·神经影像学·

高分辨率磁共振血管壁成像在慢性颈内动脉闭塞血管再通治疗中的应用

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【摘要】 **目的**　探讨高分辨率磁共振血管壁成像(HR-VWI)在慢性颈内动脉闭塞血管再通治疗中的应用价值。**方法**　2018年3月至2019年9月采用血管再通治疗11例症状性慢性颈内动脉闭塞患者，术前根据HR-VWI所示闭塞段起止部位以及闭塞段有无残腔、腔内血栓和动脉夹层分为Ⅰ型闭塞(眼段闭塞)、Ⅱ型闭塞(起始部至床突段及其近端颅内段闭塞)和Ⅲ型闭塞(起始部至眼段及其以远闭塞)，以及A型闭塞(有残腔但无腔内血栓和动脉夹层)、B型闭塞(有残腔且有腔内血栓和动脉夹层)、C型闭塞(无残腔且无腔内血栓和动脉夹层)和D型闭塞(无残腔但有腔内血栓和动脉夹层)，并与术前和术中实时DSA对比，记录血管再通率、围手术期并发症和预后。**结果**　术前HR-VWI分型Ⅰ型闭塞2例、Ⅱ型闭塞6例、Ⅲ型闭塞3例，A型闭塞4例、B型闭塞2例、C型闭塞1例、D型闭塞2例；与术中DSA相比，术前HR-VWI对残腔、腔内血栓和动脉夹层的阳性检出率为10/11，余1例(1/11)HR-VWI分型Ⅲ型闭塞患者经DSA证实为Ⅱ型闭塞。10例(10/11)血管再通成功，1例失败病例为HR-VWI分型Ⅲ-C型闭塞；2例(2/11)出现围手术期并发症。术后1和3个月病情好转者为6和7例、稳定为5和4例；术后6个月1例发生支架内再狭窄。**结论**　术前HR-VWI显示闭塞段有残腔提示血管再通成功率和手术安全性较高，管腔内有血栓增加围手术期并发症风险，但不降低血管再通成功率和预后。

【关键词】 动脉闭塞性疾病；　颈内动脉；　血管成形术；　支架；　磁共振成像

Application of high-resolution magnetic resonance imaging vascular wall imaging in endovascular recanalization of chronic internal carotid artery occlusion

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【**Abstract**】 **Objective**　To explore the application value of high-resolution magnetic resonance imaging vascular wall imaging (HR-VWI) in endovascular recanalization of chronic internal carotid artery occlusion (CICAO). **Methods**　A total of 11 patients with symptomatic CICAO were treated by recanalization from March 2018 to September 2019. The original and ferminal part of occlusion, and occlusion segment with or without residual lumen, intracavitary thrombosis and arterial dissection were shown to classify according to preoperative HR-VWI. Type Ⅰ occlusion (ocular segment occlusion), type Ⅱ occlusion [occlusion of the internal carotid artery (ICA) bulb to the clinoid process and its proximal intracranial segment] and type Ⅲ occlusion (occlusion of the ICA bulb to the ocular segment and beyond), and type A occlusion (with residual lumen but without thrombosis or arterial dissection), type B occlusion (residual lumen, thrombus and arterial dissection in residual lumen), type C occlusion (no residual lumen and no thrombus and arterial dissection) and type D occlusion (no residual lumen but with intracavitary thrombosis and arterial dissection) were recorded by with preoperative and intraoperative DSA. The

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recanalization rate, perioperative complications and prognosis were recorded. **Results** The preoperative HR-VWI showed type Ⅰ occlusion in 2 cases, type Ⅱ occlusion in 6 cases and type Ⅲ occlusion in 3 cases, and type A occlusion in 4 cases, type B occlusion in 2 cases, type C occlusion in one case and type D occlusion in 2 cases. Compared with intraoperative DSA, the positive detection rate of HR-VWI for residual lumen, intracavitary thrombosis and arterial dissection was 10/11. One case (1/11) preoperative HR-VWI classification was type Ⅲ occlusion which confirmed by intraoperative DSA really was type Ⅱ occlusion. A total of 10 patients (10/11) for recanalization, one failure case was HR-VWI classification type Ⅲ-C. Perioperative complications occurred in 2 patients (2/11). Six and 7 patients improved in the first and third month after surgery, and 5 and 4 patients were stable, one patient developed in-stent restenosis in the sixth month after the operation. **Conclusions** Preoperative HR-VWI showed residual lumen in occlusion segment indicated higher success rate of recanalization and safety, and thrombosis in the residual lumen increased the risk of perioperative complications, but did not reduce the success rate and prognosis of recanalization.

【Key words】 Arterial occlusive diseases; Carotid artery, internal; Angioplasty; Stents; Magnetic resonance imaging

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颈内动脉闭塞(ICAO)时间超过4周定义为慢性颈内动脉闭塞(CICAO),年发病率约为6/10万[1],是缺血性卒中的主要发病原因之一,且远期缺血性卒中复发率较高。尽管予以积极的药物治疗,存在严重血流动力学障碍患者,缺血性卒中年发生率仍高达10%~20%[2]。治疗方面,颅内外血管搭桥术因较高的围手术期并发症发生率以及未能降低术后缺血性卒中发生率,临床价值至今尚存争议[3-5];血管再通治疗的可行性目前已获得广泛认可[6],术后脑血流重建可以降低远期缺血性卒中复发率并改善脑灌注和神经功能[7-8]。随着手术经验的积累和神经介入材料的发展,血管再通技术有了一定程度的提高,但慢性颈内动脉闭塞血管再通成功率仍有较大差异,且可能发生致死性并发症[9-10]。慢性颈内动脉闭塞的影像学检查方法有多种,传统方法包括彩色多普勒超声(CDUS)、CTA、MRA和DSA等,尽管综合上述检查方法可以对血管闭塞原因和梗死灶部位作出初步判断,但无法清晰显示闭塞段管腔内部结构,在判断血管闭塞原因方面尚有不足。高分辨率磁共振血管壁成像(HR-VWI)可以直接显示闭塞段血管壁和管腔内部结构,明确闭塞段部位、闭塞节段和闭塞原因[11-12],采用该检查方法对符合手术指征的慢性颈内动脉闭塞患者进行术前评估,有助于术者制定个体化治疗方案,从而提高慢性颈内动脉闭塞血管再通成功率、降低围手术期并发症发生率。本研究对行血管再通治疗的症状性慢性颈内动脉闭塞患者的术前HR-VWI资料进行回顾分析,探讨该项技术在慢性颈内动脉闭塞血管再通治疗中的应用价值。

对象与方法

一、研究对象

1.纳入标准 (1)术前均行HR-VWI检查,且检查时间距手术时间<2周。(2)经DSA证实为单侧颈内动脉闭塞。(3)闭塞时间>4周。(4)既往有缺血性卒中或短暂性脑缺血发作(TIA)史且与闭塞血管相符。(5)PWI显示血流平均通过时间(MTT)和达峰时间(TTP)延长、脑血流量(CBF)下降。(6)均为血管再通术后病例。(7)所有患者及其家属均对手术方案和手术风险知情并签署知情同意书。

2.排除标准 (1)最近一次缺血性卒中至血管再通治疗时间<2周。(2)术前改良Rankin量表(mRS)评分>3分。(3)伴闭塞侧大脑中动脉闭塞(MCAO)。

3.一般资料 选择2018年3月至2019年9月在天津泰达医院神经科施行血管再通治疗的症状性慢性颈内动脉闭塞患者11例,男性8例,女性3例;年龄42~68岁,平均61岁;最近一次缺血性卒中至血管再通治疗时间16~224天,中位时间为35天。既往高血压8例、冠心病3例、2型糖尿病6例,吸烟8例、饮酒7例;术前mRS评分0分3例,1~2分7例,3分1例;头部MRI显示,陈旧性梗死灶2例,责任血

管供血区急性新发梗死灶9例。

二、研究方法

1.手术前HR-VWI检查 （1）检查方法：采用德国Siemens公司生产的MAGNETOM Prisma 3.0T MRI扫描仪，64通道头颈部线圈。HR-VWI通过反转恢复可变翻转角度快速自旋回波（IR-SPACE）抑制血流和脑脊液信号以显示管腔内部结构，然后对HR-VWI行多平面重建（MPR），行矢状位容积扫描并采集横断面图像，获得平扫和增强血管壁图像。重复时间（TR）900 ms、回波时间（TE）15 ms，翻转角度（FA）120°，扫描视野（FOV）240 mm×210 mm，矩阵384×336，层厚0.55 mm、层间距0.55 mm，扫描时间463 s，共240层，覆盖主动脉弓上缘水平至颅顶；再采用影像归档与通信系统（PACS）进行三维图像重建，重建体素0.55 mm×0.55 mm×0.55 mm。（2）结果分析：由两位神经放射科医师共同记录并分析HR-VWI结果，包括闭塞段起止部位、闭塞段有无残腔、闭塞段有无动脉夹层或血栓。根据闭塞段起止部位共分为3种类型，Ⅰ型为颈内动脉眼段闭塞，即眼动脉起始部远端至后交通动脉起始部近端闭塞，通常为动脉粥样硬化性重度狭窄进展所致（图1）；Ⅱ型为颈内动脉起始部至床突段及其近端颅内段的串联闭塞（图2）；Ⅲ型即颈内动脉起始部至眼段及其以远的串联闭塞（图3）；其中Ⅱ型和Ⅲ型为长节段闭塞。根据闭塞段有无残腔和腔内血栓共分为4种类型，A型，闭塞段有残腔但无腔内血栓和动脉夹层（图4）；B型，闭塞段有残腔且有腔内血栓和动脉夹层（图5）；C型，闭塞段无残腔且无腔内血栓和动脉夹层（图6）；D型，闭塞段无残腔但有腔内血栓和动脉夹层（图7）。

2.血管再通治疗 患者仰卧位，于气管插管全身麻醉下以Seldinger法穿刺右侧股动脉，常规行弓上、双侧颈总动脉、双侧锁骨下动脉造影，根据血管闭塞或狭窄情况，选择性行颈内动脉、颈外动脉、椎动脉造影。造影过程中通过增加对比剂剂量、增强注射压力、延长显影时间以排除假性闭塞或降低闭塞段评估误差[13]，并由两位高年资神经介入科医师共同制定血管再通方案。经右股动脉置入8F动脉鞘，全身肝素化，根据颈内动脉起始部有无残端，选择8F导引导管或Merci球囊导引导管（美国Stryker公司）、MOMA近端保护装置（美国Medtronic公司）置入病变侧颈内动脉起始部或总动脉近分叉部，于路径图引导下采用普通泥鳅导丝配合多功能造影导管尝试通过闭塞段，如果多功能造影导管能够顺利通过闭塞起始部并经造影证实远端血管正常后，可交替置入长度300 cm的X-celerator长交换导丝（美国Medtronic公司）；如果多功能造影导管无法通过闭塞起始部，更换为Pilot 50微导丝（美国Boston Scientifi公司）和Rebar-18微导管（美国Medtronic公司）通过闭塞起始部，微导管造影观察闭塞段管腔内部结构并寻找闭塞段起止部位。微导管进入闭塞段真腔后，置入长度为300 cm的长交换导丝，沿微导丝置入Gateway球囊扩张导管（美国Stryker公司），由远及近依次扩张闭塞段，存在明显狭窄、动脉夹层或不稳定血栓时，可选择适宜支架[Wallstent支架，美国Boston公司；Winspan支架，美国Stryker公司；Apollo支架，上海微创医疗器械（集团）有限公司]释放于闭塞段。术后即刻复查造影，残留狭窄率＜30%且脑梗死溶栓血流分级（TICI）≥2b级为血管再通成功[14]。

3.围手术期处理 术前均常规服用阿司匹林100 mg/d和氯吡格雷75 mg/d，连续3～5 d，若有阿司匹林或氯吡格雷相关药物不良反应，可以西洛他唑100 mg/次（2次/d）或双嘧达莫200 mg/次（2次/d）替代。不推荐术前常规检查血小板功能，除非疑似阿司匹林或氯吡格雷抵抗[15]。术后即刻行头部CT检查，排除颅内出血后常规静脉泵入替罗非班0.20～0.30 mg/h维持24 h，同时服用阿司匹林100 mg/d和氯吡格雷75 mg/d，以及阿托伐他汀20 mg/d，连续治疗6个月至1年，再改为阿司匹林100 mg/d或氯吡格雷75 mg/d联合阿托伐他汀20 mg/d长期维持。血管再通后立即通过静脉泵入α1受体拮抗剂乌拉地尔100～600 μg/min和（或）钙拮抗剂硝酸甘油25～200 μg/min控制血压，使血压维持在90～120/60～75 mm Hg（1 mm Hg=0.133 kPa）或较基础血压下降20%，并持续至术后72 h；对术前梗死灶体积较大（尤其是梗死核心位于基底节区）或术前血压不易控制的患者，术后不予复苏，继续镇静24～48 h；术后72 h内每日监测经颅多普勒超声（TCD），根据脑血流情况决定血压控制时间和镇静时间。

4.评价指标 （1）影像学：以DSA为“金标准”验证术前HR-VWI结果，术中分别观察闭塞段起止部位，闭塞段有无残腔、腔内血栓、动脉夹层或动脉狭窄，以及支架植入部位。术后即刻复查造影，采用TICI分级评价血管再通率：0级（无灌注），血管闭塞远端无前向血流；1级（弥漫无灌注），对比剂部分

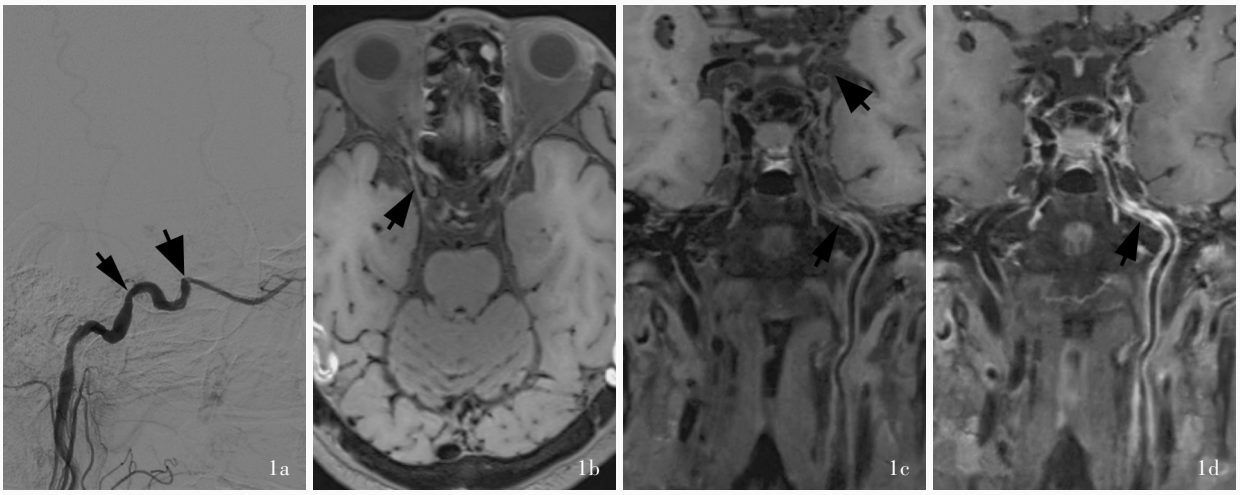


图1 Ⅰ型闭塞患者术前影像学所见 1a DSA显示右颈内动脉终止于眼段(粗箭头所示),岩骨段和海绵窦段狭窄(细箭头所示) 1b 横断面增强3D-T_1-SPACE序列显示,右颈内动脉眼段管腔消失,局部闭塞(箭头所示) 1c 冠状位MPR显示,右颈内动脉眼段闭塞(粗箭头所示),岩骨段重度狭窄(细箭头所示) 1d 冠状位增强MPR显示右颈内动脉岩骨段明显强化(箭头所示)

Figure 1 Preoperative imaging findings of CICAO type Ⅰ occlusion DSA showed right ICA terminated in the ocular segment (thick arrow indicates), and stenosis was seen at the rock bone segment and cavernous sinus segment (thin arrow indicates, Panel 1a). Axial enhanced 3D-T_1-SPACE sequence showed the lumen of the ocular segment of right ICA disappeared and locally occluded (arrow indicates, Panel 1b). MPR showed occlusion of the ocular segment of right ICA (thick arrow indicates), and severe stenosis of the rock bone segment (thin arrow indicates, Panel 1c). Coronal enhanced MPR showed significant enhancement of the rock bone segment of right ICA (arrow indicates, Panel 1d).

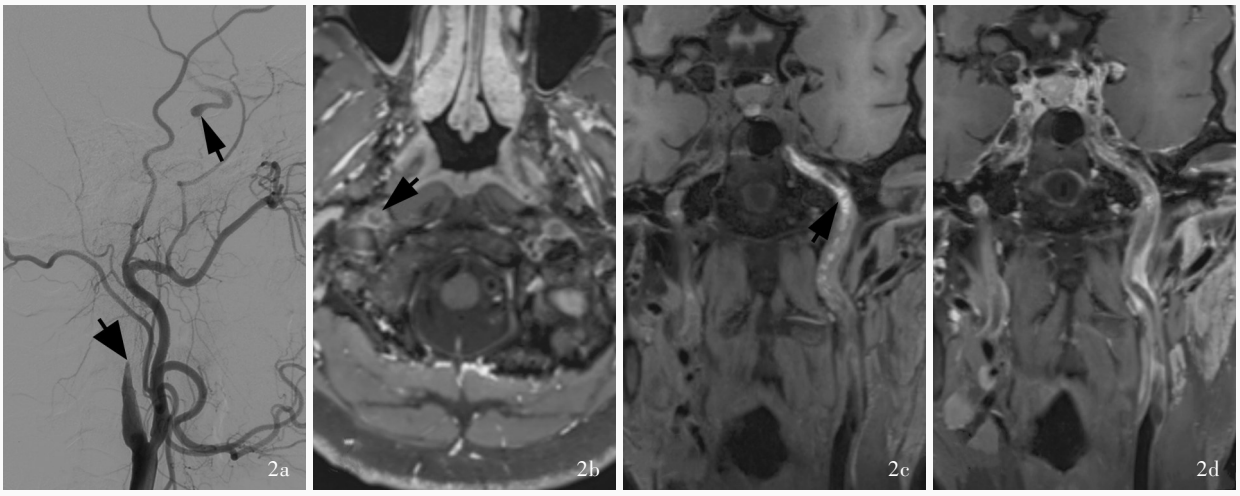


图2 Ⅱ型闭塞患者术前影像学检查所见 2a DSA显示右颈内动脉起始部闭塞,残端呈锥形(粗箭头所示),右颈外动脉经眼动脉向颅内代偿并反流至海绵窦段(细箭头所示) 2b 横断面增强3D-T_1-SPACE序列可见右颈内动脉颈段管壁内血栓伴管腔内血栓(箭头所示) 2c 冠状位MPR显示,右颈内动脉起始部至眼段管腔内和局部管壁高信号影(箭头所示) 2d 冠状位增强MPR显示,右颈内动脉颈段无明显强化,提示闭塞段管壁间血肿伴管腔内血栓

Figure 2 Preoperative imaging findings of CICAO type Ⅱ occlusion DSA showed occlusion of right ICA bulb, and tapered stump (thick arrow indicates), right ECA was compensated to the intracranial via ophthalmic artery and regurgitated to the cavernous sinus segment (thin arrow indicates, Panel 2a). Axial enhanced 3D-T_1-SPACE sequence showed that intramural thrombus of ICA with intraluminal thrombus (arrow indicates, Panel 2b). Coronal MPR showed hyperintensity in the lumen and local vessel wall from the beginning of ICA bulb to the ocular segment (arrow indicates, Panel 2c). Coronal enhanced MPR showed no obvious enhancement in the carotid segment, suggesting that the intermural hematoma in the occluded segment was associated with intravascular thrombus (Panel 2d).

通过闭塞段但不能充盈远端血管;2级(部分灌注),对比剂完全充盈动脉远端,但充盈和清除速度较正常动脉延缓,2a级为对比剂充盈<责任血管供血区的2/3、2b级为对比剂完全充盈但排空延迟;3级(完全灌注),对比剂完全、迅速充盈远端血管并迅速清除。(2)围手术期并发症:主要包括颈动脉夹层、颅内血管栓塞、颅内出血等。(3)日常生活活动能力:分别于术后1和3个月随访,通过电话或门诊采用mRS量表评价预后,mRS评分减少≥1分为改善、mRS评分无变化为稳定、mRS评分增加≥1分为加

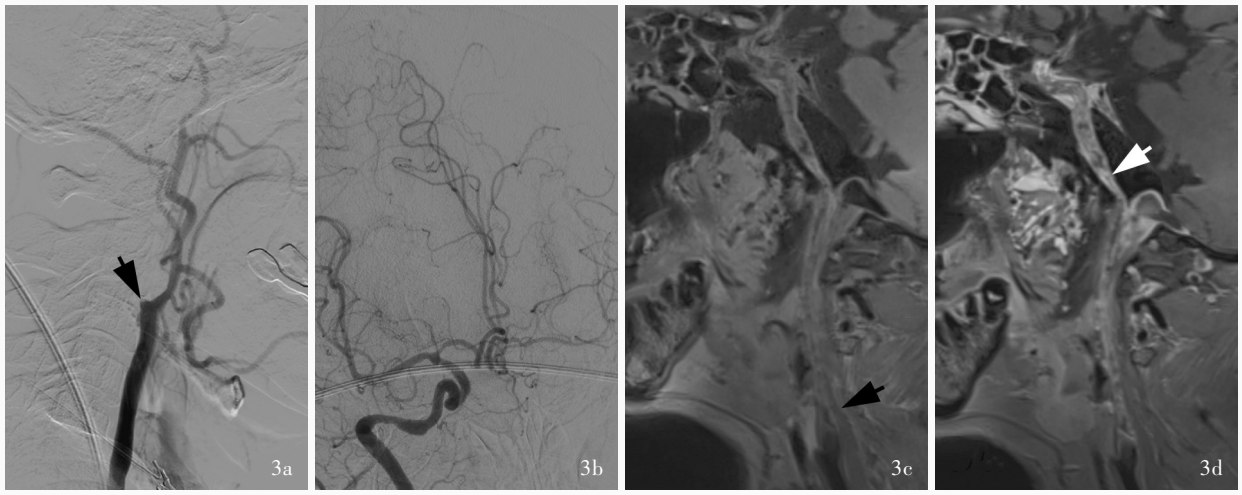


图3　Ⅲ型闭塞患者术前影像学检查所见　3a　DSA显示左颈内动脉起始部闭塞且无残端(箭头所示),颈外动脉和后交通动脉无侧支代偿　3b　DSA显示闭塞段终点为颈内动脉分叉部,仅由右前循环经前交通动脉代偿且向近端无反流　3c　矢状位MPR显示,左颈内动脉起始部至交通段闭塞(箭头所示)　3d　矢状位增强MPR显示,左颈内动脉颈段管壁局部强化(箭头所示)

Figure 3　Preoperative imaging findings of CICAO type Ⅲ occlusion　DSA showed occlusion of left ICA bulb, and no stumps (arrow indicates), no collateral compensation of ECA posterior traffic branch (Panel 3a). DSA showed the occluded segment ended in ICA traffic segment, which was only compensated by right anterior circulation through the anterior traffic artery, and there was no reflux toward the proximal end (Panel 3b). Sagittal MPR showed left ICA was occluded from the bulb to the traffic segment (arrow indicates, Panel 3c). Sagittal enhanced MPR showed local enhancement of the wall of left ICA (arrow indicates, Panel 3d).

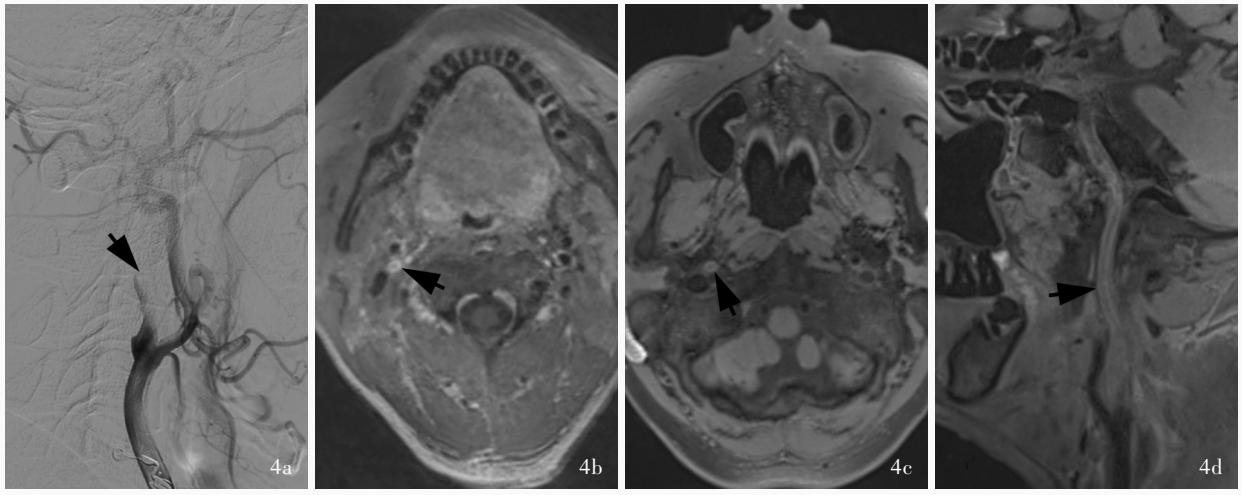


图4　A型闭塞患者术前影像学检查所见　4a　DSA显示右颈内动脉起始部闭塞(箭头所示)　4b　横断面增强3D-T_1-SPACE序列显示,右颈内动脉颈段管腔缩小,管腔内信号均匀一致,管壁呈强化征象但未见增厚(箭头所示)　4c　横断面3D-T_1-SPACE序列显示,右颈内动脉颈段管腔缩小(箭头所示)　4d　矢状位MPR显示,右颈内动脉起始部闭塞,闭塞段有长节段间隙但无腔内血栓或动脉夹层,提示闭塞段有残腔(箭头所示)

Figure 4　Preoperative imaging findings of CICAO type A occlusion　DSA showed the original part of occlusion of right ICA (arrow indicates, Panel 4a). Axial enhanced 3D-T_1-SPACE sequence showed the lumen in the carotid segment of right ICA was stenosed, the wall was enhanced without thickening (arrow indicates), and the signals in the lumen were uniform and consistent (Panel 4b). Axial 3D-T_1-SPACE sequence showed the lumen in the carotid segment of right ICA was stenosed (arrow indicates, Panel 4c). Sagittal MPR showed right ICA occlusion at the beginning with long segmental gaps but no intracavity thrombosis or arterial dissection (arrow indicates), indicating residual lumen in the occluded segment (Panel 4d).

重或恶化。(4)再狭窄发生率:术后3至6个月门诊或入院复查颈动脉超声、CTA或DSA,观察支架内再狭窄或再闭塞情况,其中,支架内狭窄率≥50%定义为再狭窄、支架内无血流(TICI分级0级)定义为再闭塞。

结　果

经术前HR-VWI检查,本组11例中Ⅰ型闭塞(眼段闭塞)2例、Ⅱ型闭塞(起始部至床突段及其近端颅内段的闭塞)6例、Ⅲ型闭塞(起始部至眼段及

图5 B型闭塞患者术前影像学检查所见 5a DSA显示右颈内动脉起始部闭塞(箭头所示) 5b,5c 横断面增强3D-T_1-SPACE序列显示,右颈内动脉颈段存在残腔(粗箭头所示),岩骨段管腔内高信号影(细箭头所示),左颈内动脉通畅 5d 矢状位增强MPR显示,右颈内动脉颈段存在残腔(粗箭头所示),岩骨段管腔内高信号影(细箭头所示),无"瓣膜征"和"双腔征",提示腔内血栓

Figure 5 Preoperative imaging findings of CICAO type B occlusion DSA showed occlusion of right ICA bulb (arrow indicates, Panel 5a). Axial enhanced 3D-T_1-SPACE sequence showed residual lumen in the carotid segment or right ICA (thick arrow indicates), hyperintensity in the lumen of the rock bone segment (thin arrow indicates), and left ICA was unobstructed (Panel 5b, 5c). Sagittal enhanced MPR showed residual lumens in the carotid segment of right ICA (thick arrow indicates), hyperintensity in the lumen of the rock-bone segment (thin arrow indicates), and no "valvular signs" or "double-lumen signs", indicating thrombosis in the vascular lumen (Panel 5d).

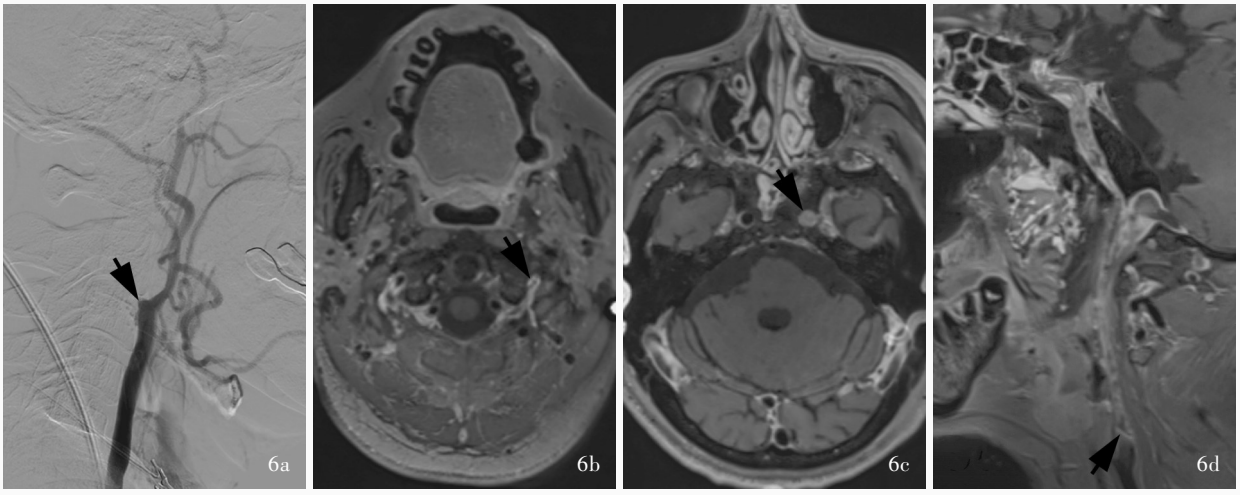


图6 C型闭塞患者术前影像学检查所见 6a DSA显示左颈内动脉起始部闭塞(箭头所示) 6b 横断面3D-T_1-SPACE序列显示,左颈内动脉颈段塌陷(箭头所示) 6c 横断面增强3D-T_1-SPACE序列显示,左颈内动脉海绵窦段流空影消失,提示闭塞(箭头所示),右颈内动脉通畅 6d 矢状位增强MPR显示,自左颈内动脉起始部至交通段闭塞(箭头所示),无真性管腔,腔内无血栓

Figure 6 Preoperative imaging findings of CICAO type C occlusion DSA showed occlusion of left ICA bulb (arrow indicates, Panel 6a). Axial 3D-T_1-SPACE sequence showed collapse of the carotid segment of left ICA (arrow indicates, Panel 6b). Axial enhanced 3D-T_1-SPACE sequence showed the cavernous sinus segment of left ICA flow-void disappeared, indicating occlusion (arrow indicates), and right ICA was unobstructed (Pane 6c). Sagittal enhanced MPR showed left ICA was occluded from the beginning to the traffic segment (arrow indicates), with no true lumen and no thrombus in the lumen (Panel 6d).

其以远的闭塞)3例;A型闭塞(有残腔但无腔内血栓和动脉夹层)4例、B型闭塞(有残腔且有腔内血栓和动脉夹层)2例、C型闭塞(无残腔且无腔内血栓和动脉夹层)1例和D型闭塞(无残腔但有腔内血栓和动脉夹层)2例。术中经DSA确认,颈内动脉眼段闭塞2例、起始部至颈段闭塞2例、起始部至颅内段的长节段闭塞7例;与术中DSA相比,术前HR-VWI对闭塞部位和管腔内部结构异常阳性检出率为10/11,仅1例(1/11)Ⅲ型闭塞患者术中DSA证实Ⅱ型闭塞。

本组10例患者血管再通成功,成功率为10/11;1例失败,为HR-VWI分型Ⅲ-C型闭塞患者,术中发现闭塞段无残腔且无腔内血栓,微导丝无法通过闭

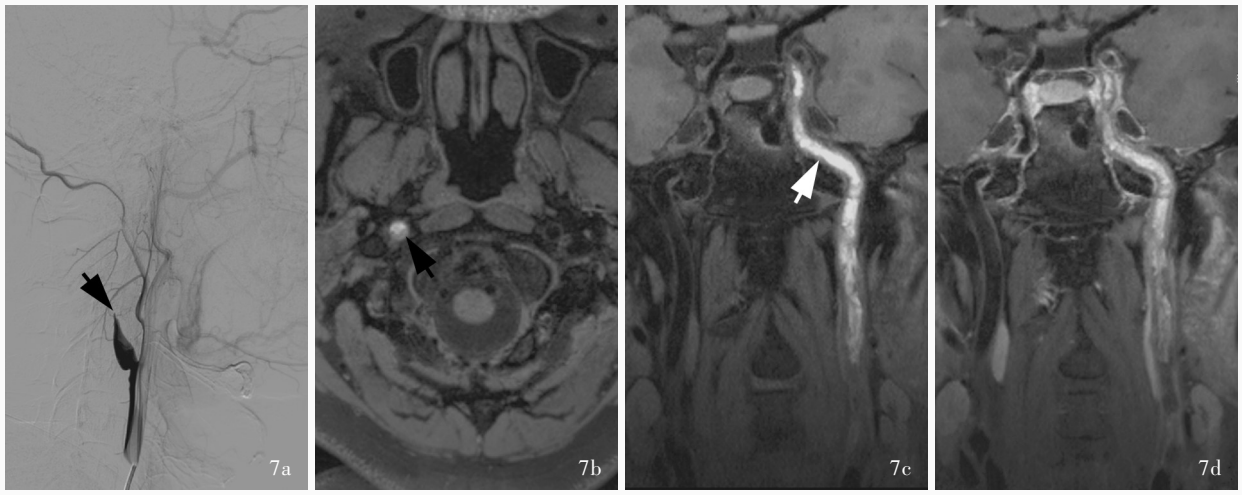


图7　D型闭塞患者术前影像学检查所见　7a　DSA显示，右颈内动脉起始部闭塞，残端呈锥形（箭头所示），右颈外动脉经眼动脉向颅内代偿，向近端无反流　7b　横断面3D-T_1-SPACE序列显示，右颈内动脉颈段管腔内混杂信号影（箭头所示），左颈内动脉流空信号　7c　冠状位MPR显示，闭塞段管腔内高信号影（箭头所示）　7d　冠状位增强MPR显示，闭塞段血管壁无明显强化，提示存在腔内血栓但无残腔

Figure 7　Preoperative imaging findings of CICAO type D occlusion　DSA showed occlusion of right ICA bulb and tapered stump (arrow indicates), right ECA was compensated to the intracranial via the ophthalmic artery, without regurgitation to the proximal end (Panel 7a). Axial 3D-T_1-SPACE sequence showed mixed signals in the carotid segment of right ICA (arrow indicates), left ICA displayed flow-void (Panel 7b). Coronal MPR showed hyperintensity in the lumen of the occluded segment (arrow indicates, Panel 7c). Coronal enhanced MPR showed no obvious reinforcement of occluded segmental vessel wall, sugesting the presence of intraluminal thrombus but no residual cavity was suggested (Panel 7d).

塞段，且颈内动脉起始部发生医原性夹层，植入1枚Wallstent支架贴敷后夹层未扩大。10例血管再通成功患者中，2例Ⅰ型闭塞和4例A型闭塞患者未发生动脉夹层、栓子脱落等围手术期并发症；2例B型闭塞患者中1例术中血栓松动游离，漂浮至破裂孔段，植入1枚Neuroform支架覆盖后血栓贴壁良好，余1例未发生围手术期并发症；2例D型闭塞患者均术中血栓松动，1例发生闭塞段内部栓子脱落至大脑中动脉，经机械取栓后血管完全再通，术后表现为无症状性缺血性卒中；1例血栓松动但未脱落，植入1枚Wallstent支架覆盖后血栓贴壁良好。术后均未出现新发神经功能障碍。

术后1个月，日常生活活动能力改善6例、稳定5例，术后3个月改善7例、稳定4例，提示术后短期内临床预后良好。术后6个月，8例进行颈动脉超声、CTA或DSA复查，其中1例HR-VWI分型Ⅱ-D型闭塞患者发生支架内再狭窄，但无神经功能障碍，再次行球囊扩张术；7例未见支架内再狭窄。11例患者临床资料参见表1。

典型病例

患者（例1）　男性，68岁。因突发左侧肢体无力3周，于2018年3月7日入院。患者入院前3周无明显诱因出现左侧肢体无力，站立困难，左手不能持物，伴言语不清和头晕，持续约30分钟自行缓解，当地医院头部MRI检查可见胼胝体压部急性梗死灶。为求进一步治疗遂入我院。入院后体格检查：四肢肌力4级、肌张力正常。术前影像学检查：DSA可见右颈内动脉起始部闭塞，颈外动脉经眼动脉向颅内代偿并向近端反流至岩骨段（图8a，8b）；PWI显示，右侧颞顶叶和半卵圆中心MTT和TTP较左侧延长，CBF较左侧略降低，脑血容量（CBV）较左侧略降低（图8c～8f）。HR-VWI显示，右颈内动脉起始部至岩骨段末端闭塞，考虑慢性动脉粥样硬化斑块形成，近端管腔尚存（HR-VWI闭塞分型Ⅱ-A型，图8g～8i）。临床诊断：右侧颈内动脉慢性闭塞，2型糖尿病。2018年3月21日行血管再通治疗，术中以多功能导管配合微导丝通过闭塞段，在球囊导引导管近端保护下，微导丝配合微导管通过岩骨段闭塞处，以2.50 mm×10.00 mm球囊扩张闭塞段，再植入4 mm×30 mm Wingspan支架覆盖岩骨段至床突段，然后以4 mm×30 mm球囊扩张颈内动脉起始部，再植入7～10 mm×40 mm Protege支架（图9）；经DSA证实为Ⅱ-A型闭塞，与术前HR-VWI分型一致。术后即刻造影，TICI分级为3级，血管再通成功，未发生围手术期并发症，共住院18天。出院后随访至术

表1 11例症状性慢性颈内动脉闭塞患者的临床资料

Table 1. Clinical data of 11 patients with symptomatic CICAO

序号	性别	年龄（岁）	DSA闭塞段起止部位	HR-VWI闭塞分型	术中DSA所见	HR-VWI与术中DSA一致性	手术相关并发症	支架植入部位	血管再通	围手术期并发症	mRS（评分）			术后6个月影像学
											术前	术后1个月	术后3个月	
1	男性	68	右颈内动脉起始部至岩段	Ⅱ-A型	右颈内动脉起始部至岩段闭塞，有残腔但无腔内血栓	一致	无	右颈内动脉起始部、岩骨段至床突段	成功	无	0	0	0	无支架内再狭窄
2	男性	42	右颈内动脉颈段至海绵窦段	Ⅱ-D型	右颈内动脉起始部至海绵窦段闭塞，无残腔，可见颈段夹层和血栓	一致	血栓脱落至大脑中动脉，予机械取栓	右颈内动脉起始部、虹吸段、岩段	成功	无症状性缺血性卒中	1	1	1	右颈内动脉海绵窦段支架内再狭窄
3	男性	61	右颈内动脉起始部至海绵窦段	Ⅱ-A型	右颈内动脉起始部至岩段闭塞，有残腔但无腔内血栓	一致	无	右颈内动脉眼段	成功	无	1	0	0	无支架内再狭窄
4	男性	61	右颈内动脉起始部至交通段	Ⅲ-C型	右颈内动脉全程闭塞，无残腔且无腔内血栓	一致	右颈内动脉起始部夹层	右颈内动脉起始部	失败	无症状性动脉夹层	0	0	0	未复查
5	男性	66	右颈内动脉眼段	Ⅰ型	右颈内动脉眼段斑块	一致	无	右颈内动脉眼段	成功	无	3	2	1	无支架内再狭窄
6	女性	49	左颈内动脉起始部至交通段	Ⅲ-B型	左颈内动脉起始部至眼段闭塞，有残腔，可见颈段血栓	一致	血栓松动游离	左颈内动脉交通段、眼段、海绵窦段	成功	无	2	1	0	无支架内再狭窄
7	男性	66	左颈内动脉起始部至颈段	Ⅱ-A型	左颈内动脉起始部至颈段闭塞，有残腔但无腔内血栓	一致	无	左颈内动脉起始部	成功	无	2	1	1	无支架内再狭窄
8	男性	47	右颈内动脉起始部至海绵窦段	Ⅱ-B型	右颈内动脉起始部至海绵窦段闭塞，有残腔，可见颈段夹层和血栓	一致	无	右颈内动脉颈段、海绵窦段	成功	无	1	0	0	无支架内再狭窄
9	男性	52	左颈内动脉起始部至颈段	Ⅱ-A型	左颈内动脉起始部至颈段闭塞，有残腔但无腔内血栓	一致	无	左颈内动脉起始部	成功	无	2	1	1	无支架内再狭窄
10	女性	49	右颈内动脉起始部至床突段	Ⅲ-D型	右颈内动脉起始部至海绵窦段闭塞，无残腔但有大量腔内血栓	非一致	血栓松动	右颈内动脉起始部、颈段、海绵窦段、岩段	成功	无	1	1	0	未复查
11	女性	65	左颈内动脉眼段	Ⅰ型	左颈内动脉眼段斑块	一致	无	左颈内动脉眼段	成功	无	0	0	0	未复查

mRS，modified Rankin Scale，改良Rankin量表；HR-VWI，high-resolution magnetic resonance imaging vascular wall imaging，高分辨率磁共振血管壁成像

后1和3个月，mRS评分均为0分。术后6个月，复查CTA未见支架内再狭窄；术后24个月复查MRA和HR-VWI显示右颈内动脉通畅（图10）。

患者（例6） 女性，49岁。因右侧肢体无力伴言语不清2周，于2018年8月26日入院。患者入院前2周无明显诱因出现右侧肢体无力，尚可独立行走和持物，伴言语不清，无认知功能障碍，无饮水呛咳、吞咽困难。入院后体格检查：言语不清，右侧肢体肌力3级、肌张力正常。术前DSA显示，左颈内动脉闭塞（图11a，11b）。PWI显示，左侧额顶颞叶和半卵圆中心MTT和TTP较右侧明显延长，CBF较右侧明显降低，CBV无降低（图11c～11f）。HR-VWI显示，左颈内动脉起始部血栓形成，可见管腔潜在通畅，眼段以远斑块致闭塞可能（HR-VWI闭塞分型Ⅲ-B型，图11g～11i）。临床诊断：左侧颈内动脉慢性闭塞，2型糖尿病，高脂血症。2018年9月19日行血管再通治疗。术中将长度为90 cm的6F长动脉鞘置于左颈总动脉近分叉部，长度115 cm的5F Navien导管置于左颈内动脉颈段抽吸取栓，经微导管造影显示眼段闭塞，微导丝配合Echelon-10微导管选择性通过闭塞段，置于大脑中动脉M1段远端，沿微导丝交替置入2 mm×15 mm球囊以及3 mm×10 mm球囊由远及近依次扩张闭塞段，植入4 mm×30 mm Wingspan支架覆盖交通段、眼段和海绵窦段（图12）；经DSA证实Ⅲ-B型闭塞，与术前HR-VWI闭塞分型一致。术中颈段血栓游离，岩骨段仍有大片附壁血栓，抽吸取栓失败，植入1枚4.50 mm×30.00 mm Neuroform支架贴敷血栓于管壁。术后即刻复查造影，TICI分级为3级，血管再通成功，未见围手术期并发症，共住院16天。出院后随访至术后1个月，mRS评分为1分、术后3个月0分；术后6个月复查颈动脉超声，显示左颈内动脉血流通畅，起始部中至重度狭窄。

讨 论

慢性颈内动脉闭塞的常见原因包括动脉粥样

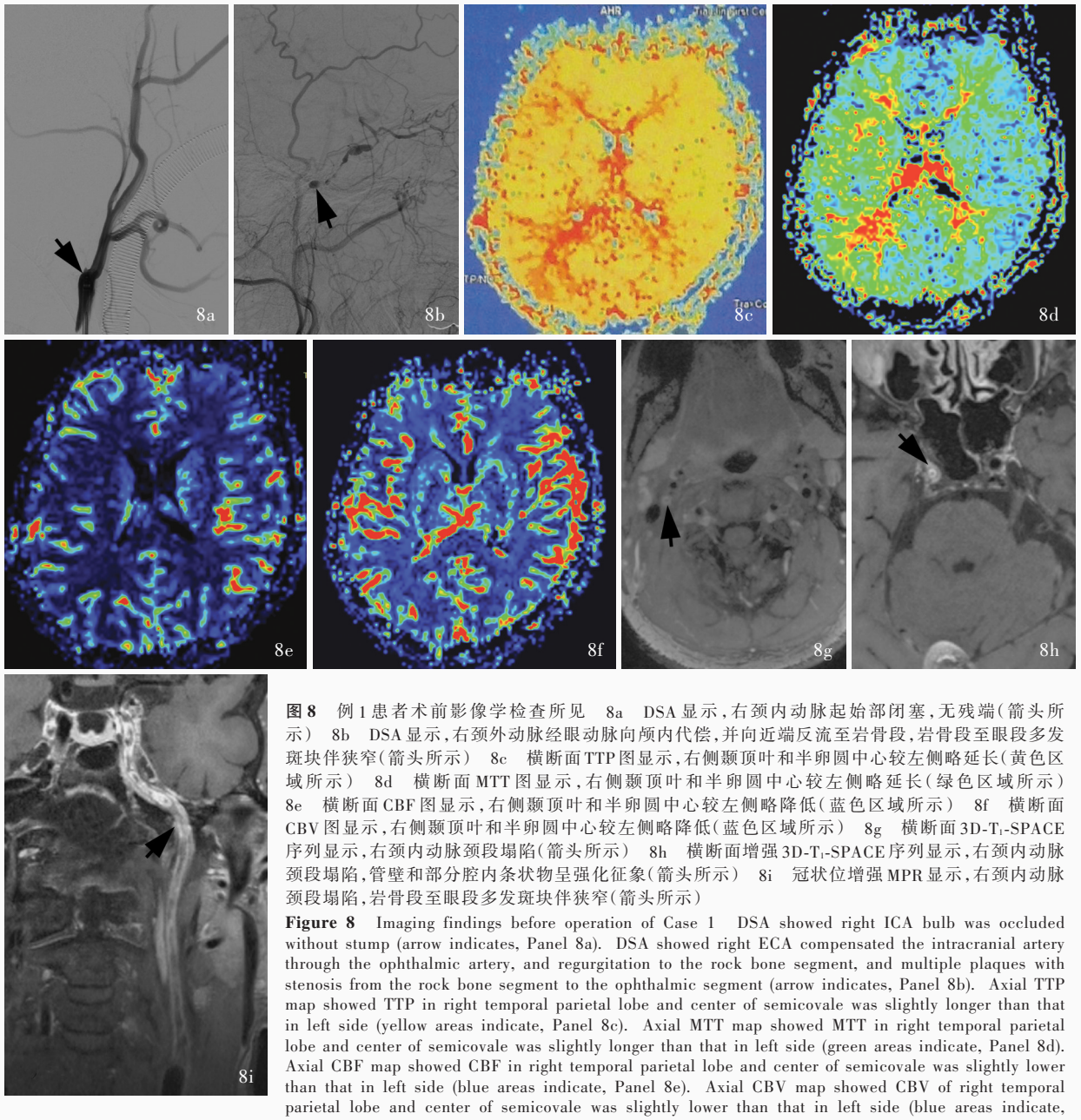
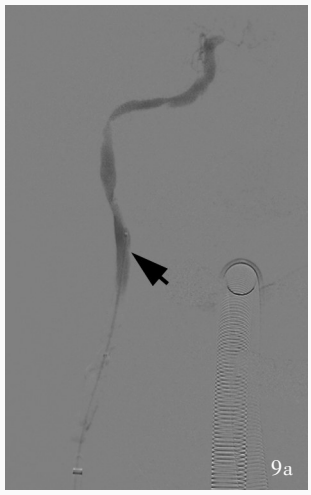
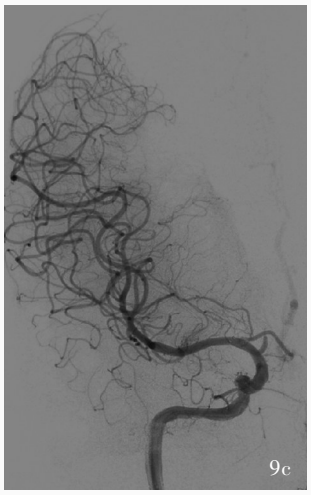


图8　例1患者术前影像学检查所见　8a　DSA显示，右颈内动脉起始部闭塞，无残端（箭头所示）　8b　DSA显示，右颈外动脉经眼动脉向颅内代偿，并向近端反流至岩骨段，岩骨段至眼段多发斑块伴狭窄（箭头所示）　8c　横断面TTP图显示，右侧颞顶叶和半卵圆中心较左侧略延长（黄色区域所示）　8d　横断面MTT图显示，右侧颞顶叶和半卵圆中心较左侧略延长（绿色区域所示）　8e　横断面CBF图显示，右侧颞顶叶和半卵圆中心较左侧略降低（蓝色区域所示）　8f　横断面CBV图显示，右侧颞顶叶和半卵圆中心较左侧略降低（蓝色区域所示）　8g　横断面3D-T_1-SPACE序列显示，右颈内动脉颈段塌陷（箭头所示）　8h　横断面增强3D-T_1-SPACE序列显示，右颈内动脉颈段塌陷，管壁和部分腔内条状物呈强化征象（箭头所示）　8i　冠状位增强MPR显示，右颈内动脉颈段塌陷，岩骨段至眼段多发斑块伴狭窄（箭头所示）

Figure 8　Imaging findings before operation of Case 1　DSA showed right ICA bulb was occluded without stump (arrow indicates, Panel 8a). DSA showed right ECA compensated the intracranial artery through the ophthalmic artery, and regurgitation to the rock bone segment, and multiple plaques with stenosis from the rock bone segment to the ophthalmic segment (arrow indicates, Panel 8b). Axial TTP map showed TTP in right temporal parietal lobe and center of semicovale was slightly longer than that in left side (yellow areas indicate, Panel 8c). Axial MTT map showed MTT in right temporal parietal lobe and center of semicovale was slightly longer than that in left side (green areas indicate, Panel 8d). Axial CBF map showed CBF in right temporal parietal lobe and center of semicovale was slightly lower than that in left side (blue areas indicate, Panel 8e). Axial CBV map showed CBV of right temporal parietal lobe and center of semicovale was slightly lower than that in left side (blue areas indicate, Panel 8f). Axial 3D-T_1-SPACE sequence showed the carotid segment of right ICA collapsed (arrow indicates, Panel 8g). Axial enhanced 3D-T_1-SPACE sequence showed the carotid segment of right ICA collapsed, the wall of the blood vessel and part of the thrombus in the lumen were enhanced (arrow indicates, Panel 8h). Coronal enhanced MPR showed the carotid segment of right ICA collapsed, and multiple plaques with stenosis from the rock bone segment to the ophthalmic segment were seen (arrow indicates, Panel 8i).

硬化、动脉夹层、动脉炎、烟雾病、肌纤维发育不良、动脉栓塞等，其中动脉粥样硬化是最主要原因[16]。对于无症状性和无法耐受手术的慢性颈内动脉闭塞患者，以抗血小板为主的药物治疗可能是最佳选择，阿司匹林联合氯吡格雷双联抗血小板治疗可进一步降低发病后90天缺血性卒中复发率，但长期疗效有所下降[17]，且增加出血风险[18]。对于有明显血流动力学障碍的慢性颈内动脉闭塞患者，颅内外血管搭桥术可在一定程度上改善脑灌注，但有研究显示，症状性慢性颈内动脉闭塞患者难以从高流量搭桥术和颞浅动脉-大脑中动脉搭桥术中获益[19-20]。颈动脉内膜切除术联合Forgaty球囊导管的复合手术对于闭塞远端位于岩骨段及以下的患者，血管再通成功率较高[21]，而对于闭塞远端位于海绵窦段以远的患者，血管再通成功率明显降低[22]。近年来，血管再通治疗作为闭塞性脑血管病的重要治疗方





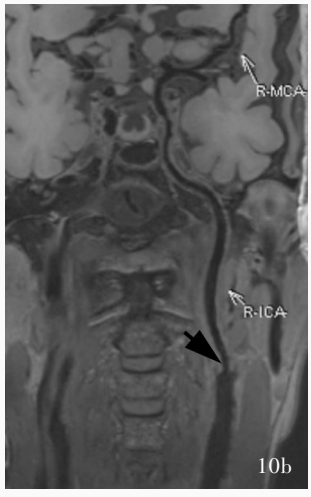


图9 例1患者术中DSA所见 9a 闭塞段内可见残腔(箭头所示),但无腔内血栓和动脉夹层形成 9b,9c 自上至下球囊扩张后,右颈内动脉岩骨段至床突段和起始部分别植入1枚支架,血管再通成功(TICI分级3级),远端血流通畅 **图10** 例1患者术后24个月影像学所见 10a MRA显示右颈内动脉通畅 10b 冠状位MPR显示,右颈内动脉起始部轻度狭窄(箭头所示),远端通畅

Figure 9 DSA findings during opration of Case 1 DSA showed residual cavity of occluded segment (arrow indicates), and no thrombosis or arterial dissection in the lumen (Panel 9a). After right ICA was dilated from top to bottom with a balloon, a stent was implanted in the siphon segment and right ICA bulb, and right ICA was successfully re-opened (TICI grade 3), the distal artery was unobstructed (Panel 9b, 9c). **Figure 10** Imaging findings at 24 months after operation of Case 1 MRA showed patency of right ICA (Panel 10a). Coronal MPR showed slight stenosis of the bulb of right ICA with patency of the distal end (arrow indicates, Panel 10b).

法逐渐广泛应用于临床,但在技术上具有一定挑战性[23]。术中可能导致颈动脉夹层、蛛网膜下腔出血或颈内动脉-海绵窦瘘等并发症,也可能发生斑块或栓子脱落栓塞远端血管致严重神经功能障碍甚至大面积脑梗死[10,24]。术者技术因素,闭塞节段管腔内是否存在血栓、残腔,以及有无动脉夹层、血管炎等病理学特点均是影响血管再通治疗成功率和围手术期并发症发生率的关键因素。

传统影像学检查(包括颈动脉超声、MRA、CTA或DSA)因各自的局限性,无法提供闭塞节段的精确信息,仅可作为初步筛查手段。尽管DSA为动态图像,可以相对清晰观察到闭塞段起止部位和形态,判断侧支代偿和近端反流情况,但因造影时信息采集时间限制和管腔内压力平衡而致血流相对静止,可能出现"假闭塞"的诊断[25];而且,DSA无法客观反映管腔内部结构,对闭塞节段的走行以及管腔内是否存在残腔、血栓、动脉夹层等具有较大的局限性。HR-VWI矢状位容积扫描和横断面图像采集,获得平扫和增强血管壁图像,通过对闭塞段内部结构进行定性和定量分析,清晰识别闭塞段起止部位,管腔内是否存在斑块、动脉夹层、血栓、残腔,及血管壁有无增厚、炎症反应及其重构情况[12,26]。HR-VWI通过黑血技术抑制流动的血流信号,使管腔内血流信号消失,从而更好地衬托管壁软组织信号;若有残腔则表现为闭塞节段残留低信号;血栓在SPACE平扫序列上表现为向管腔内突出的均匀混杂高信号影,增强扫描呈强化征象,后期血栓逐步机化后信号强度逐渐降低[27]。

本研究患者术前均行HR-VWI闭塞分型和DSA评估,术中造影确定闭塞段起止部位,有无残腔、血栓、动脉夹层和狭窄,支架植入部位,术后复查造影评价血管再通率,以及详细记录围手术期并发症。将HR-VWI分型结果与DSA进行对比分析,1例(1/11)HR-VWI分型Ⅲ型闭塞(颈内动脉全程闭塞)患

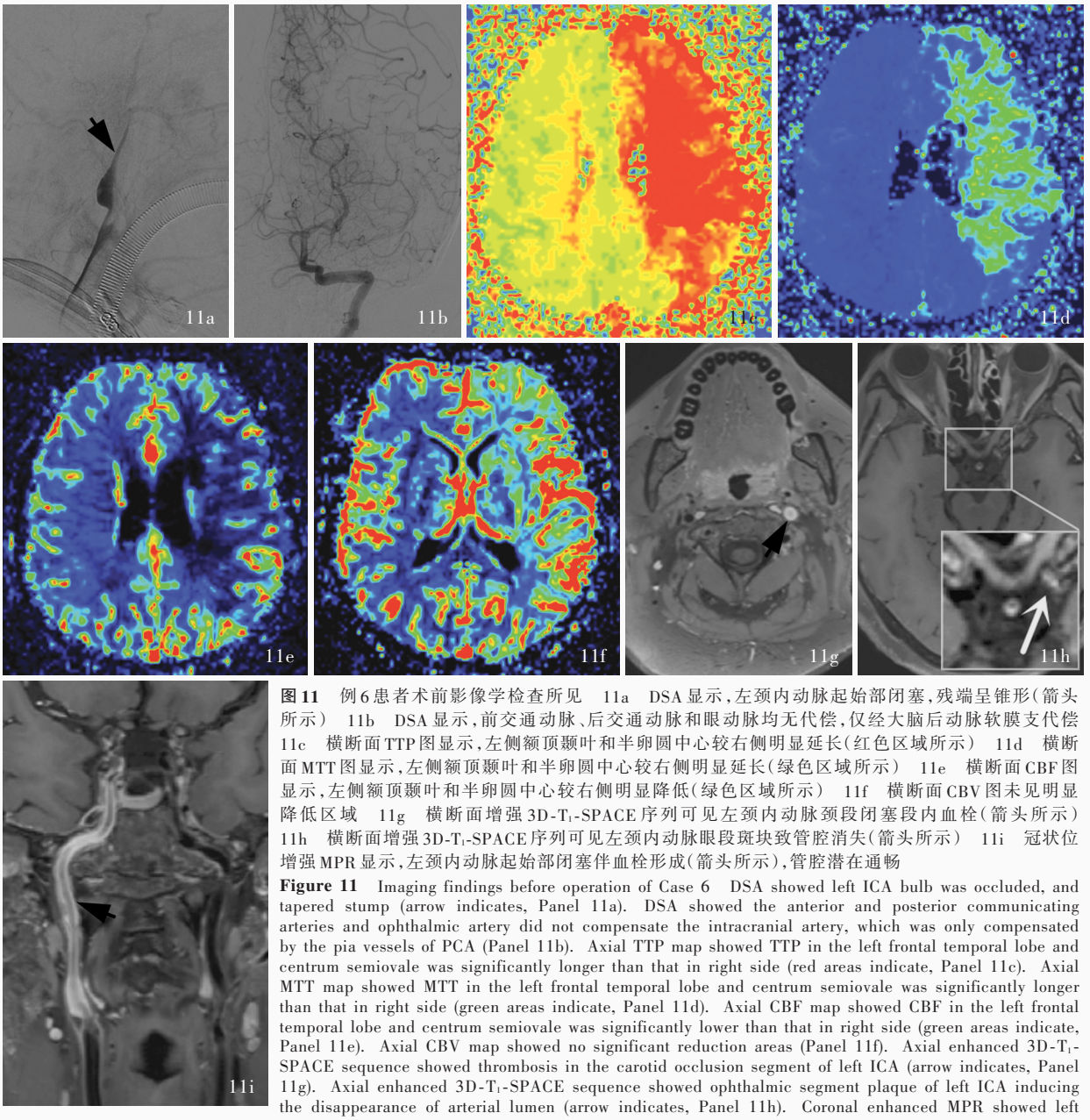


图11　例6患者术前影像学检查所见　11a　DSA显示，左颈内动脉起始部闭塞，残端呈锥形（箭头所示）　11b　DSA显示，前交通动脉、后交通动脉和眼动脉均无代偿，仅经大脑后动脉软膜支代偿　11c　横断面TTP图显示，左侧额顶颞叶和半卵圆中心较右侧明显延长（红色区域所示）　11d　横断面MTT图显示，左侧额顶颞叶和半卵圆中心较右侧明显延长（绿色区域所示）　11e　横断面CBF图显示，左侧额顶颞叶和半卵圆中心较右侧明显降低（绿色区域所示）　11f　横断面CBV图未见明显降低区域　11g　横断面增强3D-T_1-SPACE序列可见左颈内动脉颈段闭塞段内血栓（箭头所示）　11h　横断面增强3D-T_1-SPACE序列可见左颈内动脉眼段斑块致管腔消失（箭头所示）　11i　冠状位增强MPR显示，左颈内动脉起始部闭塞伴血栓形成（箭头所示），管腔潜在通畅

Figure 11　Imaging findings before operation of Case 6　DSA showed left ICA bulb was occluded, and tapered stump (arrow indicates, Panel 11a). DSA showed the anterior and posterior communicating arteries and ophthalmic artery did not compensate the intracranial artery, which was only compensated by the pia vessels of PCA (Panel 11b). Axial TTP map showed TTP in the left frontal temporal lobe and centrum semiovale was significantly longer than that in right side (red areas indicate, Panel 11c). Axial MTT map showed MTT in the left frontal temporal lobe and centrum semiovale was significantly longer than that in right side (green areas indicate, Panel 11d). Axial CBF map showed CBF in the left frontal temporal lobe and centrum semiovale was significantly lower than that in right side (green areas indicate, Panel 11e). Axial CBV map showed no significant reduction areas (Panel 11f). Axial enhanced 3D-T_1-SPACE sequence showed thrombosis in the carotid occlusion segment of left ICA (arrow indicates, Panel 11g). Axial enhanced 3D-T_1-SPACE sequence showed ophthalmic segment plaque of left ICA inducing the disappearance of arterial lumen (arrow indicates, Panel 11h). Coronal enhanced MPR showed left ICA occlusion with thrombosis (arrow indicates), and residual lumen at occluded segments (Panel 11i).

者，术前DSA显示颈内起始部至床突段闭塞并经眼动脉向颅内段微弱代偿，为Ⅱ型闭塞，术中DSA显示闭塞段为颈内动脉起始部至床突段闭塞并经眼动脉向颅内段代偿，与术前DSA判断一致；余10例（10/11）术中DSA显示的闭塞段起止部位与术前DSA和HR-VWI闭塞节段分型均一致；11例患者术中DSA显示的残腔、腔内血栓和动脉夹层情况均与HR-VWI闭塞内容分型相一致。表明对闭塞段起止部位的判断，DSA和HR-VWI均有较高的准确性；而对于闭塞节段内部情况的判断，DSA无法做出清楚的判断，而HR-VWI具有较高的准确性。

本研究有1例（1/11）血管再通失败，HR-VWI闭塞分型为Ⅲ-C型（颈内动脉全程闭塞，管腔萎缩塌陷，无残腔且无腔内血栓和动脉夹层），术中经微导管造影，闭塞段无残腔且无腔内血栓和动脉夹层，管腔内组织粘连紧密，微导丝无法通过闭塞段，并且起始部出现医原性夹层并逐渐向近端扩大，植入1枚Wallstent支架贴敷至颈内动脉起始部后夹层未

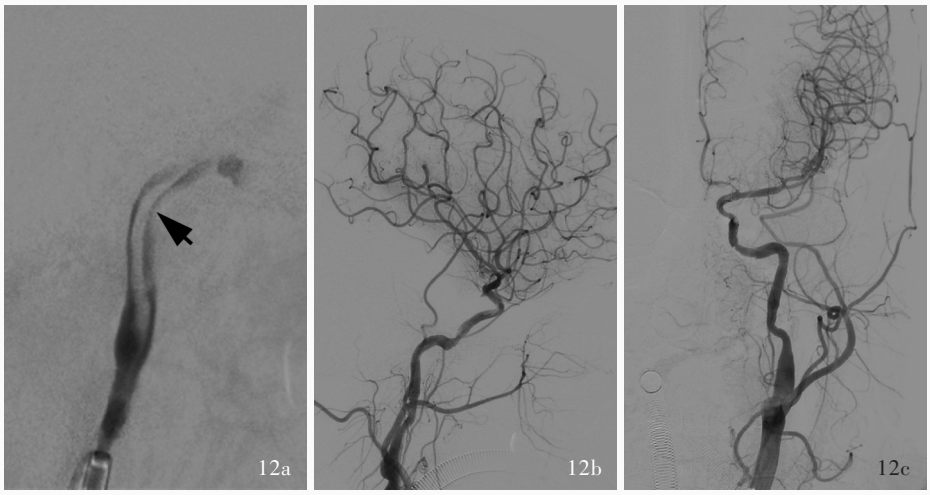


图12 例6患者术中DSA所见 12a 以泥鳅导丝配合多功能导管经左颈内动脉起始部造影显示，颈段管腔存在，闭塞段条状血栓松动游离，向远端漂浮至岩段（箭头所示） 12b，12c 开通左颈内动脉眼段后，共植入2枚支架将眼段和最终漂浮至海绵窦段的血栓一并覆盖，血栓贴壁良好，血管再通成功（TICI分级3级），远端血流通畅

Figure 12 Imaging findings during operation of Case 6 Loach guide wire and multifunctional catheter were used to enter the left internal carotid artery bulb during the operation, the presence of vascular lumen in the cervical segment could be seen, the thrombus in the occluded segment was loose and free, moving to distal of the rock bone segment (arrow indicates, Panel 12a). After opening the ophthalmic segment of left ICA, two stents were applied to cover the plaque in the ocular segment and the thrombus that eventually moved to the cavernous sinus segment, the thrombus was completely attached to the vascular wall, and the vascular recanalization was successful (TICI grade 3), and the distal end of the artery was unobstructed (Panel 12b, 12c).

再扩大，结束手术，术后无神经功能缺损。10例（10/11）血管再通成功，2例Ⅰ型闭塞和4例A型闭塞患者均血管再通成功，术中无动脉夹层、栓子脱落等并发症，提示单纯眼段闭塞以及有残腔但无腔内血栓和动脉夹层的慢性颈内动脉闭塞患者血管再通治疗安全、有效。2例B型闭塞和2例D型闭塞患者均血管再通成功，1例发生远端动脉栓塞，3例出现术中血栓松动。其中，1例B型闭塞患者为颈段条状附壁血栓，术中血栓松动并随血流向远端漂移至破裂孔段，开通眼段闭塞后植入1枚支架覆盖，血栓贴壁良好，无残留狭窄；2例D型闭塞患者术中出现血栓松动，其中1例为颈段和海绵窦段附壁血栓，术中血栓松动突入管腔，植入2枚支架覆盖，血管贴壁良好，管腔通畅，1例为闭塞段栓子脱落至大脑中动脉，机械取栓后血流通畅，术后未新增神经系统症状，复查MRI证实分水岭区新发梗死灶。由此可见，闭塞段有无残腔和腔内血栓可以影响血管再通成功率和围手术期并发症发生率。既往研究显示，颈内动脉闭塞后2周至2个月，血栓逐步机化，因其与血管壁粘连并有一定韧性，术中只要不用导丝、导管暴力推挤，一般不易破碎，支架覆盖后突出支架网孔的概率较低[28]。HR-VWI可以观察到闭塞段有无残腔和腔内血栓，有助于制定血管再通手术时间和手术方案，从而提高血管再通成功率、降低围手术期并发症。

随访至术后1个月时，改善6例，稳定5例；至术后3个月时，改善7例，稳定4例，提示术后短期内临床预后良好。术后6个月时，3例失访，余8例复查颈动脉超声、CTA或DSA，1例HR-VWI分型Ⅱ-D型闭塞患者发生支架内再狭窄，但无神经功能障碍，再次行球囊扩张术，7例未见支架内再狭窄。

本研究有一定的局限性：（1）为回顾性研究，该项技术开展时间较短，样本量相对较小，未进行统计分析。（2）未与药物治疗、复合手术、颅内外血管搭桥术等治疗方法进行对照研究，尚待进一步积累病例进行随机对照试验。（3）随访时间较短，缺少术后影像学随访资料，对远期预后的判断缺乏依据。

综上所述，HR-VWI分型与术中DSA显示的闭塞段起止部位，有无残腔、腔内血栓和动脉夹层具有较高的一致性；术前HR-VMI显示闭塞段有残腔提示血管再通成功率较高、安全性较好，管腔内有血栓可能增加围手术期手术并发症，但并不降低血管再通成功率。

利益冲突 无

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