

• 临床研究 •

多模态影像对STEMI患者急诊PCI术后MACE的预测价值

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[摘要] 目的: 探讨三维斑点追踪超声心动图(three-dimensional speckle tracking echocardiography, 3D-STE)、心肌做功(myocardial work, MW)对急性ST段抬高型心肌梗死(ST-segment elevation myocardial infarction, STEMI)患者急诊经皮冠状动脉介入治疗(primary percutaneous coronary intervention, PPCI)术后主要不良心血管事件(major adverse cardiovascular event, MACE)发生的预测价值。方法: 纳入90例行PPCI的首次STEMI患者, 术后24 h内行3D-STE、MW检查, 术后7 d内完善心脏磁共振晚期钆增强成像(cardiac magnetic resonance late gadolinium enhancement imaging, CMR-LGE)检查, 随访12个月MACE(再发心绞痛、因急性冠脉综合征行血运重建、急性心衰发作、心源性猝死)的发生情况。结果: 20例(22.2%)患者发生MACE, 单因素及多因素Cox回归分析显示梗死面积(infarction size, IS)、整体纵向应变(global longitudinal strain, GLS)、整体做功指数(global work index, GWI)为预测MACE发生的独立参数, 受试者工作特征(receiver operating characteristic, ROC)曲线显示上述指标的曲线下面积(area under the curve, AUC)分别为0.886、0.846、0.830, Delong法两两比较显示AUC值差异无统计学意义(P 均 >0.05)。联合GLS和GWI预测MACE发生的AUC值达0.939, 显著优于GLS及GWI单一参数(P 均 <0.05), 且与IS相当($P > 0.05$)。Kaplan-Meier曲线表明GLS $<-10.5%$ 、GWI >1298.5 mmHg%、IS $<26.05%$ 的患者有更高的生存率($P < 0.05$)。结论: 3D-STE及MW能较好地预测STEMI患者PPCI术后MACE的发生, 其中GLS及GWI诊断价值相似, 二者联合优于单一指标, 且与IS诊断效能相当。

[关键词] 急性ST段抬高型心肌梗死; 主要不良心血管事件; 三维斑点追踪超声心动图; 心肌做功; 心脏磁共振晚期钆增强成像

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The predictvalue of multimodal imaging for MACE in STEMI patients after primary PCI

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[Abstract] **Objective:** To investigate the predictive value of three-dimensional speckle tracking echocardiography (3D-STE) and myocardial work (MW) on major adverse cardiovascular events (MACE) in patients with acute ST-segment elevation myocardial infarction (STEMI) who underwent primary percutaneous coronary intervention (PPCI). **Methods:** Ninety patients with first concurrence of STEMI and treated with PPCI were enrolled. 3D-STE, MW assessments were performed within 24 hours following PPCI, and cardiac magnetic resonance late gadolinium enhancement imaging (CMR-LGE) was completed within 7 days post-procedure. The patients were followed up for 12 months after PPCI to track the occurrence of MACE, which included recurrent angina pectoris, revascularization due to acute coronary syndrome, acute heart failure attack, and sudden cardiac death. **Results:** Twenty patients (22.2%) experienced MACE. Univariate and multivariate COX regression analysis showed infarction size (IS), global longitudinal strain (GLS), and global work index (GWI) as independent predictors of MACEs. The area under the curve (AUC) values for these indicators from the receiver operating characteristic (ROC) curves were 0.886, 0.846 and 0.830, respectively, and pairwise comparison by Delong method showed

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no statistically significant difference in AUC values (all $P > 0.05$). The AUC value of the combined GLS and GWI in predicting MACE was 0.939, which was significantly better than either parameter alone ($P < 0.05$), and comparable to IS ($P > 0.05$). Kaplan-Meier curve showed that patients with $GLS < -10.5\%$, $GWI > 1298.5 \text{ mmHg}\%$ and $IS < 26.05\%$ had higher survival rate ($P < 0.05$). **Conclusion:** 3D-STE and MW can better predict MACE after PPCI in STEMI patients. GLS and GWI have similar diagnostic value, and their combination provides superior predictive power compared to either parameter alone, and is comparable to IS in terms of diagnostic efficiency.

[Key words] acute ST-segment elevation myocardial infarction; major adverse cardiovascular events; three-dimensional speckle tracking echocardiography (3D-STE); myocardial work; cardiac magnetic resonance late gadolinium enhancement imaging (CMR-LGE)

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急性ST段抬高型心肌梗死(ST-segment elevation myocardial infarction, STEMI)临床常见,急诊经皮冠状动脉介入治疗(primary percutaneous coronary intervention, PPCI)能最大限度挽救濒死心肌,降低病死率及改善预后^[1],但STEMI患者仍面临左室重构(left ventricular remodeling, LVR)甚至死亡的风险,特别是主要不良心血管事件(major adverse cardiovascular event, MACE)的发生,严重威胁患者的生命及生活质量^[2],故早期评估MACE发生对预后判断及治疗选择极其重要。

心脏磁共振(cardiac magnetic resonance, CMR)被认为是评价心脏结构和功能的重要方法,其中晚期钆增强(late gadolinium enhancement, LGE)成像可以高精度描述和量化心肌组织损伤,研究表明,CMR中的梗死面积(infarction size, IS)与STEMI后MACE的发生独立相关^[3]。因CMR费用昂贵,体内金属植入等原因,临床应用受到限制,而超声心动图具有经济、便捷、可床边操作等优势,临床应用广泛。二维斑点追踪超声心动图(two-dimensional speckle tracking echocardiography, 2D-STE)已被证明优于传统超声心动图,可提供更多预后信息和风险分层^[4]。然而心肌力学涉及多方向运动轴,2D-STE应用受到限制。三维斑点追踪超声心动图(three-dimensional speckle tracking echocardiography, 3D-STE)是在三维超声心动图和2D-STE基础上发展起来的超声新技术,已被证实在判断左室整体与局部功能、定量评估心肌功能方面存在较高价值^[5]。既往研究表明,相比2D-STE,3D-STE预测STEMI患者LVR及1年预后具有更好的应用价值^[6]。然而,斑点追踪超声心动图受限于负荷依赖性,影响心肌功能评估的准确性。心肌做功(myocardial work, MW)结合左室应变和无创全身动脉血压,可以提高心肌功能评估的准确性^[7-8],但目前MW对STEMI患者PPCI术后发生MACE的预测价值不明,且缺少与

3D-STE及CMR对STEMI患者预后预测的对比研究。

本研究的目的是对比早期行MW与3D-STE、CMR-LGE对STEMI患者PPCI术后发生MACE的预测价值,旨在筛选无创、经济、有效的检查评估预后,以对STEMI患者进行早期危险分层及指导治疗。

1 对象和方法

1.1 对象

本研究纳入2022年8月—2023年3月在连云港市第一人民医院住院的首次发作STEMI患者。纳入标准:①年龄 >18 岁且 <75 岁;②符合最新指南定义STEMI诊断标准^[9];③胸痛发作后12h内接受梗死相关动脉(infarct-related artery, IRA)的PPCI,术后恢复TIMI 3级血流。排除标准:①既往存在心肌梗死病史,既往行PPCI或冠状动脉旁路移植术;②合并重度瓣膜狭窄或关闭不全、肥厚型心肌病、先天性心脏病、心房颤动、恶性心律失常、心源性休克及其他系统慢性疾病;③PPCI术前行溶栓治疗;④血栓负荷重,行血栓抽吸;⑤术中出現慢血流或无复流;⑥超声心动图显影质量差;⑦存在CMR的禁忌证。本研究经连云港市第一人民医院伦理委员会批准(伦理号:2016029),所有患者均签署知情同意书。

1.2 方法

1.2.1 临床资料

记录患者入院后临床资料,包括:①年龄、性别、高血压病、糖尿病、高脂血症、术后服药情况;②实验室指标:高敏肌钙蛋白I(hypersensitive serum cardiac troponin I, hs-cTnI)及磷酸肌酸激酶(creatin kinase, CK)峰值、C-反应蛋白(C-reactive protein, CRP)、N端脑钠肽前体(N-terminal pro-brain natriuretic peptide, NT-proBNP)。完善冠脉造影,PPCI术时记录罪犯血管狭窄程度、放置支架长度、罪犯血管定位,左前降支(left anterior descending branch,

LAD)是否为梗死相关动脉(infarction related artery, IRA),并评估患者全球急性冠状动脉事件注册评分(GRACE评分),记录高危组患者(>140分)^[10]。

1.2.2 经胸超声心动图(trans-thoracic echocardiography, TTE)、3D-STE及MW

所有患者在PPCI术后24 h内行TTE、3D-STE及MW检查,测定左室射血分数(left ventricular ejection fraction, LVEF)、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)、左室收缩期达峰整体纵向应变(global longitudinal strain, GLS)、整体径向应变(global radial strain, GRS)、整体圆周应变(global circumferential strain, GCS)、整体面积应变(global area strain, GAS)及整体做功指数(global work index, GWI)、整体有效功(global constructive work, GCW)、整体无效功(global wasted work, GWW)、整体做功效率(global work efficiency, GWE)。

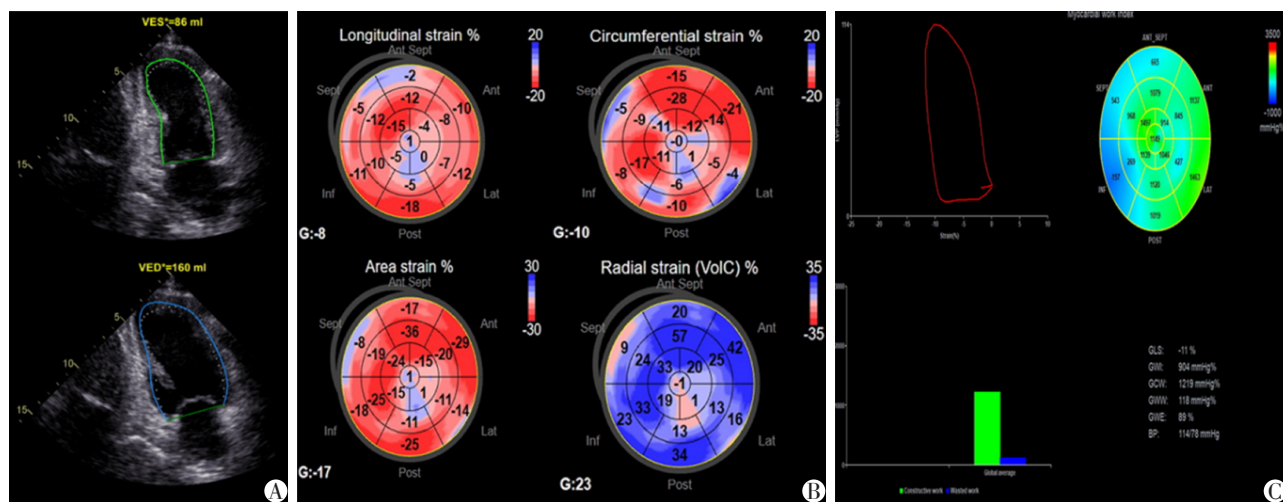
采用彩色多普勒超声诊断仪(型号:GE Vivid E 95, M5S探头, V4探头, 频率1.5~4.5 MHz)进行图像采集,采用Echo PAC 203工作站储存和分析数据。具体方法如下:①采集图像:取左侧卧位,同步连接心电图。采用美国超声心动图学会推荐的改良双平面 Simpson法测量LVEDV、LVESV及LVEF^[11]。M5S探头扫描胸骨旁及心尖部,记录并存储心尖部四腔、两腔、左室长轴切面、二尖瓣水平、乳头肌水平及心尖部左室短轴切面的二维超声图像,帧频为

50~70帧/s。V4探头扫描心尖部,获取心尖四腔或两腔切面理想图像后,嘱患者屏气,连续采集4个心动周期的锥形图像后,得出左心室三维全容积图像。②分析图像:记录并保存图像资料,上传至配套工作站进行脱机分析。应用2D-STE分析功能手动勾画心尖左室长轴、心尖四腔及心尖两腔切面左心室心内膜,软件自动生成感兴趣区(region of interest, ROI)范围,调整ROI宽度,软件自动逐帧追踪ROI内心肌运动,获取GLS。选取心尖部心内膜与二尖瓣瓣环连线中点2个点,采用3D-STE图像分析软件自动勾画左室舒张末期、收缩末期左室心内膜及心外膜边界。追踪良好后,自动生成17节段“牛眼图”,获取左室GLS、GRS、GAS、GCS。然后选择Myocardial Work分析模式,输入患者血压后,系统自动分析并通过左室压力应变环(LV-PSL)和2D GLS获取整体心肌做功指标(GWI、GCW、GWW、GWE)。以上检查均由2名具有丰富临床经验的超声科医师共同完成,所有指标均重复测量3次取平均值(图1)。

1.2.3 CMR-LGE

患者PPCI术后7 d内采用1.5T磁共振(Magnetom AVANTO,西门子公司,德国)完善CMR-LGE检查评估左心室的大小和功能,使用屏息、回顾性心电图触发的FISP明亮血液序列获得短轴(10~12片)电影图像,使用标准软件(ARGUS,西门子公司,德国)^[3]进行图像分析。

通过在舒张末期和收缩末期图像上绘制心内



A: The software tracks the entire myocardium in the four, two and three chamber of the apex of the heart, and in the middle and base segments of the parasternal short axis by tracking the spots. B: The strain parameters are calculated by the software and presented in the form of 17-segements “bull’s eye diagram”. C: LV-PSL measurement diagram.

图1 常规TTE参数(A)、3D-STE参数(B)、MW参数(C)
Figure 1 Parameters of TTE(A), 3D-STE(B) and MW(C)

膜和心外膜边界的轮廓,半自动确定左心室容积,随后0.2 mmol/kg钆喷酸二葡胺(耶拿公司,德国)静脉注射,使用心电图触发的相位敏感反转恢复(PSIR)序列采集LGE图像,短轴切片覆盖整个左心室。应用软件工具(IMPAX, Agfa HealthCare, 德国)评估过度增强(定义为远程心肌信号强度以上增加5个标准差的阈值)程度。坏死心肌百分比(定义为坏死心肌总质量与左心室心肌总质量的比值)由2名经验丰富的CMR医师对患者造影结果进行盲法分析(图2)。CMR中IS大于20%定义为大面积心肌梗死^[12]。

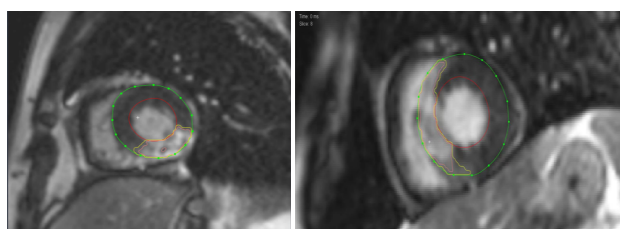


图2 心脏磁共振晚期钆增强成像(CMR-LGE)显示坏死心肌(高信号区)

Figure 2 Necrotic myocardium (high-signal zone) showed in CMR-LGE

1.2.4 随访

由1名心血管专科医生对所有患者盲法进行PPCI术后1年的MACE(包括再发心绞痛、因急性冠脉综合征行血运重建、急性心衰发作及心源性猝死^[13])随访。对于发生多次终点事件的患者,在主要终点分析中仅进行第一次终点事件的统计分析。

1.3 统计学方法

应用SPSS 27.0软件进行统计学分析,所有连续变量采用均数±标准差($\bar{x} \pm s$)或者中位数(四分位数)[$M(P_{25}, P_{75})$]表示,分类变量采用率(%)表示。组间比较,服从正态分布的连续变量采用独立样本 t 检验,不服从正态分布的连续变量采用Mann-Whitney U 检验,分类变量的比较采用卡方检验。行单因素及多因素Cox回归分析(Enter法)明确MACE发生的独立预测因素。对独立因素采用受试者工作特征(receiver operating characteristic, ROC)曲线计算各参数预测MACE的灵敏度及特异度,采用曲线下面积(area under the curve, AUC)评估检验效能,使用DeLong方法比较AUC,通过ROC曲线取得独立因素截断值,并分为高、低两组,使用R语言软件绘制Kaplan-Meier生存曲线,Log-rank检验两组差异,使用组内相关系数(intra-class correlation coefficient, ICC)评估观察者间及观察者内差异, $P < 0.05$ 为差

异有统计学意义。

2 结果

共入选134例患者,其中15例超声心动图显像不足(定义为>2非可视化节段),10例患者不能配合CMR检查,18例失访,1例患者发生非心源性死亡,最终纳入90例患者。根据PPCI术后1年内是否发生MACE,分为MACE组(20例,22.2%)与非MACE组(70例,77.8%)。其中,MACE组中5例再发心绞痛,8例因急性心衰发作再入院治疗,2例因急性冠脉综合征再次行PPCI术,2例因急性冠脉综合征行冠脉搭桥(coronary artery bypass grafting, CABG)治疗,3例发生心源性死亡。

2.1 临床资料比较

两组患者的性别、年龄、合并疾病、用药情况罪犯血管狭窄程度、支架长度、GRACE评分、峰值hs-cTnI均差异无统计学意义($P > 0.05$),MACE组LAD为IRA及大面积心肌梗死比例、峰值CK、NT-proBNP、CRP均显著高于非MACE组($P < 0.05$,表1)。

2.2 影像学参数比较

MACE组的TTE-LVEF显著低于非MACE组,TTE-LVEDV显著高于非MACE组($P < 0.05$,TTE-LVESV差异无统计学意义($P > 0.05$)).3D-STE中,MACE组的GLS、GAS、GRS、GCS显著低于非MACE组($P < 0.05$,表2)。

MW参数中,MACE组GWI、GCW、GWE显著低于非MACE组,而GWW显著高于非MACE组($P < 0.05$)。LGE-CMR参数中,MACE组IS显著高于非MACE组,而CMR-LVEF显著低于非MACE组($P < 0.05$),CMR-LVESV、CMR-LVEDV两组差异无统计学意义($P > 0.05$,表2)。

2.3 单因素及多因素Cox回归分析

将患者的临床资料、3D-STE、MW、CMR-LGE参数纳入单因素Cox回归分析,结果显示GRACE评分、峰值CK、CRP、NT-proBNP、LAD是IRA、TTE-LVEF、GLS、GCS、GAS、GRS、GWI、GCW、GWW、GWE、IS、CMR-LVEF、TTE-LVEDV为预测MACE发生的因素($P < 0.05$)。上述参数纳入多因素Cox回归分析显示,GLS、GWI、IS为预测MACE发生的独立预测因素($P < 0.05$,表3)。

2.4 ROC曲线分析

绘制ROC曲线分析显示,IS、GLS、GWI的AUC值分别为0.886、0.846、0.830,IS的灵敏度为90%,特异度78.6%;GLS灵敏度为95%,特异度77.1%;GWI

表1 两组患者临床特征比较

Table 1 Comparison of clinical characteristics between the two groups of patients

Demographics	MACE(+)(n=20)	MACE(-)(n=70)	P
Age(years, $\bar{x} \pm s$)	62.0 ± 9.2	57.1 ± 10.6	0.063
Male[n(%)]	17(85.0)	55(78.6)	0.751
Hypertension[n(%)]	9(45.0)	35(50.0)	0.693
Diabetes[n(%)]	7(35.0)	28(40.0)	0.686
Hyperlipidemia[n(%)]	9(45.0)	32(45.7)	0.955
LAD is IRA[n(%)]	15(75.0)	29(41.4)	0.008
Degree of stenosis of the IRA(% , $\bar{x} \pm s$)	92.9 ± 6.1	90.6 ± 6.0	0.138
Lengths of the stent(mm, $\bar{x} \pm s$)	48.0 ± 13.3	41.5 ± 14.3	0.077
GRACE score > 140[n(%)]	17(85.0)	41(58.6)	0.056
Extensive myocardial infarction[n(%)]	19(95.0)	44(62.9)	0.013
Peak hs-cTnI(pg/mL, $\bar{x} \pm s$)	23 418.8 ± 7 648.0	21 818.3 ± 7 052.1	0.382
Peak NT-proBNP(pg/mL, $\bar{x} \pm s$)	1 296.9 ± 230.5	1 058.3 ± 450.4	0.002
Peak CRP(mg/L, $\bar{x} \pm s$)	23.5 ± 11.9	14.7 ± 5.0	0.004
Peak CK(U/L, $\bar{x} \pm s$)	3 193.5 ± 2 296.0	2 126.3 ± 1 528.5	0.017
Aspirin[n(%)]	20(100.0)	66(94.3)	0.572
Ticagrelor[n(%)]	19(95.0)	69(98.6)	0.924
Statins[n(%)]	19(95.0)	69(98.6)	0.924
B-receptor blocker[n(%)]	20(100.0)	58(82.9)	0.061
ARNI[n(%)]	17(85.0)	57(81.4)	0.971

LAD: left anterior descending branch; IRA: infarction related artery; hs-cTnI: high sensitivity troponinI; CK: creatine kinase; ARNI: inhibitors of angiotensin receptor enkephalinase; MACE: major adverse cardiovascular events.

表2 两组患者基线影像学参数比较

Table 2 Comparison of baseline imaging parameters between the two groups of patients

Variable	MACE(+) (n=20)	MACE(-) (n=70)	P	Variable	MACE(+) (n=20)	MACE(-) (n=70)	P
TTE				MW(mmHg%)			
TTE-LVEF (%)	44.1 ± 5.6	50.2 ± 6.3	<0.001	GW	1 113.3 ± 99.2	1 322.5 ± 186.6	<0.001
TTE-LVEDV (mL)	130.6 ± 15.0	123.4 ± 13.3	0.049	GCW	1 332.7 ± 600.3	1 699.8 ± 447.6	0.004
TTE-LVESV (mL)	67.8 ± 11.8	61.8 ± 12.3	0.057	GW	330.4 ± 362.0	174.2 ± 97.4	0.002
3D-STE(%)				GWE	80.8 ± 10.3	87.9 ± 6.1	<0.001
GLS	-9.8 ± 0.7	-11.6 ± 1.6	<0.001	LGE-CMR			
GCS	-9.4 ± 2.1	-11.5 ± 2.6	0.001	IS(%)	30.4 ± 5.3	21.9 ± 4.9	<0.001
GAS	-14.9 ± 2.8	-20.2 ± 4.9	<0.001	CMR-LVEDV(mL)	150.9 ± 9.0	149.9 ± 9.7	0.702
GRS	20.3 ± 4.6	26.5 ± 7.0	<0.001	CMR-LVESV(mL)	82.2 ± 9.2	77.6 ± 9.5	0.063
				CMR-LVEF(%)	45.3 ± 3.7	48.2 ± 4.8	0.015

GLS: global longitudinal strain; GCS: global circumferential strain; GAS: global area strain; GRS: global radial strain; MW: myocardial work; GWI: global work index; GCW: global constructive work; GW: global wasted work; GWE: global work efficiency; LGE-CMR: late gadolinium enhancement imaging-cardiac magnetic resonance; IS: infarction size; LVEDV: left ventricular end diastolic volume; LVESV: left ventricular end systolic volume; LVEF: left ventricular ejection fraction.

灵敏度为100%, 特异度58.6%, GLS和GWI联合预测MACE发生的AUC值达0.939, 灵敏度为85%, 特异度为90%(图3, 表4)。使用DeLong方法比较AUC值无显著差异(GLS 0.846 vs. IS 0.886; GLS 0.846 vs.

GLS 0.846 vs. IS 0.886, P均>0.05)。而GLS+GWI联合预测MACE发生的价值显著优于GLS和GWI单一指标(P均<0.05)。GLS、GWI、IS预测MACE的ROC曲线

表3 单因素及多因素Cox回归分析

Table 3 Univariate and multivariate Cox regression analyses

Variable	Univariate analysis		Multivariate analysis	
	HR(95%CI)	P	HR(95%CI)	P
GRACE score	3.459(1.013-11.808)	0.048	6.718(0.924-48.822)	0.060
Peak CK	1.000(1.000-1.000)	0.012	1.000(0.999-1.000)	0.809
Peak CRP	1.087(1.049-1.126)	<0.001	1.074(0.995-1.159)	0.067
PeakNT-proBNP	1.001(1.000-1.002)	0.043	1.005(0.999-1.011)	0.100
LAD is IRA	0.288(0.105-0.792)	0.016	0.270(0.025-2.963)	0.284
TTE-LVEF	0.865(0.794-0.942)	<0.001	0.954(0.832-1.095)	0.505
GLS	2.042(1.461-2.855)	<0.001	2.218(1.029-4.782)	0.042
GCS	1.304(1.092-1.558)	0.003	0.609(0.281-1.321)	0.209
GAS	1.242(1.117-1.381)	<0.001	1.178(0.796-1.743)	0.414
GRS	0.877(0.814-0.945)	<0.001	1.322(0.842-2.057)	0.225
GWI	0.992(0.988-0.996)	<0.001	0.985(0.971-0.999)	0.036
GCW	0.998(0.997-0.999)	0.004	1.001(0.999-1.002)	0.319
GWW	1.002(1.001-1.003)	0.002	0.999(0.996-1.003)	0.739
GWE	0.948(0.919-0.978)	<0.001	1.004(0.912-1.105)	0.937
IS	1.235(1.139-1340)	<0.001	1.136(1.003-1.286)	0.045
CMR-LVEF	0.893(0.815-0.980)	0.016	0.773(0.585-1.022)	0.071
LVEDV	1.035(1.001-1.071)	0.044	1.039(0.987-1.094)	0.141

CK: creatine kinase; LAD: left anterior descending branch; IRA: infarct-related artery; TTE: trans-thoracic echocardiography; LVEF: left ventricular ejection fraction; GLS: global longitudinal strain; GCS: global circumferential strain; GAS: global area strain; GRS: global radial strain; MW: myocardial work; GWI: global work index; GCW: global constructive work; GWW: global wasted work; GWE: global work efficiency; LGE-CMR: late gadolinium enhancement imaging-cardiac magnetic resonance; IS: infarction size; LVEDV: left ventricular end diastolic volume; LVESV: left ventricular end systolic volume.

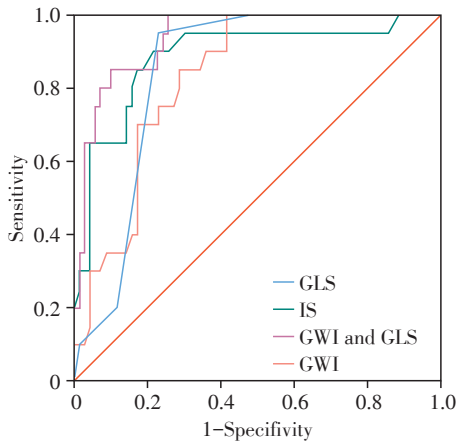


图3 各参数预测MACE发生的ROC曲线

Figure 3 ROC curves of each parameter in predicting MACE

截断值分别为-10.5%、1 298.5 mmHg、26.05%。

2.5 Kaplan-Meier生存分析

根据GLS、GWI、IS预测MACE的截断值分为高、低两组，进行Kaplan-Meier生存分析，结果显示GLS<-10.5%、GWI>1 298.5 mmHg%、IS<26.05患者有更高的无MACE生存率(P<0.05,图4)。

2.6 重复性检验

为评估检测重复性，随机选择10例患者，2名独立研究者重复测定3D-STE、MW、CMR-LGE参数以比较观察者间差异，同一名研究者间隔2周后测定上述参数以评估观察者内差异，结果显示不同观察者间及同一观察者内对各参数的评估重复性良好(表5)。

3 讨论

早期风险评估对STEMI患者极其重要，研究表明STEMI患者行PPCI后死亡率逐渐下降^[14]，但仍有大量患者因术后发生MACE而预后不佳^[2,15]。既往研究显示STEMI患者PPCI术后3年内MACE发生率高达20%，而其中超过60%发生在术后第1年，故STEMI患者PPCI术后早期行有效的检查预测MACE发生，并行危险分层，对于患者预后评价及治疗选择至关重要^[16]。本研究第一次应用3D-STE及MW对比CMR预测STEMI患者术后1年MACE的发生，发现其中GLS及GWI参数诊断效能均与CMR-IS相当，二者联合优于单一指标，有较好的临床应

表4 各参数预测MACE的ROC曲线分析

Table 4 ROC curve analysis of each parameter to predict MACE

Variable	AUC	Cutoff value	Sensitivity	Specificity	P	95%CI
IS	0.886	26.05	0.90	0.786	<0.001	0.794-0.978
GLS	0.846	-10.5	0.95	0.771	<0.001	0.768-0.925
GW1	0.830	1 298.5	1.00	0.586	<0.001	0.746-0.914
GLS+GW1	0.939	-	0.85	0.90	<0.001	0.889-0.988

IS: infarction size; GLS: global longitudinal strain; GW1: global work index.

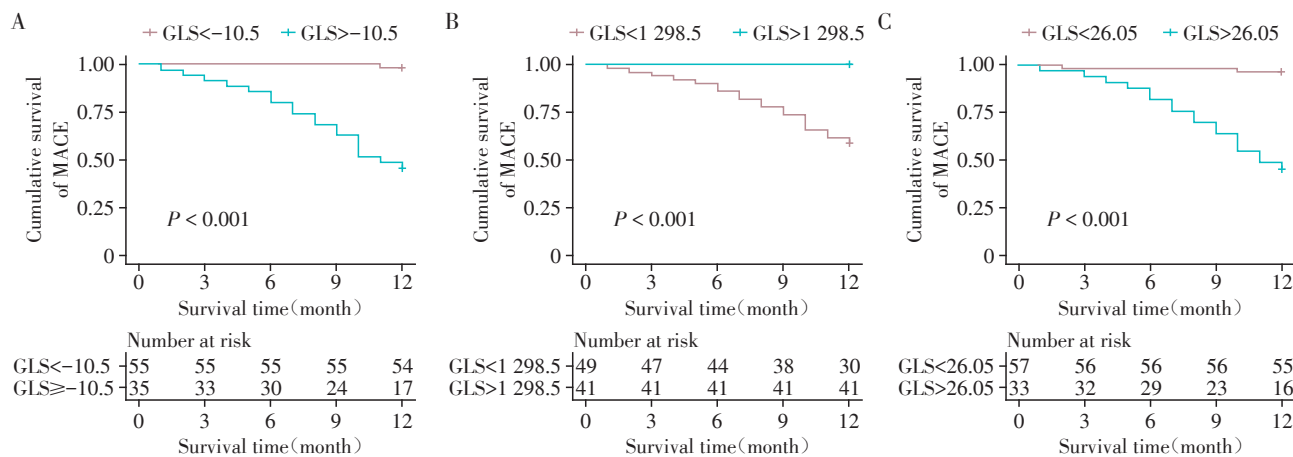


图4 GLS、GWI和IS高低两组患者的无MACE Kaplan-Meier生存曲线

Figure 4 MACE-free Kaplan-Meier survival curves for patients with high and low GLS, GWI, and IS

表5 各参数观察者间和观察者内重复性检验

Table 5 Inter-observer and intra-observer repeatability test for each parameter

Variable	Intra-observer		Inter-observer	
	ICC	95%CI	ICC	95%CI
GLS	0.725	0.431-0.881	0.759	0.487-0.897
GW1	0.762	0.491-0.898	0.722	0.416-0.880
CMR-LVEF	0.714	0.406-0.876	0.792	0.543-0.912
IS	0.777	0.519-0.905	0.828	0.617-0.928

GLS: global longitudinal strain; GW1: global work index; IS: infarction size; CMR-LVEF: cardiac magnetic resonance-left ventricular ejection fraction.

用价值。

3.1 IRA、IS与MACE

既往研究指出前壁STEMI患者发生MACE的风险较高^[17]。本研究显示LAD为IRA的MACE发生率为75.0%，与既往研究一致。Reindl等^[18]研究表明梗死严重程度与MACE风险增加独立相关，而本研究也证实在大面积心肌梗死患者中，MACE的发生率更高(30.2%)，且MACE组的CMR-LVEF低，而LVEDV较高，考虑为STEMI后左心室收缩功能受损，LVEF下降，故心脏不良事件增多，而左心室

LVEDV取决于左心室充盈压力及重构，二者均与MACE发生紧密相关^[19]。

3.2 CMR与MACE

CMR-LGE成像可以高精度地描述和量化心肌损伤，被认为是预测IS、跨壁受累程度、预后的理想工具^[18]，并且优于单光子发射计算机断层扫描^[20]。IS是心肌梗死后LVR和功能障碍的主要决定因素，同时与MACE发生密切相关^[18,21]，IS作为STEMI患者预后评估的重要指标，有重要的参考价值^[3,22]。本研究显示PPCI术后7d内CMR-IS>26.5%是STEMI患者术后1年发生MACE的独立预测因素，灵敏度和特异度达90.0%和78.6%(AUC=0.886)，并且IS>26.5%累积MACE发生率高、预后差，考虑为梗死后病变区域心肌功能丧失，非梗死区心肌代偿负荷过重，进而出现心肌肥大及纤维化，并随梗死节段扩张、瘢痕组织成熟导致房室扩张，MACE发生^[18]。

3.3 3D-STE与MACE

3D-STE克服平面依赖，提高时间与空间分辨率，被认为是优于2D-STE评估STEMI后存活心肌及预后的重要工具，有研究表明，3D-STE中的3D-GLS是STEMI后LVR及1年预后的独立预测指标，同时10年随访中发现3D-GLS仍是预后评估的较强预测

因子^[6,13]。Ravnkilde等^[23]在对235例急性冠脉综合征患者的随访中发现GLS对危险分层具有重要意义。原因为冠状动脉分支垂直于心脏表面穿透正常心肌,形成心内膜下分布^[24]。因此,心内膜下纤维最先发生血流阻断,对比中层及心外膜下心肌,心内膜下的心肌纤维对长轴方向运动的贡献最为显著。而GLS反映了心内膜下纵向心肌纤维的功能,更准确地提示缺血引起的早期心肌功能紊乱^[25]。本研究发现,GLS是评估STEMI患者PPCI术后1年MACE发生的独立预测因子,生存曲线提示GLS \geq -10.5%的患者累积MACE发生率较高,提示预后较差。

3.4 MW与MACE

3D-STE中的3D-GLS对急性STEMI患者预后具有重要的预测价值,并优于常规超声参数LVEF。然而与LVEF相似,GLS仍然具有明显的后负荷依赖性。MW是一种将左心室GLS与无创左室压力曲线结合,通过应变计算的区域缩短率乘瞬时压力来量化心肌做功的新方法,克服GLS的后负荷依赖性^[26-27]。在心肌功指标中,GWI代表左室压力-应变环路内的面积,能最全面地估计左室功能^[28]。Butcher等^[29]在239例经PCI治疗的伴LVEF降低($<40\%$)的STEMI患者中发现,较高的左室GWI值与6个月随访时LVEF密切相关。此外,在长期随访中,较低的左室GWI值与全因死亡率的增加密切相关。Timoteo等^[27]回顾性研究了200例STEMI患者,发现GWI下降与MACE升高密切相关。本研究发现GWI是预测MACE发生的独立危险因素,并且GWI \leq 1 298.5 mmHg%的患者1年的MACE累积发生率较高,预后较差。

3.5 3D-STE、MW与CMR对比

3D-STE、MW可经济、有效地评估心脏功能及预后,近年来在临床上被广泛开展^[26,30]。Dannenbery等^[31]研究发现,在70例STEMI患者中GLS应变参数与CMR-IS之间存在显著关联,Joseph等^[32]提出在STEMI中患者急性期GLS与IS密切相关,另一项研究MW与STEMI后心肌活性的研究中发现局部节段的MWI与心肌梗死的范围和透壁性呈负相关^[33]。本研究发现3D-STE(GLS)与MW(GWI)早期预测STEMI患者MACE发生的价值与CMR-IS相当(AUC $P > 0.05$),且GLS和GWI联合指标优于单一指标($P < 0.05$),为临床上早期、有效、床边评估STEMI患者预后提供帮助。

本研究存在以下不足:①单中心、小样本研究,

纳入患者存在一定局限性;②3D-STE、MW等影像质量受肥胖、心律失常等因素影响,对结果可能存在干扰;③STEMI患者左室心肌变薄,给3D-STE及MW测定带来一定困难;通过压力-应变回路计算MW,使用无创袖带血压计测量间接评估左室压力,可能存在一定误差;④STEMI患者PPCI术后1周至1个月IS变化较大,本研究仅测定心肌梗死后1周内心肌水肿最严重时的CMR-IS,存在一定局限性;⑤因样本量较少,本研究未行梗死面积及不同IRA亚组分析,未进一步分析缺血-再灌注时间等因素对预后的影响。

3D-STE及MW均有助于预测STEMI患者PPCI术后MACE的发生,尤其是GLS及GWI,其诊断价值相当,且二者联合优于单一参数,诊断效能均与CMR-IS相似,为早期评估STEMI患者预后提供经济、有效的检查方法,以便早期行危险分层并指导治疗。

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