



超声心动图评估无导线起搏器Micra AV植入后的心肌应变及心室不同步性

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· 论 著 ·

超声心动图评估无导线起搏器 Micra AV 植入后的心肌应变及心室不同步性

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[摘要] **目的** 探讨植入 Micra AV 无导线起搏器患者的左、右室心肌应变及不同步性, 并进一步分析植入位置对心肌应变及不同步性的影响。**方法** 回顾性选择 2023 年 4 月至 2023 年 12 月在复旦大学附属中山医院心内科植入 Micra AV 的患者 43 例 (Micra AV 组) 以及高度房室传导阻滞 (II 度 II 型、III 度房室传导阻滞) 患者 20 例 (传导阻滞组), 收集患者人口学信息、临床特征。采用常规超声心动图和斑点追踪成像技术获取 2 组患者的常规心超参数、心肌应变及不同步性指标, 包括心室整体纵向应变 (global longitudinal strain, GLS)、心室游离壁纵向应变 (free wall longitudinal strain, FWLS)、左室 18 节段纵向应变达峰时间离散度 (peak strain dispersion, PSD)、右室 6 节段 PSD 以及其他指标。根据 Micra AV 植入位置进一步分为中位组 (右室间隔部)、高位组 (右室流入道) 及低位组 (心尖部), 比较 3 个亚组心肌应变及不同步性指标差异。**结果** Micra AV 组左室 GLS、右室 GLS、右室 FWLS 均显著低于传导阻滞组 ($P < 0.001$), Micra AV 组的右室不同步性显著高于传导阻滞组 ($P < 0.05$)。不同植入部位心肌应变及不同步性比较显示, 高位组左室 GLS 显著高于中位组和低位组, 左室不同步性指标 Yu 指数显著低于中位组 ($P < 0.05$); 低位组右室射血分数 (right ventricular ejection fraction, RVEF) 显著低于高位组, 右室 6 节段 PSD 显著高于中位组和高位组 ($P < 0.05$)。**结论** 与高度房室传导阻滞患者相比, Micra AV 无导线起搏患者的左室及右室心肌应变减低, 且低位植入的影响更大。

[关键词] Micra AV; 无导线起搏器; 心肌应变; 心室不同步性; 斑点追踪成像技术**[中图分类号]** R 541.7 **[文献标志码]** A

Echocardiography evaluation of myocardial strain and ventricular dyssynchrony after implantation of leadless pacemaker Micra AV

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[Abstract] **Objective** To explore the left and right ventricular myocardial strain and dyssynchrony in patients with Micra AV leadless pacing implantation, and to further analyze the impact of implantation site on myocardial strain and dyssynchrony. **Methods** A retrospective study was conducted on 43 patients with Micra AV implantation and 20 patients with high-degree atrioventricular block (II degree type II and III degree atrioventricular block) at the Department of Cardiology, Zhongshan Hospital from April 2023 to December 2023. The demographic information and clinical characteristics of the patients were collected. Echocardiography and speckle tracking imaging techniques were used to obtain conventional echocardiographic parameters, myocardial strain, and dyssynchrony indices of patients in the two groups, including global longitudinal strain (GLS), free wall longitudinal strain (FWLS), peak strain dispersion (PSD) of 18 left ventricular segments, PSD of 6 right ventricular segments, and other indices. According to the implantation location of Micra AV, the patients were further divided into middle group (right ventricular septum), high group (right ventricular inflow tract), and low group (apical region), and the differences in myocardial strain and dyssynchrony indices among the three subgroups were compared. **Results** The left ventricular GLS (LVGLS), right ventricular GLS (RVGLS), and right ventricular FWLS (RVFWLS) of the Micra AV group were significantly lower than those of the conduction block group ($P < 0.001$), and the right ventricular dyssynchrony of the Micra AV group was significantly higher than that

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of the conduction block group ($P<0.05$). Comparison of myocardial strain and dyssynchrony at different implantation sites showed that the LVGLS of the high implantation group was significantly higher than that of the middle and low implantation groups, and the left ventricular dyssynchrony index Yu was significantly lower than that of the middle group ($P<0.05$); the right ventricular ejection fraction (RVEF) of the low implantation group was significantly lower than that of the high group, and the right ventricular 6-segment PSD was significantly higher than that of the middle and high implantation groups ($P<0.05$). **Conclusions** Compared with patients with high-degree atrioventricular block, patients with Micra AV leadless pacing have reduced left and right ventricular strain, and the implantation of low position had greater effect.

[Key Words] Micra AV; leadless pacemaker; myocardial strain; ventricular dyssynchrony; speckle tracking imaging

Micra AV 无导线起搏器是一种微型的单腔起搏器,其基于算法检测出心房收缩,触发心室起搏,还可以通过感应心房力学来实现房室同步 (atrioventricular synchronization, AVS),达到双腔起搏的功能^[1-4]。Micra AV 无导线起搏器可以避免传统起搏器相关的一系列不良反应,例如血肿、皮肤损伤、囊袋周围感染,以及气胸、心脏穿孔和导线脱出等导线相关并发症。然而,非生理性的右心室起搏模式可能会引起左、右心室不同步,从而出现心室重构和心功能下降^[5-10]。Micra AV 的材料为镍钛合金,大小一般为 $25.9\text{ mm}\times 6.7\text{ mm}$,通常固定在右室间隔中部(中位)或者右室流入道(高位),如果起搏参数不满意,则会调整至低位间隔(低位)。目前, Micra AV 相关的心肌应变及不同步性研究较少,本研究通过斑点追踪成像技术,评价植入 Micra AV 患者的心肌应变及心室不同步性,并探讨植入位置对左、右心功能及心室不同步性的影响。

1 资料与方法

1.1 研究对象 回顾性选择 2023 年 4 月至 2023 年 12 月在复旦大学附属中山医院心内科植入 Micra AV 无导线起搏器的患者 43 例及高度房室传导阻滞(窦房结功能正常的 II 度 II 型、III 度房室传导阻滞)患者 20 例。排除标准:心肌梗死急性期所致的高度房室传导阻滞、严重瓣膜病及图像质量差无法分析的患者。根据 Micra AV 植入位置,分为低位(心尖部)、中位(右室间隔部)及高位(右室流入道)3 个亚组。

1.2 超声心动图采集和图像分析 所有患者均采用配备 S5-1 探头的 GE E95 型超声心动仪进行检查。胸骨旁大动脉短轴采集肺动脉血流脉冲多普勒(pulsed wave, PW)图像,根据心电图选取参

考点,获得肺动脉射血前时间;在心尖五腔心切面采集主动脉血流的 PW,获得主动脉射血前时间。采集心尖四腔心、三腔心及二腔心切面及右心室优势的心尖四腔心图形。应用三维探头采集三平面三维图像,以及加载组织多普勒成像(tissue Doppler imaging, TDI)的三平面组织多普勒图像(采集帧频 >40 帧/s)。图像导入 EchoPAC 软件系统,容积数据使用体表面积(body surface area, BSA)标化,测量 3 次取平均值。

1.2.1 二维和三维心超分析心功能及心室不同步性 (1)采用双平面 Simpson 法记录左心室舒张末期容积(left ventricular end-diastolic volume, LVEDV)、左心室收缩末期容积(left ventricular end-systolic volume, LVESV)以及左心室射血分数(left ventricular ejection fraction, LVEF); (2)测量 M 型三尖瓣环收缩期最大纵向位移,获得三尖瓣环收缩期位移(tricuspid annular plane systolic excursion, TAPSE); (3)肺动脉频谱的射血前时间和主动脉频谱的射血前时间相减,获得左、右心室射血时间差,即心室间机械延迟(interventricular mechanical delay, IVMD); (4)在三维三平面图像上加载“TSI”,分别沿心肌方向描绘室间隔、后壁、前壁、下壁、侧壁的基底段和中间段达峰时间,获得 12 节段 TSI 达峰时间标准差(12-STSD,即 Yu 指数)以及室间隔-左心室后壁运动延迟(septal-posterior wall motion delay, SPWMD)。

1.2.2 斑点追踪分析心肌应变及不同步性 (1)左室应变及不同步性:使用超声自动功能成像(automated functional imaging, AFI)技术分析三平面三维图像,分别描记心动周期内心尖四腔心、三腔心、二腔心图像中的心内膜,调整追踪满意后获得左室整体纵向应变(global longitudinal

strain, GLS) 及左室 18 节段纵向应变达峰时间离散度 (peak strain dispersion, PSD); (2) 右室应变: 选择右心室优势的心尖四腔心图像, 使用 RV-AFI 技术描记右心室室间隔及游离壁, 追踪满意后获得右室整体纵向应变 (RV-GLS) 及右室游离壁纵向应变 (RV-free wall longitudinal strain, RV-FWLS); (3) 右室不同步性: 采用 Q-analysis 模式, 选择右室优势的心尖四腔心图像, 手动描绘心内膜, 调整追踪满意后系统分析获得右室应变参数及右室 6 节段 (分别为右室游离壁基底段、中间段、心尖段及室间隔基底段、中间段、心尖段) 的应变曲线, 手动测量各曲线的达峰时间, 并计算 6 个节段的达峰时间离散度 (RV-PSD)。斑点追踪分析心室不同步性的方法见图 1。

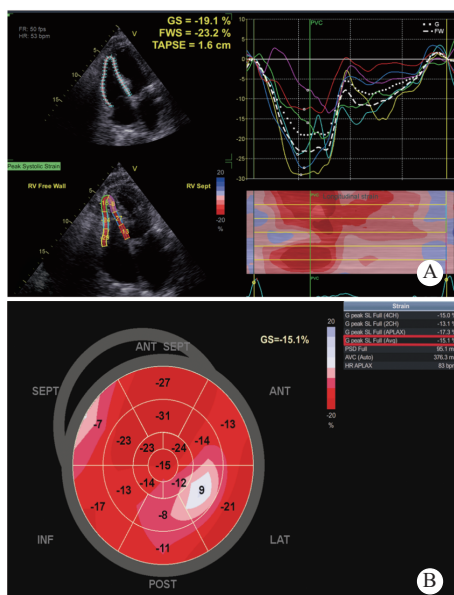


图 1 斑点追踪分析心室不同步性的方法

Figure 1 Methods of speckle tracking echocardiography analysis of ventricle dyssynchrony

A: Speckle tracking imaging was used to trace the right ventricle endocardium and obtain the longitudinal strain curves of 6 right ventricular segments, and the time to peak strain of each curve was manually record. B: Speckle tracking imaging was used to trace the three-plane left ventricle endocardium to obtain a "bull's eye map", which automatically obtained the peak strain deviation (PSD) of 18 segments (shown in red box). FR: frame rate; HR: heart rate; GS: global strain; FWS: free wall strain; TAPSE: tricuspid annular plane systolic excursion; ANT: anterior wall; LAT: lateral wall; POST: post wall; INF: inferior wall; SEPT: septum; ANT SEPT: anterior septum.

1.3 统计学处理 采用 SPSS 21.0 软件进行数据分析。正态分布的计量资料以 $\bar{x} \pm s$ 表示, 2 组间比较采用独立样本 t 检验, 多组间比较采用单因素方差分析, 两两比较采用 Bonferroni 法; 计数资料以 $n(\%)$ 表示, 采用 χ^2 检验。检验水准 (α) 为 0.05。

2 结果

2.1 Micra AV 植入位置和形态 Micra AV 起搏器植入术后超声心动图 (图 2) 显示: 在大动脉短轴 11 点至 13 点方向的右室流出道可以较清晰地观察到中位 Micra AV 起搏器的金属影, 形状呈长条形 (起搏器长轴) 或圆形 (起搏器短轴); 而在胸骨旁长轴及胸骨旁短轴乳头肌或者二尖瓣环水平右室内更容易观察到低位或高位植入的起搏器。

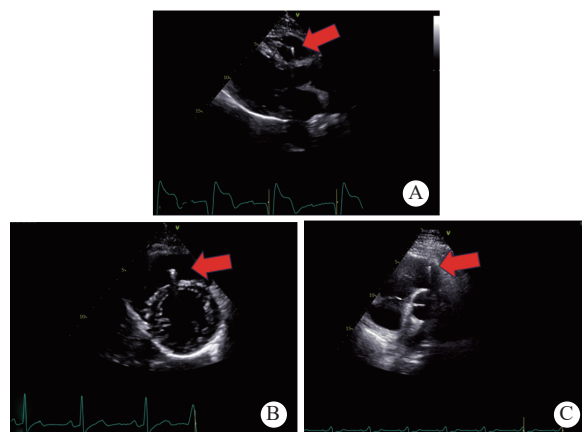


图 2 超声心动图观察 Micra AV 的常见切面
Figure 2 Common sections of Micra AV observed by echocardiography

A: The outflow tract implanted Micra AV was observed in parasternal longaxial section in a long shape (red arrow). B: The circular shape of septum implanted Micra AV (red arrow) was observed at 12 o'clock direction in the right ventricular outflow tract of the minor axial section of the great artery. C: The circular shape of apex implanted Micra AV (red arrow) was observed in the right ventricle at the level of the parasternal short axis near the papillary muscle.

2.2 Micra AV 组和传导阻滞组常规心超参数、心肌应变和不同步性比较 结果 (表 1) 显示: Micra AV 组患者 TAPSE 显著低于传导阻滞组 ($P=0.014$), 其余心超指标在两组间差异无统计学意

义。心肌应变及心室不同步性比较(表2)显示: Micra AV 组的左室 GLS、右室 GLS、右室 FWLS 均低于传导阻滞组($P<0.001$), 两组患者左室整体不同步性(左室 18 节段 PSD、

SPWMD、Yu 指数)和左、右心室间的不同步性(IVMD)差异均无统计学意义, 而 Micra AV 组右室的不同步性(右室 6 节段 PSD)高于传导阻滞组, 差异有统计学意义($P<0.05$)。

表 1 Micra AV 组和传导阻滞组常规超声心动图指标比较

Table 1 Comparison of routine echocardiographic parameters between Micra AV group and conduction block group

Index	Micra AV group (n=43)	Conduction block group (n=20)	P
Male n(%)	25(58.1)	13(65.0)	0.532
Age/year	58.3±18.6	52.5±20.3	0.733
Aortic root/mm	31.6±7.9	30.1±3.2	0.674
Left atrial diameter/mm	37.3±6.4	36.9±5.1	0.821
LVEDD/mm	47.1±5.1	46.9±4.8	0.901
LVEDS/mm	30.7±5.1	28.5±3.2	0.163
Septal thickness/mm	10.5±1.9	9.4±1.6	0.064
Posterior wall thickness/mm	9.3±1.4	8.9±1.3	0.304
LVEDV/mL	89.2±39.5	86.5±29.7	0.395
LVESV/mL	35.81±22.6	31.92±14.9	0.215
LVEF/%	54.5±20.4	65.21±6.2	0.061
Peak E velocity/(cm·s ⁻¹)	71.1±27.4	89.1±28.8	0.060
Peak A velocity/(cm·s ⁻¹)	81.0±116.5	90.1±53.5	0.544
Deceleration time/ms	181.1±72.6	194.4±106.1	0.085
Lateral wall S'/(cm·s ⁻¹)	8.0±5.1	8.9±2.7	0.904
Lateral wall e'/(cm·s ⁻¹)	8.2±5.1	12.1±6.5	0.132
Lateral wall a'/(cm·s ⁻¹)	10.2±5.1	7.8±4.7	0.313
Septum s'/(cm·s ⁻¹)	6.2±2.6	7.5±1.1	0.224
Septum e'/(cm·s ⁻¹)	5.5±2.9	7.9±2.9	0.212
Septum a'/(cm·s ⁻¹)	7.4±3.6	7.4±4.2	0.174
PASP/mmHg	30.2±8.5	31.3±14.4	0.731
RV-FAC/%	44.1±10.5	47.6±12.7	0.334
RVEDV/mL	36.1±14.1	36.3±10.9	0.961
RVESV/mL	13.9±5.7	12.7±5.3	0.484
RVEF/%	60.6±11.3	63.8±7.7	0.334
TAPSE/mm	16.5±4.1	19.9±4.4	0.014
Tricuspid valve peak A/(cm·s ⁻¹)	43.9±15.9	51.1±24.8	0.083
Tricuspid valve a'/(cm·s ⁻¹)	11.4±5.9	12.1±6.0	0.324
Tricuspid valve DT/ms	179.3±87.9	191.4±85.6	0.435
Tricuspid valve peak E/(cm·s ⁻¹)	54.1±22.2	64.8±26.6	0.232
Tricuspid valve e'/(cm·s ⁻¹)	11.2±11.1	11.8±4.2	0.962
Tricuspid valve S/(cm·s ⁻¹)	10.4±4.2	12.5±1.8	0.090

LVEDD: left ventricular end-diastolic diameter; LVEDS: left ventricular end-systolic diameter; LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; LVEF: left ventricular ejection fraction; PASP: pulmonary artery systolic pressure; RV-FAC: right ventricular-fractional area change; RVEDV: right ventricular end-diastolic volume; RVESV: right ventricular end-systolic volume; RVEF: right ventricular ejection fraction; TAPSE: tricuspid annular plane systolic excursion; DT: deceleration time.

2.3 不同起搏位置心室收缩功能及不同步性指标比较 Micra AV 植入不同位置的心室收缩及不同步性指标比较(表3)显示: 左心室指标, 低位组和中位组 GLS 均显著低于高位组($P<0.05$), 3 组的 PSD 差异无统计学意义, 高位组的 Yu 指

数显著低于中位组($P<0.05$)。右心室指标, 高位组 RVEF 显著高于低位组, 低位组 PSD 显著高于中位组和高位组($P<0.05$)。左、右心室间不同步性(IVMD)差异无统计学意义, 中位组肺动脉收缩压显著低于高位组和低位组($P<0.05$)。

表 2 Micra AV 组与传导阻滞组心肌应变及不同步性指标比较

Table 2 Comparison of ventricular strain and dyssynchrony indicators between Micra AV group and conduction block group			
Index	Micra AV group (n=43)	Conduction block group (n=20)	P
LVGLS/%	-15.7±3.84	-20.1±2.8	<0.001
LV-18 segments PSD/ms	74.9±5.7	65.15±50	0.430
RVFWLS/%	-18.3±11.6	-27.8±5.4	<0.001
RVGLS/%	-17.6±4.3	-23.3±4.9	<0.001
RV-6 segments PSD/ms	46.8±24.6	32.9±18.1	0.043
SPWMD/ms	19.4±26.5	10.0±65.7	0.550
Yu index/ms	33.1±23.4	43.28±21.8	0.354
Left ventricular pre ejection time/ms	68.0±41.0	34.7±17.6	0.012
Right ventricular pre ejection time/ms	56.5±38.4	27.6±28.8	0.023
IVMD/ms	15.0±30.9	7.07±23.5	0.404

LVGLS: left ventricle global longitudinal strain; PSD: peak strain dispersion; RVFWLS: right ventricular free wall longitudinal strain; RVGLS: right ventricular global longitudinal strain; SPWMD: septal-posterior wall motion delay; IVMD: interventricular mechanical delay.

表 3 不同起搏位置 Micra AV 的心室收缩和不同步性比较

Table 3 Comparison of ventricular function and dyssynchrony of Micra AV at different pacing sites						
Index	High group (n=15)	Middle group (n=22)	Low group (n=6)	P ₁	P ₂	P ₃
Right ventricular dyssynchrony						
RV-6 segments PSD/ms	40.5±25.9	40.9±25.0	77.7±25.4	0.96	0.02	0.02
Right ventricular systolic function						
RVFWLS/%	-18.3±4.7	-17.6±3.6	-14.1±1.2	0.58	0.15	0.09
RVGLS/%	-17.1±15.0	-20.2±6.7	-16.8±3.8	0.38	0.59	0.96
TAPSE/mm	17.7±4.7	15.7±3.7	18.0±5.2	0.18	0.39	0.91
RVEDV/mL	28.8±10.8	38.4±14.8	36.0±6.9	0.03	0.76	0.39
RVESV/mL	13.9±3.8	14.4±6.2	15.7±7.5	0.79	0.71	0.62
RVEF/%	62.0±9.9	61.3±10.8	51.8±13.9	0.10	0.92	0.02
Left ventricular systolic function						
LVEDV/mL	86.1±36.2	89.3±36.7	87.7±33.5	0.79	0.94	0.94
LVESV/mL	31.1±13.9	35.8±20.3	30.7±10.6	0.43	0.63	0.96
LVEF/%	54.9±22.6	54.6±54.9	63.3±6.4	0.96	0.49	0.52
LVGLS/%	-19.7±2.6	-14.9±3.3	-15.1±3.3	0.01	0.93	0.02
Left ventricular dyssynchrony						
LV-18 segments PSD/ms	64.8±19.8	51.8±13.9	62.0±9.9	0.16	0.65	0.76
Yu index/ms	23.0±15.9	38.1±25.1	30.7±14.4	0.03	0.56	0.56
SPWMD/ms	17.3±20.3	23.0±50.7	18.7±16.2	0.67	0.86	0.95
Dyssynchrony between left and right ventricle						
IVMD/ms	-1.4±14.4	15.6±33.2	28.7±9.2	0.06	0.43	0.08
PASP/mmHg	35.3±8.3	28.4±7.1	36.7±7.5	0.01	0.04	0.77

RVFWLS: right ventricular free wall longitudinal strain; RVGLS: right ventricular global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion; RVEDV: right ventricular end-diastolic volume; RVESV: right ventricular end-systolic volume; RVEF: right ventricular ejection fraction; RV-FAC: right ventricular-fractional area change; LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; LVEF: left ventricular ejection fraction; LVGLS: left ventricle global longitudinal strain; PSD: peak strain dispersion; SPWMD: septal-posterior wall motion delay; IVMD: interventricular mechanical delay; PASP: pulmonary artery systolic pressure. P₁: high group vs middle group; P₂: middle group vs low group; P₃: high group vs low group.

3 讨论

心肌的电活动最终转换为左、右室规律的收缩舒张活动,从而完成心脏泵的功能,其中涉及两个方面,一为心肌应变,即反映心脏的收缩能力;二为同步性,即反映心脏收缩的协调性,其中又包含左室不同步性、右室不同步性及左、右室间的不同步性。以上这些因素相互作用都会影响心脏的做功,不协调的收缩会增加心脏无做功,造成心功能减弱。Micra AV 的起搏顺序是非生理性的右室起搏。既往大量研究^[5,7,9-10]已经证实,右心起搏会导致心脏重构,尤其是右室心尖部起搏,会造成心功能减弱、心房颤动,致使心力衰竭的发生增加。本研究分析 Micra AV 对于心肌应变及心室不同步性的影响,结果显示, Micra AV 组和传导阻滞组的常规心脏大小及心脏收缩指标并无明显差异;然而,斑点追踪技术发现 Micra AV 组左室 GLS、右室 GLS 和右室 FWLS 均显著减低,且右室出现收缩不同步,提示 Micra AV 影响左、右室的收缩功能及右室收缩的同步性。

既往的研究通常更关注左室的不同步性,关于右室不同步性的研究相对较少,且主要聚焦肺动脉高压等疾病对于右室的影响^[11]。右室不同步性研究主要基于 TDI 等技术,但 TDI 只能评估心脏某一方向上的纵向位移而非实际的心脏收缩,本研究采用斑点追踪技术发现 Micra AV 患者右室收缩不同步,且心尖(低位)起搏时右室射血分数最低、右室收缩不同步性最明显、肺动脉压力最高,这可能是右室心尖部起搏容易造成起搏器综合征和心力衰竭的机制之一。此外, Micra AV 起搏中位组与高位组的右室不同步性差异无统计学意义,这与目前的临床决策是相符的。右心室的形态较为复杂,二维超声图像只能评估 6 个右室节段,并不能全面评估右室的不同步性,未来的三维超声技术有望评估所有节段的收缩差异,从而实现对右室不同步性的准确和全面评估。另外,右室的协调收缩同样具有重要意义,需要研究不同起搏模式下(双腔起搏、右室起搏、希氏束起搏、His 起搏等)右室不同步性的差异,并将其与患者预后进行相关性分析,从而为临床提供更

多参考。

Micra AV 无导线起搏器能提供双腔感知的心房同步心室抑制型起搏(atrial synchronous ventricular inhibited pacing, VDD)^[1-2,12-13],适应证主要是窦房结功能正常、主导节律为高度房室传导阻滞的患者。研究^[12,14-15]指出,年龄小、基础心率快、日常生活较活跃、房性心律失常、依赖房室同步保持心排量均不是 Micra AV 的最佳适应证,本研究年龄最小的人组患者为 18 岁,最大为 84 岁,年龄跨度较大,需要进一步的随访研究以评价远期的影响。

本研究存在一定局限性:(1)为回顾性研究,缺失 Micra AV 患者术前的基线心超图像,因此无法进行自身前后对照;同时,缺乏长期的随访数据以评估 Micra AV 的长期影响。长期存在高度房室传导阻滞会造成心功能减弱及心脏重构,但本研究植入 Micra AV 相较传导阻滞对心肌应变及心脏不同步性的影响更大,说明临床上需要持续关注植入 Micra AV 患者的心功能。(2)由于 Micra AV 感知心房机械收缩信号的模式并不能一直保持完全房室同步,植入术后房室同步率的真实数据和提高房室同步率在术后随访中非常重要^[14]。而超声心动图只能采集 3 个心动周期的图像,仅反映当下情况,不同的房室传导情况下患者的心肌应变及不同步性会存在差异,因此结果可能造成一定偏倚。(3)最近的研究^[16]证实,心房应变可以预测 Micra AV 同步性,而本文未进一步区分比较房室同步性及达到不同比例房室同步的患者。

综上所述,与高度房室传导阻滞相比, Micra AV 无导线起搏患者的左心室及右心室应变均降低,且低位植入的影响更大。Micra AV 起搏从两个方面影响心脏,心肌应变的减低和心室不同步性的增加,二者在长期的病程中可能相互影响,造成心功能及不同步性的进一步恶化。Micra AV 虽然可以改善心律失常,但右室起搏导致了不同程度的心室不同步和心功能下降,因此需要持续关注患者的心室重构及心功能变化。

伦理声明 本研究获得中山医院医学伦理委

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