·临床研究·

左室心肌做功对不同心功能分级患者左房应变的影响

王晶,穆洋,袁梦寒,徐勇*
(中国人民解放军总医院第六医学中心心血管病医学部,北京 100048)

【摘 要】 **目的** 研究高血压病患者不同心功能状态下左室心肌做功对左房储存期纵向应变(LASr)的影响。**方法** 选择2022年3月至4月解放军总医院心血管病医学部连续入组的78例高血压病患者为研究对象。根据欧洲心脏病学会(ESC)心力衰竭分类方法,将心功能正常患者纳入对照组(n=43),射血分数(EF)<50%患者纳入射血分数减低心力衰竭(EFrHF)组(n=8),EF≥50%患者纳入射血分数保留心力衰竭(EFpHF)组(n=27)。采用GE Vivid E95超声诊断仪获得并留存二维及三维超声心动图图像,选择4D auto LAQ功能计算左房容量及LASr,结合左室长轴应变与患者血压值获得的压力-应变环,获得左室心肌做功指标,包括整体做功指数(GWI)、整体有效做功(GCW)、整体无效做功(GWW)及整体做功效率(GWE)。采用SPSS 23.0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、单因素方差分析及χ^2检验。采用Pearson相关系数及协方差分析左室心肌做功指标与LASr间的相关性。**结果** 对照组与HFpEF组GWI、GCW均高于HFrEF组(P<0.01),HFrEF组与HFpEF组GWW均高于对照组(P<0.05);3组间GWE两两比较,差异均有统计学意义,且HFrEF最低,对照组高于HFpEF组(P<0.01);3组间LASr两两比较,差异均有统计学意义,且对照组LASr最高,HFrEF组LASr最低(P<0.01)。不同组别中GWI与LASr均呈线性关系,且与分组无关。在控制GWI的影响后,经协方差分析显示,心功能分级不同的患者其LASr分布有统计学意义(F=9.46;P<0.01),且心功能分级越差的患者其LASr越低。**结论** 射血分数低于50%,左室做功指数及有效做功均降低,无效做功增加,EFpHF患者有效做功可以保持正常,但已出现无效做功的增加,做功效率的降低。无论心功能分级如何,LASr随左室做功指数减低进行性下降,三维LASr可作为反映心室收缩功能的指标之一用于临床。

【关键词】 心肌做功;左房储存期纵向应变;三维超声心动图;高血压病;心力衰竭
【中图分类号】 R543 【文献标志码】 A 【DOI】 10.11915/j.issn.1671-5403.2024.11.179

Effect of left ventricle myocardial work on left atrial strain in patients with different grades of heart failure

Wang Jing, Mu Yang, Yuan Menghan, Xu Yong*
(Senior Department of Cardiology, Sixth Medical Center, Chinese PLA General Hospital, Beijing 100048, China)

【**Abstract**】 **Objective** To investigate the effect of left ventricular (LV) myocardial work on left atrial reservior function in hypertension patients with different grades of heart failure (HF). **Methods** A total of 78 hypertension patients admitted in Sixth Medical Center of Chinese PLA General Hospital from March to April 2022 were consecutively recruited in this study. According to European Society of Cardiology heart failure classification, 43 patients with normal heart function were assigned into control group, 8 patients with ejection fraction (EF) <50% into HF with reduced ejection fraction (HFrEF) group, and 27 with EF ≥50% into HF with preserved ejection fraction (HFpEF) group. Vivid E95 4D Cardiac Ultrasound Machine (GE) was used to acquire 2D and 3D echo images, and 4D auto LAQ was employed to calculate LA volume and LASr. Based on LV longitudinal strain and blood pressure, pressure-strain loop were calculated to obtain LV myocardial work indicators, including global work index (GWI), global constructive work (GCW), global waste work (GWW) and global work efficiency (GWE). SPSS statistics 23.0 was used for statistical analysis. Data comparison between two groups was performed using student's t test, ANOVA or *Chi*-square test depending on data type. Pearson correlation coefficient and covariance analysis were applied to investigate the correlation between LV myocardial work indicators and LASr. **Results** The GWI and GCW values were significantly higher in the control and HFpEF groups than the EFrHF group (P<0.01). The GWW value in the EFrHF and HFpEF groups was obviously higher than that in the control groups (P<0.05). Statistical differences were observed in the GWE value between any two groups, and the lowest value was seen in the HFrEF group, and that of the control group was higher than the EFpHF group (P<0.01). There were notably difference in LASr among the three groups, with

收稿日期:2023-10-16;**接受日期**:2023-11-28
基金项目:国家重点研发计划(2020YFC2007305)
通信作者:徐勇,E-mail:Yongxu301@163.com

the control group having the highest and the EFrHF group the smallest ($P<0.01$). A liner relationship was observed between GWI and LASr in different groups, which was independent of grouping. After controlling the effect of GWI, ANOVA indicated that significant difference was seen in LASr among the patients with different cardiac function ($F=9.46$; $P<0.01$). The worse the cardiac function was, the lower the LASr. **Conclusion** For the patients with EF <50%, both GWI and GCW values are decreased, while GWW value is increased. The HFpEF patients still have normal LV myocardial work, though with increasing GWW and declining GCW. No matter which classification of HF, LASr is reduced with the decline of GWI. 3D LA reservoir strain can be used as one of indicators for evaluating left ventricular function in clinical practice.

【**Key words**】 myocardial work; left atrial reservoir strain; 3D echocardiography; hypertension; heart failure

This work was supported by Key Research and Development Program of China (2020YFC2007305).

Corresponding author: *Xu Yong*, *E-mail*: *Yongxu301@163.com*

左室射血分数与左室长轴应变是临床最常用的评估左室收缩功能的指标,左房储存功能与左室长轴收缩功能相关,同时受心房大小、跨二尖瓣血流量、心房充盈压等因素影响[1]。现阶段心肌做功指标以左室长轴应变为基础,涵盖左室收缩期及舒张期,可从有效做功的角度评估左心室收缩功能;四维超声心动图技术可快速测定左房容积与储存功能。本研究旨在探讨高血压病患者中,心肌做功新指标与四维超声心动图技术获得的左房储存功能在评估心脏收缩功能方面的相互作用,报道如下。

1 对象与方法

1.1 研究对象

选择 2022 年 3 月至 4 月解放军总医院心血管病医学部连续入组的高血压病患者 78 例。根据 2021 年欧洲心脏病学会(European Society of Cardiology, ESC)急性和慢性心力衰竭诊断和治疗指南新分类方法[2],以左室射血分数为主要判断依据,结合患者临床症状、心室肥厚、N 末端脑钠肽前体(N-terminal pro-brain natriuretic peptide, NT-proBNP)、左房容积指数(left atrial volume index, LAVI)、E/e'等参考指标,将心功能正常患者纳入对照组($n=43$),射血分数(ejection fraction, EF)<50%患者纳入射血分数减低心力衰竭(heart failure with reduced ejection fraction, EFrHF)组($n=8$),EF≥50%患者纳入射血分数保留心力衰竭(heart failure with preserved ejection fraction, EFpHF)组($n=27$)。本研究经解放军总医院伦理委员会批准通过(编号:S2021-196-02),所有受试者检查前均签署知情同意书。

纳入标准:(1)年龄≥18 岁;(2)入院初次诊断高血压病,符合中国高血压防治指南 2018 年修订版高血压病诊断标准[3],即未使用降压药物情况下,非同日 3 次测量血压,收缩压≥140 mmHg(1 mmHg=0.133 kPa)和(或)舒张压≥90 mmHg;(3)高血压病病史明确,常规应用降压药物。排除标准:(1)血流动力学不稳定;(2)经胸超声心动图图像质量差;(3)拒绝参加临床试验。

1.2 方法

应用 GE Vivid E95 超声诊断仪,配备 M5S 探头,频率 1.4~4.6 MHz 及四维探头 4Vc-D,频率 1.4~5.2 MHz。嘱受试者左侧卧位,同步记录Ⅱ导联心电图,采集心尖四腔、三腔和两腔心切面图像(3 个心动周期)。常规超声心动图参数的测量包括左室舒张末期容积(left ventricular end diastolic volume, LVEDV)、左室收缩末期容积(left ventricular end systolic volume, LVESV)、左室射血分数(left ventricular ejection fraction, LVEF;应用双平面法测量)。通过自动功能成像(automated functional imaging, AFI)模式分别描记左室心尖四腔、三腔及两腔心切面图像的心内膜,测量左室整体长轴应变(global longitudinal strain, GLS),选择 Myocardiac Work 进一步建立左室压力-应变环(pressure-strain loop, PSL),导出数据,记录左室整体做功指数(global work index, GWI)、整体有效做功(global constructive work, GCW)、整体无效做功(global waste work, GWW)、整体做功效率(global work efficiency, GWE)。切换四维探头,图像采集过程中必须确保包括完整的左心房并且帧频要大于每秒 12 个容积帧,选择 4D auto LAQ 功能,描记左心房边界,计算左房容量及左房储存期纵向应变(LA reservoir strain, LASr),即二尖瓣开放心室收缩末期减去心室舒张末期的应变值之差(图 1)。

1.3 统计学处理

采用 SPSS 23.0 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,多组间比较采用单因素方差分析;两两比较采用 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,组间比较采用秩和检验。计数资料用例数(百分率)表示,采用 χ^2 检验。采用 Pearson 相关系数及协方差分析左室心肌做功指标与 LASr 间的相关性。$P<0.05$ 为差异有统计学意义。

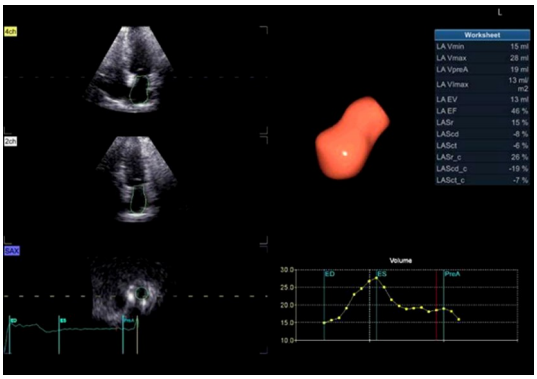


图1 四维左心房自动定量分析功能计算左心房容量及功能指标

Figure 1 Left atrial volume and function results obtained by four-dimensional left atrial automatic quantitative (4D auto LAQ technology)

2 结 果

2.1 3组患者一般资料比较

对照组与HFpEF组冠心病发病率相近,均高于HFrEF组($P<0.05$);对照组持续性心房颤动发生率最低($P<0.05$);对照组NT-proBNP水平最低($P<0.01$);HFrEF组LVEDV,LVESV及EF均显著低于对照组与HFpEF组($P<0.01$),HFrEF组与HFpEF组LAVI均高于对照组($P<0.01$);E/e'在对照组最低,HFrEF组最高($P<0.01$;表1)。

2.2 3组间心肌做功指标与三维左房储存期纵向应变的比较

对照组与HFpEF组GWI、GCW均高于HFrEF组($P<0.01$),HFrEF组与HFpEF组GWW均高于对照组($P<0.01$);3组间GWE两两比较差异均有统计学意义,且HFrEF最低,对照组高于HFpEF组($P<0.01$);3组间LASr两两比较,差异均有统计学意义,且对照组LASr最高,HFrEF组LASr最低($P<0.01$;表2,图2)。

2.3 相关性分析与协方差分析

不同组别中GWI与LASr均呈线性关系,且与分组无关,Person系数为0.43,$P<0.01$。在控制GWI的影响后,经协方差分析显示,心功能分级不同的患者其LASr分布差异有统计学意义($F=9.46$;$P<0.01$),且心功能分级越差的患者其LASr越低。

3 讨 论

通常患者EF<50%才能发现左室收缩功能减低,且高血压患者的治疗相对滞后;随着左室长轴应变技术的出现,临床可以更早发现心功能异常患者,从而可给予早期干预。随着超声心动图技术的不断进步,基于左室应变获得的左室做功指标和基于四维超声心动图技术的左房功能成为评估患者心脏功能的创新技术。本研究应用超声新技术对不同心功能分级的高血压病患者进行分析观察,发现在不同心功能分级的高血压病患者中心肌做功指标可以更早预警心功能的下降。

心肌做功指数等指标是在结合左室应变与血压基础之上获得的PSL,纳入了外周血管阻力的因素,可以获得全心动周期的左室GWI,对左室收缩及舒张发挥作用的GCW,失同步或矛盾运动等状态下形成的GWW及GWE。Russell等[4]研究已证实心肌做功新指标与正电子发射断层显像获得心肌做功及代谢数据具有良好的一致性。本研究结果中心功能

表1 3组患者一般资料比较

Table 1 Comparison of general characteristics among three groups

Group	n	Age(years, $\bar{x}\pm s$)	Male[n(%)]	BSA(m^2, $\bar{x}\pm s$)	CAD[n(%)]	DM[n(%)]	AF[n(%)]
Control	43	62.5±9.7	33(76.7)	1.87±0.16**	25(58.1)#	13(30.2)	6(13.9)*#
HFrEF	8	65.6±10.6	6(75.0)	1.76±0.23**	1(12.5)	1(12.5)	4(50.0)
HFpEF	27	67.2±10.3	14(51.9)	1.73±0.20	16(59.3)*	8(29.6)	11(40.7)
$F/H/\chi^2$		1.853	4.922	5.188	6.140	1.089	8.462
P value		0.164	0.085	0.008	0.046	0.580	0.015

Group	n	LVEDV(ml, $\bar{x}\pm s$)	LVESV(ml, $\bar{x}\pm s$)	EF(%, $\bar{x}\pm s$)	E/e'($\bar{x}\pm s$)	NT-proBNP [pg/ml, $M(Q_1, Q_3)$]	LAVI(ml/m^2, $\bar{x}\pm s$)
Control	43	68.40±19.26##	25.35±10.40##	63.16±7.43##	9.24±3.85**##	51.5(15.7,165.7)**##	23.3±6.6**##
HFrEF	8	169.87±86.42	124.12±71.91	30.88±7.92	18.20±6.21**	1042.0(518.0,4186.2)	45.2±17.0
HFpEF	27	75.11±32.77**	28.48±18.01**	64.44±8.43**	13.77±4.19	210.5(102.7,668.7)	42.1±13.4
$F/H/\chi^2$		27.778	52.236	61.817	19.737	25.244	32.705
P value		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

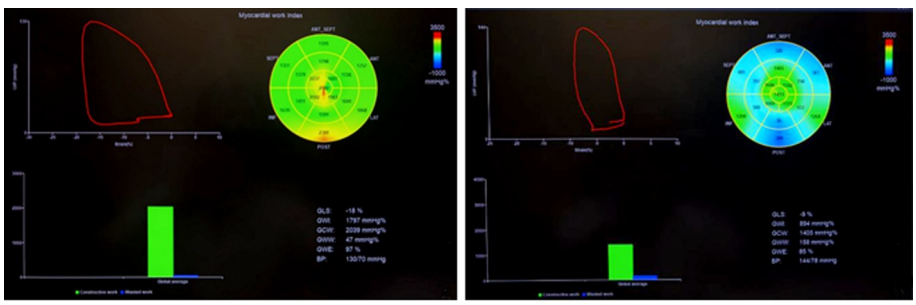
HFpEF: heart failure with preserved ejection fraction; HFrEF: heart failure with reduced ejection fraction; BSA: body surface area; CAD: coronary artery disease; DM: diabetes mellitus; AF: atrial fibrillation; LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; EF: ejection fraction; NT-proBNP: N-terminal pro-brain natriuretic peptide; LAVI: left atrial volume index. Compared with HFpEF group, *$P<0.05$; **$P<0.01$; compared with HFrEF group, #$P<0.05$; ##$P<0.01$.

表 2 3 组患者心肌做功指标与 LASr 比较

Table 2 Comparison of left ventricle myocardial work and LASr among three groups ($\bar{x}\pm s$)

Group	n	GWI(mmHg%)	GCW(mmHg%)	GWW(mmHg%)	GWE(%)	LASr(%)
Control	43	1 708.72±422.92$^{\#\#}$	2 052.65±440.37$^{\#\#}$	112.02±74.51$^{**\#\#}$	93.81±3.86$^{**\#\#}$	18.16±6.47$^{**\#\#}$
HFrEF	8	487.63±285.00	717.63±310.40	223.63±89.29	76.63±7.17**	7.00±3.70**
HFpEF	27	1 839.67±559.91$^{\#\#}$	2 250.41±612.80$^{\#\#}$	179.48±143.32	91.04±5.17	12.59±6.85
F		27.477	30.166	5.835	44.504	13.402
P value		<0.01	<0.01	0.004	<0.01	<0.01

HFpEF: heart failure with preserved ejection fraction; HFrEF: heart failure with reduced ejection fraction; GWI: global work index; GCW: global constructive work; GWW: global waste work; GWE: global work efficiency; LASr: LA reservoir strain. 1 mmHg = 0.133 kPa. Compared with HFpEF group, $^{**}P<0.01$; compared with HFrEF group, $^{\#\#}P<0.01$.



A B

图 2 左室心肌做功指标

Figure 2 Parameters of left ventricle myocardial work

Based on global longitudinal strain and blood pressure, pressure-strain loop were calculated, myocardial work indicators including global work index(GWI), global constructive work(GCW), global waste work(GWW) and global work efficiency(GWE) could be recorded using AFI model. A: control group; B: HFrEF group. Myocardial work indicators of HFrEF group were lower than control group. GLS: global longitudinal strain; GWE: global work efficiency; HFrEF: heart failure with reduced ejection fraction; AFI: automated functional imaging.

正常对照组 GCW、WI 与 GWW 与既往研究获得的正常人心肌做功参数范围相近[5]。左室心肌做功等指标是在左室应变的基础上,纳入后负荷计算获得,高血压的患者后负荷的变化性较大,心脏收缩功能失代偿后还会出现血压的下降,因此通过心肌做功来评估高血压患者的心脏功能更为完整。在不同心功能状态下,GWI 表现不同,在 EFpHF 组 GWI 仍可以保持,但 GWW 已高于正常,而 EFrHF 组,EF< 50%,GWI 低于 EF 正常组,GWW 则显著升高,GWE 在 3 组中随心功能减低而下降,EFpHF 组的 GWE 在 91%左右,已低于正常水平,提示左室做功指标包括 GWW 的升高,GWE 的下降可以在 EF 减低之前更早预警心脏收缩功能的下降。心肌做功指标有希望在临床上作为新的评估指标加入 EFpHF 的诊断,我们也将在后续工作中进行相关研究。

评估左房功能的重要指标包括左房的大小、左房 EF 值及左房应变等。随着三维超声心动图技术的进步,左房功能指标的计算也由二维进阶至三维[6],与二维技术相比,可以在一个心动周期获得四维全容积数据,减少了形态假设,更符合生理条件下的真实状态。心房大小是心房颤动的预测因子,且与患者预后相关[7,8],本研究结果的数据显示心房扩大的 EFrHF 组与 EFpHF 组心房颤动发生率均高于心房正常的对照组,与既往研究结果一致。GE 4DQ 技术提供的左房应变计算结合了左心房几何结构、运动模型及边缘检测等算法,可快速获取左房储存期、管道期及收缩期的纵向及圆周应变值,LASr 更多地反映了左房的顺应性而非收缩性,管道功能与左室舒张功能更为密切,收缩期功能则取决于心房收缩能力、左室舒张末期的压力及顺应性[9]。应用二维应变方法获得的 LASr 具有较好的可行性及可重复性,且预后预测价值更强[10,11],随着左室长轴应变的减低,左房储存期应变功能下降[12]。本研究选择三维 LASr 做为核心指标,发现其在 3 组中的差异明显,且随着左室整体做功 GWI 的降低,LASr 也随之下降,两者间呈线性关系,具备相关性,说明三维心房纵向应变的变化可以反映左室收缩功能的状态。协方差分析结果提示心功能分

级不同的患者其LASr分布有统计学意义,且心功能分级越差的患者其LASr越低。提示无论在正常人群筛查还是在心功能减低人群中,均可应用LASr反映左室收缩功能,而且三维心房应变的计算在临床操作中极为简便,相比心室应变及做功指标的计算更快速,这对于更准确地评估心室收缩功能又提供了一个便捷的临床指标。

本研究存在一定的局限性:(1)单中心,小样本研究,需要在更大样本量条件下进行相关结论的验证;(2)本研究聚焦在部分超声指标的评估,更多数据及指标需要在今后的工作中纳入考虑。

综上,高血压病患者EF<50%,左室做功指数及有效做功均降低,无效做功增加,EFpHF患者有效做功可以保持正常,但已出现无效做功增加、做功效率降低的情况。无论心功能分级如何,LASr随左室做功指数减低进行性下降,三维LASr可作为反映心室收缩功能的指标之一用于临床。

【参考文献】

[1] Gillebert TC. Left atrial reservoir and booster function in HFrEF: implications for diastolic function[J]. JACC Cardiovasc Imaging, 2020, 3(5): 1116-1118. DOI: 10.1016/j.jcmg.2020.01.007.

[2] McDonagh TA, Metra M, Adamo M, *et al*. 2021 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure[J]. Eur Heart J, 2021, 42(36): 3599-3726. DOI: 10.1093/eurheartj/ehab368.

[3] 《中国高血压防治指南》修订委员会. 中国高血压防治指南2018年修订版[J]. 心脑血管病防治, 2019, 19(1): 1-44.

[4] Russell K, Eriksen M, Aaberge L, *et al*. A novel clinical method for quantification of regional left ventricular pressure strain loop area: a non-invasive index of myocardial work[J]. Eur Heart J, 2012, 33(6): 724-733. DOI: 10.1093/eurheartj/ehs016.

[5] Tretter JT, Pradhan S, Truong VT, *et al*. Non-invasive left ventricular myocardial work indices in healthy adolescents at rest[J]. Int J Cardiovasc Imaging, 2021, 37(8): 2429-2438. DOI: 10.1007/s10554-021-02218-y.

[6] Thomas L, Marwick TH, Popescu BA, *et al*. Left atrial structure and function, and left ventricular diastolic dysfunction: JACC state-of-the-art review[J]. J Am Coll Cardiol, 2019, 73(15): 1961-1977. DOI: 10.1016/j.jacc.2019.01.059.

[7] Triposkiadis F, Pieske B, Butler J, *et al*. Global left atrial failure in heart failure[J]. Eur J Heart Fail, 2016, 18(11): 1307-1320. DOI: 10.1002/ejhf.645.

[8] Walters TE, Ellims AH, Kalman JM. The role of left atrial imaging in the management of atrial fibrillation[J]. Prog Cardiovasc Dis, 2015, 58(2): 136-151. DOI: 10.1016/j.pcad.2015.07.010.

[9] Litwin SE. Left atrial strain: a single parameter for assessing the dark side of the cardiac cycle? [J]. JACC Cardiovasc Imaging, 2020, 13(10): 2114-2116. DOI: 10.1016/j.jcmg.2020.07.037.

[10] Todaro MC, Choudhuri I, Belohlavek M, *et al*. New echocardiographic techniques for evaluation of left atrial mechanics[J]. Eur Heart J Cardiovasc Imaging, 2012, 13(12): 973-984. DOI: 10.1093/ehjci/jes174.

[11] Cameli M, Lisi M, Focardi M, *et al*. Left atrial deformation analysis by speckle tracking echocardiography for prediction of cardiovascular outcomes[J]. Am J Cardiol, 2012, 110(2): 264-269. DOI: 10.1016/j.amjcard.2012.03.022.

[12] Hwang IC, Cho GY, Choi HM, *et al*. H_2FPEF score reflects the left atrial strain and predicts prognosis in patients with heart failure with preserved ejection fraction[J]. J Card Fail, 2021, 27(2): 198-207. DOI: 10.1016/j.cardfail.2020.09.474.

(编辑:温玲玲)