·临床研究·

老年心房颤动患者高功率短时程射频消融远期随访的单中心研究

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【摘 要】 **目的** 评估老年心房颤动患者高功率短时程(HPSD)射频消融术后12~36个月心房颤动复发风险,并探讨其安全性及复发预测因素。**方法** 回顾性分析2020年1月至2022年12月在联勤保障部队第983医院行射频消融的139例老年心房颤动患者的临床资料,根据消融策略分为HPSD组(n=72)与常规低功率长时程(LPLD)组(n=67)。收集基线资料、术前心脏超声参数及手术数据,术后随访12~36个月。采用SPSS 21.0软件进行数据分析。根据数据类型,组间比较分别采用t检验、Mann-Whitney U检验及χ^2检验。采用logistic回归分析术后心房颤动复发独立危险因素,采用Kaplan-Meier分析HPSD组和LPLD组远期无心房颤动复发率。**结果** HPSD组较LPLD组显著缩短双侧肺静脉消融时间,差异均有统计学意义[右:(14.97±3.70)和(18.00±3.56)min,左:(13.54±5.59)和(16.30±4.37)min;均P<0.05]。logistic分析显示,持续性心房颤动(OR=5.50,95%CI 1.994~15.171)、心力衰竭(OR=7.92,95%CI 2.484~25.257)、左房内径(OR=1.111,95%CI 1.028~1.202)及左室内径(OR=1.105,95%CI 1.030~1.186)增大是术后复发的独立危险因素(均P<0.05)。HPSD组和LPLD组12~36个月累积复发率比较,差异无统计学意义[33.3%(24/72)和37.3%(25/67),P=0.634]。**结论** HPSD策略可提高心房颤动消融手术效率且不增加中远期复发风险,而持续性心房颤动、心力衰竭及心脏结构重构(左房/左室增大)是老年心房颤动患者术后复发的关键预测因素。

【关键词】 老年人;心房颤动;射频消融;高功率短时程

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Long-term follow-up of high-power short-duration radiofrequency ablation in elderly patients with atrial fibrillation: a single-center study

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【**Abstract**】 **Objective** To assess the risk of atrial fibrillation (AF) recurrence at 12-36 months after high-power short-duration (HPSD) radiofrequency ablation post-procedure in elderly patients with AF and to investigate its safety and predictors for recurrence. **Methods** A retrospective analysis was conducted of the clinical data of 139 elderly AF patients who underwent catheter ablation at the 983rd Hospital of the Joint Logistics Support Force from January 2020 to December 2022. According to the ablation strategy, they were divided into HPSD group (n=72) and low-power long-duration (LPLD) group (n=67). Baseline data, preoperative echocardiographic parameters, and procedural data were collected. The patients were followed up for 12-36 months postoperatively. SPSS 21.0 was used for statistical analysis. Data comparison between two groups was performed using t test, Mann-Whitney U test or χ^2 test depending on data type. Logistic regression was used to identify independent risk factors for postoperative AF recurrence. Kaplan-Meier analysis was employed to assess the long-term AF-free survival rates in the HPSD and LPLD groups. **Results** The HPSD group showed significantly shorter ablation times for bilateral pulmonary veins isolation than the LPLD group [right: (14.97±3.70) *vs* (18.00±3.56) min; left: (13.54±5.59) *vs* (16.30±4.37) min; both P<0.05]. Logistic regression analysis identified persistent AF (OR=5.50, 95%CI 1.994-15.171), heart failure (OR=7.92, 95%CI 2.484-25.257), left atrial diameter (OR=1.111, 95%CI 1.028-1.202), and left ventricular diameter (OR=1.105 per mm, 95%CI 1.030-1.186) as independent risk factors for recurrence (all P<0.05). No statistically significant difference in cumulative recurrence rates was observed between the HPSD and LPLD groups at 12-36 months [33.3% (24/72) *vs* 37.3% (25/67), P=0.634]. **Conclusion** HPSD ablation improves procedural efficiency without increasing mid-to-long-term recurrence risk. Persistent AF, heart failure, and cardiac structural remodeling (left atrial/ventricular enlargement) are key predictors of recurrence in elderly AF patients.

【**Key words**】 aged; atrial fibrillation; radiofrequency ablation; high-power short-duration

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心房颤动(atrial fibrillation, AF)消融策略历经革新,高功率短时程(high-power short-duration, HPSD; 40~90 W)消融正逐步取代传统低功率长时程(low-power long-duration, LPLD; 25~35 W)消融。循证医学证据表明,HPSD 消融可显著缩短手术时间(降低 28%)、提升单圈肺静脉隔离率(提高 15%)并维持安全性[1],其核心机制在于电阻性热传导优势——相同能量下,HPSD 消融通过集中产热形成更宽(+35%)、更均匀的透壁损伤,同时减少组织水肿和邻近器官(食管/膈神经)损伤风险[2]。消融指数(ablation index, AI)的引入进一步优化了 HPSD 消融,其整合接触压力、时间、能量及导管稳定性的量化参数(AI=CF×时间×功率积分),为精准控制消融深度提供保障[3]。尽管 HPSD 消融前景广阔,其临床应用仍面临三大问题,具体如下。(1)技术异质性:功率范围(40~90 W)与时程(5~20 s)缺乏统一标准,尤其超高功率(90 W)策略的安全性证据不足[4];(2)人群特异性缺失:老年患者(>60 岁)因心房结构薄(平均 2.1 mm 和青年 2.8 mm)、合并症多,其 HPSD 消融疗效与风险尚无专门研究[5,6];(3)长期预后不明:现有研究随访期多≤12 个月,AI 指导下的 HPSD 消融能否降低远期肺静脉电传导再恢复率(当前 8%~22%)[3]仍需验证。本研究为回顾性对照观察单中心研究,旨在探讨老年 AF 患者在 AI 指导下进行高功率短时程消融的即刻效果和远期预后,为其应用提供更多临床证据。

1 对象与方法

1.1 研究对象

连续纳入 2020 年 1 月至 2022 年 12 月联勤保障部队第九八三医院心血管内科首次行射频消融治疗的老年 AF 患者。本研究符合 2013 年修订的《赫尔辛基宣言》原则,纳入患者均签署知情同意书,本研究获得联勤保障部队第九八三医院伦理委员会批准,伦理号:2022-YK-025-01。

纳入标准:(1)术前符合 2020 年欧洲心脏病学会AF 管理指南中射频消融适应证;(2)年龄≥60 岁;(3)为首次接受 AF 射频消融治疗。排除标准:(1)随访期间确诊如急性心肌梗死、甲状腺功能亢进、肥厚型心肌病、扩张型心肌病、风湿性心脏病等可直接导致 AF 发作的器质性疾病;(2)随访期间再次接受射频消融、冷冻球囊、脉冲磁场消融等治疗 AF 的介入操作;(3)随访期间接受心脏外科手术。

1.2 方法

1.2.1 一般资料 采集患者一般资料,包括年龄、性别、体质量指数(body mass index, BMI)、随访时间、伴随疾病、吸烟、饮酒及术前使用抗心律失常药物情况;术前通过心脏彩色超声观察左心房内径、右心房内径、左心室内径、右心室内径、二尖瓣及三尖瓣器质性反流情况等。

1.2.2 手术过程 所有手术均由同一术者完成。术中根据消融功率不同,分为 HPSD 组(n=72 例)和 LPLD 组(n=67 例)。高功率短时程消融组前壁、后壁、顶部及底部消融功率均为 40 W,常规功率消融组前壁消融功率为 35 W,后壁、顶部及底部消融功率 30 W。两组消融过程中压力均保持在 5~20 g,两组 AI 值相同,左心房嵴部 AI 值 500、前壁 AI 值 480、后壁 AI 值 380、顶部及底部 AI 值 400(图 1)。术中记录手术相关指标(手术时间、X 线透视时间、单圈隔离率、肺静脉隔离靶点数、肺静脉电传导再恢复率)及相关手术并发症情况。

1.2.3 术后随访 通过门诊及动态心电图对患者进行 12~36 个月随访,观察 AF 复发率和风险因素。

1.3 统计学处理

采用 SPSS 21.0 统计软件进行数据分析。符合正态分布的计量资料用均数±标准差($\bar{x}\pm s$)表示,采用 t 检验;非正态分布的计量资料,用中位数(四分位数间距)[$M(Q_1, Q_3)$]表示,采用 Mann-Whitney U 检验。计数资料用例数(百分率)表示,采用 χ^2 检验。采用 logistic 回归分析术后 AF 或房性心动过速(atrial tachycardia, AT)复发独立危险因素,采用 Kaplan-Meier 分析 HPSD 组和 LPLD 组远期无 AF 或 AT 复发率。P<0.05 为差异有统计学意义。

2 结 果

2.1 两组患者基线资料的单因素分析

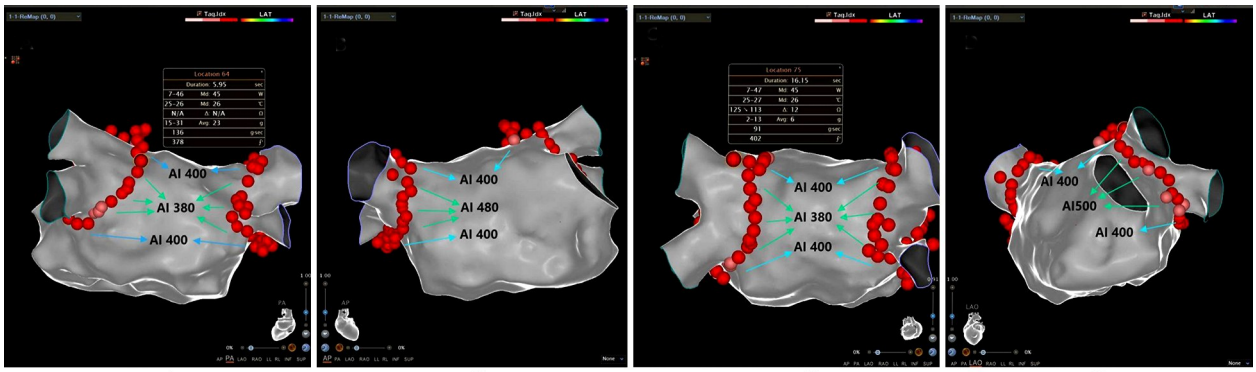
与 LPLD 组比较,HPSD 组患者右心房内径较大(P<0.05);其他资料比较差异无统计学意义(P>0.05;表 1)。

2.2 两组患者围手术期消融和并发症情况

与 LPLD 组比较,HPSD 组患者手术时间、射频消融时间、X 线透视时间均明显缩短,差异有统计学意义(P<0.001);肺静脉单圈隔离率、肺静脉消融靶点数、即刻肺静脉电传导恢复率均明显减少(均 P<0.01)。HPSD 组相关并发症如热损伤、血管穿刺并发症、心包渗出等与 LPLD 组类似,差异均无统计学意义(均 P>0.05;表 2)。

2.3 两组患者术后用药及随访情况

与 LPLD 组相比,HPSD 组患者术后长期使用抗心律失常药物、随访时间及 AF 或 AT 复发率差异无统计学意义(P>0.05;表 3)。



A B C D

图 1 高功率短时程消融心房不同部位 AI 值

Figure 1 AI values of HPSD ablation at different atrial sites

A: PA view shows posterior wall, roof and floor of the left atrium; B: AP view shows anterior wall, roof and floor of the left atrium; C: corrected PA view shows posterior wall, roof and floor of the left atrium; D: LAO view shows appendage ridge, roof and floor of the left atrium.
AI: ablation index; HPSD: high-power short-duration; PA: posterior-anterior; AP: anterior-posterior; LAO: left anterior oblique.

表 1 两组患者基线资料的单因素分析

Table 1 Univariate analysis of baseline data of the two groups

Factor	HPSD group(n=72)	LPLD group(n=67)	χ^2/t	P value
Male[n(%)]	42(58.3)	39(58.2)	0.853	0.998
Age(years, $\bar{x}\pm s$)	67.25±4.85	65.79±3.31	0.853	0.395
BMI(kg/m^2, $\bar{x}\pm s$)	26.35±3.66	25.74±2.69	1.120	0.265
History of smoking[n(%)]	24(33.3)	24(35.8)	0.095	0.758
History of alcohol abuse[n(%)]	12(16.6)	15(22.4)	0.726	0.394
History of AF[month, $M(Q_1,Q_3)$]	12(2,60)	18(2,60)	0.649	0.517
Type of AF(proportion of persistent AF)	15(20.9)	15(22.4)	6, 497	0.731
Hypertension[n(%)]	42(58.3)	47(70.1)	2.104	0.147
Chronic obstructive pulmonary disease[n(%)]	3(4.2)	3(4.5)	0.008	0.928
Coronary artery disease[n(%)]	28(38.9)	27(40.2)	0.029	0.865
Diabetes mellitus[n(%)]	22(30.6)	19(28.3)	0.081	0.777
Cardiac failure[n(%)]	9(14.3)	6(9.0)	0.453	0.501
Estimated glomerular filtration rate[ml/(min · 1.73m^2), $\bar{x}\pm s$]	98.27±31.83	105.76±34.41	−1.338	0.183
Pre-procedure use of antiarrhythmic drugs[n(%)]	35(48.6)	36(53.7)	0.272	0.602
Left atrium diameter(mm, $\bar{x}\pm s$)	38.38±5.33	39.30±4.62	−1.083	0.281
Left ventricle diameter(mm, $\bar{x}\pm s$)	47.57±4.72	48.71±6.15	−1.227	0.222
Right atrium diameter(mm, $\bar{x}\pm s$)	33.22±5.12	31.20±3.97	2, 470	0.015
Right ventricle diameter(mm, $\bar{x}\pm s$)	26.00±3.42	27.22±3.92	−1.958	0.052
Ejection fraction(%, $\bar{x}\pm s$)	66.12±12.67	68.14±14.82	0.948	0.345
Mitral regurgitation[n(%)]	11(15.2)	7(10.4)	0.718	0.397
Tricuspid regurgitation[n(%)]	9(12.5)	8(12.0)	0.100	0.92

HPSD: high-power short-duration; LPLD: low-power long-duration; BMI: body mass index; AF: atrial fibrillation.

表 2 两组患者围手术期相关消融和并发症指标比较

Table 2 Comparison of perioperative ablation and complication indicators between two groups

Item	HPSD group(n=72)	LPLD group(n=67)	χ^2/t	P value
Procedural duration(min, $\bar{x}\pm s$)	112.6±18.4	149.3±27.6	−9.283	<0.001
Radiofrequency application duration(s, $\bar{x}\pm s$)	25.8±4.8	32.7±5.6	−7.816	<0.001
X-ray exposure duration(min, $\bar{x}\pm s$)	4.1±1.8	8.9±3.4	−10.50	<0.001
First-pass isolation rate(%, $\bar{x}\pm s$)	94.2±3.7	76.5±4.5	28.27	<0.001
Time of right pulmonary vein ablation(min, $\bar{x}\pm s$)	14.97±3.70	18.00±3.56	−4.921	<0.001
Time of left pulmonary vein ablation(min, $\bar{x}\pm s$)	13.54±5.59	16.30±4.37	−3.227	0.002
Pulmonary veins isolation target lesions(n/patient, $\bar{x}\pm s$)	49.3±9.6	73.8±10.7	−14.23	<0.001
Acute pulmonary veins re-connection rate[n(%)]	7.1±2.7	22.4±4.3	−25.31	<0.001
Esophageal thermal injury rate[n(%)]	5(6.9)	7(10.4)	0.540	0.462
Vasculalr access complications[n(%)]	3(4.2)	2(3.0)	0.140	0.709
Pericardial effusion[n(%)]	1(1.4)	2(3.0)	0.419	0.518

HPSD: high-power short-duration; LPLD: low-power long-duration.

表 3 两组患者术后用药及随访情况比较

Table 3 Comparison of post-ablation medication and follow-up between two groups

Group	*n*	Dronedarone/amiodarone [*n*(%)]	Propafenone [*n*(%)]	Beta-blockers [*n*(%)]	Follow-up time (months, $\bar{x}\pm s$)	AF/AT recurrence [*n*(%)]
HPSD	72	25(53.2)	35(48.6)	27(37.5)	24.21±4.48	24(33.3)
LPLD	67	32(47.8)	25(37.3)	22(32.8)	23.78±5.49	25(37.3)
χ^2/t		2.439	1.806	0.331	0.507	0.241
P value		0.118	0.179	0.565	0.613	0.624

AF: atrial fibrillation; AT: atrial tachycardia; HSPD: high-power short-duration; LPLD: low-power long-duration.

2.4 AF 复发风险因素及远期无复发率分析

logistic 回归分析结果显示:持续性 AF、心力衰竭、左房内径、左室内径是 AF 或 AT 复发的独立危险因素(表 4);Kaplan-Meier 分析表明射频消融术后 12~36 个月内,接受 HPSD 消融患者较 LPLD 消融患者 AF 或 AT 复发率无明显差异(图 2)。

表 4 随访期间复发危险因素的 logistic 回归分析

Table 4 Logistic regression analysis of risk factors for recurrence during the follow-up period

Factor	*SE*	*B*	*Wald* χ^2	*OR*(95%*CI*)	*P* value
History of AF	0.003	0.004	2.535	1.004(0.999,1.010)	0.111
Type of AF	0.518	1.705	10.844	5.523(1.994,15.171)	<0.001
Cardiac dysfunction	0.592	2.069	12.232	7.921(2.484,25.257)	<0.001
Left atrium	0.041	0.106	7.005	1.111(1.028,1.202)	<0.001
Left ventricle	0.036	0.109	7.815	1.105(1.030,1.186)	0.005
Mitral valve organic regurgitation	0.521	1.296	6.191	3.654(1.317,10.140)	0.013
Right pulmonary vein ablation time	0.052	0.011	0.042	1.011(0.916,1.114)	0.841
Left pulmonary vein ablation time	0.038	0.053	1.916	1.054(0.978,1.054)	0.166
Ablation modalities	0.391	0.173	0.195	1.188(0.552,2.558)	0.659

AF: atrial fibrillation.

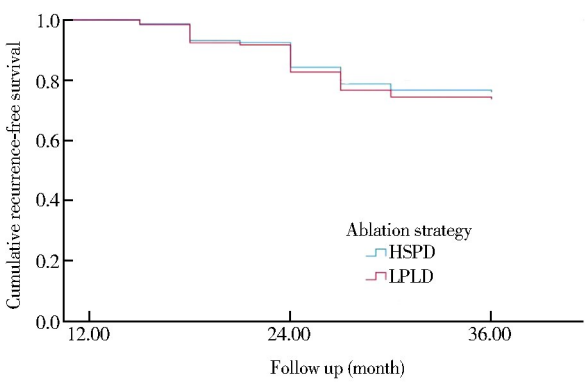


图 2 两组术后无复发率 Kaplan-Meier 分析曲线

Figure 2 Kaplan-Meier analysis of recurrence-free survival between two groups

AF: atrial fibrillation; HSPD: high-power short-duration; LPLD: low-power long-duration.

3 讨 论

本研究结果显示:(1)HPSD 消融策略的手术时间和 X 线透视时间明显缩短,手术时间较 LPLD 消融缩短接近三分之一;(2)HPSD 消融策略没有增加相关并发症的趋势;(3)HPSD 消融策略与 LPLD 消融策略具有类似临床效果,HPSD 消融策略较 LPLD 消融策略随访 1 年以上 AF 复发率有降低趋势,3 年随访 AF 复发率相当。

AF 消融术后肺静脉电传导再恢复是复发的重要机制[5]。前瞻性临床研究验证了 HPSD 消融的实践价值:Leo 等[7]运用损伤范围指数(lesion size index, LSI)对比发现,40 W 组较 20 W 组不仅缩短 30%手术时间,更显著提高肺静脉单圈隔离率(82%和 64%),并使 3 年复发风险降幅达 45%。Shin 等[8]证实 50 W 方案较常规功率有效缩减 35%消融时间,且安全性指标相当(心脏压塞发生率 0.3%和 0.4%),1 年随访结果显示总体复发率 16%且无 AF 类型差异。多项研究分析一致证实,HPSD 策略可平均缩短 42 min 手术时间(95% *CI* 35~50),降低 38%术中即刻电传导恢复,这一优势延伸至超高功率超短时程实验方案仍保持显著[9,10]。本研究结果表明 HPSD 消融的手术时间、X 线透视时间、肺静脉隔离靶点数、单圈隔离率、肺静脉电传导再恢复率均明显减少,与国外研究结果[11]类似。

AI 指导的射频消融技术通过预设靶点损伤指数显著提升手术精准度,多项研究证实其具有三大临床优势:(1)缩短手术总时长(Δ−23 min)、消融时长(Δ−11 min)和透视时长(Δ−8 min);(2)实现组织损伤深度与解剖适配性(左房后壁 AI 370 和前壁 AI 480);(3)降低 35%肺静脉传导再恢复风险[3,12,13]。本研究的 AI 设定(后壁 380/前壁 480/嵴部 500)与主流方案(目标值 550/400)存在梯度差异,但仍达到平均超过 90%的单圈隔离率。本研究参数匹配的解剖逻辑:后壁较低的 AI 设定(380 和 400~550)旨在平衡透壁损伤(*OR* = 1.45)与食管热损伤(esophageal thermal injury, ETI)风险(*HR* = 0.62),

符合当前指南推荐[14]。超高功率超短时程消融可以尽量避免损伤,但消融的即刻成功率可能会因为无法充分达到透壁损伤而降低[15]。本研究结果表明,AI指导下的HPSD消融(40 W)是安全且有效的,可以将局部能量和消融时间降至足以形成透壁损伤的最低水平。值得注意的是,后壁BOX消融不会增加ETI的风险,将后壁消融的AI目标值设定为380能够明显减少ETI的发生[16]。

老年组与非老年组HPSD术后1年无AF生存率相似(76%和73%~80%),但老年患者复发风险仍受年龄、左房增大、持续性AF等因素影响[17,18]。LPLD组肺静脉电传导再恢复率更高(HPSD 20%和LPLD 30%),而HPSD形成更均匀透壁损伤[9]。本研究中HPSD消融肺静脉电传导再恢复率更低(7.1%,95% *CI* 4.1~8.9),相关的推测机制如下:(1)老年患者心房纤维化、脂肪浸润增加,电阻升高,HPSD电阻热更易形成表浅宽大损伤,但透壁性依赖AI精准调控(后壁AI需更低)[15];(2)老年患者传导热衰减快,HPSD减少深层组织水肿,降低肺静脉再传导,但需避免超高功率(如90 W)因组织脆弱导致穿孔风险[15,19];(3)老年患者常合并糖尿病、心力衰竭,炎症修复能力下降,HPSD减少组织应激反应,降低术后心房基质恶化风险[17]。因此,HPSD在老年患者中安全性优于LPLD,但需严格控制后壁AI值(≤380)及接触压力(<10 g)。

综上,左心房不同部位采用不同AI值设定指导下HPSD消融,即刻肺静脉电传导再恢复率明显降低,远期预后与LPLD消融策略相当,热损伤风险有降低趋势。老年AF患者中,持续性AF、心力衰竭、左房内径增大、左室内径增大是AF复发的独立风险因素,HPSD消融不会增加术后12~36个月内复发率。

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