NATIONAL INSTITUTE FOR CLINICAL EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedures overview of radiofrequency ablation for atrial fibrillation as an associated procedure with other cardiac surgery

Introduction

This overview has been prepared to assist members of the Interventional Procedures Advisory Committee (IPAC) in making recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and specialist opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in July 2004.

Procedure name

- Radiofrequency ablation for atrial fibrillation as an associated procedure with other cardiac surgery.

Specialty societies

- Society of Cardiothoracic Surgeons in Great Britain and Ireland.
- British Pacing and Electrophysiology Group.

Description

Indications

Atrial fibrillation.

Atrial fibrillation is the irregular and rapid beating of the upper two chambers of the heart (the atria). It may be classified as paroxysmal, persistent or permanent. It is the most common type of arrhythmia, affecting approximately 0.5% of the adult population[1]. The incidence increases markedly with age. Patients with atrial fibrillation may be asymptomatic or they may have symptoms including palpitations, dizziness and breathlessness. They also have an increased risk of stroke as a result of blood clots forming in the left atrium and then embolising to the brain.

Although atrial fibrillation may occur in the absence of other heart disease, it is particularly common in patients with mitral valve disease. Patients with a history of atrial fibrillation for longer than a year are less likely to be restored to normal sinus rhythm after mitral valve surgery alone than patients with intermittent atrial fibrillation or those who have had atrial fibrillation for less than a year.

Current treatment and alternatives

Conservative treatments include medications to control the heart rhythm and rate, electrical cardioversion and anticoagulants to prevent blood clots forming. A surgical treatment known as the Cox maze procedure was developed to treat atrial fibrillation. This is usually performed at the same time as open heart surgery for another indication, such as mitral valve disease. Multiple strategically placed incisions are made in both atria to isolate and stop the abnormal electrical impulses. All the incisions are then sutured and a 'maze' of scar tissue subsequently forms at the incision sites, which blocks the electrical impulses from travelling through the atrium. A single pathway is left intact for the impulse to travel between the chambers of the heart.

What the procedure involves

Radiofrequency ablation of the atria can be performed via a catheter introduced through a femoral vein but surgical radiofrequency ablation for atrial fibrillation is typically carried out in patients undergoing concomitant open-heart surgery, including mitral valve replacement or repair. Radiofrequency is used to create lines of ablation rather than the incisions created in the traditional Cox maze surgery. The procedure may be carried out on both atria or on the left atrium only.

Mitral valve surgery is usually performed through a median sternotomy. The patient is connected to a cardiopulmonary bypass machine and an incision is made to enter the left atrium. Radiofrequency ablation may be performed before or after the concomitant cardiac surgical procedure. A flexible radiofrequency probe is used to create linear ablation lesions in the left atrium. The heat generated by the probe coagulates the heart tissue, forming scars along the ablation lines that disrupt the transmission of the electrical impulses. The procedure may then be repeated in the right atrium. The ablation can be performed from within or outside the atrium.

The alternative Cox maze procedure is complex and time consuming. The radiofrequency ablation approach takes less time and is reported to be easier to perform.

Efficacy

In one small randomised controlled trial, 82% (9/11) of patients having atrial radiofrequency ablation and a mitral valve replacement were in sinus rhythm at 12 months, compared with 21% (3/14) of patients having a mitral valve replacement alone ($p < 0.05$). One non randomised controlled trial reported that 81% (83/102) of patients having atrial radiofrequency ablation and cardiac surgery were in sinus rhythm at a mean follow-up of 12.5 months, compared with 11% (3/27) of patients having cardiac surgery without radiofrequency ablation ($p < 0.0001$).

A second non-randomised controlled trial compared radiofrequency ablation with the traditional Cox maze procedure. This reported that 89% of patients having radiofrequency ablation were in sinus rhythm, compared with 69% of patients treated with the Cox maze surgery ($p = 0.53$).

One Specialist Advisor mentioned that the conversion to sinus rhythm is temporary and that antiarrhythmia drugs are required for at least 6 months after the procedure. Another Specialist Advisor stated that there are uncertainties about the efficacy because there is a lack of unanimity as to the correct lesion set to use.

Safety

Because the radiofrequency ablation is performed with concomitant cardiac surgery, it is difficult to differentiate those complications that are specifically related to the radiofrequency ablation.

In-hospital mortality was reported by six studies, including a total of 841 patients, and ranged from 0.8% (1/132) to 7.5% (3/40). One death was reported to be the result of an oesophageal perforation. One study noted that none of the perioperative deaths were considered to be related to the use of radiofrequency ablation.

Two studies reported that 2% (3/132) and 8% (18/234) of patients needed reexploration for bleeding and two studies reported that 0.8% (2/234) and 8% (16/200) of patients had reoperations. Other less common complications included the need for an intraaortic balloon pump, sternal wound infection, stroke, atrio-oesophageal perforation and left atrial thrombus.

The Specialist Advisors listed the potential adverse effects as heart block, perforation of the heart, coronary artery damage and perforation of the oesophagus.

Literature review

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to intraoperative radiofrequency ablation for atrial fibrillation with mitral valve surgery. Searches were conducted via the following databases, covering the period from their commencement to April 2004 (updated to January 2005): MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and Science Citation Index. Trial registries and the Internet were also searched. No language restriction was applied to the searches.

The following selection criteria (Table 1) were applied to the abstracts identified by the literature search. Where these criteria could not be determined from the abstracts the full paper was retrieved.

Table 1 Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies included. Emphasis was placed on identifying good quality studies. Case-series with fewer than 40 cases were excluded. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, laboratory or animal study.
Patient	Patients with atrial fibrillation and requiring concomitant cardiac surgery.
Intervention/test	Intraoperative radiofrequency ablation of the atria.
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the overview

This overview is based on seven studies, including one small randomised controlled trial[2], two non-randomised comparative studies[3,4] and four case series studies.[5,6,7,8]

The randomised controlled trial and one of the non-randomised comparative studies compare patients given intraoperative radiofrequency ablation of the atria and heart

surgery with those patients given heart surgery only.[2,3] The second non-randomised comparative study compares patients given intraoperative radiofrequency of the atria with patients treated with conventional Cox maze surgery.[4]

Table 2 Summary of key efficacy and safety findings on intraoperative radiofrequency ablation for atrial fibrillation with concomitant cardiac surgery

Study Details	Key efficacy findings	Key safety findings	Comments
Deneke T (2002)[2] Randomised controlled trial 1998 – 1999 Germany 30 patients • 50% (15/30) mitral valve replacement and intraoperative radiofrequency ablation • 50% (15/30) mitral valve replacement only Mean age: 68 years (range 49 to 77 years) 30% (9/30) men, 70% (21/30) women Follow-up: 12 months Indications: mitral valve disease and chronic atrial fibrillation (permanent atrial fibrillation for 1 year or at least two non-successful medical or electrical cardioversions 6 months before surgery)	Spontaneous conversion to sinus rhythm on postoperative day 1: • mitral valve replacement and radiofrequency ablation = 53.3% (8/15) • mitral valve replacement only = 26.7% (4/15) Sinus rhythm after postoperative electric direct current shock cardioversion: • mitral valve replacement and radiofrequency ablation = 50.0% (3/6) • mitral valve replacement only = 0% (0/2) Sinus rhythm at 12 month follow-up (with or without electric direct current shock cardioversion): • mitral valve replacement and radiofrequency ablation = 81.8% (9/11) • mitral valve replacement only = 21.4% (3/14) $p < 0.05$ Overall survival at 12 months: • mitral valve replacement and radiofrequency ablation = 73.3% (11/15) • mitral valve replacement only = 93.3% (14/15) $p = 0.131$	**Complications** No systemic thromboembolic complications Deaths in patients treated with mitral valve replacement and radiofrequency ablation: • 1 after 40 days due to renal bleeding • 1 after 45 days from mediastinitis • 1 after 4 months due to sudden cardiac event • 1 after 7 months due to respiratory insufficiency following severe lung fibrosis Deaths in patients treated with mitral valve replacement only: 1 after 10 months due to respiratory insufficiency following chronic obstructive bronchial disease	Method of randomisation not described. Biatrial ablation. Small patient numbers. Short term follow-up. Cooled-tip radiofrequency probe used (irrigated with saline). Antiarrhythmia medication was administered to all patients after the procedure.

Study Details	Key efficacy findings	Key safety findings	Comments
Mantovan R (2003)[3] Non-randomised controlled study (multicentre) 1999 – 2001 Italy 130 patients • 79.2% (103/130) intraoperative radiofrequency ablation • 20.8% (27/130) cardiac surgery without radiofrequency ablation Mean age: • radiofrequency ablation = 62 years • surgery only = 64 years 34.6% (45/130) men, 65.4% (85/130) women Mean follow-up: 12.5 months (range 4 to 24 months) Mean duration of preoperative atrial fibrillation: • radiofrequency ablation = 42 months • surgery only = 40 months Concomitant surgical procedures: mitral valve surgery (n = 114), aortic valve surgery (n = 41), tricuspid surgery (n = 22), coronary artery bypass (n = 8), atrial septal defect (n = 6), other (n = 2)	Sinus rhythm after surgery: • radiofrequency ablation = 79% (81/103) • surgery only = 26% (7/27) p < 0.0001 Sinus rhythm at follow-up: • radiofrequency ablation = 81% (83/102) • surgery only = 11% (3/27) p < 0.0001 Biatrial contraction in patients with sinus rhythm: • radiofrequency ablation = 79.5% (66/83) • surgery only = 100% (3/3)	**Complications** Radiofrequency ablation: • left atrial thrombus = 2.9% (3/103) • in-hospital mortality = 1.0% (1/103) (after oesophageal perforation) • pneumothorax = 1.0% (1/103) • pleural effusion = 1.0% (1/103) • transitory ischaemic attack = 1.0% (1/103) • atrioventricular block = 1.0% (1/103) Surgery only: • pericardial blood effusion = 7.4% (2/27) • peritoneal blood effusion = 3.7% (1/27) Deaths during follow-up • radiofrequency ablation = 2.9% (3/102) • surgery only = 7.4% (2/27)	Consecutive patients. No randomisation. There were no significant differences in baseline characteristics between the two groups. Ablation of left atrium only. Post-surgical antiarrhythmic treatment was given at the discretion of the surgeon – about two-thirds of patients were taking antiarrhythmic drugs after the procedure. Thermaline radiofrequency probe (EP Technologies, Sunnyvale, USA).

Study Details	Key efficacy findings	Key safety findings	Comments
Chiappini B (2004)[4] Retrospective, non-randomised controlled study 1995 – 2002 Italy 70 patients • 57.1% (40/70) intraoperative radiofrequency ablation • 42.9% (30/70) Cox maze operation Mean age: • Radiofrequency ablation = 62.0 years • Cox maze = 60.9 years 20% (14/70) men, 80% (56/70) women Mean follow-up: 15.5 months (range 7 to 74 months) Mean duration of preoperative atrial fibrillation: • Radiofrequency ablation = 61.9 months • Cox maze = 53.5 months Concomitant surgical procedures: mitral valve replacement (n = 17), mitral valve replacement plus tricuspid valveplasty (n = 24), mitral and aortic valve replacement (n = 12), mitral and aortic valve replacement plus tricuspid valveplasty (n = 13), other (n = 4)	Sinus rhythm at discharge: • radiofrequency ablation = 85% • Cox maze operation = 73.3% p = 0.2 Overall survival at follow-up: • radiofrequency ablation = 92.8% • Cox maze operation = 90.4% p = 0.91 Sinus rhythm at follow-up (12-lead ECG): • radiofrequency ablation = 88.5% • Cox maze operation = 68.9% p = 0.53 Biatrial contraction at follow-up (transthoracic Doppler echocardiography): • radiofrequency ablation = 76.5% • Cox maze operation = 70.4% p = 0.65	**Complications** In-hospital mortality: • radiofrequency ablation = 7.5% (3/40) • Cox maze operation = 6.7% (2/30) Postoperative bradycardia requiring permanent pacemaker: • radiofrequency ablation = 7.5% (3/40) • Cox maze operation = 6.7% (2/30)	No randomisation. Biatrial ablation. Maze III operations performed between 1995 and 2001. Radiofrequency ablation performed from 2001 onwards. Mean follow-up for Maze III patients statistically significantly longer than radiofrequency ablation patients (73.2 months versus 16.5 months, $p < 0.05$). Antiarrhythmia medication was administered to all patients for 6 months after the procedure. The authors note that transthoracic echocardiography can induce false results specifically in patients with prosthetic valves. Episodes of asymptomatic atrial fibrillation may have been missed. Cobra Flex radiofrequency probe (Boston Scientific, San Jose, USA).

Study Details	Key efficacy findings	Key safety findings	Comments
Mohr FW (2002)[5] Case-series 1998 – 2001 Germany 234 patients Mean age: 62.8 years 61% (143/234) men, 39% (91/234) women Follow-up: 12 months Concomitant surgical procedures: mitral valve replacement or repair (n = 95), coronary artery bypass graft surgery with or without another procedure (n = 54), aortic valve replacement (n = 11) Indications: chronic persistent atrial fibrillation or symptomatic paroxysmal atrial fibrillation refractory to medical treatment	Sinus rhythm immediately after surgery = 83.3% (195/234) Sinus rhythm at discharge = 83.9% (188/224) Sinus rhythm at 6 months = 81.1% (99/122) Sinus rhythm at 12 months = 72.5% (58/80)	**Complications** • In-hospital mortality = 4.2% (10/234) • Reexploration for bleeding = 7.7% (18/234) • Reoperation within 5 days = 0.8% (2/234) • Use of intraaortic balloon pump = 2.1% (5/234) • Use of extracorporeal membrane oxygenation = 0.8% (2/234) • Sternal wound infection = 0.8% (2/234) • Perioperative ischaemia = 0.4% (1/234) • Stroke = 1.3% (3/234) • Atrio-oesophageal perforation = 1.3% (3/234) During follow-up: • Deaths = 2.1% (5/234)	Patient selection not described. Ablation of left atrium only. 74 patients had isolated intraoperative radiofrequency ablation alone, through minimally invasive techniques. When the procedure was first performed, a transoesophageal echocardiography probe was left in place before and 3 to 6 days after the operation. The authors state that they no longer leave the probe in the oesophagus during ablation and have switched to transthoracic echocardiography, in order to prevent oesophageal perforations. T-shaped radiofrequency ablation probe (Osypka GmbH, Grenzach-Wyhlen, Germany).

Study Details	Key efficacy findings	Key safety findings	Comments
Sie HT (2004)[6] Case-series 1995 – 2001 The Netherlands 200 patients Mean age: 68 years (range 31 to 84 years) 46% (92/200) men, 54% (108/200) women Mean follow-up: 40 months (range 12 to 80 months) Concomitant surgical procedures: mitral valve replacement or repair (n = 162), coronary artery bypass graft surgery (n = 13), aortic valve surgery (n = 12), miscellaneous heart procedure (n = 13) Indications: structural heart disease with chronic atrial fibrillation of at least 1 year's duration	At latest follow-up: Sinus or atrial rhythm = 73.4% (116/158) Successful elimination of atrial fibrillation in patients with mitral valve related procedures ranged from 72% to 87%	**Complications** • In-hospital mortality = 3.5% (7/200) • Re-thoracotomy = 8.0% (16/200) • Use of intraaortic balloon pump = 4.0% (8/200) • Sternal wound infection = 1.5% (3/200) • Endocarditis = 0.5% (1/200) • Stroke = 0.5% (1/200) • Atrioventricular conduction block = 0.5% (1/200) • Constrictive pericarditis = 1% (2/200) During follow-up: • Deaths = 13.5% (27/200) (8 due to end-stage heart failure, 4 due to stroke, 2 due to cancer, 1 due to gastrointestinal ischaemia/infarction and 13 due to miscellaneous causes)	Consecutive patients. Biatrial ablation. 81% (162/200) patients had mitral valve surgery, 19% (38/200) patients had other heart surgery. Cooled-tip radiofrequency probe used (irrigated with saline). 4.8% (8/166) patients lost to follow-up. Postoperative atrial arrhythmias were treated with medication and tapered gradually after sinus rhythm was considered to be stable. Custom-made radiofrequency probe used initially and then cooled tip Medtronic Cardioblate pen used for last 27 patients.

Study Details	Key efficacy findings	Key safety findings	Comments
Benussi S (2002)[7] Case-series 1998 – 2001 Italy 132 patients Mean age: 58.5 years 48.5% (64/132) men, 51.5% (68/132) women Mean follow-up: 16.9 months Concomitant surgical procedures: mitral valve repair or replacement (n = 129), tricuspid anuloplasty (n = 31), aortic valve replacement (n = 7), miscellanous (n = 4). 37 patients had more than one procedure. Indications: chronic atrial fibrillation lasting at least 6 months or paroxysmal atrial fibrillation refractory to medications	Overall 3-year survival = 94% Sinus rhythm after surgery = 96.2% (127/132) Freedom from atrial fibrillation at 1 year = 79% Freedom from atrial fibrillation at 3 years = 77% Biatrial contraction was recovered in all patients with stable sinus rhythm after surgery	**Complications** • Reexploration for bleeding = 2.3% (3/132) • Sternal wound infection = 0.8% (1/132) • In-hospital mortality = 0.8% (1/132) • 30 day mortality (after discharge) = 1.5% (2/132) • Early postoperative arrhythmia = 49.2% (65/132) During follow-up: • Deaths = 2.3% (3/132) (1 from sudden death, 1 due to stroke and 1 from mediastinal lymphoma).	Consecutive patients. Ablation of left atrium only. Age was significantly associated with a higher risk of atrial fibrillation recurrence. Antiarrhythmia medication was administered to all patients for at least 6 months and then tapered off in the presence of a stable sinus rhythm. Custom made radiofrequency probe used initially, followed by ThermaLine (Boston Scientific, USA), followed by Cobra (Boston Scientific).

Study Details	Key efficacy findings	Key safety findings	Comments
Raman J (2003)[8] Case-series (multicentre trial) 2000 – 2002 Australia and New Zealand 132 patients Mean age: 66 years (range 21 to 86 years) 69% (91/132) men, 31% (41/132) women Mean follow-up: 6.4 months (range 3 to 24 months) Mean duration of preoperative atrial fibrillation: 36 months (range 1 to 120 months) Concomitant surgical procedures: mitral valve surgery (n = 79), coronary artery bypass grafting (n = 19), aortic valve surgery (n = 9) Indications: established atrial fibrillation In patients undergoing conventional cardiac surgical procedures	Sinus recovery rate at 3 months = 84% (72/87) Sinus recovery rate at 6 months = 90% (45/50) Postoperative external cardioversion = 7.6% (10/132) Permanent pacemaker implanted = 3.0% (4/132)	**Complications** • Perioperative mortality = 6.8% (9/132) No intraoperative atrial perforations or perioperative tissue perforations During follow-up: • Readmissions for recurrent atrial fibrillation, sinus bradycardia , or both = 4.5% (6/132) • Deaths = 0.8% (1/132) (due to infective endocarditis complicated by liver failure)	Patient selection not described. Ablation of left atrium only. No perioperative deaths were considered to be related to the use of radiofrequency ablation. 65.9% (87/132) patients evaluated at 3 months, 37.9% (50/132) at 6 months and 11.4% (15/132) at 12 months. Patients were encouraged to take antiarrhythmia medication for 6 months after the procedure, but there was variable compliance by treating surgeons and patients. Cobra radiofrequency probe (EP Technologies, Boston Scientific, USA).

Validity and generalisability of the studies

- There are many aspects of the radiofrequency ablation procedure that varied within and among studies, including the pattern of ablation lesions, the type of radiofrequency probe, the cardiopulmonary bypass strategy, and the postoperative regimen of antiarrhythmic drugs. This needs to be taken into consideration when the safety and efficacy are compared among studies.

- The studies had different inclusion criteria with regards to duration of atrial fibrillation. Some studies included only patients with atrial fibrillation duration of more than a year and these patients are reported to be less likely to remain in sinus rhythm after surgery than patients with a shorter duration of atrial fibrillation.

- The one randomised controlled trial, comparing patients treated with mitral valve surgery and intraoperative radiofrequency ablation with patients treated with mitral valve surgery only, was very small. The study included only 30 patients followed up for 12 months.

- Patients were treated with concomitant heart surgery and some of the reported complications would have been due to this surgery rather than to the radiofrequency ablation procedure.

Specialist advisors' opinions

Specialist advice was sought from consultants who have been nominated or ratified by their Specialist Society or Royal College.

- Radiofrequency is one of several energy sources that can be used to treat atrial fibrillation.
- Radiofrequency ablation is easier to perform than the original Cox maze procedure.
- There is a lack of unanimity as to the correct lesion set to use.

Issues for consideration by IPAC

None other than those described above.

References

1 Grubb NR, Furniss S. Radiofrequency ablation for atrial fibrillation. *British Medical Journal* 2001; 322: 777–80.

2 Deneke T, Khargi K, Grewe PH, et al. Efficacy of an additional MAZE procedure using cooled-tip radiofrequency ablation in patients with chronic atrial fibrillation and mitral valve disease. *European Heart Journal* 2002; 23: 558–66.

3 Mantovan R, Raviele A, Buja G, et al. Left atrial radiofrequency ablation during cardiac surgery in patients with atrial fibrillation. *Journal of Cardiovascular Electrophysiology* 2003; 14: 1289–95.

4 Chiappini B, Martìn-Suàrez S, LoForte A, et al. Cox/Maze III operation versus radiofrequency ablation for the surgical treatment of atrial fibrillation: a comparative study. *Annals of Thoracic Surgery* 2004; 77: 87–92.

5 Mohr FW, Fabricius AM, Falk V, et al. Curative treatment of atrial fibrillation with intraoperative radiofrequency ablation: Short-term and midterm results. *The Journal of Thoracic and Cardiovascular Surgery* 2002; 123: 919–27.

6 Sie HT, Beukema WP, Elvan A, et al. Long-term results of irrigated radiofrequency modified maze procedure in 200 patients with concomitant cardiac surgery: six years experience. *Annals of Thoracic Surgery* 2004; 77: 512–7.

7 Benussi S, Nascimbene S, Agricola E, et al. Surgical ablation of atrial fibrillation using the epicardial radiofrequency approach: mid-term results and risk analysis. *Annals of Thoracic Surgery* 2002; 74: 1050–7.

8 Raman J, Ishikawa S, Storer MM, et al. Surgical radiofrequency ablation of both atria for atrial fibrillation: results of a multicenter trial. *The Journal of Thoracic and Cardiovascular Surgery* 2003; 126: 1357–66.

Appendix A: Additional papers on radiofrequency ablation for atrial fibrillation as an associated procedure with other cardiac surgery not included in the summary tables

Article title	Number of patients/ follow-up	Comments	Direction of conclusions
Alfieri O. Surgical treatment of atrial fibrillation: summary of current experience. *Heart Surgery Forum* 2003; 6: 103.	215 patients. 3 year follow-up.	Case-series. Conference abstract. "mostly mitral valve repair or replacement"	In-hospital mortality = 1.4%. Overall 3 year survival = 93%. Sinus rhythm = 78%.
Benussi S, Pappone C, Nascimbene S, et al. A simple way to treat chronic atrial fibrillation during mitral valve surgery: the epicardial radiofrequency approach. *European Journal of Cardio-thoracic Surgery* 2000; 17: 524–9.	40 patients. Mean follow-up 12 months.	Case-series. Patients likely to be included in reference 6. 100% (40/40) patients had mitral valve surgery.	In-hospital mortality = 2.5%. Sinus rhythm at follow-up = 77%.
Chen MC, Chang JP, Guo GBF, et al. Atrial size reduction as a predictor of the success of radiofrequency maze procedure for chronic atrial fibrillation in patients undergoing concomitant valvular surgery. *Journal of Cardiovascular Electrophysiology* 2001; 12: 867–74.	61 patients with ablation and valve surgery. 58 patients with valve surgery only. 3 month follow-up.	Non-randomised comparative study. Combination of radiofrequency and cryoablation used.	Ablation: In-hospital mortality = 4.9% Sinus rhythm at 3 months = 78% Control: In-hospital mortality = 6.9% Sinus rhythm at 3 months = 11%
Chiappini B, Martin-Suàrez, LoForte A, et al. Surgery for atrial fibrillation using radiofrequency catheter ablation. *The Journal of Thoracic and Cardiovascular Surgery.* 2003; 126: 1788–91.	40 patients. Mean follow-up 16.5 months.	Case-series. Patients likely to be included in reference 4. 95% (38/40) valve surgery, 2.5% (1/40) CABG.	In-hospital mortality = 7.5% Sinus rhythm = 88.5%.
Colangelo N, Benussi S, Nascimbene S, et al. Cardiopulmonary bypass strategy during concomitant surgical treatment of mitral valve disease and atrial fibrillation. *Perfusion* 2003; 18: 19–24.	157 patients.	Case-series. Patients likely to be included in reference 6.	No procedure-related complications. Sinus rhythm = 97%.
Deneke T, Khargi K, Grewe PH, et al. Left atrial versus bi-atrial maze operation using intraoperatively cooled-tip radiofrequency ablation in patients undergoing open-heart surgery. *Journal of the American College of Cardiology* 2002; 39: 1644–50.	70 patients. Follow-up between 1 and 50 months.	Non-randomised study, comparing left atrial with biatrial. 60% (42/70) valve surgery, 40% (28/70) CABG & valve surgery.	Left atrial ablation is as effective as biatrial procedure.

Article title	Number of patients/ follow-up	Comments	Direction of conclusions
Doll N, Borger M, Fabricius A, et al. Esophageal perforation during left atrial radiofrequency ablation: Is the risk too high? *The Journal of Thoracic and Cardiovascular Surgery* 2003; 125: 836–42.	387 patients.	Case-series. Paper focuses on 133 patients treated with minimally invasive isolated intraoperative radio-frequency ablation. 33% (129/387) Isolated procedures, 42% (163/387) mitral valve surgery, 25% (95/387) CABG, atrial septal defect or aortic valve surgery.	1% (4/387) oesophageal perforation (all in patients with minimally invasive procedure). The centre has now stopped using intraoperative radiofrequency ablation.
Gillinov AM, McCarthy PM. Atricure bipolar radiofrequency clamp for intraoperative ablation of atrial fibrillation. *Annals of Thoracic Surgery* 2002; 74, (6): 2165–8.	120 patients.	Case-series. Lesion sets varied.	No device-related complications.
Fayad G, Le Tourneau T, Modine T, et al. One-year clinical and echocardiographic follow-up after endocardial radiofrequency ablation for atrial fibrillation during mitral valve surgery. *Journal of the American College of Cardiology.* 2003; 41: 499	58 patients. 12 month follow-up.	Case-series. Conference abstract. 100% (58/58) mitral valve surgery)	1 death, 1 permanent AV block requiring pacemaker. Sinus rhythm = 67%.
Gillinov AM, McCarthy PM, Blackstone EH, et al. Bipolar radiofrequency to ablate atrial fibrillation in patients undergoing mitral valve surgery. *Heart Surgery Forum* 2004; 7: E147–52	108 patients. 3 month follow-up.	Case-series.	85% patients free of atrial fibrillation or atrial flutter.
Ishikawa S, Raman JS, Buxton BF. Mid-term results of intraoperative radiofrequency ablation. *Kitakanto Medical Journal* 2003; 53: 37–41.	87 patients. Mean follow-up 6 months.	Case-series. Patients likely to be included in reference 7. 67% (58/87) mitral valve surgery, 18% (16/87) CABG.	Sinus rhythm at 12 months = 93%.
Kobza R, Kottkamp H, Dorszewski A, et al. Stable secondary arrhythmias late after intraoperative radiofrequency ablation of atrial fibrillation: incidence, mechanisms, and treatment. *Journal of Cardiovascular Electrophysiology* 2004; 15: 1246–9.	129 patients. Mean follow-up = 20 months.	Case-series. Minimally invasive surgical techniques used.	Sustained stable secondary arrhythmias = 6% (8/129).
Kottkamp H, Hindricks G, Autschbach R, et al. Specific linear left atrial lesions in atrial fibrillation: intraoperative radiofrequency ablation using minimally invasive surgical techniques. *Journal of the American College of Cardiology* 2002; 40: 475–80.	70 patients. Mean follow-up 18.5 months.	Case-series.	Sinus rhythm at 6 months = 93%. Sinus rhythm at 12 months = 95% (permanent AF) and 97% (paroxysmal AF). 1 oesophageal perforation, 1 circumflex coronary artery stenosis.
Melo J, Adragão, Neves J, et al. Endocardial and epicardial radiofrequency ablation in the treatment of atrial fibrillation with a new intra-operative device. *European Journal of Cardio-thoracic Surgery* 2000; 18: 182–6.	65 patients. 6 month follow-up.	Case-series. 89% (58/65) mitral valve surgery, 6% (4/65) CABG.	No mortality. No serious complications. Sinus rhythm = 34%.

Melo J, Adragão, Neves J, et al. Surgery for atrial fibrillation using radiofrequency catheter ablation: assessment of results at one year. *European Journal of Cardio-thoracic Surgery* 1999; 15: 851–5.	43 patients. Maximum follow-up 20 months.	Case-series. 98% (42/43) mitral valve surgery.	No mortality. Sinus rhythm = 30%.

Article title	Number of patients/ follow-up	Comments	Direction of conclusions
Mohr F, Fabricius A, Falk V, et al. Curative treatment of atrial fibrillation with intraoperative radiofrequency ablation: short-term and midterm results. *Journal of Thoracic & Cardiovascular Surgery* 2002; 123: 919–27.	234 patients.	Case-series. 41% mitral valve surgery 5% coronary heart bypass grafting. 31% RFA alone.	Sinus rhythm = 84%. Pacemakers = 10%, 4% in-hospital mortality, 30-day mortality = 2%. Oesophageal injury = 1%.
Pasic M, Bergs P, Muller P, et al. Intraoperative radiofrequency maze ablation for atrial fibrillation: the Berlin modification. *Annals of Thoracic Surgery* 2001; 72: 1484–90.	48 patients. Mean follow-up = 4 months.	Case-series. 56% (27/48) valve surgery or CABG, 44% (21/48) combined.	Sinus rhythm = 59% (16/27) at 1 month.
Ruchat P, Schlaepfer J, Delabays A, et al. Left atrial radiofrequency compartmentalization for chronic atrial fibrillation during heart surgery. *Thorac Cardiov Surg* 2002; 50: 155–9.	40 patients. Mean follow-up 12.5 months.	Case-series. Left atrial ablation. 78% (31/40) mitral valve surgery, 2.5% (1/40) CABG.	No complications related to radiofrequency ablation. Mortality = 7.5%. Sinus rhythm = 68%.
Sie HT, Beukema WP, Ramdat Misier AR, et al. The radiofrequency modified maze procedure. A less invasive surgical approach to atrial fibrillation during open-heart surgery. *European Journal of Cardio-thoracic Surgery* 2001; 19: 443–7.	72 patients. (117 concomitant procedures) Mean follow-up 20 months.	Case-series. Patients likely to be included in reference 5. 62% (72/117) mitral valve surgery, 36% (42/117) tricuspid valve repair.	Mortality = 2.7%. Morbidity = 19% (excluding recurrent atrial fibrillation). Sinus rhythm = 76%.
Starck C, Botha CA, Roser D, et al. Results of a modified left atrial maze procedure as a combined procedure. *Thorac Cardiov Surg* 2003; 51: 147–53.	100 patients. Mean follow-up 7 months.	Case-series. 43% (43/100) mitral valve disease, 28% (28/100) aortic valve disease, 27% (27/100) coronary artery disease.	80% patients had sinus rhythm and atrial contraction.
Williams MR, Stewart JR, Bolling SF, et al. Surgical treatment of atrial fibrillation using radiofrequency energy. 2001; 71, 1639–43.	48 patients. Mean follow-up 4 months	Case-series.	12.5% (6/48) mortality. Sinus rhythm = 81%.

Appendix B: Literature search for radiofrequency ablation for atrial fibrillation as an associated procedure with other cardiac surgery

The following search strategy was used to identify papers in Medline. A similar strategy was used to identify papers in EMBASE, Current Contents, PreMedline and all EMB databases.

For all other databases a simple search strategy using the key words in the title was employed.

1. atrial fibrillation.mp. or Atrial Fibrillation/
2. intraoperative.mp.
3. ablation.mp.
4. radiofrequency.mp.
5. 2 and 3 and 4
6. RFA.mp.
7. 5 or 6
8. 1 and 7