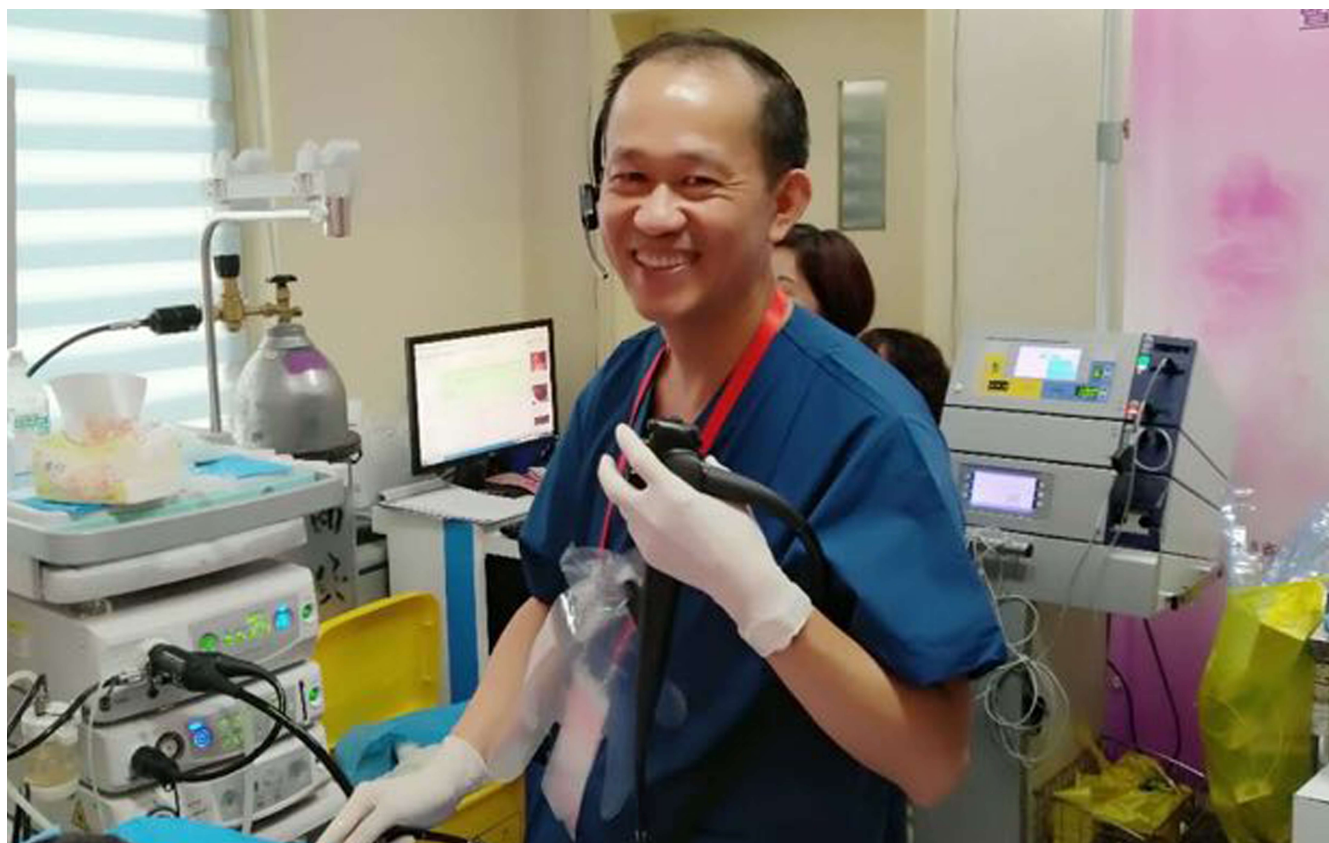


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目次

2019年7月28日 第27卷 第14期 (总第634期)

述评

851 肠道血流的CT和MRI评估

任小军

基础研究

857 下调MiR-221对胃癌顺铂耐药细胞增殖及顺铂敏感性的影响及其相关机制

徐丽娜, 金莉娜

864 miR-567靶向TRPM8调控结直肠癌细胞增殖凋亡的分子机制

杨庆华, 陈栋

临床研究

872 CBX2蛋白在胃癌中的表达水平及临床意义

何怡岚, 张波

878 剪切波超声弹性成像测定脂肪肝患者颈动脉斑块硬度及其与血脂水平相关性

欧阳骏, 张心荣, 王小伟

883 抗*H. pylori*治疗对胆石症患者胆汁*H. pylori* DNA、PLA₂活性及免疫功能的影响

朱蔓然, 宁雪莲, 姚卫民, 郭勇杭, 何丽娟, 卢如相

889 体部立体定向放射治疗结肠癌伴肺转移的临床特点Meta分析

刘海源, 雷鑫明

文献综述

898 泄泻肝气乘脾证的研究进展

刘娅薇, 惠华英, 谭周进

903 胆囊癌的分子基因学研究进展

杨敏丽, 戴树龙

907 肠道产丁酸菌防治炎症性肠病的机制研究进展

陈映宇, 毛联智, 刘华缓, 孙素霞

消 息

- 856 《世界华人消化杂志》栏目设置
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Contents

Volume 27 Number 14 Jul 28, 2019

EDITORIAL

- 851 CT and MRI assessment of intestinal blood flow

Ren XJ

BASIC RESEARCH

- 857 Effect of down-regulation of miR-221 on cell proliferation and cisplatin sensitivity in cisplatin-resistant gastric cancer cells and underlying mechanism

Xu LN, Jin LN

- 864 MiR-567 regulates proliferation and apoptosis of colorectal cancer cells by targeting TRPM8

Yang QH, Chen D

CLINICAL RESEARCH

- 872 Clinical significance of expression of CBX2 in gastric cancer

He YL, Zhang B

- 878 Assessment of carotid plaque hardness in patients with fatty liver by shear wave elastography: Correlation with blood lipid levels

Ouyang J, Zhang XR, Wang XW

- 883 Effect of anti-*Helicobacter pylori* therapy on bile *H. pylori* DNA and PLA₂ activity and immune function in patients with cholelithiasis

Zhu MR, Ning XL, Yao WM, Guo YH, He LJ, Lu RX

- 889 A meta-analysis of stereotactic radiotherapy for pulmonary oligometastases from colorectal cancer

Liu HY, Lei XM

REVIEW

- 898 Progress in research of syndrome of diarrhea with Ganqi Chengpi

Liu YW, Hui HY, Tan ZJ

- 903 Advances in research of molecular genetics of gallbladder cancer

Yang ML, Dai SL

- 907 Mechanism of gut butyric acid producing bacteria for prevention and treatment of inflammatory bowel disease

Chen YY, Mao LZ, Liu HH, Sun SX

Contents

World Chinese Journal of Digestology
Volume 27 Number 14 Jul 28, 2019

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肠道血流的CT和MRI评估

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CT and MRI assessment of intestinal blood flow

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Abstract

The accuracy of multi-slice computed tomography (CT) in the diagnosis of acute mesenteric ischemia is very high, however, it cannot demonstrate the small embolus of blood vessels and abnormal intestinal blood flow. The intestinal blood flow in chronic mesenteric ischemia decreases whereas there are few morphology changes, which leads to a high misdiagnosis rate of CT

and CT angiography. In addition, inflammatory bowel disease, intestinal tumors, and portal hypertension can be diagnosed definitely by conventional CT, but the hemodynamics and microcirculation in these conditions cannot be assessed, which affects the accuracy of clinical staging and the assessment of therapeutic effect. For intestinal diseases, especially mesenteric ischemia, therefore, it is needed not only to make CT morphologic diagnosis but also to further assess the abnormal intestinal blood flow. In recent years, more and more CT and magnetic resonance imaging (MRI)-related new techniques for assessing blood flow have emerged, including CT perfusion, spectral CT imaging, magnetic resonance perfusion imaging, and phase contrast MRI. This paper reviews the clinical application and progress of these techniques for assessing intestinal blood flow.

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Key Words: Bowel; Blood flow perfusion; Computed tomography; Phase contrast magnetic resonance imaging

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摘要

多层计算机体层摄影(computed tomography, CT)诊断急性肠缺血的准确性高,但不能显示血管的微小栓子及肠道血流异常,慢性肠缺血的肠道血流量降低,而形态学改变少,CT及CT血管造影误诊率高.此外,炎症性肠病、肠道肿瘤和门静脉高压等疾病,常规CT虽然可以明确诊断,但无法评估病变血流动力学和微循环血流,影响临床对疾病的准确分期、治疗和评估疗效.因此,对肠道疾病,尤其是肠缺血,不但需要CT做出形态学诊断,更需要进一步评估肠道

血流异常. 近年, CT和磁共振成像(magnetic resonance imaging, MRI)评估血流的新技术日益增多, 包括CT和MRI灌注成像, CT能谱成像及相位对比MRI, 本文就其对肠道血流的评估研究和临床应用做一论述.

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关键词: 肠; 血流灌注; 计算机体层摄影; 相位对比磁共振成像

核心提要: 肠缺血、炎症性肠病、肠道肿瘤和门静脉高压等疾病, 不但需要多层计算机体层摄影(computed tomography, CT)做出形态学诊断, 更需要评估病变血流动力学和微循环血流. CT和磁共振成像(magnetic resonance imaging, MRI)灌注成像对组织的微循环评估价值高, 但受肠道壁薄和蠕动限制. CT能谱成像, 用于肠道部分肿瘤和炎症性肠病的鉴别诊断, 尚未用于肠缺血研究. 相位对比MRI对肠系膜血流显示好, 尤其4D Flow MRI扫描范围大, 可显示任意平面内的血流和血管壁参数, 可能成为评估肠道血流和门静脉高压的新的发展方向, 但设备和技术复杂, 仍需要进一步研究缩短扫描时间、提高图像质量及在门静脉系统和肠道疾病的血流动力学开展广泛深入的研究.

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0 引言

随着后64排多层计算机体层摄影(computed tomography, CT)的快速发展, 其在肠道疾病的诊断中发挥着越来越重要的作用. 其诊断急性肠缺血的准确性高, 但不能显示血管的微小栓子及肠道血流异常, 导致部分急性肠缺血误诊^[1-3]. 慢性肠缺血的肠道血流量(blood flow, BF)降低, 而形态学改变少, CT及CT血管造影(CT angiography, CTA)误诊率达30%-78%^[4-7]. 此外, 炎症性肠病、肠道肿瘤和门静脉高压等疾病, 常规CT虽然可以明确诊断, 但无法评估病变血流动力学和微循环血流, 影响临床对疾病的准确分期、治疗和评估疗效. 因此, 对肠道疾病, 尤其是肠缺血, 不但需要CT及CTA做出形态学诊断, 更需要进一步评估肠道血流异常. 评估肠道血流的传统影像学方法为多普勒超声显像和数字减影血管造影(digital subtraction angiography, DSA). 多普勒超声无射线辐射, 对婴幼儿肠道血流评估具有优势, 但易受肥胖、肠道胀气等因素影响, 肠系膜血管分支及远段病变易漏诊, 因此, 在肠道的临床应用受限. 肠系膜DSA检查有创、复杂、费时并对非血管病变诊断价值有限, 对肠缺血的诊

断已被快速发展的多层CT和CTA取代, 目前主要用于肠系膜血运重建的血管成形治疗. 近年, CT和磁共振成像(magnetic resonance imaging, MRI)评估血流的新技术日益增多, 包括CT和MR灌注成像, CT能谱成像及相位对比MRI(phase contrast MRI, PC MRI), 本文就其对肠道血流的评估研究和临床应用做一论述.

1 CT对肠道血流的评估

传统CT通过增强后肠壁强化程度粗略反映肠壁的血流多少, 与正常肠壁比较, 肠壁强化增加反映BF增多, 强化减弱反映BF减少, 不能量化血流和对血流轻度改变做出准确评估. CTA可从形态上评估供应肠系膜血流的腹腔动脉、肠系膜上动脉和肠系膜下动脉三支血管有无狭窄和闭塞, 也无法准确评估BF的改变. 可评估肠道血流的CT检查技术有CT灌注成像(CT Perfusion, CTP)和CT能谱成像.

1.1 CTP 该技术是通过重复扫描感兴趣区, 测量静脉注射的对比剂在组织的瞬时分布, 采集形态学和功能灌注信息, 获得组织的多个血流参数: BF、血容量(blood volume, BV)、平均通过时间(mean transit time, MTT)和表面通透性(permeability surface, PS). 多层CT灌注扫描速度慢、范围小、辐射剂量大, 又由于受呼吸运动、肠道蠕动和肠壁较薄难以测量等因素的影响, 小肠CTP难度大, 临床研究和应用少, 仅限于实验研究. 近年, 由于动态容积CT(dynamic volume CT, 东芝640层CT, 西门子3代双源CT)的发展, 扫描速度显著加快, 覆盖范围增大, CTP射线剂量甚至低于传统CT三期增强扫描^[8-10], 可克服小肠CTP的一些难点检测肠道微循环血流, 尤其是对肠缺血的研究前景广阔. Shi等^[11]应用128层CT在动物实验中对52头猪的肠系膜上动脉结扎后做小肠CTP研究, 均取得成功, 发现再灌注小肠的BF、BV、MTT在灌注损伤后显著降低, PS在灌注损伤后进行性降低, 并且缺血再灌注肠壁的BF和BV与肠壁组织的丙二醛显著负相关, 与超氧化物显著正相关. 因此, CTP的血流参数BF、BV、MTT可反映缺血肠壁的再灌注损伤程度.

结直肠位置相对固定, 肠壁较厚, CTP更易成功, 因此, CTP对结直肠血流的临床研究较多. Khan等^[12]通过4层CT的CTP研究发现, 近端结肠(升结肠和横结肠)BF高于远端(降结肠、乙状结肠和直肠), 并且23%的结肠CTP不成功. 直肠癌化疗和放疗后可根据CTP的血流改变评估疗效^[13], 直肠癌较正常直肠的BF高, MTT短, 化疗和放疗有效的直肠癌的BF显著降低, MTT延长, 并且血流信息的改变出现在肿瘤形态改变之前, 而化疗和放疗无效的直肠癌的BF和MTT改变不明显. 术前CTP评估结直肠癌病理分级和微血管生成对判断疗效和预后

具有潜在价值. 高分化肿瘤的BF和BV值显著高于中、低分化的肿瘤, 但CT灌注参数与肿瘤生物学行为相关的微血管密度(microvessel density, MVD)之间无显著相关性^[14-17], 可能因为CT灌注测量的是肿瘤微循环量化的血流, 而MVD是形态学上的微血管计数. Kim等^[17]对乙状结肠及直肠癌术前CTP研究发现不同的结果, 中分化结直肠癌的BF高于分化好和分化差的肿瘤, 而MTT低于分化好和分化差肿瘤, 分化差的肿瘤MVD最大, 认为CTP在区分肿瘤分化程度的价值有限. 多种结、直肠癌CTP研究结果不完全一致, 是由于CTP技术包括多种变量: CT灌注扫描方案、对比剂注射流速、肿瘤的异质性和分析软件, 这些技术不标准化, 可能导致灌注分析结果不同.

1.2 CT能谱成像 CT能谱成像是采用单X线管瞬时切换技术或双X线管技术, 进行高低能量两组数据采集, 可以获得物质分离图像, 敏感识别CT增强后动脉期及静脉期局部组织中的碘浓度(iodine density, IC), 并计算出标准化碘浓度(normalized iodine density, NIC), 间接反映组织内动脉和静脉的BF, 非直接显示血流参数. CT能谱成像临床多用于肺栓塞和肝硬化的血流动力学研究^[18-20], 在肠道用于部分肿瘤和炎症性肠病的鉴别诊断^[21-23], 尚未用于肠缺血研究. CT能谱成像可敏感识别部分炎症和肿瘤或不同肿瘤之间IC的差异, 即动脉或动、静脉血流的差异, 对其进行鉴别诊断. 炎症性肠病反应性增生淋巴结在动脉期的碘含量高于结直肠癌转移性淋巴结的碘含量^[21], 小肠腺瘤动、静脉双期的IC和NIC均高于原发性小肠淋巴瘤^[22], 反映了炎性淋巴结与结直肠癌转移性淋巴结之间的动脉血流, 小肠腺瘤与原发性小肠淋巴瘤之间动、静脉双期的血流存在差异. 结肠腺瘤及肿块型腺癌CT难以鉴别, CT能谱成像在动脉期40 keV和50 keV下, 腺瘤的CT值低于肿块型腺癌, 而静脉期和平衡期无此差异, 反映了腺瘤的动脉供血低于肿块型腺癌, 利用动脉期IC值差异可对两者进行鉴别诊断^[23]. 定量测定动、静脉双期的IC和NIC有助于评估结直肠癌的分化程度, 中、高分化结直肠癌的IC和NIC在动、静脉双期均低于低分化结直肠癌, 其中动脉期的NIC诊断价值最大^[24,25]. 新辅助治疗前后肿瘤组织的微循环血流发生改变, 在CT能谱成像中表现为肿瘤组织的IC、有效原子序数等定量参数发生改变, 因此, CT能谱成像可以评估直肠癌新辅助治疗疗效^[26].

2 MRI对肠道血流的评估

2.1 PC MRI

2.1.1 PC MRI原理及特点: PC MRI包括二维相位对比(2D PC)、三维相位对比(3D PC)、电影相位对比(Cine

PC)和四维相位对比(4D PC, 四维流MRI, 4D Flow MRI)技术. PC MRI技术是通过流体相位编码, 利用血液流动产生的相位变化来测量血流速度, 既能显示血管解剖结构又能提供血流方向、速度及流量等血液动力学参数. 3D PC扫描时间长, 应用少. 2D PC及Cine PC应用最广, 但2D PC不足以评估复杂的三维血流动力学. 4D PC是随时间变化的三维方向PC MRI, 可回顾性分析任一位置、任一成像平面内的血流方向、流速大小, 能获得血管壁面剪切力(wall shear stress, WSS)和振动剪切指数(oscillatory shear index, OSI)等更多的血流动力学参数^[27], 扫描范围大, 图像质量好, 不同的操作者之间变异小, 最大流速、平均流速和BV的血流量化信息与Doppler超声具有显著相关性^[28,29]. 近几年随着软件和技术的发展, 门静脉系统4D flow MRI扫描时间可从10-12 min减少到3-4 min, 联合应用高效螺旋采集和动态压缩感知加速技术的4D flow MRI, 可以一次屏气(18-25 s)综合评估腹部主要血管(门静脉系统、肠系膜动脉、脾动脉及肾动脉等)的血流动力学^[30,31].

2.1.2 PC MRI在肠道的应用: PC MRI主要用于测量肠系膜动脉和门静脉系统血流动力学. 肝硬化门静脉高压的准确评估需要侵入性测量肝静脉压力梯度, Palaniyappan等^[32]及Gouya等^[33]研究发现, 肝静脉压力梯度与肝脏MRI的T1弛豫时间、脾动脉和肠系膜上动脉流速以及奇静脉BF显著相关, 因此, 应用2D PC MRI检测脾动脉和肠系膜上动脉流速、奇静脉BF可以代替肝静脉压力梯度测量评估门静脉高压. Cine PC MRI对胃十二指肠动脉血流显示率达100%^[34], 在腹腔干狭窄时, 胃十二指肠动脉血流可能停滞或逆流, 胰十二指肠切除术或肝移植术前, 应用Cine PC MRI对胃十二指肠动脉血流动力学评估非常重要, 可避免无血流动力学意义的不必要的血管重建. 应用2D PC MRI, 在静脉注射促胰液素后测量胃肠道和胰腺的血流变化^[35], 以及对心脏病患者测量肝脏和肠道血流信息^[36], 以便临床对疾病准确评估并指导治疗.

4D flow MRI测得的血流参数可重复性强, 与2D PC测得的平均流速、峰值流速和净流量一致性好^[37]. 应用4D flow MRI可发现餐后正常人和肝硬化门静脉高压患者的门静脉、SMV、SMA的BF增加, 肝动脉和脾静脉血流降低, 餐后儿童和年轻成人腹部总体BF增加30%, SMA的BF可增加三倍^[38,39], 肝硬化患者餐后肠系膜静脉血流增加较正常人减少, 其血流增加机制受损, 门静脉高压患者脾静脉内餐前的向肝性血流, 餐后可能转换为离肝性血流^[40], 这对准确评估门静脉系统血流动力学和门静脉高压具有重要意义. 应用4D flow MRI检测腹腔干狭窄或闭塞引起胃十二指肠动脉瘤患者, 不但可发

现胃十二指肠动脉和肝总动脉逆向血流, 还可发现胃十二指肠动脉BF增加, WSS和OSI分布不均匀, OSI显著增高^[41], 这些改变对研究血管壁动脉粥样硬化退变和动脉瘤形成机制具有重要价值. 门静脉高压TIPS术后, 4D flow MRI可监测TIPS支架内和门静脉系统的血流, 以评估疗效和随访^[42].

2.2 磁共振灌注成像 用于肠道的磁共振灌注成像为T1加权动态增强扫描, 即动态增强MRI(DCE-MRI), 是利用快速成像序列, 连续、重复扫描, 获取注入对比剂前后组织多个时期的一系列连续动态增强图像, 经过计算和分析, 获得反映组织微循环功能的多个参数. 常用参数有: 容量转移常数(Ktrans)、速率常数(Kep)、血管外细胞外间隙容积分数(Ve)等, 并可获得时间信号曲线(time signal curve, TIC). Ktrans代表对比剂从血管至组织间隙的过程, 反映了组织内毛细血管通透性及血浆流量, Ktrans越高表示组织内血管通透性及血浆流量越高. Kep表示对比剂返回到血管内廓清的过程. DCE-MRI可诊断CT和MRI难以诊断的慢性肠缺血. 空腹时, 正常人和慢性肠缺血患者DCE-MRI的肠壁最大强化值及信噪比(signal to noise ratio, SNR)无显著性差异; 餐后, 慢性肠缺血的肠壁最大强化值及SNR较正常肠壁显著降低, 反映了慢性肠缺血患者的肠壁血流储备能力下降^[43]. 小肠克罗恩病DCE-MRI的参数与肠壁厚度和克罗恩病MRI活动分数显著相关, 对正常肠段和病变肠段的鉴别诊断具有重要价值^[44,45], 而Wilkens等^[46]以病理的炎症活动性和纤维化为标准, 发现克罗恩病DCE-MRI参数与炎症活动性和纤维化无相关性, MRI不能鉴别克罗恩病炎症活动性和纤维化, 这可能与克罗恩病炎症活动性标准、扫描序列和技术标准不一致有关. DCE-MRI能反映直肠癌的微循环血流, Ktrans值及TIC可用于评价直肠癌的恶性程度, Ktrans值越高, 肿瘤分化程度越低, Dukes分期越高^[47,48]. Sudarski等^[8]比较直肠癌的3T磁共振灌注成像与三代双源容积CTP发现, 两者均可区分肿瘤与正常直肠壁, 而容积CT灌注参数变异更小.

3 其它影像学方法对肠道血流的评估

其它评估肠道血流的影像学方法除了多普勒超声和DSA外, 还有少量应用于临床的荧光血管造影(fluorescence angiography)、吲哚青绿荧光显像(indocyanine green fluorescence imaging)和近红外光谱分析(Near-infrared spectroscopy), 这些检测方法间接反映局部组织血供情况, 而不能量化血流. 荧光血管造影可评估结直肠切除术中吻合口的血流灌注情况, 成功率达99%, 在近端切缘时根据血流灌注可能改变手术计划, 避免吻合口瘘发生^[49]. 吲哚青绿荧光显像可了解嵌顿疝外科术中嵌顿肠段是

否存在血流, 避免可恢复的嵌顿肠段被手术切除^[50]. 近红外光谱分析(Near-infrared spectroscopy)可非侵入性检测局部组织氧合状态, 提示低循环血流和低灌注, 早产儿坏死性小肠结肠炎腹部近红外光谱值降低、变化值增大, 有助于坏死性小肠结肠炎的早期诊断和治疗^[51,52].

4 结论

肠缺血、炎症性肠病、肠道肿瘤和门静脉高压等疾病, 需要评估病变血流动力学和微循环血流, CT和MRI灌注成像对组织的微循环评估价值高, 但受肠道壁薄和蠕动限制. CT能谱成像, 用于肠道部分肿瘤和炎症性肠病的鉴别诊断, 尚未用于肠缺血研究. PC MRI对肠系膜血流显示好, 尤其4D Flow MRI扫描范围大, 可显示任意平面内的血流和血管壁参数, 可能成为评估肠道血流和门静脉高压的新的发展方向, 但设备和技术复杂, 仍需要进一步研究缩短扫描时间、提高图像质量及在门静脉系统和肠道疾病的血流动力学开展广泛深入的研究.

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