Surgical treatment of atrial fibrillation

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Surgery aims to eliminate atrial fibrillation (AF) through direct modification of the arrhythmogenic substratum. The Maze procedure, developed two decades ago, has proven to be clearly effective in restoring sinus rhythm in AF patients with or without associated organic cardiac disorders. Indications for surgery may be tailored to the clinical situation involved. In patients with continuous AF associated with structural heart disease (eg, valvular, congenital or coronary artery disease), the performance of a concomitant AF ablation procedure proven to add minimal morbidity to the operation may be highly beneficial to patient outcome. It is likely, although not entirely proven, that the restoration and maintenance of sinus rhythm after mitral valve surgery promotes survival by preventing tachycardia-induced cardiomyopathy and stroke. Novel strategies for AF surgery involve the use of alternate energy sources to create the lines of block in the atria and the simplification of the lesion pattern compared with the earlier Cox-Maze procedure. Published clinical data support the contention that left atrial ablation techniques performed concomitantly with valvular and/or coronary artery bypass surgery are likely to result in a 70% to 90% cure rate of AF in patients with preoperatively documented AF. Despite the lack of evidence for long-term outcome benefit, intraoperative pulmonary vein ablation, feasible with minimal morbidity, clearly appears to be an improvement over simply ignoring AF in patients undergoing cardiac surgery. Left atrial appendectomy appears warranted in patients with chronic persistent AF.

Key Words: *Arrhythmia surgery; Atrial fibrillation surgery; Left atrial appendage; Radiofrequency; Stroke; Valvular atrial fibrillation*

Le traitement chirurgical de la fibrillation auriculaire

La chirurgie vise à mettre fin à la fibrillation auriculaire (FA) par une modification directe du substrat arythmogène. La technique du labyrinthe, mise au point il y a une vingtaine d'années, s'est montrée vraiment efficace pour rétablir le rythme sinusal chez des patients atteints de FA, associée ou non à des troubles cardiaques organiques. Les indications de la chirurgie peuvent être adaptées à différentes situations cliniques. Dans les cas de FA permanente, associée à une cardiopathie structurale (lésion valvulaire, congénitale ou coronarienne), la réalisation d'une intervention concomitante de suppression de la FA, qui augmente de très peu le risque de morbidité associé à l'opération peut s'avérer grandement bénéfique. Par ailleurs, il est probable, mais non confirmé encore, que le rétablissement et le maintien du rythme sinusal après une opération valvulaire mitrale puissent améliorer la survie en prévenant la myocardiopathie d'origine tachycardique et les accidents vasculaires cérébraux. Des techniques chirurgicales novatrices utilisent des sources nouvelles d'énergie pour créer les lignes de segmentation des oreillettes tout en simplifiant la forme des lésions par rapport à celles produites par l'intervention originelle de Cox, en labyrinthe. Des données cliniques publiées étayent le point de vue selon lequel les techniques d'ablation tissulaire de l'oreillette gauche, pratiquées en même temps qu'une intervention chirurgicale valvulaire ou un pontage coronarien sont susceptibles de se solder par un taux de guérison de 70 % à 90 % chez les patients souffrant de FA avérée en phase préopératoire. Malgré l'absence de données sur les résultats à long terme, l'ablation peropératoire des veines pulmonaires, intervention réalisable tout en étant associée à une très faible morbidité, paraît comme une nette amélioration par rapport au simple traitement abstentionniste de la FA chez les patients subissant une opération cardiaque. Enfin, l'auriculectomie gauche semble justifiée chez les patients présentant de la FA chronique.

RECOMMENDATIONS

Class I

1) Patients undergoing intraoperative ablation of atrial fibrillation (AF) should be anticoagulated postoperatively unless they have a strong contraindication to oral anticoagulation therapy (level of evidence C).

Class IIa

1) In patients undergoing mitral valve replacement or repair with a history of symptomatic persistent or paroxysmal AF, concomitant intraoperative AF ablation should be considered to increase the likelihood of the restoration of sinus rhythm (level of evidence B).

Class IIb

1) Patients with symptomatic persistent or paroxysmal AF undergoing other cardiac surgery (eg, coronary artery bypass grafting, aortic valve replacement or both) may be considered for intraoperative AF ablation (level of evidence C).
2) Patients with refractory, symptomatic AF not associated with organic heart disease and without comorbidities may be considered for surgical ablation when other nonpharmacological procedures have failed (level of evidence C).
3) Patients who have undergone intraoperative AF ablation should be re-evaluated for anticoagulation therapy after three months of follow-up according to the general recommendations made after valvular surgery (level of evidence C).

INTRODUCTION

Earlier attempts at surgical therapy of AF targeted the reduction of rapid ventricular rate by interrupting the nodohisian pathway and inserting a permanent pacemaker (1). Soon after these first attempts at ventricular rate control, Scheinman et al (2)

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introduced the concept of catheter-based ablation techniques. However, these procedures led to permanent pacemaker dependency. To overcome this problem, surgical procedures aimed at preserving the patient's own sinus nodal function were introduced (3-5). In spite of the relative success in suppressing most of the symptoms associated with uncontrolled ventricular response, these procedures hardly offered any advantage over radiofrequency catheter ablation of the nodohisian pathway (6).

Further developments in arrhythmia surgery were aimed at the elimination of AF through direct modification of the arrhythmogenic substrate. Varying degrees of surgical modification may be tailored to the clinical situation involved (7). In the case of occasional paroxysmal 'lone' AF, where symptoms may be the main treatment objective, the invasiveness of surgical therapy has a major impact on decision making. However, in patients with structural heart disease (eg, valvular or congenital) or associated coronary artery disease, the performance of a concomitant AF ablation procedure, proven to add minimal morbidity to the operation, may be highly beneficial to patient outcome.

INDICATIONS FOR SURGICAL THERAPY

The physiological objectives of AF surgery are to prevent symptoms associated with rapid and irregular heart beat, to avoid blood stasis in the atrium and the attendant risk of thromboembolic events, and to preserve atrial function, which ensures optimal cardiac performance. However, the clinical value of surgical AF ablation procedures needs to be assessed with respect to the rate of freedom from AF recurrence, the rate of freedom from thromboembolic events, and the improvement of long-term survival.

The need for AF surgery during mitral valve operations

There is no large-scale randomized clinical trial that demonstrates the long-term benefits of a concomitant Maze procedure or any of its later modifications. However, inferences can be made based on a historical comparison of the results of valvular operations. The maintenance of sinus rhythm after successful cardioversion promotes both atrioventricular synchrony and active diastolic ventricular filling (8). The restoration and maintenance of sinus rhythm after mitral valve surgery may improve survival by preventing tachycardia-induced cardiomyopathy and stroke. AF occurs in 30% to 50% of patients undergoing mitral valve surgery (9-13). These studies have also demonstrated that preoperative AF is a strong determinant of postoperative AF (9-13). According to Jessurun et al (14), preoperative sinus rhythm, preoperative paroxysmal AF and preoperative chronic continuous AF would confer a relative risk of AF recurrence of 1.18 (95% CI 54±79), 2.35 (95% CI 18±54) and 19.2 (95% CI 0.8±12), respectively. In the same study, AF continued in 94% of the cases with preoperative chronic AF, whereas sinus rhythm persisted in 86% of patients undergoing mitral valve surgery with preoperative sinus rhythm (14). Similarly, paroxysmal AF persisted after surgery in 95% of the patients with preoperative AF, despite antiarrhythmic drugs. At the end of follow-up, more patients with preoperative chronic AF had died than those with preoperative sinus rhythm or paroxysmal AF, and AF persisting after surgery tended to determine survival (P=0.05). Other studies (13,15) also showed that patients with AF had a worse survival rate after mitral valve repair than patients in sinus rhythm.

Results of the Maze-III procedure

Interpretation of published results from the classic Maze-III procedure is confounded by the inconsistency of patient selection regarding the severity of symptoms, the type and duration of AF, and whether the operation was performed for 'lone' or 'valvular' AF. Reports (16-20) of the Cox-Maze operation have demonstrated a long-term elimination of AF in 84% to 98% of cases. Only a few studies have demonstrated a long-term benefit of the Maze procedure in reducing late morbidity and improving functional outcomes. Bando et al (21) showed that the addition of a Maze procedure to mitral valve operations did not increase morbidity in the immediate postoperative period. Their results indicated that a combined Maze procedure restored sinus rhythm in 84% of patients at three years after surgery, whereas only 6% of patients with mitral valve replacement alone avoided recurrent AF. Although survival benefit from the Maze procedure is not yet fully demonstrated, a number of reports (16-26), mainly with case-matched comparisons, have shown that the procedure is highly effective in restoring sinus rhythm compared with valvular surgery alone. Of further interest, 97% of the patients in the series by Bando et al (21) were free from late stroke at five years after surgery, compared with only 79% of patients who underwent mitral valve replacement alone. That study also showed that, according to multivariate analysis, the omission of a Maze procedure was the most significant risk factor for the development of late stroke. However, their selection criteria for actually performing a Maze procedure may have introduced a significant bias, suggesting that more diseased atria are more important for patient outcome than the arrhythmia itself.

Some surgeons suggest avoiding the Maze procedure in addition to mitral valve replacement with mechanical valves, arguing that these patients receive permanent systemic anticoagulation therapy anyway. However, in the study by Bando et al (21), most of the late strokes among patients receiving warfarin occurred in patients with mechanical valves. These findings confirmed that the restoration of sinus rhythm after mitral valve surgery by a Maze procedure is the most effective means of preventing late strokes, even for patients with mechanical valves. This propensity to reduce stroke rate may be related to the resection of the left atrial appendage and to the preserved atrial transport function. Several groups have reported their results with Doppler echocardiography after AF surgery. Most of them claimed a 75% to 90% incidence of biatrial contraction (27-32). However, atrial function is likely to remain abnormal in such patients who already have damaged atria (28). The resection or obliteration of the left atrial appendage may have contributed to the low incidence of late stroke. Although controversial, left atrial appendectomy is considered to have a high potential for stroke rate reduction in several studies (33-36). However, at least two reports (36,37) suggest that incomplete obliteration of the left atrial appendage may, in fact, promote stroke.

In summary, the Maze procedure has proven effective in restoring sinus rhythm in AF patients with or without associated organic cardiac disorders. Although attempts to restore postoperative sinus rhythm at the time of mitral valve surgery may appear worthwhile, the definitive proof of a long-term survival benefit has yet to be determined in a randomized study.

CHANGING CONCEPTS IN AF SURGERY

For arrhythmias associated with stable macroreentrant circuits (eg, Wolff-Parkinson-White syndrome), the ablation process

TABLE 1
Energy sources for atrial fibrillation surgical ablation

Radiofrequency	Nonirrigated monopolar coil
	Irrigated monopolar coil
	Irrigated tip
	Nonirrigated bipolar jaws
	Irrigated, malleable bipolar jaws
Microwave	Rigid linear probe
	Flexible catheter
Cryoablation	Malleable linear coil
	Rigid focal probes
Laser	Rigid linear probe*
High-frequency ultrasounds	Flexible catheter*

**Not yet commercially available in Canada*

TABLE 2
Summary of atrial fibrillation (AF) surgical approaches

Procedure	Advantages	Disadvantages
Cox-Maze-III (Cut-and-sew)	High success rate (freedom from AF); low TEE rate	Increased operative difficulty/time; reduced atrial function
Full Maze-III design using ablation energy	Easier to learn; proven efficacy (85% early, 75% late freedom from AF)	Risk of left atrial flutter; unknown effect on late survival
Left atrial RF ablation including LAA resection	Easy to perform with valvular surgery (75% to 88% freedom from AF after five years)	Does not address right atrial flutter; unknown effect on late survival
Pulmonary veins 'en bloc' isolation	Easier to perform; amenable to minimally invasive approaches	Does not address right atrial flutter; unknown effect on late TEE rate and late survival

LAA Left atrial appendage; RF Radiofrequency; TEE Thromboembolism

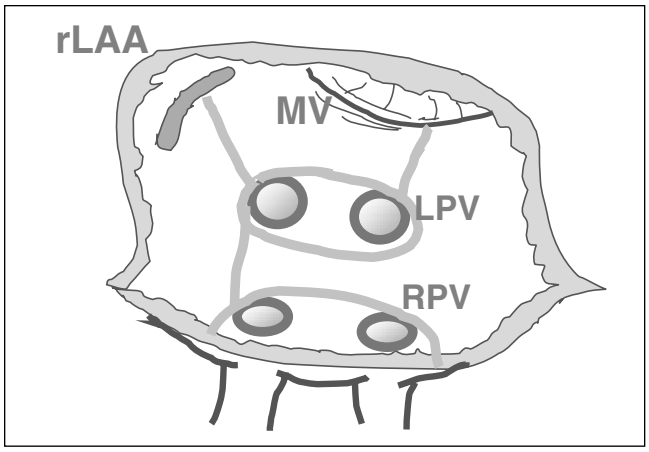

Figure 1) *Left atrial lesion pattern currently used for atrial fibrillation ablation. Inside view of the left atrium from an atriotomy in the Waterston groove (standard for mitral valve [MV] surgery). Pulmonary veins are encircled in pairs. Connecting lesions are made between pulmonary veins, the mitral valve annulus and the left atrial appendage, which is resected or tightly closed. LPV Left pulmonary veins; rLAA Resected left atrial appendage; RPV Right pulmonary veins*

follows the classic paradigm of arrhythmia surgery that is based on the identification of the arrhythmia mechanism, the anatomical localization of the arrhythmogenic substrate and the design of effective surgical technique ablating the determined target (38,39). The same paradigm linked to the use of radiofrequency energy led to the development of percutaneous procedures that have proven to be highly effective for arrhythmias due to discrete anatomical substrates (40). AF, however, remains the most complex and least understood among the supraventricular arrhythmias, despite the significant research advances that have taken place in the past few years (41). Nevertheless, nearly two decades ago, a group at Washington University (St Louis, Missouri, USA) (42-44) came up with the idea that multiple lesions created in both atria aimed at suppressing all possible AF mechanisms might lead to an effective procedure. The two major principles of the operation were the fragmentation of the atria into smaller myocardial segments not able to withstand microreentrant circuits, and the creation of connecting lines of block to the mitral and tricuspid valve annuli to prevent macroreentry in the left or right atria. Although these concepts aimed for the suppression of the maintenance mechanism of AF, they inadvertently affected the triggering mechanisms through the isolation of the pulmonary veins. New information on the electrophysiological triggers of AF came well after the development phase of the Cox-Maze procedure. A major step in the understanding of AF came more recently when Haissaguerre et al (45) found that ectopic activity initiating AF originates in the pulmonary vein ostia. This work had a remarkable impact on the clinical management of AF (40), and not only paved the way to catheter-based interventions, but also contributed to the design of new operative approaches. Although it appears quite clear that ectopic foci within or near the pulmonary vein orifices are the major arrhythmogenic event in patients with paroxysmal AF, intraoperative mapping studies in patients with mitral valve disease are rather scarce (46-51). Moreover, in most series, the success rate achieved by Cox et al (16) could hardly be duplicated, as the rate of freedom from AF recurrence varied between 70% and 90% (17-19,21-25). The Cox-Maze procedure was also performed at the expense of long pump runs, prolonged cardioplegic arrest, increased risk of bleeding, increased risk of postoperative fluid retention and poor atrial function (24). The new knowledge regarding the role of pulmonary vein-left atrial junction, combined with the low adoption rate of the Maze procedure in the surgical community, led several groups to evaluate novel strategies based on the following changes: the use of alternate energy sources replacing cutting and sewing to create the lines of block (Table 1); and the simplification of the lesion pattern consisting of the omission of some of the Maze-III incisions (Table 2 and Figure 1).

The first attempts at replacing the Maze incisions were based on radiofrequency energy (52-60). Sie et al (53) and Güden et al (54) used an irrigated tip monopolar radiofrequency catheter, with which lesions can be drawn on the endocardium with a pen-like action. Actuarial freedom from AF was 80% and 70% at three and five years, respectively. Raman et al (32) used a dry monopolar coil to create right and left atrial lesions, and they reported 100% freedom from AF at 12 months. Clinical data suggest that left atrial ablation alone can afford the same results as biatrial ablation (54,56-58,60).

Although variable, reported results indicate success rates ranging between 70% and 90% (52-60). Mohr et al (58) achieved an 85% cure rate with a continuous lesion connecting all four pulmonary veins to the mitral valve annulus. Smaller series using left atrial ablation patterns with microwave energy or cryosurgery have also reported acceptable results (61,62). The difficulty in drawing any firm conclusion from these data comes from the fact that these series are not comparable in terms of incidence of type of AF, duration of AF before the operation, the definition of success, the left atrial diameter and the lesion pattern itself. Many series indicate that large quiescent atria and an AF duration of more than 15 years would hamper the expected benefit of the procedure (18-24). Figure 1 shows the most commonly used left atrial lesion pattern. This pattern, created by means of either irrigated tip or coiled monopolar radiofrequency devices, only takes approximately 14 min to complete (55). Despite this apparent simplicity, damage to adjacent structures (eg, esophageal perforation) may occur, particularly with the use of dry monopolar coil radiofrequency devices (63). Finally, the feasibility of left atrial ablation on the closed heart would be of particular interest in patients with aortic valve diseases or coronary bypass procedures. This will be made possible by the refinement of newer devices (eg, bipolar radiofrequency clamps) (61,64).

Although these comments seem to favour the use of intraoperative AF ablation devices in patients with documented AF preoperatively (see recommendations), we believe that in patients undergoing mitral valve surgery without documented AF before surgery, there is no evidence to date supporting prophylactic intraoperative ablation. Elderly patients (over 80 years of age) or patients with a high risk of perioperative morbidity/mortality with few or no AF symptoms should not undergo intraoperative ablation therapy for AF. Younger patients with documented asymptomatic AF undergoing mitral valve surgery should be considered for the AF ablation procedure only in centres with considerable experience in AF surgery, given the fact that the proposed procedure should not add any risk to the primary operation.

APPROACHES TO 'LONE' AF

Approaches to the patient with 'lone' AF should be entirely different from that of the patient with concomitant cardiac pathologies. In the former case, epicardial ablation with microwave technology with open chest, thoracoscopic or robotic techniques is currently under development (61,65). To date, the role of these procedures as a stand-alone alternative or combined with catheter-based techniques is not known.

In summary, published clinical data suggest that left atrial ablation performed concomitantly with valvular and/or coronary artery bypass surgery is likely to afford a 70% to 90% cure rate in patients with preoperatively documented AF. Despite the lack of evidence of its long-term outcome benefit, intraoperative pulmonary vein ablation, feasible with minimal morbidity, appears to be a promising procedure to reduce postoperative AF in patients undergoing cardiac surgery. Left atrial appendectomy appears warranted in patients with chronic persistent AF.

REFERENCES

1. Sealy WC, Gallagher JJ, Kasell J. His bundle interruption for control of inappropriate ventricular responses to atrial arrhythmias. Ann Thorac Surg 1981;32:429-38.
2. Scheinman MM, Morady F, Hess DS, Gonzalez R. Catheter-induced ablation of the atrioventricular junction to control refractory supraventricular arrhythmias. JAMA 1982;248:851-5.
3. Williams JM, Ungerleider GK, Lofland GK, Cox JL. Left atrial isolation: A new technique for the treatment of supraventricular arrhythmias. J Thorac Cardiovasc Surg 1980;80:373-80.
4. Sueda T, Nagata H, Shikata H, et al. Simple left atrial procedure for chronic atrial fibrillation associated with mitral valve disease. Ann Thorac Surg 1996;62:1796-800.
5. Leitch JW, Klein G, Yee R, Guiraudon G. Sinus node atrioventricular node isolation: Long-term results with the "corridor" operation for atrial fibrillation. J Am Coll Cardiol 1991;17:970-5.
6. van Hemel NM, Defauw JJ, Kingma JH, et al. Long-term results of the corridor operation for atrial fibrillation. Br Heart J 1994;71:170-6.
7. Cox JL. Atrial fibrillation I: A new classification system. J Thorac Cardiovasc Surg 2003;126:1686-92.
8. Gosselink AT, Crijns HJ, Hamer HP, Hillege H, Lie KI. Changes in left and right atrial size after cardioversion of atrial fibrillation: Role of mitral valve disease. J Am Coll Cardiol 1993;22:1666-72.
9. Chua YL, Schaff HV, Orszulak TA, Morris JJ. Outcome of mitral valve repair in patients with preoperative atrial fibrillation. Should the maze procedure be combined with mitral valvuloplasty? J Thorac Cardiovasc Surg 1994;107:408-15.
10. Brodell GK, Cosgrove D, Schiavone W, Underwood DA, Loop FD. Cardiac rhythm and conduction disturbances in patients undergoing mitral valve surgery. Cleve Clin J Med 1991;58:397-9.
11. Hansen JF, Andersen E, Olesen KH, et al. DC-conversion of atrial fibrillation after mitral valve operation. An analysis of the long-term results. Scand J Thorac Cardiovasc Surg 1979;13:267-70.
12. Flugelman MY, Hasin Y, Katznelson N, Kriwisky M, Shefer A, Gotsman MS. Restoration and maintenance of sinus rhythm after mitral valve surgery for mitral stenosis. Am J Cardiol 1984;54:617-9.
13. Obadia JF, el Farra M, Bastien OH, Lievre M, Martelloni Y, Chassignolle JF. Outcome of atrial fibrillation after mitral valve repair. J Thorac Cardiovasc Surg 1997;114:179-85.
14. Jessurun ER, van Hemel NM, Kelder JC, et al. Mitral valve surgery and atrial fibrillation: Is atrial fibrillation surgery also needed? Eur J Cardiothorac Surg 2000;17:530-7.
15. Lim E, Barlow CW, Hosseinpour AR, et al. Influence of atrial fibrillation on outcome following mitral valve repair. Circulation 2001;104(Suppl 1):I59-63.
16. Cox JL, Ad N, Palazzo T, et al. Current status of the Maze procedure for the treatment of atrial fibrillation. Semin Thorac Cardiovasc Surg 2000;12:15-9.
17. Handa N, Schaff HV, Morris JJ, Anderson BJ, Kopecky SL, Enriquez-Sarano M. Outcome of valve repair and the Cox maze procedure for mitral regurgitation and associated atrial fibrillation. J Thorac Cardiovasc Surg 1999;118:628-35.
18. Schaff HV, Dearani JA, Daly RC, Orszulak TA, Danielson GK. Cox-Maze procedure for atrial fibrillation: Mayo Clinic experience. Semin Thorac Cardiovasc Surg 2000;12:30-7.
19. Kosakai Y. Treatment of atrial fibrillation using the Maze procedure: The Japanese experience. Semin Thorac Cardiovasc Surg 2000;12:44-52.
20. Prasad SM, Maniar HS, Camillo CJ, et al. The Cox maze III procedure for atrial fibrillation: Long-term efficacy in patients undergoing lone versus concomitant procedures. J Thorac Cardiovasc Surg 2003;126:1822-8.
21. Bando K, Kobayashi J, Kosakai Y, et al. Impact of Cox maze procedure on outcome in patients with atrial fibrillation and mitral valve disease. J Thorac Cardiovasc Surg 2002;124:575-83.
22. Raanani E, Albage A, David TE, Yau TM, Armstrong S. The efficacy of the Cox/maze procedure combined with mitral valve surgery: A matched control study. Eur J Cardiothorac Surg 2001;19:438-42.
23. Jatene MB, Marcial MB, Tarasoutchi F, Cardoso RA, Pomerantzeff P, Jatene AD. Influence of the maze procedure on the treatment of rheumatic atrial fibrillation – evaluation of rhythm control and clinical outcome in a comparative study. Eur J Cardiothorac Surg 2000;17:117-24.
24. Kawaguchi AT, Kosakai Y, Sasako Y, Eishi K, Nakano K, Kawashima Y. Risks and benefits of combined maze procedure for atrial fibrillation associated with organic heart disease. J Am Coll Cardiol 1996;28:985-90.

25. Guang Y, Zhen-jie C, Yong LW, Tong L, Ying L. Evaluation of clinical treatment of atrial fibrillation associated with rheumatic mitral valve disease by radiofrequency ablation. Eur J Cardiothorac Surg 2002;21:249-54.
26. Cox JL, Ad N, Palazzo T. Impact of the maze procedure on the stroke rate in patients with atrial fibrillation. J Thorac Cardiovasc Surg 1999;118:833-40.
27. Itoh T, Okamoto H, Nimi T, et al. Left atrial function after Cox's maze operation concomitant with mitral valve operation. Ann Thorac Surg 1995;60:354-60.
28. Kondo H, Scalia G, Stugaard M, Vargo RL, Stewart WJ, McCarthy PM. Preserved volume change with long axis shortening of left atrium after MAZE surgery. Circulation 1996;94(Suppl I):I-316.
29. Ueshima K, Hashimoto K, Chiba M, et al. Recovery of atrial function after combined treatment with surgical repair for organic heart disease and maze procedure for atrial fibrillation. J Thorac Cardiovasc Surg 1997;113:214-5.
30. Albirini A, Scalia GM, Murray RD, et al. Left and right atrial transport function after the Maze procedure for atrial fibrillation: An echocardiographic Doppler follow-up study. J Am Soc Echocardiogr 1997;10:937-45.
31. Yashima N, Nasu M, Kawazoe K, Hiramori K. Serial evaluation of atrial function by Doppler echocardiography after the maze procedure for chronic atrial fibrillation. Eur Heart J 1997;18:496-502.
32. Raman J, Ishikawa S, Storer MM, Power JM. Surgical radiofrequency ablation of both atria for atrial fibrillation: Results of a multicenter trial. J Thorac Cardiovasc Surg 2003;126:1357-65.
33. Blackshear JL, Odell JA. Appendage obliteration to reduce stroke in cardiac surgical patients with atrial fibrillation. Ann Thorac Surg 1996;61:755-9.
34. Johnson WD, Ganjoo AK, Stone CD, Srivyas RC, Howard M. The left atrial appendage: Our most lethal human attachment! Surgical implications. Eur J Cardiothorac Surg 2000;17:718-22.
35. Halperin JL, Gomberg-Maitland M. Obliteration of the left atrial appendage for prevention of thromboembolism. J Am Coll Cardiol 2003;42:1259-61.
36. Garcia-Fernandez M, Perez-David E, Quiles J, et al. Role of the left atrial appendage obliteration in stroke reduction in patients with mitral valve prosthesis: A transesophageal echocardiographic study. J Am Coll Cardiol 2003;42:1253-8.
37. Pennec PY, Jobic Y, Blanc JJ, Bezon E, Barra JA. Assessment of different procedures for surgical left atrial appendage exclusion. Ann Thorac Surg 2003;76:2168-9.
38. Pagé PL. Surgery for cardiac arrhythmias. In: Zipes DP, Jalife J, eds. Cardiac Electrophysiology: From Cell to Bedside. Philadelphia: WB Saunders Co, 2004:Chapter 120:1104-15.
39. Schuessler RB. Do we need a map to get through the maze? J Thorac Cardiovasc Surg 2004;127:627-8.
40. Morady F. Catheter ablation of supraventricular arrhythmias: State of the art. Pacing Clin Electrophysiol 2004;27:125-42.
41. Nattel S. New ideas about atrial fibrillation 50 years on. Nature 2002;415:219-26.
42. Cox JL, Schuessler RB, D'Agostino HJ Jr, et al. The surgical treatment of atrial fibrillation. III. Development of a definitive surgical procedure. J Thorac Cardiovasc Surg 1991;101:569-83.
43. Cox JL. Atrial fibrillation II: Rationale for surgical treatment. J Thorac Cardiovasc Surg 2003;126:1693-9.
44. Cox JL. Cardiac surgery for arrhythmias. Pacing Clin Electrophysiol 2004;27:266-82.
45. Haissaguerre M, Jais P, Shah DC, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med 1998;339:659-66.
46. Cox JL, Canavan TE, Schuessler RB, et al. The surgical treatment of atrial fibrillation. II. Intraoperative electrophysiologic mapping and description of the electrophysiologic basis of atrial flutter and atrial fibrillation. J Thorac Cardiovasc Surg 1991;101:406-26.
47. Harada A, Sasaki K, Fukushima T, et al. Atrial activation during chronic atrial fibrillation in patients with isolated mitral valve disease. Ann Thorac Surg 1996;61:104-12.
48. Nitta T, Ishii Y, Miyagi Y, Ohmori H, Sakamoto S, Tanaka S. Concurrent multiple left atrial focal activations with fibrillatory conduction and right atrial focal or reentrant activation as the mechanism in atrial fibrillation. J Thorac Cardiovasc Surg 2004;127:770-8.
49. Konings KT, Kirchhof CJ, Smeets JR, Wellens HJ, Penn OC, Allessie MA. High-density mapping of electrically induced atrial fibrillation in humans. Circulation 1994;89:1665-80.
50. Nitta T, Ohmori H, Sakamoto S, Miyagi Y, Kanno S, Shimizu K. Map-guided surgery for atrial fibrillation. J Thorac Cardiovasc Surg 2005;129:291-9.
51. Yamauchi S, Ogasawara H, Saji Y, Bessho R, Miyagi Y, Fujii M. Efficacy of intraoperative mapping to optimize the surgical ablation of atrial fibrillation in cardiac surgery. Ann Thorac Surg 2002;74:450-7.
52. Chiappini B, Martìn-Suàrez S, LoForte A, Arpesella G, Di Bartolomeo R, Marinelli G. Cox/Maze III operation versus radiofrequency ablation for the surgical treatment of atrial fibrillation: A comparative study. Ann Thorac Surg 2004;77:87-92.
53. Sie HT, Beukema WP, Misier AR, et al. Radiofrequency modified maze in patients with atrial fibrillation undergoing concomitant cardiac surgery. J Thorac Cardiovasc Surg 2001;122:249-56.
54. Güden M, Akpinar B, Sanisoglu I, Sagbas E, Bayindir O. Intraoperative saline-irrigated radiofrequency modified Maze procedure for atrial fibrillation. Ann Thorac Surg 2002;74:S1301-6.
55. Pasic M, Bergs P, Müller P, et al. Intraoperative radiofrequency maze ablation for atrial fibrillation: The Berlin modification. Ann Thorac Surg 2001;72:1484-91.
56. Melo J, Adragao P, Neves J, et al. Surgery for atrial fibrillation using radiofrequency catheter ablation: Assessment of results at one year. Eur J Cardiothorac Surg 1999;15:851-5.
57. Benussi S, Nascimbene S, Agricola E, et al. Surgical ablation of atrial fibrillation using the epicardial radiofrequency approach: Mid-term results and risk analysis. Ann Thorac Surg 2002;74:1050-7.
58. Mohr FW, Fabricius A, Falk V, et al. Curative treatment of atrial fibrillation with intraoperative radiofrequency ablation: Short-term and midterm results. J Thorac Cardiovasc Surg 2002;123:919-27.
59. Sie HT, Beukema WP, Elvan A, Ramdat Misier AR. Long-term results of irrigated radiofrequency modified maze procedure in 200 patients with concomitant cardiac surgery: Six years experience. Ann Thorac Surg 2004;77:512-7.
60. Deneke T, Khargi K, Grewe PH, et al. Left atrial versus bi-atrial Maze operation using intraoperative cooled-tip radiofrequency ablation in patients undergoing open-heart surgery: Safety and efficacy. J Am Coll Cardiol 2002;39:1644-50.
61. Maessen JG, Nijs JF, Smeets JL, Vainer J, Mochtar B. Beating-heart surgical treatment of atrial fibrillation with microwave ablation. Ann Thorac Surg 2002;74:S1307-11.
62. Doll N, Kiaii BB, Fabricius AM, et al. Intraoperative left atrial ablation (for atrial fibrillation) using a new argon cryocatheter: Early clinical experience. Ann Thorac Surg 2003;76:1711-5.
63. Doll N, Borger MA, Fabricius A, et al. Esophageal perforation during left atrial radiofrequency ablation: Is the risk too high? J Thorac Cardiovasc Surg 2003;125:836-42.
64. Bonanomi G, Schwartzman D, Francischelli D, Hebsgaard K, Zenati MA. A new device for beating heart bipolar radiofrequency atrial ablation. J Thorac Cardiovasc Surg 2003;126:1859-66.
65. Saltman AE, Rosenthal LS, Francalancia NA, Lahey SJ. A completely endoscopic approach to microwave ablation for atrial fibrillation. Heart Surg Forum 2003;6:E38-41.