心脏磁共振成像对右心室流出道的评估及临床应用

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【摘要】右心室流出道作为右心室的组成部分,对疾病有重要的诊断及预后价值,心脏磁共振成像可实现对右心室流出道的多平面成像。现总结基于磁共振图像对右心室流出道的评估参数及临床应用。

【关键词】右心室流出道;磁共振成像
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Evaluation and Clinical Application of Cardiac Magnetic Resonance Imaging to Right Ventricular Outflow Tract

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【**Abstract**】As an important part of the right ventricle, right ventricular outflow tract has diagnostic and prognostic value for diseases. Cardiac magnetic resonance imaging can image the right ventricular outflow tract in multi-planes. This paper reviews and summarized the parameters and clinical application of right ventricular outflow tract based on magnetic resonance imaging.

【**Key words**】Right ventricular outflow tract; Magnetic resonance imaging

右心室由流入道、心尖小梁部和流出道三部分组成[1]。右心室流入道是房室连接处到三尖瓣乳头肌附着点处的部分,心尖小梁部是三尖瓣乳头肌附着点处到流出道起始点处的部分,流出道从心尖小梁部的远端延伸到肺动脉瓣环处[2]。目前对右心室的评价多关注右心室整体的功能,在法洛四联症矫正术(repaired tetralogy of Fallot, rTOF)后、肺动脉高压以及致心律失常型右心室心肌病等疾病中,右心室流出道(RVOT)直接暴露在压力、容量负荷下,当右心室的整体功能尚处于代偿期时,RVOT 结构和功能已发生改变,这种情况下进行 RVOT 的准确评估对疾病的早期诊治至关重要。目前作为评估右心室金标准的心脏磁共振成像可实现对 RVOT 多视角、多方面的分析。现综述当前有关心脏磁共振成像评估 RVOT 的常用参数指标,并对其临床应用做一概述。

1 RVOT 功能的评估参数

1.1 RVOT 射血分数

右室射血分数(left ventricular ejection fraction, RVEF)目前是评价右心室功能的"金标准",在临床上广泛应用。现阶段主要应用的是右心室整体射血分数,分不同部分描述 RVEF 的研究相对较少。借助心脏磁共振 RVOT 切面、右心室两腔心切面、四腔心切面,结合其在电影序列中的运动情况,可在短轴电影上清楚地识别出 RVOT 部分,通过后处理软件在舒张末期及收缩末期勾画 RVOT 内膜轮廓,可得到 RVOT 射血分数。在 rTOF 后患者中,流出道的收缩功能显著差于右心室其他部分,整体射血分数可处于代偿范围,对流出道射血分数的评估很有意义。Bodhey 等[2]发现,在正常情况下,RVOT 射血分数为 54.8%,占右心室整体射血量的 25.1%,但在法洛四联症(tetralogy of Fallot, TOF)患者中,流出道的射血分数为 28.5%,占右心室整体射血量的 12.8%。van der Hulst 等[3]发

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现,在 TOF 患者中,流出道的射血分数明显下降,而心尖部的射血分数相对保留。并且在 rTOF 患者中,流出道射血分数同右心室整体和右心室其他部分的射血分数相比,与反映活动耐量指标的最大耗氧量相关性最好($r=0.59$),经过多因素校正后是运动耐量下降的唯一独立预测因素($\beta=0.442$)[4]。Wald 等[5]在 rTOF 患者中的研究也有相似的结论,流出道射血分数和最大耗氧量预测值的相关性最好($r=0.56$),是有氧耐量的唯一独立预测因子。

1.2 RVOT 内径

在压力、容量负荷等情况下,流出道可出现扩张、室壁瘤等改变。其扩张的程度可反映疾病的严重程度。致心律失常型右心室心肌病/发育不良(arrhythmogenic right ventricular cardiomyopathy/dysplasia, ARVC/D)的 2010 年修订版指南,将 RVOT 的内径作为诊断标准之一,并推荐了二维心脏超声图像测量 RVOT 内径的方法及测量参考值:胸骨旁左室长轴 RVOT(RVOT-PLAX)内径≥32 mm,胸骨旁左室短轴 RVOT(RVOT-PSAX)内径≥36 mm[6]。此外,2015 年版修订的右心室大小测量的指南中,建议对右心室大小的全面评估应测量 6 条径线,其中包括 RVOT-PLAX 和 RVOT-PSAX[7]。Borgquist 等[8]关于评价彩色超声和磁共振对 ARVC/D 诊断价值的研究发现,病变轻微者,超声对其内径等的评估并不可靠,而磁共振图像所得流出道内径对疾病的诊断效果更好。Gotschy 等[9]的研究比较了超声和磁共振图像关于流出道内径测量的准确性和重复性,发现心脏磁共振图像分析所得 RVOT-PLAX 内径、RVOT-PSAX 内径与心脏彩色超声图像所测得参数均有良好的相关性($r=0.87$, $r=0.75$),而磁共振测量方法的观察者内和观察者间重复性均优于超声心动图。

1.3 RVOT 应变

应变是指相对于初始形状的形变能力,是反映心室壁运动功能的指标之一。有研究发现右心室应变能力的下降较射血分数下降更为明显,是反映右心室功能更为敏感的指标[10-11]。目前对于右心室应变的研究大多基于四腔心切面的右心室侧壁和室间隔,而右心室是一个新月形的不对称结构,对压力和容量负荷的应答程度不同,在疾病过程中也不是同步受累,单个切面的应力分析只能很小程度地反映右心室功能,因此,ESC 推荐从多个平面对右心室进行综合评估[12]。最近一些基于多平面右心室应变的研究发现,应变能力的下降在右心室不同区域下降的程度不同,Fayad 等[13]发现在肺动脉高压中,RVOT 应变下降比右心室其他区域更显著。Anwar 等[14]发现,在 TOF 术后患者中,右心室整体及 RVOT 的纵向应变下降均较 RVEF 下降更明显,并且,RVOT 纵向应变和右心室整体纵向应变相比,RVOT 纵向应变与右心室整体功能的相关性更好(流出道应变 $r=0.53$,右心室整体应变 $r=0.35$)。

1.4 RVOT 运动异常

运动异常表现为运动能力减弱,局部反向收缩以及收缩不同步。在 ARVC 的 2010 年修订版诊断指南中,将右心室室壁的局部收缩减弱、反向收缩及收缩不同步作为心脏磁共振诊断 ARVC/D 的主要指标之一[6]。室壁运动异常的评估为定性评估,具有主观依赖性,有研究提供了半定量的方法,可用来评价流出道室壁异常运动。Davlouros 等[15]的研究将运动能力减弱定义为:在收缩期感兴趣区域室壁增厚 <10%。Puranik 等[16]在他的研究中将流出道反向运动定义为在 RVOT 矢状位切面,流出道前壁在收缩期向胸骨方向反常运动 >5 mm,评估收缩不同步可通过应变达峰时间来进行评估[17]。Oechslin 等[18]在 rTOF 的患者中均发现 RVOT 运动异常和肺动脉瓣反流都与右心室扩张及右心室肥厚独立相关。

1.5 RVOT 延迟强化

目前关于 RVOT 纤维化改变的机制不是很明确,一些研究认为长期的缺氧可能是导致 RVOT 心肌纤维化的原因[19],例如在 rTOF 患者中,漏斗部切除可影响微循环系统,导致长期缺氧,最终出现纤维化[20]。也有研究认为因肺动脉瓣反流引起的右心室扩张也会导致 RVOT 心肌的纤维化[21]。关于心肌延迟强化的评估,可选用定性和定量的方法。定量评估现阶段普遍应用的有全宽半峰法和标准差法,全宽半峰法是以瘢痕内最高信号的一半作为阈值,超过该值代表纤维化,标准差法则选取瘢痕远端部位的正常心肌信号作为参考,超过该参考值预设的 n 个 SD 代表纤维化形成(不同疾病设置不同的 SD)[22-23]。目前,关于 RVOT 延迟强化的研究较少,Wald 等[5]在 rTOF 患者中利用定量评分的方法,发现 RVOT 延迟强化评分与右心室整体射血分数有良好的相关性($r=-0.33$)。

2 RVOT 功能评估的临床应用

2.1 TOF

TOF 表现为室间隔缺损、主动脉骑跨,继而引起 RVOT 梗阻、右心室肥厚。RVOT 的异常是 TOF 解剖异常的标志,表现为肺动脉漏斗部的梗阻、漏斗间隔部的消失,甚至漏斗间隔部、隔缘肉柱等的肥厚[24]。

在 rTOF 患者中,右心室的整体功能可通过减少肺动脉瓣反流处于代偿状态,RVOT 在这种代偿机制中起主要作用[25]。RVOT 功能障碍除了与压力、容量负荷有关,还与手术瘢痕导致的纤维化有关[2,26]。Uebing 等[20]还发现,TOF 术后患者 RVOT 的扩张及纤维化导致流出道成为恶性心律失常的常见发生部位。目前关于 TOF 术后患者在 RVOT 方面的研究发现:(1)流出道的射血分数较右心室其他部分下降更明显[2,26];(2)流出道射血分数同右心室整体和右心室其他部分的射血分数相比,与最大耗氧量预计值的相关性最好[5,27];(3)RVOT 运动异常与右心室扩张及右心室肥厚独立相关[15-16];(4)RVOT 纵向应变与右心室整体纵向应变相比,与 RVEF、肺动脉瓣反流、右室舒张末期容积、右心室收缩末期容积相关性更好[14];(5)在右心室不同区域中,流出道发生运动障碍和延迟强化的概率最高,并且和活动耐量的相关性更好[5]。

2.2 肺动脉高压

肺动脉高压是以肺动脉压力升高为特征的一种疾病,定义为在海平面上平均肺动脉压力超过 25 mm Hg(1 mm Hg = 0.133 3 kPa)[28],在肺动脉高压的晚期,通常出现右心室肥厚及右心衰竭。以往的研究发现右室受累并不是同步发生的[29],Zagorski 等[30]发现,在慢性肺血栓性肺动脉高压小鼠中,当 RVOT 出现明显膨出及功能障碍时,流入道和心尖小梁部的变化并不明显。Calcutteea 等[31]发现,在肺动脉高压中,RVOT 内径增宽,功能下降,并且流出道的应变率是预测右心室整体功能的因子。Lindqvist 等[32]的研究也发现,流出道是保证右心室功能代偿的重要部分,并且和其他部分相比,对发现肺动脉高压更敏感。目前关于肺动脉高压患者在 RVOT 方面的研究发现:(1)在肺动脉高压中,RVOT 出现形态重构及功能下降比右心室其他部分受累更早[30];(2)流出道的应变率是右心室整体功能的唯一预测因子[31];(3)和右心室其他部分相比,流出道功能障碍对于发现肺动脉高压更敏感[32];(4)流出道的应变下降较右心室其他部分更明显[13]。

2.3 ARVC/D

ARVC/D 是一种常染色体介导的显性遗传病,病理表现为正常右心室心肌被纤维-脂肪组织替代[33],表现为心室游离壁局部变薄、局部室壁瘤以及 RVOT 的扩张,并最终累及左心室[34]。由于发病率较低,缺少单一的确定性诊断实验,ARVC/D 的诊断较为困难[35],需结合多项诊断条目,RVOT 内径作为其诊断标准之一[6]。目前关于 ARVC/D 在 RVOT 方面的研究发现:(1)基于心脏磁共振图像所得 RVOT 内径诊断 ARVC/D 有较好的敏感性和特异性;(2)和正常对照相比,ARVC/D RVOT 的纵向应变及径向应变较右心室整体应变下降更明显[36]。

3 结语

目前越来越多的研究发现结构不对称的右心室,其不同部分对右心室整体功能的贡献程度不同,在疾病过程中受累不同步,对疾病应答程度不一,由于 RVOT 直接暴露于压力及容量负荷,在一些疾病中,其出现重构及功能障碍更早、更严重。心脏磁共振可从多个层面显示 RVOT,但关注流出道的研究少,其在不同疾病中的诊断及预后价值需被进一步验证。

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