无创影像学在冠状动脉慢性完全闭塞病变血运重建中的应用

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【摘要】 冠状动脉慢性完全闭塞(CTO)病变占冠状动脉造影确诊为冠心病的 20% ~30%。尽管经皮冠状动脉介入治疗(PCI)技术发展迅速,但 CTO-PCI 仍然是冠心病治疗领域最后的壁垒,CTO-PCI 失败最常见的原因是导丝或球囊无法通过闭塞病变及球囊不能充分扩张,而冠状动脉夹层、穿孔及同侧侧支损伤则是常见的操作并发症。因此,PCI 前需要综合考虑病变的解剖特征、存活心肌及患者的一般情况,选择适合 CTO-PCI 的患者,现就无创影像学在 CTO-PCI 中的应用进行简要综述。

【关键词】 冠心病;慢性完全闭塞;无创影像学;心肌活性;经皮冠状动脉介入治疗;冠状动脉 CT 血管成像;管腔内衰减梯度
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Application of Noninvasive Imaging in Revascularization of Chronic Total Occlusion of Coronary Artery

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【Abstract】 Chronic total occlusion (CTO) of coronary artery accounts for 20% ~30% of coronary heart disease diagnosed by coronary angiography. Despite the rapid development of percutaneous coronary intervention (PCI) technology, CTO-PCI is still the last barrier in the field of coronary heart disease treatment. The most common reason for CTO-PCI failure is that the guide wire or balloon cannot pass through the occlusive lesion and the balloon cannot fully expand. Coronary artery dissection, perforation and injury of ipsilateral collateral are common operational complications. Therefore, before PCI, it is necessary to comprehensively consider the anatomical characteristics of lesions, viable myocardium and the general situation of patients, and select patients suitable for CTO-PCI. Therefore, this article briefly reviews the application of non-invasive imaging in CTO-PCI.

【Key words】 Coronary heart disease; Chronic total occlusion; Noninvasive imaging; Myocardial viability; Percutaneous coronary intervention; Coronary artery computed tomography angiography; Transluminal attenuation gradient

冠状动脉慢性完全闭塞(chronic total occlusion, CTO)指冠状动脉完全闭塞,前向血流 TIMI 0 级,且闭塞时间≥3 个月的病变[1]。

慢性缺血缺氧会使正常的心肌细胞逐渐转为以冬眠细胞为主的存活心肌[2],如果不及时复流,存活心肌最终会成为梗死心肌。2019 年,Brilakis 等[1]提出 CTO 病变经皮冠状动脉介入治疗(percutaneous coronary intervention, PCI)的 7 大准则,指出经验丰富的术者及诊疗中心基于此 7 项准则实施 CTO-PCI,有 85% 左右的技术成功率及 3% 左右的并发症发生率[3-4]。指南[5]也建议在具有 PCI 指征的患者中实施 CTO-PCI 是可行的,并将 CTO-PCI 列为Ⅱa 级适应证,同时指出对存活心肌的评估在临床决策及 CTO-PCI 术后收缩功能的改善中意义重大[6]。研究[7-8]表明,成功的 CTO-PCI 可缓解胸痛,显著降低主要不良心血管事件的风险。

CTO 病变解剖复杂,影像学检查可在术前对 CTO 病变的解剖学特征及存活心肌进行无创评估及风险分层,有助于选择适合接受 PCI 的 CTO 患者。现就无创影像学在 CTO-PCI 中的应用展开综述。

1 冠状动脉 CT 血管成像

冠状动脉 CT 血管成像(coronary artery computed tomography angiography, CCTA)是诊断冠心病首选的无创检查,可多角度观察闭塞段解剖特征,对成功开通 CTO 病变至关重要[9-10]。术前正确评估 CTO 病变近端的位置和形态是选择 CTO-PCI 最佳入路的关键[1],模糊的闭塞近端与血管造影复杂性的增加及手术成功率的降低相关[11],重度钙化是影响导丝通过闭塞段

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的主要因素[12]。病变长度、钙化程度及负性重塑是 CTO-PCI 失败的主要预测因素[13], Opolski 等[14]研究表明, CCTA 评估闭塞段为多节段闭塞、钝性残端、闭塞段血管迂曲、严重钙化、闭塞时间≥12 个月及既往 PCI 失败是预测导丝 30 min 内是否能成功通过闭塞段的独立预测因素,危险因素越多, CTO-PCI 的成功率越低。术前评估病变,无上述危险因素时,导丝 30 min 内通过闭塞段的成功率为 95%,当危险因素≥3 个时,在同样的时间内,导丝通过病变的成功率≤24%。但是逆行技术可以提高解剖结构复杂的 CTO 患者 PCI 的成功率,尤其是在有侧支循环的患者中,逆行 PCI 成功的可能性更高[15],而侧支循环的管径和迂曲程度是术者追踪侧支循环及逆行 PCI 成功的独立血管学预测因素[16]。Sugaya 等[17]研究表明相比于冠状动脉造影, CCTA 显示侧支循环的准确性为 74.5%,对侧支循环进行分级的整体准确性为 78%,评估侧支循环迂曲程度的准确性为 72.7%, CCTA 上显影的侧支循环,导丝通过的成功率为 74.1%,损伤率为 11.1%。此外, Choi 等[18]研究表明冠状动脉管腔内衰减梯度(transluminal attenuation gradient, TAG)可以反映侧支循环血流的功能范围和方向, TAG 是基于 CCTA 图像计算管腔内某点的放射性衰减值与从冠状动脉开口至该点轴向距离之间的线性回归系数, TAG 随着侧支循环分级的增加而增高, TAG > −7.6 HU/10 mm 对发育良好的侧支循环具有中等的预测性能。Li 等[19]提出反向衰减梯度 >0 HU/10 mm 提示 CTO 病变远段的血流是由侧支循环提供的逆行血流,另外,反向衰减梯度联合病变长度及桥接侧支循环对鉴别 CTO 和次全闭塞的敏感性为 90%、特异性为 93%、准确性为 92%[19]。综上,术前正确评估 CTO 病变可以提高 CTO 病变的开通率,降低冠状动脉穿孔及围手术期心肌梗死的发生率[10],同时,术前亦可通过 CCTA 评估 CTO 开通难易程度等级,有效预测 CTO-PCI 成功率[12,14]。

2　心脏磁共振

心脏磁共振(cardiac magnetic resonance, CMR)的时间空间分辨率高且重现性好,可对心脏功能、灌注情况及解剖结构同期评估[20],钆对比剂延迟增强磁共振(late gadolinium enhancement magnetic resonance, LGE-MR)评估心肌活性最常用[21],由于钆对比剂主要分布在细胞外间隙,当心肌细胞代谢降低,细胞外间隙增大,对比剂排泄延迟、滞留增加,在 T1 上呈明亮的高信号,尤其是轻微的心内膜下心肌梗死,相比于核医学, LGE-MR 的敏感性更高[22]。另外, LGE-MR 评估梗死心肌的透壁程度与心肌功能改善明显相关,当透壁程度 <25% 时,成功的 CTO-PCI 术后 5 个月心肌功能显著改善,而透壁程度 >75% 时,心肌功能在 PCI 术后 5 个月及 3 年并无明显改善[23-24]。虽然 LGE-MR 可以检测心肌是否存活,但是不能评估梗死心肌的严重程度及心外膜未增强的心肌是否存活,而细胞外体积分数是对细胞外体积的定量测量,心肌损伤越严重,细胞外体积越大,可同时评估梗死心肌的严重程度及心外膜未增强的心肌活性,为 LGE-MR 预测 CTO 患者血运重建后心肌功能的恢复提供了增量价值[25]。此外,不同于 CMR 组织追踪(CMR-feature tracking, CMR-FT)技术, LGE-MR 评估损伤心肌依赖于与正常心肌的差异,在一定程度上会造成假阴性, CMR-FT 是通过心肌应变的相关参数,评估心肌在径向、纵向及周向三个方向的变形能力,从而检测损伤心肌及心肌损伤程度。研究[26]表明,在 CTO 血管供应的心肌节段,尽管 LGE 阴性,但是收缩期纵向应变率明显低于正常对照组。张丽君等[27]认为尽管单支 CTO 患者的射血分数保留,但是整体及 CTO 区域的心肌应变能力已经降低,梗死面积越大,径向和周向应变能力下降越明显,因此 CMR-FT 可以早期识别具有左心室功能损害的 CTO 患者。但是, CMR-FT 采用二维还是三维测量心肌应变能力尚未达成共识,还需进一步研究。

3　超声心动图

超声心动图通过评估心肌的收缩储备能力及室壁运动异常来检测存活心肌,其中,小剂量多巴酚丁胺超声心动图是检测存活心肌的可靠方法。Li 等[28]研究表明,小剂量多巴酚丁胺超声心动图评估存活心肌的敏感性、特异性及准确性分别为 68.5%、63.0% 和 66.7%,联合斑点追踪成像(speckle tracking imaging, STI)技术评价存活心肌的敏感性、特异性和准确性升高到 91.7%、90% 和 90.6%。STI 是在高帧频二维灰度超声成像的基础上,识别心肌内回声斑点的空间运动,追踪其在每帧图像中的位置及不同帧图像之间同一位置的心肌运动轨迹,不受声束方向与室壁运动方向夹角的影响,可检测早期心室功能障碍。研究表明纵向应变和纵向应变率是评价存活心肌的独立参数[29],同时,纵向应变对缺血负荷的降低更为敏感,亦可早期评估成功的 CTO-PCI 后左心室功能变化[30]。纵向应变主要受心内膜下纵行走行的心肌纤维影响,评估梗死心肌透壁程度的准确性不及周向应力,当周向应力截断值为 −10.5 时,检测透壁瘢痕心肌的敏感性(71%)和特异性(73%)较高[31]。但是 2D-STI 仅能检测心肌纵向或径向的二维形变,心肌纤维又是在三维空间上的复杂形态变化,通过对心脏进

行全容积成像并在三维空间上更精确地追踪心肌斑点运动轨迹的 3D-STI 弥补了 2D-STI 的不足。

4 核素心肌显像

核素心肌显像分为心肌灌注显像和代谢显像。^{18}F-氟代脱氧葡萄糖(^{18}F-fluorodeoxyglucose, ^{18}F-FDG)正电子发射断层成像(positron emission tomography, PET)心肌代谢显像是评价存活心肌的“金标准”,需与静息心肌灌注显像联合应用。如果心肌灌注减低/缺损区心肌^{18}F-FDG 代谢正常/增加(灌注-代谢不匹配),则表明存在心肌缺血但心肌存活,而心肌灌注减低区无^{18}F-FDG 代谢(灌注-代谢匹配),则为梗死心肌[32]。研究[33]表明,存活心肌≥7% 的患者行 PCI 后可降低心源性死亡率、心肌梗死再发率及心源性再住院率。此外,良好的侧支循环虽然可以降低 CTO 患者心肌梗死的发生率、缓解心肌缺血并维持左心室功能,但是翟光耀等[34]认为^{18}F-FDG 代谢显像确定的 CTO 患者的心肌存活范围与侧支循环无明显相关,侧支循环不良的 CTO 患者也有心肌存活。这与 Dong 等[35]的研究结果一致,可能是因为冠状动脉造影无法检测到维持心肌灌注及活性的微小血管和供体血管,及 CTO 闭塞血管间的压力梯度的降低不利于侧支循环的形成[36],故而相比于侧支循环,^{18}F-FDG PET 心肌显像评估 CTO 病变区域梗死及存活心肌范围价值更大。因此,CTO-PCI 术前行核素心肌显像评估 CTO 病变区域的存活心肌,对于改善患者的生活质量及预后具有重要的指导意义。

5 总结

介入开通 CTO 病变是目前治疗 CTO 病变的手段之一,术前评估存活心肌有助于选择从成功的 CTO-PCI 中获益的患者,CMR 对内膜下心肌梗死更为敏感,细胞外体积分数可以评估梗死心肌的严重程度及心外膜未增强的心肌是否存活,CMR-FT 可早期识别心室功能受损的患者,超声心动图可动态检测并评估病变,3D-STI 技术在三维空间上评估心肌活性,进一步提高准确性。核素心肌显像可以同时评估心肌活性及半定量缺血心肌,CCTA 提供全面评估 CTO 病变的解剖特征,对 PCI 进行难易程度分级,指导介入治疗。综上所述,术前选择合理的成像方式评估 CTO 患者的存活心肌及病变的解剖特征,有助于选择适合行 PCI 的患者、制定合适的手术方案并提高 CTO-PCI 成功率。

参 考 文 献

[1] Brilakis ES, Mashayekhi K, Tsuchikane E, et al. Guiding principles for chronic total occlusion percutaneous coronary intervention[J]. Circulation, 2019, 140(5):420-433.

[2] Almeida AG, Carpenter JP, Cameli M, et al. Multimodality imaging of myocardial viability: an expert consensus document from the European Association of Cardiovascular Imaging (EACVI)[J]. Eur Heart J Cardiovasc Imaging, 2021, 22(8):e97-e125.

[3] Tajti P, Karmpaliotis D, Alaswad K, et al. The hybrid approach to chronic total occlusion percutaneous coronary intervention: update from the PROGRESS CTO registry[J]. JACC Cardiovasc Interv, 2018, 11(14):1325-1335.

[4] Quadros A, Belli KC, de Paula JET, et al. Chronic total occlusion percutaneous coronary intervention in Latin America[J]. Catheter Cardiovasc Interv, 2020, 96(5):1046-1055.

[5] Levine GN, Bates ER, Blankenship JC, et al. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions[J]. Circulation, 2011, 124(23):e574-e651.

[6] Garcia MJ, Kwong RY, Scherrer-Crosbie M, et al. State of the art: imaging for myocardial viability: a scientific statement from the American Heart Association[J]. Circ Cardiovasc Imaging, 2020, 13(7):e000053.

[7] Yang L, Guo L, Lv H, et al. Predictors of adverse events among chronic total occlusion patients undergoing successful percutaneous coronary intervention and medical therapy[J]. Clin Interv Aging, 2021, 16:1847-1855.

[8] Werner GS, Martin-Yuste V, Hildick-Smith D, et al. A randomized multicentre trial to compare revascularization with optimal medical therapy for the treatment of chronic total coronary occlusions[J]. Eur Heart J, 2018, 39(26):2484-2493.

[9] Rubinshtein R, Danenberg H. Preprocedural coronary CT angiography effect on the likelihood to restore flow in chronic total occlusion[J]. JACC Cardiovasc Imaging, 2021, 14(10):2005-2007.

[10] Hong SJ, Kim BK, Cho I, et al. Effect of coronary CTA on chronic total occlusion percutaneous coronary intervention: a randomized trial[J]. JACC Cardiovasc Imaging, 2021, 14(10):1993-2004.

[11] Karatasakis A, Danek BA, Karmpaliotis D, et al. Impact of proximal cap ambiguity on outcomes of chronic total occlusion percutaneous coronary intervention: insights from a multicenter US registry[J]. J Invasive Cardiol, 2016, 28(10):391-396.

[12] Yu CW, Lee HJ, Suh J, et al. Coronary computed tomography angiography predicts guidewire crossing and success of percutaneous intervention for chronic total occlusion: Korean multicenter CTO CT registry score as a tool for assessing difficulty in chronic total occlusion percutaneous coronary intervention[J]. Circ Cardiovasc Imaging, 2017, 10(4):e005800.

[13] Werner GS. Use of coronary computed tomographic angiography to facilitate percutaneous coronary intervention of chronic total occlusions[J]. Circ Cardiovasc Interv, 2019, 12(10):e007387.

[14] Opolski MP, Achenbach S, Schuhback A, et al. Coronary computed tomographic prediction rule for time-efficient guidewire crossing through chronic total occlusion: insights from the CT-RECTOR multicenter registry (Computed Tomography Registry of Chronic Total Occlusion Revascularization)[J]. JACC Cardiovasc Interv, 2015, 8(2):257-267.

[15] Karmpaliotis D, Karatasakis A, Alaswad K, et al. Outcomes with the use of the retrograde approach for coronary chronic total occlusion interventions in a contemporary multicenter US registry[J]. Circ Cardiovasc Interv, 2016, 9(6): 10.1161/CIRCINTERVENTIONS.115.003434 e003434.

[16] Huang CC, Lee CK, Meng SW, et al. Collateral channel size and tortuosity predict retrograde percutaneous coronary intervention success for chronic total occlusion[J]. Circ Cardiovasc Interv, 2018, 11(1):e5124.

[17] Sugaya T, Oyama-Manabe N, Yamaguchi T, et al. Visualization of collateral channels with coronary computed tomography angiography for the retrograde approach in percutaneous coronary intervention for chronic total occlusion[J]. J Cardiovasc Comput Tomogr, 2016, 10(2):128-134.

[18] Choi JH, Kim EK, Kim SM, et al. Noninvasive evaluation of coronary collateral arterial flow by coronary computed tomographic angiography[J]. Circ Cardiovasc Imaging, 2014, 7(3): 482-490.
[19] Li M, Zhang J, Pan J, et al. Obstructive coronary artery disease: reverse attenuation gradient sign at CT indicates distal retrograde flow—A useful sign for differentiating chronic total occlusion from subtotal occlusion[J]. Radiology, 2013, 266(3): 766-772.
[20] 杨雪瑶, 栗佳男, 韩烨, 等. 应用心脏磁共振成像评估冠状动脉慢性完全闭塞病变供血心肌活性研究[J]. 中国介入心脏病学杂志, 2019, 27(1): 28-34.
[21] Parikh K, Choy-Shan A, Ghesani M, et al. Multimodality imaging of myocardial viability[J]. Curr Cardiol Rep, 2021, 23(1): 5.
[22] Li JN, He Y, Dong W, et al. Comparison of cardiac MRI with PET for assessment of myocardial viability in patients with coronary chronic total occlusion[J]. Clin Radiol, 2019, 74(5): 410-411.
[23] Baks T, van Geuns RJ, Duncker DJ, et al. Prediction of left ventricular function after drug-eluting stent implantation for chronic total coronary occlusions[J]. J Am Coll Cardiol, 2006, 47(4): 721-725.
[24] Kirschbaum SW, Baks T, van den Ent M, et al. Evaluation of left ventricular function three years after percutaneous recanalization of chronic total coronary occlusions[J]. Am J Cardiol, 2008, 101(2): 179-185.
[25] Chen Y, Zheng X, Jin H, et al. Role of myocardial extracellular volume fraction measured with magnetic resonance imaging in the prediction of left ventricular functional outcome after revascularization of chronic total occlusion of coronary arteries[J]. Korean J Radiol, 2019, 20(1): 83-93.
[26] Zhang C, Li X, Mou A, et al. Assessment of late gadolinium enhancement-negative chronic total occlusion by longitudinal strain analysis using cardiac magnetic resonance imaging[J]. Acta Radiol, 2022, 63(12): 1634-1642.
[27] 张丽君, 田晋帆, 杨雪瑶, 等. 心脏磁共振评估冠状动脉慢性完全闭塞性病变患者左心室心肌应变的临床价值[J]. 中华心血管病杂志, 2021, 49(6): 601-609.
[28] Li L, Wang F, Xu T, et al. The detection of viable myocardium by low-dose dobutamine stress speckle tracking echocardiography in patients with old myocardial infarction[J]. J Clin Ultrasound, 2016, 44(9): 545-554.
[29] Liu K, Wang Y, Hao Q, et al. Evaluation of myocardial viability in patients with acute myocardial infarction: layer-specific analysis of 2-dimensional speckle tracking echocardiography[J]. Medicine (Baltimore), 2019, 98(3): e13959.
[30] Wang P, Liu Y, Ren L. Evaluation of left ventricular function after percutaneous recanalization of chronic coronary occlusions: the role of two-dimensional speckle tracking echocardiography[J]. Herz, 2019, 44(2): 170-174.
[31] Nakachi T, Kato S, Saito N, et al. Non-invasive evaluation of patients undergoing percutaneous coronary intervention for chronic total occlusion[J]. J Clin Med, 2021, 10(20): 4712.
[32] Allahwala UK, Brilakis ES, Kiat H, et al. The indications and utility of adjunctive imaging modalities for chronic total occlusion (CTO) intervention [J]. J Nucl Cardiol, 2021, 28(6): 2597-2608.
[33] D'Egidio G, Nichol G, Williams KA, et al. Increasing benefit from revascularization is associated with increasing amounts of myocardial hibernation: a substudy of the PARR-2 trial[J]. JACC Cardiovasc Imaging, 2009, 2(9): 1060-1068.
[34] 翟光耀, 王建龙, 刘宇扬, 等. (18)F-FDG PET/CT 心肌代谢显像和侧支循环形成对于冠状动脉慢性闭塞性病变心功能预后价值的比较分析[J]. 中华医学杂志, 2018, 98(17): 1342-1346.
[35] Dong W, Li J, Mi H, et al. Relationship between collateral circulation and myocardial viability of ^{18}F-FDG PET/CT subtended by chronic total occluded coronary arteries[J]. Ann Nucl Med, 2018, 32(3): 197-205.
[36] 马兴鸿, 汪蕾, 方纬. 核素心肌显像在冠状动脉慢性完全闭塞临床诊疗中的应用价值[J]. 心血管病学进展, 2022, 43(4): 313-317.

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[32] Tsukizawa T, Fujihara M. Relationship between in-hospital event rates and high bleeding risk score in patients undergoing primary percutaneous coronary intervention for acute myocardial infarction[J]. Cardiovasc Interv Ther, 2022, 37(3): 490-496.
[33] Garot P, Neylon A, Morice MC, et al. Bleeding risk differences after TAVR according to the ARC-HBR criteria: insights from SCOPE 2 [J]. EuroIntervention, 2022, 18(6): 503-513.
[34] Montalto C, Munafò AR, Arzuffi L, et al. Validation of the ARC-HBR criteria in 68,874 patients undergoing PCI: a systematic review and meta-analysis[J]. Hellenic J Cardiol, 2022, 66: 59-66.
[35] Tan JWC, Chew DP, Brieger D, et al. 2020 Asian Pacific Society of Cardiology Consensus Recommendations on antithrombotic management for high-risk chronic coronary syndrome[J]. Eur Cardiol, 2021, 16: e26.
[36] Dong L, Lu C, Wensen C, et al. Performance of PRECISE-DAPT and age-bleeding-organ dysfunction score for predicting bleeding complication during dual antiplatelet therapy in Chinese elderly patients[J]. Front Cardiovasc Med, 2022, 9: 910805.

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