·复杂颅内动脉瘤颅内-颅内血管搭桥术·

复杂颅内动脉瘤颅内-颅内血管搭桥术

苏赢　刘佩玺　史源　李培良　安庆祝　田彦龙　朱巍

【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及安全性。**方法与结果**　纳入2015年1月至2023年12月在复旦大学附属华山医院行颅内-颅内血管搭桥术的32例复杂颅内动脉瘤患者，手术方式为脑血管原位重建、再移植、再吻合及短距桥接，其中大脑中动脉动脉瘤（16例）原位重建5例，再移植1例，再吻合3例，短距桥接7例；大脑前动脉动脉瘤（8例）原位重建5例，再移植3例；前交通动脉动脉瘤（2例）均为原位重建；后循环动脉瘤（6例）原位重建3例，再吻合2例，短距桥接1例。术中桥血管通畅率达100%，无桥血管闭塞患者。参与术后6个月以上影像学随访的23例患者影像学均未见明显复发；参与改良Rankin量表随访的28例患者中5分1例，3分5例，2分2例，1分1例，0分19例。术后出现出血性并发症3例（9.37%），缺血性并发症10例（31.25%），无患者接受非计划二次手术治疗并发症。**结论**　颅内-颅内血管搭桥术治疗复杂颅内动脉瘤疗效及安全性较好，在复杂颅内动脉瘤的显微外科治疗中具有独特优势。

【关键词】 颅内动脉瘤；　脑血管重建术；　血流动力学

The application of intracranial - intracranial bypass for the treatment of complex intracranial aneurysms

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【**Abstract**】 **Objective**　To explore the efficacy and safety of intracranial-intracranial bypass for the treatment of complex intracranial aneurysms. **Methods and Results**　A total of 32 patients with complex intracranial aneurysms who were hospitalized for treatment at Huashan Hospital, Fudan University from January 2015 to December 2023 were included. Surgical methods included in-situ bypass, reimplantation, reanastomosis and bypass with interposition graft. For middle cerebral artery (MCA) aneurysms (n = 16), there were 5 cases of in-situ bypass, one case of reimplantation, 3 cases of reanastomosis, and 7 cases of bypass with interposition graft. For anterior cerebral artery (ACA) aneurysms (n = 8), there were 5 cases of in-situ bypass and 3 cases of reimplantation. For anterior communicating artery (ACoA) aneurysms (n = 2), both cases were in-situ bypass. For posterior circulation aneurysms (n = 6), there were 3 cases of in-situ bypass, 2 cases of reanastomosis, and one case of bypass with interposition graft. The intraoperative graft vessels patency rate was 100%. Among the 23 patients who participated in follow-up imaging for more than 6 months postoperatively, no obvious recurrence was indicated by imaging. Among the 28 patients who participated in modified Rankin Scale (mRS) follow-up, there was one case of 5, 5 cases of 3, 2 cases of 2, one case of 1, and 19 cases of 0. Postoperative hemorrhagic complications occurred in 3 cases (9.37%),

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and ischemic complications occurred in 10 cases (31.25%), with no patients requiring unplanned secondary surgery for complication treatment. **Conclusions** Intracranial-intracranial bypass has good efficacy and safety for the treatment of complex intracranial aneurysms and has unique advantages in the microsurgical treatment of complex intracranial aneurysms.

【Key words】 Intracranial aneurysm; Cerebral revascularization; Hemodynamics

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颅内动脉瘤是神经外科常见疾病，破裂后的残疾和死亡风险提高。随着神经介入技术的迅速发展，大型、复杂动脉瘤如特殊形态动脉瘤或瘤体包含动脉穿支等的治疗策略已从传统的显微外科手术转变为血管内治疗，然而，对于部分常规介入栓塞和开颅夹闭无法治愈的复杂动脉瘤，脑血管搭桥术仍显示出其实用性，随着显微外科技术的进步，颅内-颅内血管搭桥术在上述复杂动脉瘤治疗中的应用也日益增多。基于此，本文探讨在神经介入技术迅猛发展的背景下，颅内-颅内血管搭桥术治疗复杂动脉瘤的有效性和安全性，以期实现该技术的临床推广应用。

对象与方法

一、观察对象

1. 纳入标准 （1）纳入直径＞10 mm或非囊性（夹层、梭形、蛇形）复杂动脉瘤。（2）年龄12～85岁。（3）治疗方式为借助/不借助桥血管的颅内-颅内血管搭桥术。（4）破裂动脉瘤患者术前均完善头部CT及CTA检查；未破裂动脉瘤患者术前完善头部CT、CTA及DSA检查。

2. 排除标准 （1）临床信息及资料不全无法回溯病程和影像学特征的病例。（2）术中更改手术方案为孤立或夹闭动脉瘤或颅外-颅内血管搭桥术。（3）因其他非颅内病变原因出现围手术期并发症。

3. 一般资料 纳入2015年1月至2023年12月在复旦大学附属华山医院神经外科住院并采用颅内-颅内血管搭桥术治疗的复杂颅内动脉瘤患者共32例，男性17例，女性15例；年龄17～74岁，平均为（50±15）岁；动脉瘤位于大脑中动脉（MCA）16例，大脑前动脉（ACA）8例，前交通动脉（ACoA）2例，以及后循环6例；3例动脉瘤破裂致蛛网膜下腔出血，余29例为未破裂动脉瘤；非囊性动脉瘤15例，直径＞10 mm动脉瘤10例，其中直径＞10 mm的非囊性动脉瘤7例。

二、研究方法

1. 手术方法 患者术前均经充分评估并制定手术方案，备桡动脉（RA）搭桥患者术前完善Allen试验评估尺动脉代偿能力，在充分告知手术方案及风险的前提下签署手术知情同意书并接受手术治疗。手术方式包括脑血管原位重建（in-situ bypass）、再移植（reimplantation）、再吻合（reanastomosis），及利用桥血管的短距桥接（intracranial-intracranial bypass with interposition graft）。（1）脑血管原位重建：原位重建通常在脑血管搭桥供体和受体平行且紧密相邻时进行桥血管供体的侧侧吻合，该操作通常在动脉瘤的远端进行，无需额外的桥血管也无需头皮相关动脉（如颞浅动脉或枕动脉），在血流动力学上也可达到血流量的较好匹配。（2）再移植：通常是将动脉瘤远端血管通过端侧吻合的方式利用局部解剖毗邻关系吻合在另一正常血管上，通过这一正常血管和端侧吻合的方式向动脉瘤远端正常血管供血。（3）再吻合：动脉瘤切除后再次通过端端吻合方式将载瘤动脉两端重新吻合，恢复原始血流。（4）利用桥血管的短距桥接：是颅内-颅内血管搭桥术中需要桥血管的一种血流重建模式，系需重建的两根动脉之间由于空间距离过大或吻合口张力过大，需通过额外的桥血管将两根动脉沟通的搭桥方式。桥血管通常来自桡动脉或大隐静脉（GSV），桥血管两端通过端端或端侧两种方法完成吻合。

2. 疗效评价 （1）血管吻合即时通畅性：通过术中吲哚菁绿荧光血管造影术（ICGA）或术中DSA进行判断。（2）复发：随访期间采用头部CTA或头部MRA观察动脉瘤是否显影判断复发。（3）神经功能恢复情况：随访期间采用改良Rankin量表（mRS）评估患者神经功能恢复情况，0分，无症状，基本正常

生活;1分,虽然有症状,但不影响日常生活;2分,轻残,但仍能生活自理;3分,中残,需要帮助完成日常事务;4分,重残,生活需要长期帮助;5分,严重残疾,卧床,无法生活自理,完全依赖他人照顾;6分,死亡。评分越低、神经功能恢复越佳。

3.安全性评价 主要记录围手术期的出血和缺血事件,术后当日及术后1 d复查头部CT,明确是否存在术区出血;围手术期复查头部MRI(DWI)明确是否有缺血性并发症。同时统计患者住院时间。

结 果

在动脉瘤的处理上,直接夹闭或塑形夹闭4例,孤立或切除18例,近端和(或)远端阻断10例。在搭桥方式的选择上,不同位置的动脉瘤血流重建方式不同,16例大脑中动脉动脉瘤的血流重建中,多种重建方式均有应用,原位重建5例、再移植1例、再吻合3例、短距桥接7例(图1);8例大脑前动脉动脉瘤的血流重建由于纵裂的解剖结构,则以原位重建为主(5例,图2),另外3例完成再移植;2例前交通动脉动脉瘤均为大脑前动脉侧侧吻合进行的原位重建;6例后循环动脉瘤的血流重建中,3例原位重建、2例再吻合,1例短距桥接(表1)。

术中桥血管通畅率达100%,无桥血管闭塞患者;术后6个月以上的影像学随访率为71.87%(23/32),参与随访的23例患者影像学均未见明显复发;mRS评分电话回访率为87.50%(28/32),时间为术后3~96个月,中位时间为22(12,34)个月,mRS评分5分1例、3分5例、2分2例、1分1例、0分19例。

术后患者出现出血性并发症3例(9.37%),分别出现在1例(例9)大脑中动脉动脉瘤、1例(例32)前交通动脉动脉瘤和1例(例24)大脑前动脉A2段动脉瘤患者中,为术区脑实质出血,主要为脑挫裂伤,前两例经保守治疗后好转(mRS评分为零),大脑前动脉A2段动脉瘤患者遗留偏瘫(mRS评分3分),无患者接受非计划二次手术治疗并发症。缺血性并发症10例(31.25%),为载瘤动脉远端供血区及动脉瘤累及穿支脑梗死,1例(例31)前交通动脉动脉瘤和2例(例19、例22)大脑前动脉A2段动脉瘤患者经保守治疗后好转(mRS评分≤2分),7例(例2、例3、例5、例7、例8、例13、例14)大脑中动脉动脉瘤患者中3例(例2、例5、例8)遗留严重神经功能障碍(mRS评分>2分),无患者接受非计划二次手术治疗并发症。除1例(例15)多囊肾患者因术后转至肾病科进行透析无法统计住院时间外,余31例患者的住院时间为11~43 d,平均为(21.40±7.73)d。

讨 论

自1991年Guido Guglielmi发明可解脱弹簧圈并上市以来,为一部分难以夹闭的动脉瘤提供了快速、安全、有效的处理方案[1-4]。随后,血流导向装置(FD)的推出和应用对大型、宽颈颈内动脉动脉瘤的安全性和有效性得到验证[5-8]。针对未破裂血泡样、夹层、梭形或巨大型超过颈内动脉末端的动脉瘤,血流导向装置的超适应证也取得了不错的疗效,甚至在部分类型中成为一线治疗方案[9-14]。结合本研究所述动脉瘤的位置可以看出,由于脑池的天然解剖结构,颅内-颅内血管搭桥术被广泛用于大脑中动脉动脉瘤(侧裂池)、大脑前动脉动脉瘤(纵裂池)和小脑后下动脉(PICA)动脉瘤(小脑延髓池),在无法保留动脉瘤附近血供的情况下,则选择使用短的桥血管进行短距桥接方式[15]。相较而言,大脑前动脉动脉瘤的处理无更优的颅外-颅内血管搭桥术来替代,但是针对大脑中动脉复杂动脉瘤和小脑后下动脉动脉瘤,颞浅动脉-大脑中动脉(STA-MCA)搭桥术和枕动脉-小脑后下动脉(OA-PICA)搭桥术均为颅内-颅内血管搭桥术的替代方案。

颅内-颅内血管搭桥术是在Micheal Lawton、Robert F. Spetzler、Juha Hernesniemi、Tanikawa Rokuya等多位脑血管外科医师的推动下逐渐发展起来的[16-17],该术式使得并非所有血流重建均需要获取桥血管且进行2次吻合(如原位吻合),同时规避了颞浅动脉或枕动脉在血流量上的短板,在一定程度上简化了手术操作,缩短了手术时间,也避免了额外的皮肤切口和为桥血管预留的骨瓣缺损。在搭桥术式的选择上,既往文献已有不少总结和归纳[18],本中心也开展了一系列新的术式重建血流,如以大脑前动脉A1段为供体动脉、桡动脉为桥血管的短距桥接术式[19](图1),该术式通过近端阻断联合远端血流重建,是处理大脑中动脉M1段动脉瘤的经典术式,以A1段为供体的桡动脉搭桥在血流量和吻合口直径方面均更好匹配,且A1段与M2段的桥血管长度比颈外动脉(ECA)与M2段的桥血管长度更短;但颞浅动脉的两支均建议保留,如果出现桥血管术中并发症,颞浅动脉的两支搭桥可以作为挽救治疗的有效手段。该术式不仅适用于大脑中动脉复杂动脉瘤的治疗,也在大脑后动脉动脉瘤搭

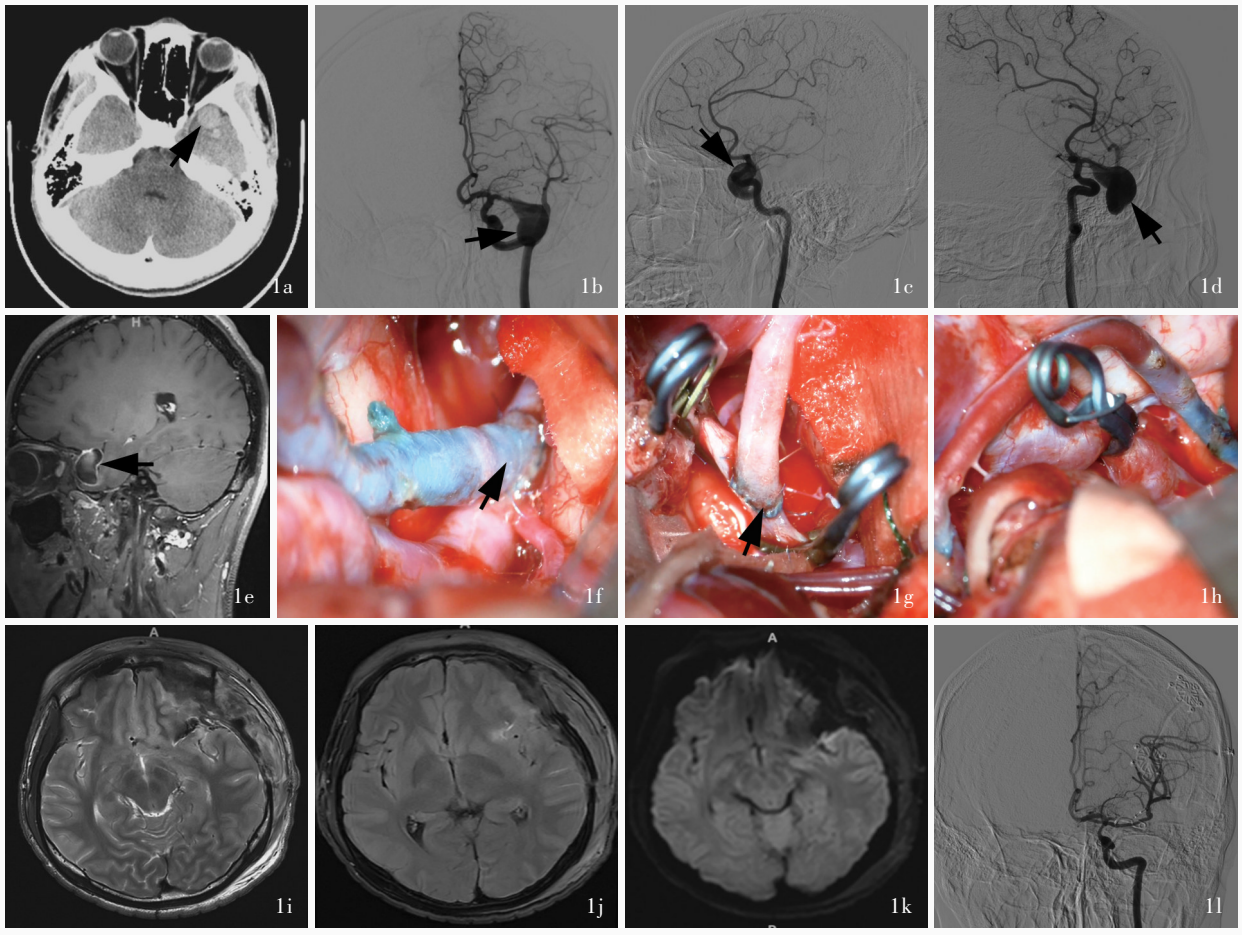

图1　男性患者(例16),17岁,因反复头痛5年,于2023年6月入院。临床诊断为左大脑中动脉M1段夹层动脉瘤,行A1-RA-M2搭桥术。手术思路及方案:动脉瘤位于左大脑中动脉M1段末端,为夹层动脉瘤,无法常规夹闭及塑形,血流重建方式选取桡动脉作为桥血管,行A1-RA-M2搭桥术,由于动脉瘤体有动脉穿支发出,故行近端阻断,穿支血供来自远端桥血管。手术前后影像学及术中所见　1a　术前横断面CT显示左侧颞叶前方高密度影(箭头所示)　1b~1d　术前正位、侧位、斜位DSA显示左大脑中动脉M1段夹层动脉瘤(箭头所示)　1e　术前增强VW-HRMRI显示动脉瘤壁明显强化伴瘤内高低混杂信号影,提示湍流(箭头所示)　1f　术中可见桡动脉(箭头所示)与大脑前动脉A1段的端侧吻合口　1g　术中可见桡动脉与大脑中动脉M2段的端侧吻合口(箭头所示)　1h　动脉瘤近端阻断　1i~1k　术后第3天横断面T_2WI、抑脂T_2-FLAIR成像、DWI均未见术区明显水肿及缺血　1l　术后第4天复查左颈内动脉DSA,未见左大脑中动脉M1段动脉瘤显影,桥血管通畅

Figure 1　A 17-year-old male patient (Case 16) was admitted (June 2023) due to recurrent headache for 5 years. The clinical diagnosis was dissection aneurysm of the M1 segment of left MCA, and A1-RA-M2 bypass was performed. Surgical approach and plan: the aneurysm was located at the end of the M1 segment of left MCA and was a dissection aneurysm, making conventional clipping and aneurysmoraphy unfeasible. The RA was chosen as the graft for blood flow reconstruction, and A1-RA-M2 bridge was conducted. Because the aneurysm had perforating arteries, proximal occlusion was performed, with the perforators receiving blood supply from the distal bypass graft. Preoperative and postoperative imaging and intraoperative findings　Preoperative axial CT showed a high-density lesion in the anterior left temporal lobe (arrow indicates, Panel 1a). Preoperative anteroposterior, lateral and oblique DSA showed a dissection aneurysm in the M1 segment of left MCA (arrows indicate, Panel 1b-1d). Preoperative enhanced VW-HRMRI showed significant enhancement of the aneurysm wall with intra sac mix signals showing turbulent blood flow inside the aneurysm (arrow indicates, Panel 1e). Intraoperative end-to-side anastomosis between RA (arrow indicates) and A1 (Panel 1f). End-to-side anastomosis between RA and M2 (arrow indicates, Panel 1g). Proximal occlusion of the aneurysm (Panel 1h). Postoperative axial T_2WI (Panel 1i), fat suppression T_2-FLAIR (Panel 1j) and DWI (Panel 1k) showed no significant edema or ischemia in the surgical area on the 3rd day after operation. Postoperative DSA of the left ICA showed no aneurysm visualization, and the graft was patent on the 4th day after operation (Panel 1l).

桥术中有所应用[20]。同时,动脉瘤切除术后的原位重建,也不仅仅限于端端吻合重建载瘤动脉,“Y”形分叉部血管重建同样具有可行性[21]。

是否需要搭桥以及如何选择颅内-颅内血管搭桥术,术前的影像学评估极其重要。除常见的不适合血管内治疗的情况,如无法耐受抗血小板治疗、感染性动脉瘤、明显占位效应动脉瘤等,在常规复杂动脉瘤的术前评估中,动脉瘤大小和是否为囊性并非决定是否需要血管搭桥术的指征,而是需要极具个体化的术前多模态评估。DSA可清晰提示血

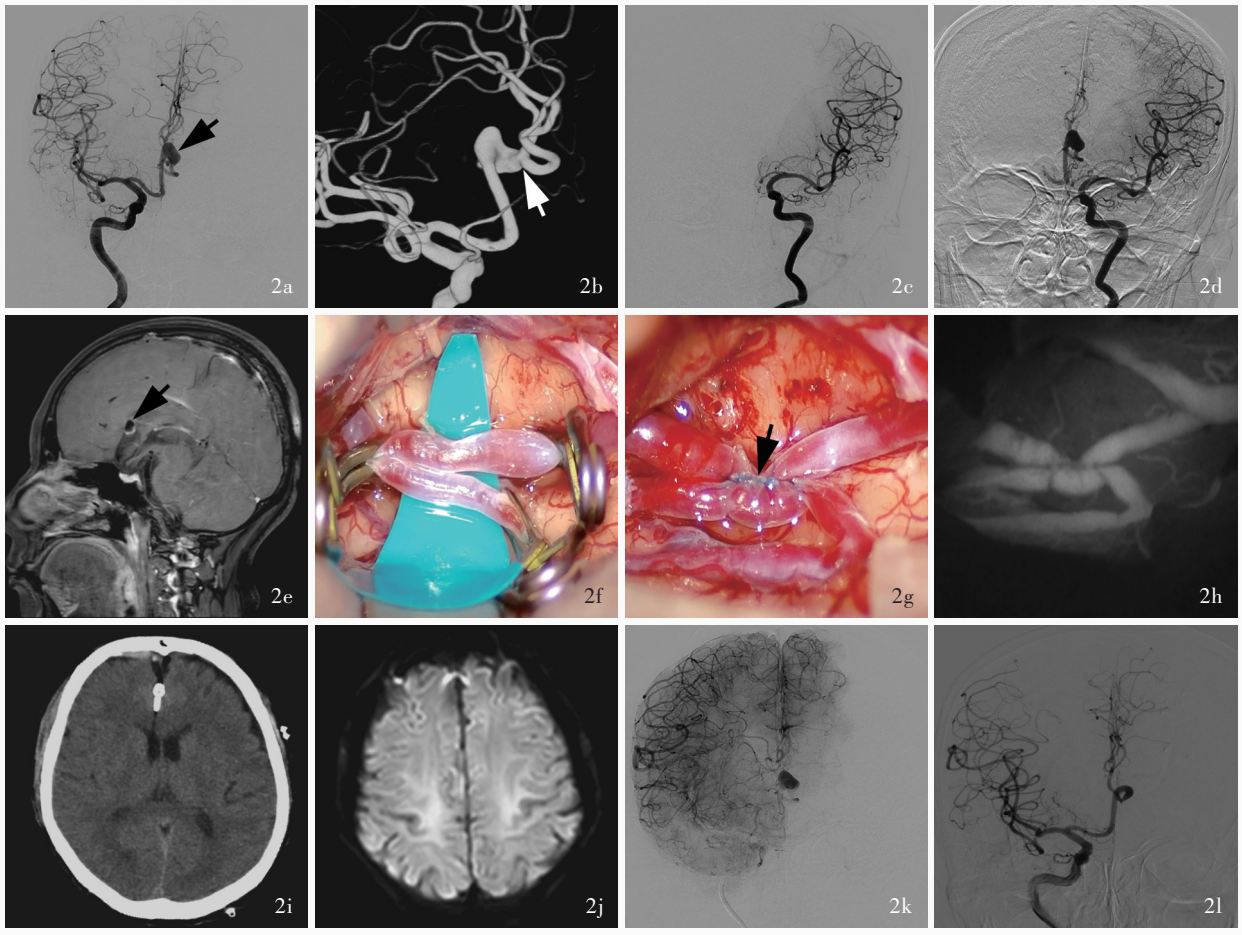

图2　女性患者(例23),57岁,因舌部麻木4个月,体检发现动脉瘤,于2022年2月入院。临床诊断为右大脑前动脉A2段与A3段分叉部动脉瘤,拟分阶段搭桥后行血管内血流导向装置植入术。手术思路及方案:动脉瘤位于分叉部,植入血流导向装置可引起另一支A3的血流量变化,有可能引起A3段供血区域脑梗死;载瘤动脉已动脉瘤化,无正常载瘤动脉,常规开颅夹闭和塑形困难且易复发,先行A3-A3侧侧吻合建立A3段远端血供,再二期植入血流导向装置,利用血流导向装置重塑载瘤动脉。手术前后影像学检查及术中所见　2a　术前右颈内动脉DSA显示,右大脑前动脉A2段与A3段分叉部动脉瘤(箭头所示)　2b　术前右颈内动脉DSA三维容积重建显示动脉瘤位于右大脑前动脉A2段与A3段分叉部,累及两支A3段(箭头所示)　2c　术前左颈内动脉DSA显示,双侧大脑前动脉未显影　2d　右颈内动脉压颈试验提示前交通开放　2e　术前增强VW-HRMRI显示动脉瘤壁明显强化(箭头所示)　2f　术中显露两支A3段　2g　术中可见两支A3段侧侧吻合口(箭头所示)　2h　术中ICGA提示双侧A3段通畅　2i　术后第1天复查CT未见明显出血　2j　术后第3天横断面DWI未见明显脑梗死　2k　二期手术植入血流导向装置后行右颈内动脉DSA显示动脉瘤内对比剂明显滞留　2l　术后8个月复查右颈内动脉DSA,动脉期显示动脉瘤已消失

Figure 2　A 57-year-old female patient (Case 23) was admitted (February 2022) due to an aneurysm was found during physical examination becase of experiencing tongue numbness for 4 months. The clinical diagnosis was an aneurysm at the A2-A3 bifurcation of right ACA. A staged approach was planned: performing a bypass first, followed by the implantation of a flow diverter. Surgical strategy and plan: the aneurysm was located at the bifurcation, and the implantation of the flow diverter could alter the blood flow to the other A3, which might cause cerebral infarction in the region supplied by A3. The parent artery had already developed aneurysmal changes, with no normal proximal artery, making conventional craniotomy for clipping and remodeling difficult and prone to recurrence. A3-A3 side-to-side anastomosis was first performed to establish distal A3 blood supply, followed by the placement of a flow diverter in a second stage to remodel the aneurysmal artery. Preoperative and postoperative imaging and intraoperative findings　Preoperative right ICA DSA showed an aneurysm at the A2-A3 bifurcation (arrow indicates, Panel 2a). Preoperative right ICA DSA 3D volume reconstruction showed the aneurysm located at the A2-A3 bifurcation involving both A3 branches (arrow indicates, Panel 2b). Left ICA DSA showed no bilateral ACA (Panel 2c). The right ICA neck compression test indicated open ACoA (Panel 2d). Preoperative enhanced VW-HRMRI showed significant enhancement of the aneurysm wall (arrow indicates, Panel 2e). Intraoperative exposure of both A3 branches (Panel 2f). The side-to-side anastomosis of both A3 branches (arrow indicates, Panel 2g). Intraoperative ICGA showed patency of both A3 branches (Panel 2h). Postoperative axial CT showed no obvious bleeding on the 1st day after operation (Panel 2i). Postoperative axial DWI showed no significant cerebral infarction on the 3rd day after operation (Panel 2j). In second stage operation, right ICA DSA after flow diverter placement showed significant retention of contrast agent within the aneurysm (Panel 2k). Eight months after operation, right ICA DSA showed disappearance of the aneurysm (Panel 2l).

管内信息,针对不适合血流导向装置(如载瘤动脉重度狭窄、动脉瘤累及重要分支等)和弹簧圈栓塞(如占位效应明显)的病例,可以进行初步判断,以决定是否需要开颅手术;高分辨率磁共振血管壁成

表1 32例复杂颅内动脉瘤患者动脉瘤部位及颅内-颅内血管搭桥术方式

Table 1. The locations and surgical methods for the treatment of complex intracranial aneurysms with intracranial-intracranial bypass in 32 cases

序号	动脉瘤部位	特殊动脉瘤	动脉瘤处理方式	血流重建方式
1	MCA M2	非囊性动脉瘤	近端阻断	M2-M2侧侧吻合
2	MCA M2	>10 mm	夹闭	M2-M2端侧吻合
3	MCA M1	>10 mm	孤立	A1-RA-M3
4	MCA M2	非囊性动脉瘤	切除	M2-M2端端吻合
5	MCA M3	>10 mm	切除	M3-M3端端吻合
6	MCA M1	非囊性动脉瘤	孤立	A1-RA-M2
7	MCA M1-M2分叉部	非囊性动脉瘤	近端阻断	A1-RA-M2
8	MCA M1-M2分叉部	>10 mm	孤立	M3-M3侧侧吻合
9	MCA M1-M2分叉部	>10 mm	近端阻断	A1-RA-M2
10	MCA M2	>10 mm，非囊性动脉瘤	孤立	A1-RA-M2+M2-M2侧侧吻合
11	MCA M1-M2分叉部	非囊性动脉瘤	夹闭	M2-M2侧侧吻合
12	MCA M1-M2分叉部	非囊性动脉瘤	塑形夹闭	M2-M2侧侧吻合
13	MCA M1-M2分叉部	>10 mm，非囊性动脉瘤	切除	“Y”形吻合
14	MCA M1	>10 mm	近端阻断	A1-RA-M2
15	MCA M2	非囊性动脉瘤	孤立	M3-M3侧侧吻合
16	MCA M1	非囊性动脉瘤	近端阻断	A1-RA-M2
17	ACA A4	>10 mm，非囊性动脉瘤	切除	A3-A3端侧吻合
18	ACA A3	非囊性动脉瘤	孤立	A3-A3侧侧吻合
19	ACA A2	>10 mm，非囊性动脉瘤	孤立	A3-A3端侧吻合
20	ACA A2	>10 mm，非囊性动脉瘤	孤立	A3-A3侧侧吻合
21	ACA A2	>10 mm	孤立	A3-A3侧侧吻合
22	ACA A2	非囊性动脉瘤	夹闭	A3-A3侧侧吻合
23	ACA A2-A3分叉部	>10 mm，非囊性动脉瘤	远端阻断	A3-A3侧侧吻合
24	ACA A2	>10 mm	近端阻断	A3-A3端侧吻合
25	PICA-PCA P2远端	非囊性动脉瘤	切除	PICA-PICA端端吻合
26	PICA起始部	>10 mm，非囊性动脉瘤	孤立	PICA-PICA侧侧吻合
27	PICA起始部	非囊性动脉瘤	切除	PICA-PICA端端吻合
28	PICA起始部	非囊性动脉瘤	孤立	PICA-PICA侧侧吻合
29	PCA P1	非囊性动脉瘤	远端阻断	A1-RA-P2
30	PICA-PCA P2远端	非囊性动脉瘤	孤立	PICA-PICA侧侧吻合
31	ACoA	>10 mm	近端阻断	A3-A3侧侧吻合
32	ACoA	>10 mm	近端阻断	A2-A2侧侧吻合

MCA，middle cerebral artery，大脑中动脉；ACA，anterior cerebral artery，大脑前动脉；PICA，posterior inferior cerebellar artery，小脑后下动脉；PCA，posterior cerebral artery，大脑后动脉；ACoA，anterior communicating artery，前交通动脉；RA，radial artery，桡动脉

像（VW-HRMRI）是影像学评估的另一重要方式，与脑血管造影提供的信息不同，VW-HRMRI可显示血管壁是否有壁间血栓和是否有瘤颈斑块等重要信息，这些都是决定能否常规夹闭的重要因素[22-25]。在手术策略的判定方面，部分复杂动脉瘤无法通过单一的手术策略治愈，特殊病例需要结合血管搭桥术和血管内治疗的分阶段治疗方式进行治疗（图2）。本研究例23患者在进行手术规划时认为，常规的单一动脉瘤术式均无法更好治愈动脉瘤且可以较确切地避免并发症，故我们采用颅内-颅内血管搭桥术二期植入血流导向装置的分期术式，先重建血流再以血流导向装置的血管内治疗方式，使患者获得治愈。

术前多模态评估可在大多数情况下预判搭桥术式，颅内-颅内血管搭桥术在操作方面仍需大量练习。颅内-颅内血管搭桥术通常基于深部血管吻合技巧，在狭小的解剖间隙中进行，且吻合操作位置较深，所需要的吻合时间较浅部吻合长，这意味着操作血管的临时阻断时间相应延长。脑血管原位重建多基于相互平行的两根动脉进行侧侧吻合，在深部吻合操作中侧侧吻合的难度更大，更易导致吻合口狭窄或闭塞；再移植技术是颅外-颅内血管搭桥术的颅内操作演变，也是脑血管病外科医师最为熟悉的端侧吻合操作；再吻合技术最为关键的是吻合口张力的判断，在高吻合口张力情况下，通常吻合困难，缝线易撕破血管壁，操作时间延长，血管狭窄率和闭塞率升高，但亦不可为吻合口张力而残留动脉瘤化的载瘤动脉，当吻合存在困难时，可考虑借助桥血管的短距桥接；短距桥接需借助流量合适的桥血管，通过两次吻合完成血流重建，颅内-颅内血管搭桥术无需很长的桥血管，故在取桥血管的同时可适当缩小桥血管切口，减少创伤。

本研究影像学随访的动脉瘤均未见明显复发，提示颅内-颅内血管搭桥术是一种效果较好的治疗手段。但仍有部分并发症出现，由于手术时间长，脑血管吻合对术野的空间要求高，仍有少部分患者出现出血性并发症，但围手术期缺血性并发症比出血性并发症发生率高，可能是由于临时阻断的时间稍长和血流重建后的桥血管流量在短时间无法代偿的原因，经过扩容等治疗，桥血管往往可根据血流量出现代偿，长期随访的mRS评分并未增加，围手术期影像学提示缺血的患者，也仅有个别出现缺血相关神经功能障碍。

在神经介入技术迅猛发展的时代，优秀且多样的血流导向装置取得显著进展和广泛应用，针对复

杂颅内动脉瘤的治疗，颅内-颅内血管搭桥术提供了一种有效和高度个性化的治疗选择，在特定病例中显示出其特有的优势和必要性。但这一技术的开展仍需有经验的神经外科、神经介入、神经影像、神经电生理、神经外科护理和神经麻醉团队进行细致的术前多模态评估、精准的手术执行及围手术期管理。后续研究和技术创新将进一步优化手术成果，降低围手术期并发症风险，改善患者生活质量。

利益冲突 无

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