·专家论坛·

心房颤动外科手术的发展与评价

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[摘要] 随着电生理学对房颤机制的深入研究和新型标测技术消融能源的发展，房颤的外科治疗不断取得新的突破。由 Cox 迷宫手术的复杂术式逐渐向左迷宫、放射迷宫衍变。减少创伤提高治愈率，成为房颤外科治疗不断追求的新目标。本文概述了房颤外科治疗的各种术式设计原理和房颤根治术新消融技术的应用及其疗效评价。

[关键词] 心房颤动；手术；电生理学

[中图分类号] R 541.75 **[文献标识码]** A **[文章编号]** 0258-879X(2005)02-0124-03

Surgical intervention of atrial fibrillation: a review of development

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[ABSTRACT] With the in-depth research on the electrophysiological mechanism of atrial fibrillation (AF) and development of new mapping and ablation techniques, breakthroughs were frequently achieved in the surgical intervention for atrial fibrillation. From the complex Cox maze procedure to the left atrial maze procedure and radial maze procedure, the high successful rate and elimination of trauma have become the objective in the surgical intervention of atrial fibrillation. In this review we summarized the principle of all kinds of surgical procedures for atrial fibrillation and the application of new ablation technique for radical cure of AF and the effectiveness evaluation of these treatments.

[KEY WORDS] atrial fibrillation; operation; electrophysiological

[Acad J Sec Mil Med Univ, 2005, 26(2): 124-126]

心房颤动（房颤）是一种临床极为常见且危害严重的心律失常，在一般人群中的发病率为0.4%～2.0%，60 岁以上为 5%～10%；在器质性心脏病中发病率明显增加，在需行二尖瓣手术的患者中房颤的发生率达 50%以上，在冠脉旁路移植术中占 5%，在先心病的房缺和 Ebstein 的心脏畸形中有 40%～60%合并房颤，有心脏扩大及心力衰竭的患者中房颤发生率高达 40%。房颤可使心功能临界状态的患者发生明显的心力衰竭，房颤引起的脑卒中的平均年发病率高达 4.5%。因此房颤患者经内科治疗失败后，特别是合并器质性心脏病者，应积极进行外科治疗[1]。

1 房颤的电生理机制研究

房颤的发生机制学说有二：(1)一个或多个异位灶学说；(2)为多个子波学说。至今仍没有一种确切的理论能够解释所有房颤发生的机制，可能房颤本来就是多种机制并存和结合作用的结果。房颤持续维持的重要原因是心房组织内折返激动的持续存在，其根源来自心房组织的电重构和解剖重构。电重构主要是心房组织离子通道性质的改变导致心房组织有效不应期进行性缩短和电传导速度减慢，产生的折返激动波长缩短。心房内允许存在的折返环数量增加，提高房颤的稳定性。本期专题刊登的 2 项研究[2,3]即对此进行了报道。该研究涉及的风湿性心脏病心房组织连接蛋白的表达即证实了其组织重构对房颤产生的影响。

2 房颤迷宫手术的发展与评价

随着电生理学对房颤研究的深入，房颤的迷宫手术从标准迷宫手术发展到放射性切口的迷宫手术，以及左或右侧迷宫手术。

2.1 迷宫Ⅲ手术 1991 年 Cox 经动物实验和临床电生理研究发现房颤时心房肌存在多个大折返环围绕界嵴、腔静脉口和肺静脉口，其折返路径飘忽不定，瞬间即变，无法按电生理标测的路径指导手术，从而创造了能经心房多个切口阻断一切折返并使窦性激动能经特定的路径同步激动心房至房室结的迷宫手术。迷宫Ⅲ手术是从迷宫Ⅰ、Ⅱ型手术改进而来的，减少了手术的切口范围，避免了窦房结动脉的损伤和缩小左房隔离的范围，达到更好的心率变时性反应和心房功能的恢复。

标准迷宫手术包括迷宫Ⅲ型手术病例最多，随访

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时间最长和治疗效果最好，是开展房颤最早、最有效的外科治疗方法，带动了房颤外科治疗的全面发展，具有里程碑性质的功绩。Cox 从 1987 年 9 月到 2001 年 1 月共作了 346 例迷宫手术，其中迷宫Ⅲ型手术 300 例，1992 年 3 月开始微创迷宫Ⅲ型手术，1999 年不用体外循环按迷宫Ⅲ型手术路线冷冻消融 2 例。手术死亡率 2%～3%，包括高危险再次手术病例。治疗心房颤动成功率为 99%，右心房功能恢复 99%，左心房 93%[4]。本刊报道的一组迷宫与二尖瓣替换同期手术的 8 年随访，是国内随访期最长的报道，也显示了 100%的房颤治愈率[5]。

2.2 **左侧迷宫手术** Harada 等在慢性房颤合并单纯二尖瓣患者术中应用两心房心外膜电生理标测，发现左心耳和(或)左肺静脉口处有规则的反复激动，从而认为左心房是此类患者房颤的来源，提出并施行左侧迷宫手术。该手术方法仅作迷宫Ⅲ型手术的左心房部分，开创了应用心外膜电生理标测指导下进行迷宫手术的先河，为发展各种消融术奠定了实践基础，但其效果不如迷宫Ⅲ型手术。2001 年报告 32 例左侧迷宫和二尖瓣手术，术后 3 年房颤消失率为 74%，右心房功能恢复为 100%，左心房为 60%[6,7]。

2.3 **右侧迷宫手术** 1996 年经动物实验证实缝合界嵴可诱发折返性心房扑动和颤动。继而对继发性孔房缺和 Ebstein 心脏畸形合并房颤者施行心内修复时加用右侧迷宫手术，右心增大者则作部分右心房切除。1998 年报告了 15 例 Ebstein 心脏畸形、2 例先天性三尖瓣关闭不全和 1 例继发性房间隔缺损合并房扑和房颤，均施行右侧迷宫手术和上述三种心脏畸形修复手术，出院时 16 例为窦性心律，2 例交界心律，心功能均为Ⅰ级。

2.4 **放射性切口迷宫手术** 1999 年 Nitta 等[8]根据左心房激动顺序和冠状动脉分布而设计出放射性切口迷宫手术，希望达到较迷宫Ⅲ型手术更加符合心房激动顺序和维护左心房功能。手术方法如迷宫Ⅲ型右心房切口和缝合，但不切除右心耳，房间隔作一向上切口。左心房部分不用环绕肺静脉口的左心房隔离术，而在每个肺静脉口周围冷冻，切除左心耳，两肺上静脉上方作一横切口至右心耳切口，两肺下静脉下方作一横切口至前外交界处二尖瓣环。

放射迷宫术仅在少数单位开展，随访时间较短，长期效果有待观察，但放射性切口迷宫手术不切除右心耳，左心房无隔离区，术后保持左右心房功能较迷宫Ⅲ型手术好。1997～2003 年共作放射性切口手术 100 例，年龄(62±10)岁，82 例有心脏瓣膜病，9 例先心病，其余 9 例无心脏病。7 例有左心房血栓，无手术死亡，成功率为 91%，术后左心房功能良好，随访最长时间 74 个月(平均 35 个月)，无血栓栓塞并发症[9]。　　但是，迷宫Ⅲ型手术、放射性切口迷宫手术、左侧和右侧手术均需切开和缝合，均具有手术复杂、手术时间长、术后并发症多，特别是术后出血和病窦发生率高，仅在少数医疗中心应用。

3 改良迷宫手术及其评价

近 6 年来，许多国内外心脏外科医师弃用迷宫手术的切开/缝合方法，根据迷宫手术线路，应用冷冻、射频、微波和激光等外科消融术。

3.1 **冷冻消融术** 冷冻消融术应用液氮或二氧化碳气体经探头作用于心房肌，温度 −60℃，时间 2～3 min。组织损伤为术后 24 h 冰结/溶解，48 h 后炎症/出血，12 周组织纤维化和瘢痕，阻止电传导。其优点为基本保持组织结构，产生肌细胞均匀的损伤，而胶原纤维不受影响，消融部位的组织框架保持完整，形成瘢痕后不会破裂，消融部位的内膜也不受损伤，血栓形成极少。缺点是有时冷冻损伤不能透过整个肌层，组织解冻后会造成复发。2002 年 Yamauchi 等[10]报告 40 例在心外膜电生理标测下进行左心房局部冷冻消融术，均同时作了二尖瓣或房间隔缺损等手术。其中 11 例标测到异位灶(5)，折返环路(6)，均作了心内膜局部冷冻，9 例恢复窦性心律，2 例病窦综合征作了永久起搏，29 例"7"形路线冷冻。无死亡，31 例(77.3%) 窦性心律，6 例仍有心房颤动以及 3 例永久性起搏。

3.2 **射频消融术** 射频消融是应用分子振动产生热能，探头接触心房壁部位的温度为 50～60℃，时间 90～120 s。组织反应为局部心肌凝固，细胞和胶原纤维破坏产生不可逆损伤，数周后形成瘢痕。其缺点探头接触心房部位不能保证均能透壁，还有穿孔的危险。射频消融术路线较多，一为眼镜形路线，环绕两侧肺上下静脉各作一椭圆形圈，由其中一圈路线连接到二尖瓣环；二为马蹄形路线，连接左下肺静脉-右肺上静脉-右肺下静脉并连接到二尖瓣环；三为左和右心房路线，经心外膜或心内膜射频消融，左侧为眼镜形路线，右侧为右心房外侧纵行和峡部路线[11,12]。

针对瓣膜合并房颤的患者，2002 年 Mohr 等[13]

报告 234 例射频消融术，其中 160 例同时作了其他心脏病手术，经两心房顶部切口，消融路线位于四个肺静脉之间，经心内膜温度 60℃，时间 20 s。术后出院时，188 例（83.9%）为窦性心律，36 例为心房颤动，20 例永久性起搏。术后 12 个月（80/88）随诊 80 例中，57 例（72.5%）保持窦性心律，术后有 3 例在食管超声心动图检查时发现左心房食管瘘，再手术后 1 例死亡，2 例生存。2004 年报告 43 例双极射频消融术治疗心房颤动，主动脉阻断时间 43 分；明显少于标准迷宫Ⅲ型手术 93 分；同期附加手术分别为 92 分、122 分。随访（7.4±5.5）个月，无肺动脉狭窄，左心房功能保持良好，成功率 95%。

3.3　*微波消融术*　微波消融术的能量为 40～45 W，频率为 50～60 Hz，温度 50℃，时间 20～30 s，产生心房肌肉烧伤，中心为坏死心肌，周围为壁内出血，心内膜凝固有少许血栓，6 个月发现结实瘢痕。消融线路一为环绕四个肺静脉左心房隔离圈加至二尖瓣环路线，二为马蹄形路线。2002 年 Knaut 等[14]报告 105 例二尖瓣等手术和房颤微波消融术。消融能量 65 W，时间 45 s。手术后死亡 1 例，死于右心衰竭。随访 6 个月 69 例，42 例（61%）为窦性心律，24 例（34.8%）为房颤，3 例（4.2%）为房扑。随访 1 年 64 例，58%为窦性心律，34.8%房颤，以及 3 例房扑。

3.4　*激光消融术*　2002 年 Williams 等[15]报告激光探头治疗心房颤动，速度快（左心房隔离仅须 4 min），共作 9 例，透壁心肌和脂肪，经心内膜或心外膜有效和安全。3 个月后 9 例中 8 例为窦性心律，6 个月后有 8 例为窦性心律。

近 6 年来应用不同能量如冷冻消融术、射频消融术、微波消融术，其中冷冻消融术安全性好，两心房经心外膜射频消融效果最好，左心房心内膜射频消融可产生肺静脉口狭窄和左心房食管瘘。瞻望未来，合并心脏病的慢性房颤可进行心脏病手术同时加用冷冻和射频消融术，有经验的单位仍可施行各种不同的迷宫手术。在心房心外膜标测和心脏跳动下作射频消融术，经心外膜两心房路线消融将是研究和发展方向。

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[收稿日期]　2004-12-27　　**[修回日期]**　2005-01-09

[本文编辑]　尹　茶

• Original article •

Electrophysiologic study of f-wave amplitude in chronic atrial fibrillation associated with rheumatic heart disease

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[**ABSTRACT**] **Objective**: To investigate the electrophysiologic characteristics of f-wave amplitude and to evaluate its role in development and persistence of chronic atrial fibrillation (AF) associated with rheumatic heart disease (RHD). **Methods**: Epicardial mapping was performed in 44 patients with chronic AF of RHD who underwent heart valve surgery. Ten patients with supraventricular tachycardia served as the control group. **Results**: The f-wave amplitude of left atrium (LA) and middle and low LA posterior regions were significantly lower than those of the control group. The f-wave amplitudes of the upper, middle and low sections in LA posterior region were significantly lower than those in right atrium (RA) ($P<0.05$). The f-wave amplitudes were compared before and after electrocardioversion in 14 patients with chronic AF. The mean atrial electrogram amplitude during sinus rhythm was significantly higher than that during AF ($P<0.01$). The f-wave amplitude in left appendage was higher than that in LA posterior region (the upper, middle and the lower part), $P<0.05$. The f-wave amplitude in the upper section of LA was significantly higher than that in the middle section. The f-wave amplitude in AF group was not correlated to the diameter or volume of both atria. **Conclusion**: There are amplitudes differences between the upper, middle and lower LA, suggesting that the middle and lower sections of LA posterior wall may be the region producing anisotropy and reentrant circle.

[**KEY WORDS**] rheumatic heart disease; atrial fibrillation; f-wave amplitude; electrophysiology

[Acad J Sec Mil Med Univ, 2005, 26(2): 127-130]

Atrial wave amplitude is related to compound vector during depolarization of myocardial cells and membrane potentials. Atrial fibrillation (AF) and change of electrophysiological characters in atrial myocytes lead to reentrant circles with different amplitudes and directions: functional syncytium of cell depolarization disappears and anisotropy of atrial activated wave and broken f-wave appears. F-wave amplitude is of great significance in elucidating the mechanism of AF. In order to clarify the role of atrial wave amplitude in producing and maintaining AF, this study investigated wave amplitude of chronic AF in patients with rheumatic heart disease (RHD).

1 MATERIALS AND METHODS

1.1 Study population The study population consisted of 44 patients [15 men and 29 women; mean age, (42.84±10.50) years, ranging 20-64 years] with RHD (2-30 years) and symptomatic chronic AF [(69.2±27.9) months, ranging 3 months-10 years]. Seventeen patients had mitral valve lesions, 4 had mitral and aortic valve lesions, 10 had mitral, aortic and tricuspid valve lesions, and 13 had mitral and tricuspid valve lesions. Patients with atrioventricular pathway or double ways of atrioventricular node, who had undergone radiofrequency ablation, were chosen as control group [3 men and 7 women; mean age, (35.72±12.36) years, ranging 15-52 years]. No patients in control group had organic heart diseases or induced AF in routine electrophysiologic examination.

1.2 Epicardial mapping After sternum dissection and bicaval cannulation, epicardial mapping was performed before cardiopulmonary bypass. Button electrodes with a 1 mm interval were sutured in the right and left appendages and anterior wall of the right ventricle. Halo catheters were used for mapping right and left appendages and posterior wall of artia with a 1 mm interval-double electrodes and the distance between each pair of double electrodes being 7 mm. 16-lead synchronic map and lead II of body surface ECG were recorded (voltage 1 to 2.5 mV/cm and paper velocity 50 to 200 mm/s). Electrocardioversion was performed

[**Foundation**] This project is supported by the National Natural Science Fundation of China (30070749).

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after mapping. The atrial wave amplitudes of 14 patients undergoing successful electrocardioversion and complete recording were compared before and after electrocardioversion.

1.3 Electrophysiologic examination Antiarrhythmic drugs were discontinued for more than 5 half life periods before intracardiac electrophysiologic examination. Catheters with electrodes were placed in the high right atrium (HRA), His bundle, coronary sinus (CS) and the right ventricular apex (RVA) by puncturing right venae jugularis interna and left and right venae femoralis. Atrial regional electric activation of 12 points were recorded during sinus rhythm by ablation electrode on HRA, the lateral wall of right atrium, posterior wall of right atrium, superior, middle and inferior interauricular septum, distal(CSd), middle(CSm) and proximal(CSp), then the perimeter, voltage and atrium activation time were measured, and HRA, His bundle, CS, RVA, and mapping points of ablation electrode were recorded (voltage 1 mV/cm and paper velocity 50 to 200 mm/s).

1.4 Analysis of mapped materials Peak amplitudes of the highest A-wave *in situ* zigzag were measured during sinus rhythm. Mean value was calculated for 10 peak amplitudes of A-wave at random. F-wave amplitude in AF was chosen *in situ* zigzag according to isoelectric line. Mean value was calculated for 25 peak f-wave amplitudes. Peak amplitudes of the biggest f-wave *in situ* zigzag were chosen at 200 ms interval if the isoelectric line did not appear, and mean value was calculated for 25 consecutive peak amplitudes of f-wave.

1.5 Statistical processing Values are represented as $\bar{x} \pm s$. Variables were compared by matched, Student t test.

2 RESULTS

2.1 Comparison between f-wave amplitude in AF group and A-wave in control group There was no significant difference between f-wave amplitude of the right atrium(RA) in AF group and A-wave in the control group. The f-wave amplitudes in middle and lower LA posterior regions were significantly lower than A-wave in the control group (Tab 1).

Tab 1 Comparison of f-wave amplitude between AF group and control group and between different sites in AF group

($\bar{x} \pm s$, U/mV)

Group	n	RA				LA			
		Appendage	Upper	Middle	Lower	Appendage	Upper	Middle	Lower
AF	44	1.43±1.10=	1.50±1.03==	1.62±1.08==	1.55±1.26==	1.21±1.32	1.01±1.08△△▲	0.68±0.61**△△	0.77±0.69**△△
Control	10	2.21±0.50	1.66±0.18	2.14±0.83	1.64±0.94	1.34±0.92	1.68±1.08	2.34±1.16	2.08±1.37

** $P<0.01$ *vs* control group; △△ $P<0.01$ *vs* appendage of LA; ▲ $P<0.05$ *vs* middle part of LA; = $P<0.05$, == $P<0.01$ *vs* the same index of LA. RA: Right atrium; LA: Left artium

2.2 Comparison of f-wave amplitudes at diffferent places in AF group The f-wave amplitudes of the upper, middle and lower sections of LA posterior region were significantly lower than those in the RA($P<0.05$, $P<0.01$)(Tab 1). The f-wave amplitudes of the left appendage in AF group were significantly higher than those of the LA upper, middle and lower section in LA($P<0.01$). The f-wave amplitudes of the LA upper section was significantly higher than that of the LA middle sections ($P<0.05$).

2.3 Comparison of atrial wave amplitudes before and after electrocardioversion in AF group As Tab 2 shows, the A-wave amplitude during sinus rhythm was significantly higher than f-wave amplitude during AF in 14 patients ($P<0.01$).

2.4 Correlation analysis Diameter of the RA in AF group was (5.81±1.49) cm and volume was (79.14 ± 70.32) cm^3; diameter of the LA was (7.24±0.89) cm and volme was (216.15±100.19) cm^3. There was no correlation in different sites of LA and RA between f-wave amplitudes and its internal diameter or volume(Tab 3).

Tab 2 Comparison of f-wave amplitudes with A-wave amplitudes before and after electrocardioversion in AF group

(n=14, $\bar{x}\pm s$, U/mV)

Index	RA				LA			
	Appendage	Upper	Middle	Lower	Appendage	Upper	Middle	Lower
f-wave amplitudes before electrocardioversion	1.33±1.04	1.36±0.99	1.27±1.35	1.47±1.02	1.62±1.28	0.73±1.01	0.63±0.62	0.82±0.62
A-wave amplitudes after electrocardioversion	2.30±1.45**	1.91±1.59**	1.39±0.93**	1.61±1.22**	1.95±1.56**	1.83±1.54**	1.74±1.51**	1.69±1.34**

** $P<0.01$ *vs* f-wave amplitudes before electrocardioversion. RA: Right atrium; LA: Left atrium

Tab 3 Correlation coefficient between f-wave amplitudes of different sections of LA and RA and their corresponding diameters and volumes

Site	RA				LA			
	r^a	P^a	r^b	P^b	r^a	P^a	r^b	P^b
Appendage	−0.16	0.33	−0.16	0.35	−0.18	0.30	−0.02	0.93
Upper	−0.06	0.69	−0.30	0.06	−0.21	0.20	0.05	0.77
Middle	0.05	0.75	0.07	0.66	−0.07	0.65	−0.12	0.48
Lower	−0.14	0.38	0.02	0.89	−0.02	0.89	−0.17	0.31

a: Internal diameter; b: Volume

3 DISCUSSION

One of the major characters of AF is the absence of P wave and a series of fast continuous and irregular activated waves of the atrium on ECG, which was called f-wave on ECG. The shape, size, and interval of f-wave are different in the same lead. F-wave may be bulky or slender, therefore, f-wave is called a bulky pattern if f-wave amplitude is more than 1 mm and a slender pattern if f-wave amplitude is less than 1 mm. Generally, AF rate is slow in bulky f-wave while it is fast in slender f-wave, which can not easily beconverted into sinus rhythm by quinidine or electrocardioversion. Recognitio of AF by common ECG can not meet the need of electrophysiologic study for AF. There are few studies[1] concerning f-wave amplitude by intra-atrium mapping, and no studies on f-wave amplitude of chronic AF with RHD have been reported. Sixty-nine patients with auto-captured pacemakers were tested for myocardial f-wave amplitude during sinus rhythm, paroxysmal AF and atrial flutter by Wood *et al*[2] in 1996 using atrial bipolar pacemakers. They found that A-wave amplitude was (1.59±1.36) mV during sinus rhythm in 25 patients with paroxysmal AF, while f-wave amplitude was (0.77±0.58) mV ($P<0.0001$) during AF rhythm. A-wave amplitude was (1.81±2.07) mV during sinus rhythm in 44 patients with atrial flutter, while f-wave amplitude was (1.50±1.81) mV ($P<0.0001$) during atrial flutter rhythm. F-wave amplitude during AF and atrial flutter rhythm was only 20% the A-wave amplitude during sinus rhythm, and A-wave amplitude during sinus rhythm was correlated with f-wave amplitude during AF and atrial flutter rhythm (r values were 0.79 and 0.94 respectively, both $P<0.0001$). This was only one section bipolar mapping of HRA and the subjects were patients with paroxysmal AF or atrial flutter. The present study, using 16 leads synchronized epicardial mapping in 44 patients with RHD and chronic AF, found that f-wave amplitudes of the LA middle and lower sections were significantly lower than A-wave in the control group ($P<0.01$) and f-wave amplitudes of the LA middle and lower sections were significantly lower than those in right atrium($P<0.05$). F-wave amplitude values of middle and lower section in LA were (0.68±0.61) and (0.77±0.69) mV. The reason for lower amplitude may be related to myocardial anisotropy resulting from mitral valve pathological changes with RHD. F-wave amplitude is high on mapping electrograms if overall depolarized vector is high at the same time because f-wave is the reflection of overall vector. Myocardial bundle is separated with connective tissue if regional myocardial fibre become degenerative, which then lead to overall depolarized current with anisotropy and overall lowered depolarized vector, and last to a lowered f-wave amplitude. In our series of studies we found that the f-wave amplitudes of the middle section in LA posterior region were the lowest and the effective refractory periods were the shortest and positively correlated with wavelength index, which showed that the myocardium is anisotropy and become reentrant easily. It is notable that A-