·复杂颅内动脉瘤颅内-颅内血管搭桥术·

颅内-颅内血管搭桥术治疗九例复杂颅内动脉瘤疗效分析

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【摘要】 **目的** 探讨颅内-颅内血管搭桥术治疗复杂颅内动脉瘤的疗效。**方法** 纳入2014年2月至2020年5月在中南大学湘雅医院行颅内-颅内血管搭桥术的9例复杂颅内动脉瘤患者，采用桥血管移植搭桥或传出动脉（受体动脉）再植术。术后行CTA或DSA检查桥血管通畅情况、动脉瘤夹闭或切除情况、随访期间检查动脉瘤新发情况；并于出院时及随访期间采用改良Rankin量表（mRS）评估神经功能预后。**结果** 采用桡动脉（RA）或大隐静脉（GSV）移植桥血管4例，传出动脉（受体动脉）再植术5例，分别为大脑中动脉M2-RA-M2搭桥术1例、大脑前动脉A3-GSV-A3搭桥术1例、大脑后动脉P2-RA-P2搭桥术1例、颈内动脉（ICA）海绵窦段-GSV-ICA搭桥术1例、大脑中动脉M2下干-M2上干搭桥术1例、大脑前动脉A3-对侧A3搭桥术2例、小脑后下动脉-小脑前下动脉搭桥术2例。术后3 d复查CTA均显示桥血管通畅，未见动脉瘤显影；出院后3个月2例失访，余7例复查CTA或DSA均显示桥血管通畅，无动脉瘤新发；此7例患者长期随访，随访时间30.71个月，mRS评分均≤1分。**结论** 颅内-颅内血管搭桥术适用于常规手术难以处理的复杂颅内动脉瘤等疾病，具有所需桥血管短、更符合生理状态血流动力学等优势。

【关键词】 颅内动脉瘤； 脑血管重建术； 桡动脉； 隐静脉

Intracranial-intracranial bypass for the treatment of complex intracranial aneurysms: 9 cases report

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【**Abstract**】 **Objective** To explore the efficacy and advantages of intracranial-intracranial bypass for the treatment of complex intracranial aneurysms. **Methods** A total of 9 patients with complex intracranial aneurysms who underwent intracranial-intracranial bypass in Xiangya Hospital of Central South University from February 2014 to May 2020 were included, and were treated with grafts bypass or reimplantation of recipient arteries. All cases underwent CTA or DSA to detect the patent of grafts, whether aneurysms were completely clipped or resected and aneurysms recurrence occurred during the follow-up. Modified Rankin Scale (mRS) was used to evaluate the neurological prognosis at discharge and during the follow-up. **Results** Radial artery (RA) or great saphenous vein (GSV) was used for interposition in 4 cases, and recipient arteries were used for reimplantation in 5 cases. Of 4 cases of interposition, the cavernous sinus seoment of internal carotid artery (ICA)-GSV-ICA bypass was adopted in one case, middle cerebral artery (MCA) M2-RA-M2 bypass in one case, anterior cerebral artery (ACA) A3-GSV-A3 bypass in one case, posterior cerebral artery (PCA) P2-RA-P2 bypass in one case. Of 5 cases of reimplantation, MCA M2 inferior trunk was reimplanted to M2 superior trunk in one case, ACA A3 was reimplanted to contralateral A3 in 2 cases, the posterior inferior cerebellar artery (PICA) was reimplanted to the anterior inferior cerebellar artery (AICA) in 2 cases. CTA in 3 d postoperatively showed all cases grafts were patent and aneurysms disappeared. After 3 months of discharge, 2 were lost to follow-up. The other 7 cases kept the patency of grafts and no new aneurysms, and were constantly followed up, with an average follow-up time of 30.71 months, and mRS score was 1 or lower. **Conclusions** Intracranial-intracranial bypass can be

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applied for complex intracranial aneurysms that are difficult for conventional surgical treatment to solve. Compared with extracranial-intracranial bypass, its grafts are shorter and its hemodynamics features are more in line with physiological conditions.

【**Key words**】 Intracranial aneurysm; Cerebral revascularization; Radial artery; Saphenous vein
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随着神经介入材料尤其是血流导向装置和扰流装置的发展，颅内动脉侧壁和分叉部动脉瘤的治愈率进一步提高，大部分颅内动脉瘤已逐步从开颅夹闭手术步入介入栓塞手术治疗时代。然而对于一些复杂颅内动脉瘤以及累及颅内血管的外伤、肿瘤等的治疗，脑血管搭桥术仍是不可或缺的重要技术手段[1-6]。19世纪60年代末，Yasargil和Donaghy开展并推广颞浅动脉-大脑中动脉（STA-MCA）搭桥术[7]，即第一代脑血管搭桥术，至今仍是最常见、最广泛应用、最简单的颅外-颅内血管搭桥术，用于治疗颅内动脉瘤、烟雾病以及颅内动脉粥样硬化性狭窄和闭塞等疾病[8-9]。该术式采用头皮颞浅动脉与大脑表面血管进行吻合，其缺点为血流量较小。应用桥血管在颈动脉与颅内动脉之间建立旁路为第二代脑血管搭桥术，常用桥血管为大隐静脉（GSV）或桡动脉（RA）[10-11]，但该术式创口偏大，桥血管走行较长，有时难以找到合适的自体供体动脉。而后发展的颅内-颅内血管搭桥术不仅降低对桥血管的长度要求，而且搭桥后更符合生理状态下的血流动力学特点[10,12]，是治疗复杂颅内动脉瘤等的有效方法[11,13]。基于此，本研究回顾总结中南大学湘雅医院2014年2月至2020年5月采用颅内-颅内血管搭桥术治疗的9例复杂颅内动脉瘤患者的临床经过，以为该项技术的临床开展提供经验指导。

对象与方法

一、研究对象

选择中南大学湘雅医院神经外科2014年2月至2020年5月收治的9例行颅内-颅内血管搭桥术的患者，术前均经头部CTA或DSA明确诊断为复杂颅内动脉瘤，且手术前后临床资料、影像学资料完整；所有患者或其家属均对手术过程知情并签署知情同意书。男性4例，女性5例；年龄34～56岁，平均为（42.67±6.89）岁；临床表现为头痛、呕吐4例，头痛2例，意识障碍2例，头痛、头晕1例；术前影像学显示，大脑中动脉M2段动脉瘤2例、大脑前动脉（ACA）A3段动脉瘤2例、大脑前动脉A3段动脉瘤并重度狭窄1例、大脑后动脉（PCA）P2段动脉瘤1例、小脑后下动脉（PICA）动脉瘤2例、颈内动脉（ICA）海绵窦段外伤性假性动脉瘤1例（表1）。

二、研究方法

1.颅内-颅内血管搭桥术 （1）术前评估：除常规术前检查外，所有患者均行DSA或CTA检查。若需取桡动脉作为桥血管，术前行Allen试验以评价前臂动脉的侧支代偿；若取大隐静脉作为桥血管，有条件的情况下行下肢CTV，以确定下肢血流及管径情况。（2）手术过程：所有患者均在全身麻醉下行常规开颅切口（如翼点入路切口），充分显露术野，显露需行搭桥的血管（如行大脑中动脉M2-M2搭桥术，则需充分显露大脑中动脉M2段上干和下干）。根据需处理的动脉瘤毗邻关系确定吻合方式及是否使用桥血管。如需桥血管，则另一组手术医师在开颅过程中行前臂或下肢切口取桡动脉或大隐静脉。若行传出动脉（受体动脉）再植术，则将动脉瘤两端的载瘤动脉阻断后，将载瘤动脉与动脉瘤远端离断，并与毗邻动脉进行端侧吻合，完成传出动脉再植入后，夹闭动脉瘤近端，切除动脉瘤。若行桥血管移植搭桥，则将动脉瘤两端的载瘤动脉阻断后，取桥血管与传出动脉进行端侧吻合，再将桥血管另一端与动脉瘤近端载瘤动脉传入动脉进行端侧或端端吻合，随后取永久动脉瘤夹将动脉瘤孤立或切除。完成后，通过吲哚菁绿荧光血管造影术（ICGA）确认吻合口无渗血和桥血管通畅。

2.疗效评价 所有患者均在术后3 d内行CTA以检查桥血管通畅情况、动脉瘤夹闭或切除情况；术后3个月行CTA或DSA随访以确认桥血管通畅情况；之后每年完善一次CTA检查以确认桥血管通畅及动脉瘤新发。并于出院时及随访期采用改良Rankin量表（mRS）评估患者的神经功能预后，0分，完全无症状；1分，尽管有症状，但未见明显残疾，能完成所有经常从事的职责与活动；2分，轻残，不能完成所有以前能从事的活动，但能处理个人事务

表1 9例行颅内-颅内血管搭桥术的复杂颅内动脉瘤患者的临床资料

Table 1. Clinical data of 9 cases with complex intracranial aneurysms who underwent intracranial-intracranial bypass

序号	性别	年龄（岁）	临床表现	术前影像学检查（CTA/DSA）	搭桥情况（吻合情况）	术后3 d影像学检查（CTA/DSA）	出院时mRS（评分）	末次随访时mRS（评分）
1	女性	43	头痛、头晕11年	右MCA M2段梭形动脉瘤	M2-RA-M2（近端端端吻合-远端端侧吻合）	桥血管通畅，动脉瘤消失	1	0
2	女性	56	头痛、呕吐2个月	右ACA A3段梭形动脉瘤并重度狭窄	A3-GSV-A3（端侧吻合-端侧吻合）	桥血管通畅，动脉瘤消失	0	0
3	男性	36	外伤后意识障碍10 h（外院手术中大出血，纱布填塞后送至我院）	右ICA海绵窦段外伤性假性动脉瘤	ICA海绵窦段-GSV-ICA（端端吻合-端端吻合）	桥血管通畅，动脉瘤消失	1	1
4	男性	34	突发意识障碍后头痛、呕吐3 d	左PCA P2段动脉瘤，蛛网膜下腔出血	P2-RA-P2（端端吻合-端端吻合）	桥血管通畅，动脉瘤消失	1	1
5	女性	48	头痛3个月	左ACA A3段梭形动脉瘤	A3-对侧A3（端侧吻合）	桥血管通畅，动脉瘤消失	1	0
6	女性	38	头痛1年	右MCA M2段梭形动脉瘤	M2下干-M2上干（端侧吻合）	桥血管通畅，动脉瘤消失	1	1
7	女性	47	头痛、呕吐3个月	左PICA夹层动脉瘤	PICA-AICA（端侧吻合）	桥血管通畅，动脉瘤消失	1	失访
8	男性	43	突发意识障碍2 d	左PICA夹层动脉瘤	PICA-AICA（端侧吻合）	桥血管通畅，动脉瘤消失	1	0
9	男性	39	头痛、呕吐2年	右ACA A3段梭形动脉瘤	A3-对侧A3（端侧吻合）	桥血管通畅，动脉瘤消失	0	失访

mRS, modified Rankin Scale, 改良Rankin量表；MCA, middle cerebral artery, 大脑中动脉；ACA, anterior cerebral artery, 大脑前动脉；ICA, internal carotid artery, 颈内动脉；PCA, posterior cerebral artery, 大脑后动脉；PICA, posterior inferior cerebellar artery, 小脑后下动脉；RA, radial artery, 桡动脉；GSV, great saphenous vein, 大隐静脉；AICA, anterior inferior cerebellar artery, 小脑前下动脉

而无需帮助；3分，中残，需要一些协助，但行走无需协助；4分，重残，离开他人协助不能行走，生活不能自理；5分，严重残疾，卧床不起、大小便失禁，需持续护理和照顾；6分，死亡。

结　果

搭桥情况：采用桥血管移植搭桥4例，其中MCA M2-RA-M2（近端端端吻合-远端端侧吻合）搭桥术1例（例1）、ACA A3-GSV-A3（端侧吻合-端侧吻合）搭桥术1例（例2，图1）、PCA P2-RA-P2（端端吻合-端端吻合）搭桥术1例（例4，图2），以及ICA海绵窦段-GSV-ICA（端端吻合-端端吻合）搭桥术1例（例3，图3）；传出动脉（受体动脉）再植术5例，其中MCA M2下干-M2上干搭桥术1例（例6）、ACA A3-对侧A3搭桥术2例（例5、例9），以及PICA-AICA搭桥术2例（例7、例8）。术后影像学复查情况：9例患者术后3 d复查CTA均显示桥血管通畅，未见动脉瘤显影。出院后3个月有2例（例7、例9）失访；余7例获得长期随访，随访时间为术后3个月至6年，平均30.71个月，此7例患者术后长期随访复查CTA或DSA均显示桥血管通畅，未见动脉瘤新发。出院时及随访情况：出院时所有患者临床症状均较术前缓解，无死亡患者，无神经功能障碍，mRS评分≤1分。获得长期随访的7例患者末次随访时mRS评分均≤1分（表1）。

讨　论

近10年来，随着神经介入材料和技术发展迅速，血管内治疗在脑血管病中的应用越来越广泛，但搭桥技术作为累及颅内血管的外伤、肿瘤和血管病的补救或终极治疗方案，在将来很长一段时间仍颇具应用前景。脑血管搭桥术一般用于代替或补偿脑血流，如复杂颅内动脉瘤孤立术或烟雾病的搭桥治疗。

有学者根据脑血管搭桥术的发展演变，将其分为四代[9,14-15]。第一代脑血管搭桥术指将自体头皮游离颞浅动脉与大脑中动脉进行吻合，该技术可用于治疗烟雾病和部分需要替代或补偿脑血流的颅内动脉瘤夹闭术或孤立术等，但其血流量较小，亦称为低流量颅外-颅内血管搭桥术。第二代脑血管搭桥术以大隐静脉或桡动脉作为桥血管连接颈外动脉（ECA）与大脑中动脉，由于桥血管管径变粗，明显提高了血流量，适用于处理累及大血管的复杂颅内动脉瘤和肿瘤等；通常供体动脉选择颈部的颈总动脉（CCA）、颈外动脉，受体动脉选择大脑中动脉M2段、颈内动脉床突段或大脑后动脉P2段等，桥血管需要穿行皮下或下颌骨内侧的组织隧道，因此第二代脑血管搭桥术通常行头部、颈部和桥血管3处

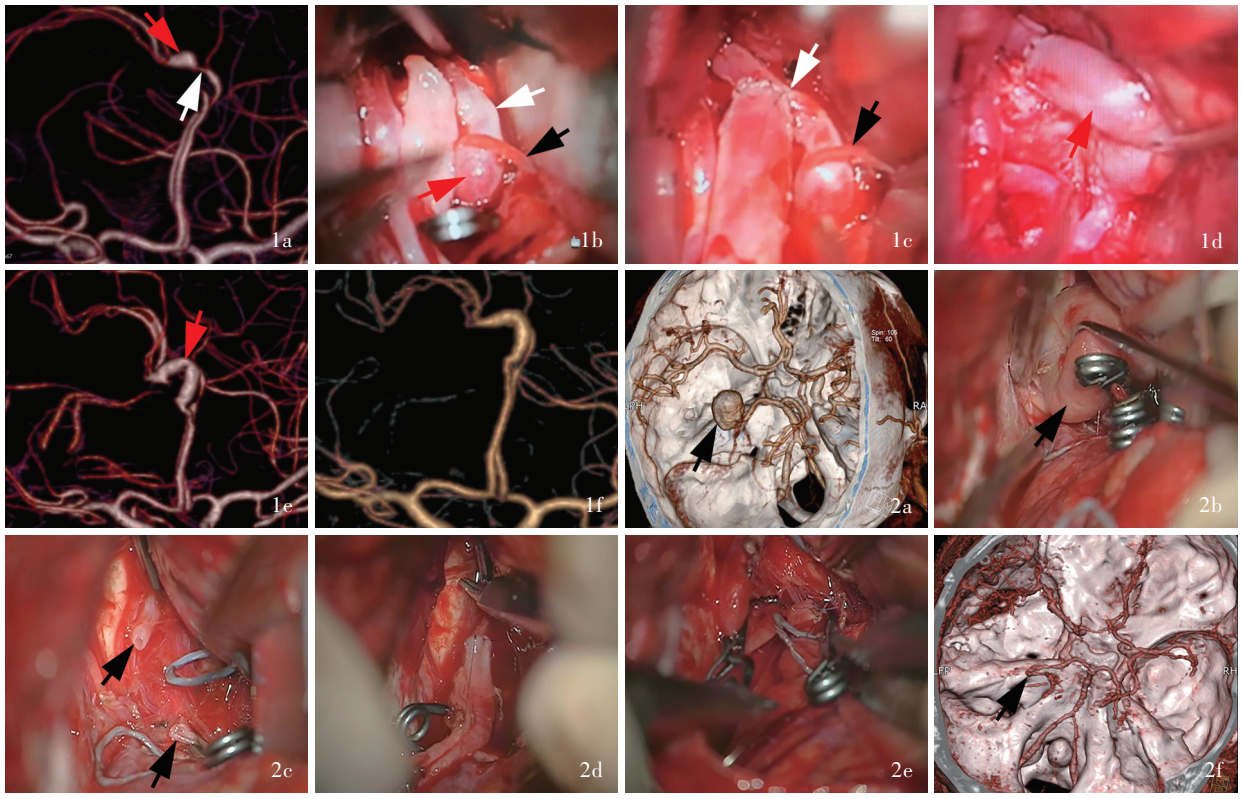

图1　例2患者手术前后影像学及术中所见　1a　术前CTA三维容积重建显示，右大脑前动脉A3段梭形动脉瘤（红色箭头所示）并重度狭窄（白色箭头所示）　1b　术中可见大脑前动脉狭窄（白色箭头所示）、动脉瘤（红色箭头所示），以及由大脑前动脉发出的穿支动脉（黑色箭头所示）　1c　取大隐静脉在狭窄近端与动脉瘤远端分别行端侧吻合（白色箭头示狭窄近端吻合口，黑色箭头示大脑前动脉发出的穿支动脉）　1d　完成吻合后，放开阻断，可见桥血管通畅（红色箭头所示），吻合口无渗血　1e　术后第1天复查CTA三维容积重建，桥血管通畅（红色箭头所示），动脉瘤消失　1f　术后1年复查CTA三维容积重建，桥血管通畅　**图2**　例4患者手术前后影像学及术中所见　2a　术前CTA三维容积重建显示，左大脑后动脉P2段动脉瘤（箭头所示）　2b　术中充分显露动脉瘤（箭头所示），可见瘤颈较厚，无法夹闭　2c　将动脉瘤切除后，可见P2段残端（箭头所示）　2d　取桡动脉为桥血管，P2段近端与桡动脉吻合　2e　P2段远端与桡动脉吻合　2f　术后第1天复查CTA三维容积重建，桥血管通畅（箭头所示），动脉瘤消失

Figure 1　Preoperative and postoperative imaging and intraoperative findings of Case 2　Preoperative CTA 3D volume reconstruction showed fusiform aneurysm (red arrow indicates) and severe stenosis (white arrow indicates) in the A3 segment of right ACA (Panel 1a). The stenosis of ACA (white arrow indicates), the aneurysm (red arrow indicates), and the perforating artery from ACA (black arrow indicates) were seen during operation (Panel 1b). The GSV was anastomosed to the proximal artery of the stenosis and the distal artery of the aneurysm (white arrow indicated the anastomosis at the proximal artery of the stenosis, and black arrow indicated the perforating artery from ACA; Panel 1c). After the anastomosis was completed, clips were released to show that the graft was patent (red arrow indicates, Panel 1d). CTA 3D volume reconstruction on the first day postoperatively showed the graft was patent (red arrow indicates) and the aneurysm disappeared (Panel 1e). CTA 3D volume reconstruction after one year postoperatively showed the patent graft (Panel 1f).　**Figure 2**　Preoperative and postoperative imaging and intraoperative findings of Case 4　Preoperative CTA 3D volume reconstruction showed an aneurysm on the P2 segment of left PCA (arrow indicates, Panel 2a). After the aneurysm was fully exposed (arrow indicates), we found that the aneurysm neck was thick, and could not be clipped (Panel 2b). The aneurysm was resected, two ends of the P2 segment of PCA were seen (arrows indicate, Panel 2c). The RA was used as the graft for bypass, and the proximal end of P2 was anastomosed to the RA (Panel 2d). The distal end of P2 was anastomosed to the RA (Panel 2e). CTA 3D volume reconstruction on the first day postoperatively showed the graft was patent (arrow indicates) and the aneurysm disappeared (Panel 2f).

切口，需要的桥血管长度达20 cm以上，且整条血管直径要求比较均匀，不能出现大的分支等[16]。一般只有体格健壮的男性和部分女性的桡动脉或大隐静脉能满足第二代脑血管搭桥术对桥血管长度和管径的要求。有学者曾探索使用上颌动脉作为供体动脉，以期降低对桥血管长度的要求，并减少颈部切口[10]，但该方法存在一些缺点，由于采用上颌动脉作为供体动脉，需要显露和牵开的颞肌范围较大，术后患者的颞肌萎缩明显，对容貌影响明显；部分患者上颌动脉存在变异，走行在翼肌内侧，无法显露，导致搭桥不能进行[17]。第三代脑血管搭桥术也称为颅内-颅内血管搭桥术或原位搭桥术，第三代脑血管搭桥术降低了第二代脑血管搭桥术对桥血管长度的要求[11]，同时搭桥完成后更符合正常脑血流动力学特点[18]。而将以上3种传统的搭桥方式组合运用，并运用多种吻合方式进行多次吻合时，则

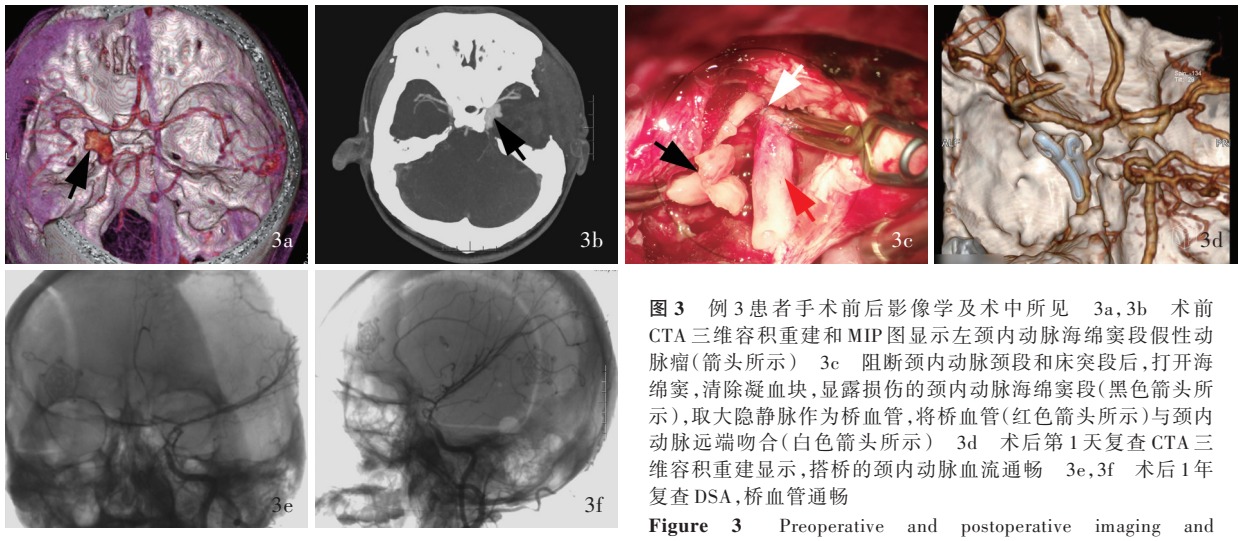

图3　例3患者手术前后影像学及术中所见　3a，3b　术前CTA三维容积重建和MIP图显示左颈内动脉海绵窦段假性动脉瘤（箭头所示）　3c　阻断颈内动脉颈段和床突段后，打开海绵窦，清除凝血块，显露损伤的颈内动脉海绵窦段（黑色箭头所示），取大隐静脉作为桥血管，将桥血管（红色箭头所示）与颈内动脉远端吻合（白色箭头所示）　3d　术后第1天复查CTA三维容积重建显示，搭桥的颈内动脉血流通畅　3e，3f　术后1年复查DSA，桥血管通畅

Figure 3　Preoperative and postoperative imaging and intraoperative findings of Case 3　Preoperative CTA 3D volume reconstruction (Panel 3a) and MIP (Panel 3b) showed a pseudoaneurysm in the cavernous sinus segment of left ICA (arrows indicate). After clipping the cervical and clinoid process segments of the ICA, the cavernous sinus was opened, blood clots were cleared, and the cavernous sinus segment of the injured ICA was exposed (black arrow indicates). A GSV was used as the graft (red arrow indicates) which was anastomosed to the distal end of the ICA (white arrow indicates, Panel 3c). CTA 3D volume reconstruction on the first day postoperatively showed the ICA was patent (Panel 3d). DSA one year after operation showed the patent graft vessel (Panel 3e, 3f).

被称为第四代脑血管搭桥术，常用于累及多条动脉的分叉部动脉瘤的治疗。

本研究所用技术均为第三代颅内-颅内血管搭桥术，该技术通常包括原有动脉的再吻合、传出动脉（受体动脉）再植术、移植桥血管重建原有动脉或分叉部。本研究有4例采用桥血管移植搭桥的方式，术中通常保持一定桥血管长度冗余，使得在缝合吻合口两侧时，可摆动桥血管达到充分显露和易于操作的目的[12,19]；另有5例采用就近取供体动脉的方式进行受体动脉的再植入，如ACA A3-对侧A3、PICA-AICA、MCA M2下干-M2上干的方式。而能否采用传出动脉（受体动脉）再植实现搭桥，主要视供体动脉与受体动脉走行的相对距离而定[19-20]，该方法对受体动脉可游离的长度有一定要求，有时甚至需要牺牲受体动脉的部分分支，以达到将受体动脉近端牵拉至供体动脉进行吻合的目的，故该搭桥方式常由于受体动脉游离长度有限，影响吻合口背侧的显露，增加缝合难度。在使用移植桥血管的方式时，为缩短阻断载瘤动脉带来的缺血时间，同时降低吻合难度，我们通常使用端侧吻合；而受体动脉毗邻脑动脉再植入的搭桥方式，通常是进行端侧吻合。由于颅内-颅内血管搭桥术的吻合方式采用原位方式，搭桥近端吻合口的位置几乎无可选择余地[4]，有时缝合部位会较深，操作在吻合口背面进行，不似第二代脑血管搭桥术可选择较浅的大脑中动脉M2段表面作为吻合口[20]。

虽然搭桥技术不断发展和迭代，但新一代搭桥技术的应用并非代表既往搭桥技术的终结，如颞浅动脉与大脑中动脉吻合的第一代脑血管搭桥术目前仍广泛应用于烟雾病的治疗，且如果颅内-颅内血管搭桥术的拟吻合动脉粥样硬化严重、吻合难度较大，亦可考虑仍使用第二代脑血管搭桥术。如遇复杂颅内动脉瘤的处理，甚至需要几代搭桥方式组合运用的第四代脑血管搭桥术[15,21]。因此在临床实践中，对于搭桥方式的选择应基于适合患者、简化手术、降低风险的原则。

利益冲突　无

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