous arrhythmia unresponsive to any cardioversion. 8
Cardiac tissue, especially the pulmonary veins, can also be ablated through use of percutaneous catheter-based ablation techniques, for example percutaneous catheter radiofrequency ablation. However the procedure requires pre- and intra-operative imaging and often requires repeated applications to achieve AF absence (normal sinus rhythm) and carries risks such as pulmonary vein stenosis. \(^7,9\)

Minimally invasive cardiac surgery will still require the patient to be under general anaesthesia, but without the need to make large incisions through the chest wall (i.e. avoiding open-chest or open-heart surgery). Instead smaller incisions are made in one or both of the sides of the chest with special probes inserted to deliver the necessary equipment to the heart. The major advantage is that the surgery is conducted ‘off-pump’, that is, the patient’s own heart remains beating throughout. Compared with standard cardiothoracic surgery, minimally invasive surgery is considered to result in fewer intra- and post-operative complications, shorter duration of surgery and faster recovery. \(^2,10\)

The NHS North East Treatment Advisory Group has been requested, by the Coronary Heart Disease Commissioners Group of the North of England Cardiovascular Network to conduct an appraisal of and issue a treatment recommendation for the [intervention] following receipt of a specific service development request from a single treatment centre. The centre currently provides the intervention although there is currently no agreement in place for NHS North East patients.
Clinical Evidence

An extensive literature search specifically for the use of bipolar RF ablation techniques via minimally invasive surgery for the stand-alone treatment of AF revealed a large volume of data, all of which has been published within the preceding ten years. This data is summarised in Appendix 1. Note that there is a wider volume of associated evidence relating to use of; unipolar RF ablation, minimally invasive surgical ablation using non-RF energy sources, conventional open surgical RF ablation, RF ablation carried out during other scheduled cardiac surgery (i.e. not stand alone ablation). This has not been considered within this appraisal.

Summary of the clinical evidence

Despite the large volume of data summarised in appendix 1 this is not believed to be exhaustive as identifying the relevant evidence was confounded by highly varied terminology. Indeed, much of the data was identified via cross-referencing of other articles or reviews articles. No comparative studies were identified, which is surprising given the wide use of percutaneous catheter ablation procedures, a procedure that might reasonably have made for a useful control group.

There are some consistent features of the data:

Study design - all are case series reports, some prospective with specific criteria defined, others retrospective with less stringent criteria.

Basic patient demographics – mean ages were consistently in the 6th and 7th decades of life and gender was heavily skewed towards males. However, although mean ages showed little variation the actual ages of included patients did vary considerably between some relatively young and some more elderly patients.

Efficacy – where differentially reported, attainment of normal hearth rhythm was greatest in patients with paroxysmal AF with slightly lower rates in persistent AF and noticeably lower rates again in permanent AF. Efficacy rates were typically > 80% and often > 90% with paroxysmal and persistent AF, compared with permanent AF where rates were often < 70%. Permanent AF cases were usually the minority group accounting for < 25% in each case series.

There are also some inconsistent features in the evidence base:

Reporting of end points – most studies report the attainment of normal sinus rhythm as the ultimate goal of therapy however the method of ascertaining this endpoint varied between electrocardiogram and more robust 24-hr monitoring.
Regardless, the pattern of results remained, with greatest efficacy seen in paroxysmal > persistent >> permanent. Some studies also defined absence of AF only where drug treatment was also ceased.

Follow-up – there is considerable variation in follow-up ranging from three months to more than two years. Follow-up does not obviously correlate with efficacy although there may be a trend towards lower efficacy with longer follow-up leading to uncertainty about the long term benefits of treatment.

Pre-surgical interventions – where reported, there was considerable variation in the extent of application of other interventions to manage AF such as catheter ablation, pharmacological cardioversion and electrical cardioversion.

Surgical technique - there were variations in the specific surgical procedures used. Most case series utilised video-assisted bilateral minithoracotomy for bilateral pulmonary vein isolation. Many teams would also intend to exclude the left atrial appendage using different techniques. However LAA exclusion was not always achieved with variable completion rates evident. More recent case series sometimes involved the ablation of specific ganglionic plexi and other electrical foci which testing, usually intra-operatively, had identified as being arrhythmogenic. None of the case series reports had attempted to achieve the full Cox-maze set of lesions, which are presumed to be too complex for existing minimally invasive surgical techniques. There is evidence for stand-alone Cox-maze lesion ablation but not using minimally invasive surgical techniques. It is possible that, as surgical techniques advance, it does become possible to achieve the full Cox-maze lesion set via minimally invasive surgical techniques. The Cox-maze lesion set is still considered to be the most effective treatment for AF although the surgery required to achieve it may present a high risk unless open-chest surgery is being performed anyway, e.g. for valve repair/replacement.

Post-surgical interventions – in many cases an eventual cure was only achieved with extensive use of other interventions including drugs, surgical interventions and electrophysiological interventions. However the rates or reporting thereof was inconsistent between studies.

Safety - It is difficult to accurately calculate the complication rate, whether serious/major or minor complications. This is partly due to differences in the surgical techniques but also due to inconsistent reporting between studies. It would appear that the rate is seldom > 10%. Overall safety is not well reported and is seldom the focus of the clinical reports. Safety may be highly dependent on local practices and experience.
Guidance

NICE has published interventional procedure guidance regarding several aspects of cardiac ablation for AF including, in January 2009, guidance specifically for minimally invasive RF ablation. Since the associated evidence overview was completed in May 2008, a large volume of new evidence has become available (see appendix 1). Some of the studies referred to in appendix 1 of this report were also included in the NICE evidence overview. NICE guidance focused primarily on four cases series reports with 138 patients (references A, E, K and Q in appendix 1; other included references are C and R plus a case report). NICE guidance summarised as:  

‘There is evidence of efficacy for thorascopic epicardial radiofrequency ablation for atrial fibrillation (AF) in the short term and in small numbers of patients. The assessment of cardiac rhythm during follow-up varied between studies, and some patients were concomitantly treated with anti-arrhythmic medication. Evidence on safety shows a low incidence of serious complications but this is also based on a limited number of patients. Therefore the procedure should only be used with special arrangements for clinical governance, consent and audit or research.’

Guidance has also been published jointly from several European and American cardiac clinical groups. These guidelines were published in 2007 before much of the evidence relating to stand-alone minimally invasive surgical ablation was published, with a greater proportion of evidence relating to open-chest surgery. Nonetheless, the guidelines make the following recommendation:  

‘Stand-alone AF surgery should be considered for symptomatic AF patients who prefer a surgical approach, have failed one or more attempts at catheter ablation, or are not candidates for catheter ablation. Minimally invasive approaches presently in development could expand the indications for stand-alone surgery [for] AF in the future.’

However the guidance also cautions:  

‘The referral of patients for surgery with symptomatic, medically refractory AF in lieu of catheter ablation remains controversial. There have been no head-to-head comparisons of the outcomes of catheter and surgical ablation of AF. The decision-making in these instances needs to be based on each institution’s experience with catheter ablation and surgical ablation of AF, the relative outcomes and risks of each in the individual patient, and patient preference.’
Cost analysis

It is assumed that minimally invasive cardiac surgery with RF ablation is performed under payment-by-results tariff code EA22Z ‘Other complex cardiac surgery with percutaneous coronary intervention, pacing, EP or RFA’ at £13,107. It is expected that there will be no additional tariff-excluded costs incurred with this tariff code. Note that this differs to the original application which assumed a tariff code of EA20Z ‘Other complex cardiac surgery and Re-do’s’ plus tariff-excluded equipment at a total cost of £13,761. This suggests that the equipment cost is £4,505 based on the 2010 tariff value. The current value of EA20Z is £9,827 which would suggest that if the application cost assumptions are correct the 2011-12 price of the intervention would be £14,332. Therefore the intervention cost used in this analysis is £1,225 less than that estimated by the clinical team.

The number of procedures which are expected to be performed has been estimated at 50 per annum for a population catchment of 1.5 million. The estimate has been derived thus:

Acute trust catchment population for specialist cardiology referrals: 1.5 million
Incidence of AF in general population: 1.28% = 19,200
AF population referred to acute services: 5% = 960
Referred to arrhythmia service: 750 (i.e. 78%)
Suitable for ablation therapy: 30% = 225
Likely to be treated with stand-alone minimally invasive RF ablation: 20% = 45 (rounded to 50)

Some of these figures do not appear to be based on any robust data. Nonetheless, if this estimate is assumed to be correct, and the treatment was available throughout NHS North East (e.g. if other treatment centres also provided the intervention) then the estimated annual treatment pool within NHS North East will be about 100 patients.

If this intervention is not available potential patients might reasonably be expected to be treated with an alternative intervention. For example, patients might instead be treated with percutaneous catheter ablation, under tariff code EA29Z ‘Percutaneous complex ablation (includes atrial fibrillation or ventricular tachycardia)’ with a value of £3,149. The original application indicates that the minimum cost of catheter ablation is £5,342 which includes the cost of tariff-excluded consumables. Therefore the consumables are estimated to cost £2,084 suggesting that the current value of this intervention is actually £5,426. The
original application states that it is not uncommon for more than one episode of catheter ablation to be required until an effective cure is achieved, thus actual costs are estimated at £10,852 for two interventions and £16,278 for three interventions. No evidence is provided to estimate the number of catheter ablation procedures that could be avoided if a patient is successfully cured with stand-alone minimally invasive RF ablation for AF and therefore a mean cost for catheter ablation has not calculated. A re-ablation rate of 20 to 40% has been reported in cases of recurrent AF or atrial tachycardia following a prior ablation procedure.  

Table 1. Estimated cost per annum for NHS North East primary care organisations for stand-alone minimally invasive RF ablation of AF

<table>
<thead>
<tr>
<th>Primary Care Cluster</th>
<th>Primary Care Trust</th>
<th>NHS North East population</th>
<th>Interventions per annum</th>
<th>Cost of interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durham &amp; Darlington</td>
<td>County Durham</td>
<td>20.0%</td>
<td>24</td>
<td>£315,000</td>
</tr>
<tr>
<td></td>
<td>Darlington</td>
<td>3.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North of Tyne</td>
<td>Newcastle</td>
<td>10.2%</td>
<td>30</td>
<td>£393,000</td>
</tr>
<tr>
<td></td>
<td>North Tyneside</td>
<td>8.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Northumberland</td>
<td>12.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South of Tyne</td>
<td>Gateshead</td>
<td>7.5%</td>
<td>24</td>
<td>£315,000</td>
</tr>
<tr>
<td></td>
<td>South Tyneside</td>
<td>5.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sunderland</td>
<td>10.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tees</td>
<td>Hartlepool</td>
<td>3.6%</td>
<td>22</td>
<td>£288,000</td>
</tr>
<tr>
<td></td>
<td>Middlesbrough</td>
<td>5.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>North Tees</td>
<td>7.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Redcar &amp; Cleveland</td>
<td>5.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHS North East</td>
<td></td>
<td>100%</td>
<td>100</td>
<td>£1.311 million</td>
</tr>
</tbody>
</table>

In addition to off-set costs relating to other cardiac interventions, the studies (appendix 1) also demonstrated high rates of medication withdrawal in patients who achieve normal heart rhythm. However, the potential direct savings from reduced medication use are limited as many of the drugs used to treat AF are low-cost. Additional savings may be realised indirectly through reduced medication use (e.g. from a reduction in adverse effects) although the impact is likely to be limited and difficult to predict. More significant savings can be realised where a patient is able to cease anticoagulant drug therapy especially if it is associated with frequent monitoring such as with warfarin.
Points to consider

Stand-alone minimally invasive surgical RF ablation therapy for AF has demonstrated high rates of efficacy in numerous studies with typical rates of 70 to 80% or more. However, there is considerable variation in the specific procedure undertaken. In addition, the evidence indicates that cure rates are greatest with paroxysmal AF with slightly lower cure rates in persistent AF and lower still with permanent AF. The quality of the evidence is generally poor with no randomised or comparative studies.

Stand-alone minimally invasive surgical RF ablation is associated with a significant burden of complications although patients may already be at higher risk of such complications by the nature and severity of the underlying condition. Indeed, minimally invasive techniques have been developed to minimise surgical risks compared with open-chest surgery. In addition to surgical complications, a significant proportion of patients are only able to achieve normal heart rhythm with further interventions such as cardioversion and catheter ablation. Therefore it is not possible to consider the intervention as singularly curative.

The original application indicates that the intervention is considered only when catheter ablation therapy is contra-indicated. Examples of situations in which catheter ablation is contra-indicated include:

- Patients at high risk of stroke
- Patients who are highly anxious of a higher risk of stroke associated with catheter ablation
- Patients unsuitable for anticoagulation
- Technical or anatomical difficulties which preclude catheter ablation

The cost of the intervention is estimated at about £13,000. This does not include the cost of associated complications. Substantial offset costs may exist, for example catheter ablation is estimated to cost about £5,500 per episode of which multiple episodes are often required, and other savings may arise through reduced medication use. The estimated patient population within NHS North East is 100 per annum. No epidemiological data was identified to support this estimate and therefore its reliability is not known. The cost of treating 100 patients is estimated at about £1.3 million.

The intervention is already provided at the treatment centre from which the application originates. However the intervention is not currently provided for NHS North East patients as there is currently no agreement in place. No additional equipment or training requirements are anticipated.
References

1. NICE. Interventional procedures overview of radiofrequency ablation for atrial fibrillation as an associated procedure with other cardiac surgery. July 2004

2. NICE. Interventional procedure overview of thorascopic epicardial radiofrequency ablation for atrial fibrillation. May 2008

3. NICE. Interventional procedures overview of microwave ablation for atrial fibrillation as an associated procedure with other cardiac surgery. July 2004

4. NICE. Interventional procedure overview of high-intensity focused ultrasound ablation for atrial fibrillation as an associated procedure with other cardiac surgery. October 2005

5. NICE. Interventional procedures overview of cryoablation for atrial fibrillation as an associated procedure with other cardiac surgery. July 2004


9. NICE. Percutaneous (non-thorascopic) epicardial catheter radiofrequency ablation for atrial fibrillation: Interventional procedure guidance 294. March 2009


Author’s declaration. The author has no relevant interests to declare.
### Appendix 1. Summary table of published studies relating to stand-alone minimally invasive bipolar radiofrequency ablation for the treatment of atrial fibrillation

<table>
<thead>
<tr>
<th>Ref</th>
<th>Patients</th>
<th>Technique</th>
<th>Follow-up</th>
<th>Outcome</th>
<th>Complications</th>
</tr>
</thead>
</table>
| A   | n = 70  
Mean age 53 yrs  | Minithoracotomy to right PVI and mitral annulus isolation | 12 months. | ~96% in sinus rhythm | One oesophageal perforation. One coronary artery stenosis. |
| B   | n = 74  
Mean age 53 yrs  | Minithoracotomy to right PVI and mitral annulus isolation | Up to 12 months | Sinus rhythm at discharge: 92%; at 6 months (n = 38) 97%; at 12 months (n = 16) 94%. | Frequent, but not reported for specific subgroup. |
| C   | n = 27  
Mean age 57 yrs  | VAT bilateral PVI and LAA exclusion | 3 months (n = 23) | Absence of AF: 92% | None. |
| D   | n = 9    
Mean age 60 yrs  | Thoracoscopic bilateral PVI and LAA exclusion | Mean 9.3 months (range 8 to 11) | Sinus rhythm: 78% | Two unilateral diaphragm paralysis |
| E   | n = 20   
Mean age 57 yrs  | Minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi | 3 months | Sinus rhythm: 90% | Three instances of peri- or post-operative bleeding with one conversion to open chest surgery. |
| F   | n = 10   
Mean age 51 yrs  | VAT bilateral PVI | Mean 6 months (range 3 to 12) | Absence of AF: 80% | Six instances of post-operative complications. |
| G   | n = 100  
Mean age 65 yrs  | VA minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi | Not clear. Mean 13.6 months; all had assessment at 3 months | Normal sinus rhythm: 87%
By baseline AF subtype:
Persist: 96%
Paroxysmal: 93%
Permanent: 71%
(p = 0.03) | Post-operative procedure-related complications: 14%
Including permanent pacemaker: 5%
No conversions to open-chest surgery or in-hospital fatalities (≤ 30 days). |
| H   | n = 43   
Mean age 57 yrs  | Thorascopic bilateral PVI, LAA exclusion and ablation of ganglionic plexi | Only 33 patients with 12 month efficacy assessments. Safety data from whole cohort. | Absence of AF: 76%
QoL (SF36) improved significantly compared with baseline in seven of eight domains. Total symptom scores (range 5 to 25) significantly decreased from baseline; 15.2 to 10.7 (p = 0.02). | One procedure not completed due to intra-operative bleeding and several procedures not completed as intended due to complications. There were no peri-operative or late fatalities directly related to the surgery. There were 17 major peri-operative complications including six haemorrhages, and five late surgical complications. |
Appendix 1 continued.

<table>
<thead>
<tr>
<th>Ref</th>
<th>Patients</th>
<th>Technique</th>
<th>Follow-up</th>
<th>Outcome</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>I *</td>
<td>n = 203</td>
<td>Mean age 61 yrs</td>
<td>VA minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>Not specified. Mean 10 months.</td>
<td>Normal sinus rhythm: 83% No surgery-related fatalities. 11 serious procedure-related adverse events.</td>
</tr>
<tr>
<td>J</td>
<td>n = 74</td>
<td>Mean age 60 yrs</td>
<td>VA minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>6 months (n = 70)</td>
<td>Normal sinus rhythm: 74 to 93% depending on measurement method Four serious operative complications including one fatality.</td>
</tr>
<tr>
<td>K</td>
<td>n = 26</td>
<td>Mean age 55 yrs</td>
<td>VA minithoracotomy to bilateral PVI and LAA exclusion</td>
<td>Mean 8.1 months (range 6.2 to 11.3)</td>
<td>Sinus rhythm: 69% No major operative complications or fatalities, two serious operative complications.</td>
</tr>
<tr>
<td>L**</td>
<td>n = 52</td>
<td>Mean age 60 yrs</td>
<td>VA minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>12 months</td>
<td>Normal sinus rhythm: 81 to 86% depending on measurement method No major operative complications or fatalities, one minor operative complication, three patients later required permanent pacemaker and two patients had subsequent cardioversion.</td>
</tr>
<tr>
<td>M</td>
<td>n = 45</td>
<td>Mean age 64 yrs</td>
<td>Minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>One-year</td>
<td>Sinus rhythm and absence of AF drugs: 62% There were five serious peri- and post-operative complications and no fatalities.</td>
</tr>
<tr>
<td>N</td>
<td>n = 46</td>
<td>Mean age ~63 yrs</td>
<td>Minithoracotomy to bilateral PVI</td>
<td>6 months</td>
<td>Recurrence of AF: 13% (n = 6) Significant improvement in functional ability. No cases of post-operative bleeding or infectious complications. No fatalities. Extensive use of additional rhythm control methods (e.g. 46% underwent electrical cardioversion).</td>
</tr>
<tr>
<td>O ***</td>
<td>n = 45</td>
<td>Mean age not stated</td>
<td>Minithoracotomy to bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>Mean 29 months</td>
<td>Absence of atrial tachycardia: 35% Recurrence: 65% No fatalities. Three transient ischaemic attacks occurring 9 to 30 months post-surgery.</td>
</tr>
</tbody>
</table>
Appendix 1 continued.

<table>
<thead>
<tr>
<th>Ref</th>
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<th>Technique</th>
<th>Follow-up</th>
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<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>n = 81</td>
<td>VAT bilateral PVI and LAA exclusion</td>
<td>6 months (n = 79) and 12 months (n = 49)</td>
<td>Normal sinus rhythm: 79% and 80% respectively</td>
<td>One required open-heart surgery. One death cerebral infarction &lt; 30 days of surgery. One patient re-intubated and one case of acute heart failure.</td>
</tr>
<tr>
<td>Q</td>
<td>n = 22</td>
<td>VAT bilateral PVI and LAA exclusion</td>
<td>Mean 18 months (range 12 to 27)</td>
<td>Normal sinus rhythm: 91%</td>
<td>Two major surgical complications. One patient underwent subsequent catheter ablation.</td>
</tr>
<tr>
<td>R</td>
<td>n = 6</td>
<td>VAT bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>3 months (n = 4)</td>
<td>Normal sinus rhythm: 100%</td>
<td>Subsequent post-operative electrical cardioversion in three patients.</td>
</tr>
<tr>
<td>S</td>
<td>N = 20</td>
<td>VAT to bilateral PVI, LAA exclusion and ablation of ganglionic plexi</td>
<td>Mean 17 months</td>
<td>Failure not otherwise specified (assumed to be recurrence of AF): 25%</td>
<td>One incident of haemothorax which required transfusion. No other complications.</td>
</tr>
</tbody>
</table>

**Key**

AF: Atrial fibrillation. LAA: Left atrial appendage. PVI: Pulmonary vein isolation. QoL: Quality of life. SF36: Short-form 36 health questionnaire. VAT: Video-assisted thoracotomy or thoracoscopy.

* : Abstract data only. Some indications that there is cross-over of patient cohorts reported in references G and I.
**: Some patients also previously reported within reference J.
***: Abstract data only. Possibly some cross-over of patient cohorts reported in reference M.
References (Appendix 1 only)


O. Han FT et al. Long-term follow-up results of minimally invasive surgical ablation for atrial fibrillation (MISAA). Heart Rhythm 2010;7(5):S23-4


