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·综 述 General review·

磁共振血管成像技术在颅内动脉瘤的临床应用

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【摘要】 数字减影血管造影术(DSA)作为颅内动脉瘤(IAN)诊断金标准,其有创、检查费用昂贵以及对比剂肾毒性而应用受限。近 30 年来磁共振血管成像(MRA)技术快速发展,其无创性、高分辨力等特点使该技术可替代 DSA 应用于大部分动脉瘤患者的临床诊断和随访中,其中时间飞越 MRA(time of flight magnetic resonance angiography,TOF-MRA) 对直径小于 5 mm 的小动脉瘤诊断灵敏度达 98.2% ~ 98.7%;对比增强 MRA (contrast enhanced MRA,CE-MRA) 对颅内动脉瘤的灵敏度和特异度分别高达 95% ~ 100%和 73% ~ 100%;相位对比血管成像(phase contrast MRA,PC-MRA)对直径大于 5 mm 的颅内动脉瘤诊断特异度高达 100%。上述血管成像技术均可清晰显示颅内动脉瘤,但其成像特点和临床应用范围各异。本文就不同 MRA 技术的方法、临床应用的选择、比较以及新进展做综述。

【关键词】 动脉瘤; 磁共振血管成像; 时间飞越法; 相位对比法; 对比增强

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The clinical application of magnetic resonance angiography in diagnosing intracranial aneurysms

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【Abstract】 Although digital subtraction angiography (DSA) has been used as the gold standard for the diagnosis of intracranial aneurysms, its clinical use is somewhat limited by its invasiveness, high medical cost and potential risk of nephrotoxicity. For the past three decades, the magnetic resonance angiography (MRA) techniques have been developed rapidly. As a non-invasive technique with high resolution ability, MRA can replace DSA for the diagnosis of intracranial aneurysms in most clinical situations. The time-of-flight MRA (TOF-MRA) carries a diagnostic sensitivity of up to 98.2% - 98.7% for tiny intracranial aneurysms (< 5 mm), while the diagnostic sensitivity and specificity of contrast enhanced MRA (CE-MRA) for intracranial aneurysms are as high as 95% - 100% and 73% - 100% respectively. The diagnostic specificity of phase-contrast MRA (PC-MRA) for intracranial aneurysms (> 5 mm) reaches as high as 100%. All the above mentioned MRA techniques can clearly display the intracranial aneurysms although their imaging characteristics and clinical applications are different from each other. This paper aims to make a brief review concerning the principles, clinical applications and recent progress of some MRA techniques. (J Intervent Radiol, 2014, 23: 826-830)

【Key words】 aneurysm; magnetic resonance angiography; time-of-flight technique; phase-contrast technique; contrast-enhancement

颅内动脉瘤(intracranial aneurysm,IAN)发病机制未明,其形成是遗传学、血流动力学以及后天退行性改变等多种因素综合作用的结果,最终导致动脉内腔异常扩张而形成的一种血管瘤样突起[1]。IAN 破裂是引起蛛网膜下腔出血(subarachnoid hemorrhage,SAH)最常见的原因,约占所有脑血管病变的 25%,其破裂受瘤体大小、位置和形态的多重影响[2-6]。颅内动脉瘤的原发出血、动脉痉挛以及再出血致残和致死率均较高,因此需要早期诊断和治疗。传统的 DSA 是 IAN 诊断、成像的金标准[7-8],但存在侵袭性、高费用和对比剂过敏等缺点。磁共振血管成像技术 (MRA) 在过去近 30 年中迅猛发

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展,由于其具有高分辨率、低风险、操作简单以及避免了对比剂过敏、肾毒性和可能发生的中枢神经系统并发症等特点已被广泛应用于 IAN 的诊断和随访中[9]。通过血管重建和调整旋转角度,MRA 能清晰显示动脉瘤及其与血管的关系, 即 MRA 除了能直接显示动脉瘤的大小、部位、形态和载瘤动脉等,还可选择多角度观察动脉瘤的整体情况。本文旨在比较各种 MRA 技术在 IAN 诊断的应用范围。

1 MRA 检查方法概述

MRA 是利用血管内流动血液与周围静止组织信号的差别来凸显和观察目标血管[10]。目前最常用的技术可分为两类,一是非增强 MRA,如时间飞跃 MRA (time of flight MAR,TOF-MRA) 和相位对比 MRA(phase contrast MRA,PC-MRA);二是利用顺磁性对比剂缩短血液 T1 时间的对比增强 MRA (contrast enhanced MRA,CE-MRA)。

1.1 常用 MRA 技术

1.1.1 TOF-MRA TOF-MRA 是利用脉冲激发和回波接受的时间间隔中血流位置发生的变化进行成像的。可分为 2D TOF-MRA、3D TOF-MRA,基于各自不同的优缺点可应用于不同的血管疾病中。由于 2D TOF-MRA 成像层面厚,分辨率低,较少应用于脑血管成像。3D TOF-MRA 是针对多个薄层进行容积性激发和采集,较常用于头颅成像。其空间分辨率较高且受血液湍流影响小; 同时图像信噪比较高、重建后图像质量较好。但在静脉血管显示方面不如 2D TOF-MRA; 背景组织信号抑制效果欠佳; 扫描时间长。

1.1.2 PC-MRA PC-MRA 是利用流动血液在受激励共振过程中其相位变化与其速度的对应关系原理而成像。其背景组织信号抑制效果好于 TOF-MRA 并有利于慢血流的显像。由于必须按 3 个流动方向做 3 次采集,导致成像时间较长而降低了分辨率;且其编码流速会直接影响图像质量。

1.1.3 CE-MRA CE-MRA 的原理就是通过注射对比剂改变血液的 T1 值, 使其缩短并利用快速梯度回波序列使得目标血管显影。它能更好地显示血管腔和血管狭窄程度; 相比非强化无对比剂 MRA 不易漏诊动脉瘤;成像速度较快提高了分辨率。但由于需要注射对比剂,仍存在对比剂过敏或肾毒性等潜在的不良反应。

1.2 各项 MRA 检查技术的临床应用

1.2.1 TOF-MRA TOF-MRA 是最常用的筛查 IAN 的技术。其成像质量和动脉瘤大小[11-15]、位置[11,16]均相关。据沙琳等[17]报道,TOF-MRA 对 IAN 诊断的灵敏度和特异度分别为 83.3%和 46.4%, 正确率达到 73%。Li 等[18]发现,3D TOF MRA 对直径小于 5 mm 的小动脉瘤准确性达 96% ~ 97%,灵敏度达 98.2% ~ 98.7%,特异度为 93.2% ~ 94.8%。

1.2.2 PC-MRA 相比 TOF-MRA,PC-MRA 在动脉瘤影像学诊断的应用尚在探索阶段,国内外相关文献报道不多。Huston 等[19]指出,TOF 和 PC 法的图像质量在直径 3 ~ 15 mm 的 IAN 中无明显差异,但 PC 法对直径大于 15 mm 的 IAN 成像质量优于 TOF 法。戴平丰等[20]发现,PC-MRA 对直径大于 5 mm 的 IAN 诊断特异度高达 100%,灵敏度为 81.8%。张洪英等[21]认为在动脉瘤破裂后出血的亚急性期,出血灶的高铁血红蛋白在 TOF 上显示为高信号, 结合 3D PC 法可以修正并获得动脉瘤的清晰图像。

1.2.3 CE-MRA CE-MRA 检查速度快, 对流速导致的伪影不敏感,获得的图像视野大,能突出显示各段血管的病变细节,特别是对小动脉瘤体颈的细节显示,优于非增强 MRA。同时,该项技术丰富的后处理方法如 MIP 和 SVR 能清晰显示动脉瘤与血管的解剖关系;MPR 对颅内动脉瘤内部结构显示较好[22],3 项后处理技术可起到互相补充的作用,从而提高了 CE-MRA 对颅内动脉瘤诊断的敏感性和特异性,分别可高达 95% ~ 100%和 73% ~ 100%[23-24]。

2 不同技术临床应用比较及选择

上述 3 项 MRA 技术都有其不同应用范围, Gibbs 等[25]比较了 IAN 患者在 3.0 T TOF-MRA 和 3.0 T CE-MRA 的图像质量, 发现 3.0-T TOF MRA 图像质量优于 3.0-T CE MRA;同时 TOF-MRA 由于视野范围较大而不易漏诊小直径动脉瘤,3.0 T CE-MRA 则更适用于血流较慢或动脉远端的动脉瘤。对于动脉瘤伴出血或瘤栓,CE-MRA 有独特的优势[26-27]。Tabuchi 等[28]报道 1 例系统性红斑狼疮合并肾衰竭的患者大脑中动脉开窗畸形伴动脉瘤破裂,发现应用 3D TOF-MRA 能准确显示动脉瘤与畸形血管之间的关系。在动脉瘤线圈介入治疗随访中,Pierot 等[29]通过比较 3.0 T 3D-TOF MRA 和 CE-MRA,在 3.0 T 3D-TOF MRA 和 CE-MRA 对动脉瘤残余的发现率相似的前提下,3D-TOF MRA 对线圈显示更佳。同时,对比剂的高费用、肾毒性、过敏反应以及患者不适反应等均限制了 CE-MRA 在长期随访中的应用。因此,3.0 T 3D-TOF MRA 成为动脉瘤患者介入

治疗随访的首选影像学检查方法。而 CE-MRA 因其成像速度快且较少受伪影干扰,更适合急性 IAN 破裂的危重患者。PC-MRA 可以显示大动脉瘤内部的血流动力学信息,且受出血灶信号改变影响较小,但其分辨率和小动脉瘤检出的敏感性均低于 TOF-MRA 而受限于动脉瘤直径较小患者的临床应用[19-20]。因此,对患者检查方式的选择应综合各方面因素,选择针对不同情况的最佳适用技术。

3 MRA 的新进展

Kang 等[30]将 MRA 场强提高至 7.0 T。3.0 到 7.0 T 场强的变化中信噪比几乎呈线性上升,从而获得了更好的背景抑制,提高了分辨率,缩短了检查时间。Wrede 等[31]发现 7.0 T TOF-MRA 在显示动脉瘤体颈的细节方面优于 1.5 T TOF-MRA,可提供观察血管微观结构的高分辨率图像,但高场强是否优于低场强仍待验证。Yang 等[32]将全自动计算机辅助检测技术 (computer-aided detection,CAD) 与 3D-TOF MRA 相结合,提高小直径动脉瘤诊断的灵敏度至 91%,高于之前报道的 35%[33-35]。其可作为一项 TOF-MRA 辅助技术,标记感兴趣局域从而简化诊断过程。Stivaros 等[36]在 3D-TOF MRA 加入黑血(BB)序列后,能更清晰地显示 IAN 与其供血动脉分支间的关联以及动脉瘤颈的细节,尤其是局部有血肿和慢血流时,可以弥补 3D-TOF 的不足,同时 BB 技术能抑制动脉瘤栓塞术后残留血栓的高信号[37]。但 BB 序列的补充也延长了检查时间,适用于不宜反复血管成像检查的患者。近年来新采用的高分辨率 3D TOF-MRA 单根血管显影技术应用于疑似动脉瘤患者诊断中[38],也是一项诊断 IAN 的影像新技术。

Edelman 等[39-40]提出基于 3D CE-MRA 的偏共振增强血管成像(off resonance contrast angiography,ORCA) 技术可利用对比剂在血管内外的浓度差产生的共振频率位移进行成像,几乎完全抑制背景信号,由于无需减影从而避免了减影中信噪比的降低,此外还避免了与图像不匹配的伪影产生,尤其适用于观察动脉瘤介入治疗过程。高限制背向投影(highly constrained back projection,HYPR)[41-42]技术应用于时间分辨的 3D CE-MRA 可减少伪影,在提高重建速度的同时保留较高的信噪比,在动脉瘤诊断方面具有一定的临床应用潜力。随着 k 空间采集技术的改良,3D CE-MRA 的层块采集时间大大缩短,提高了时间分辨率,其中时间分辨对比剂动态显像技术 (three-dimenstional time-resolved imaging of contrast Kinetics,3D-TRICKS)[43-44]用于动脉瘤以及动脉瘤线圈栓塞术后的多项研究表明,相比非时间分辨 CE-MRA,其无需注射对比剂行预试验,减少了流动伪影和静脉污染,能更好地显示动脉瘤和载瘤动脉的关系以及动脉瘤介入治疗的线圈形态,大大提高了成像质量。由 TRICKS 技术改良的欠样椭圆中心采集重建技术 (undersampled elliptical Centric View-Order)[45]在保留较高的 SNR 的基础上,明显提高了时间分辨率,但其在 IAN 中的应用仍需进一步探索。将 k 空间时间广用线性采集加速技术 (k-t broad-use linear acqusition speed-up technique, BLAST)[46]应用于 3D PC-MRA 的可减少传统重建技术引起的动脉瘤图像伪影,获得更高的信噪比。

作为传统 MRI 技术的补充,MRA 因其安全、可重复性而适用于未破 IAN 筛查、动脉瘤术后随访、IAN 合并出血或肾功能受损的患者。但是,MRA 的空间分辨率仍低于传统的 DSA 技术,当瘤体直径 ≤ 3 mm 时灵敏度和特异度明显降低[11-15,47];无法清晰显示瘤体、瘤颈和载瘤动脉以及三者之间的关系[48],从而无法充分提供动脉瘤线圈介入治疗指征;亚急性出血产生的短 T1 效应可导致出血与流动血流相似[49],从而降低了对 TOF-MRA IAN 诊断的灵敏度和特异度,急性 SAH 患者产生的运动伪影也降低了 MRA 图像质量[50],因此 MRA 不能完全替代 DSA。然而,随着 MRA 新技术以及高场强的应用,其空间、时间分辨率不断提高伴随伪影的减少和高信噪比的保留,MRA 在血管疾病诊断方面将会具有更广阔的应用范围和更突出的临床价值。

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