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· 论 著 ·

血流导向装置治疗复杂颅内动脉瘤单中心经验

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[摘要] **目的** 评价应用 Tubridge 和 Pipeline 血流导向装置治疗复杂颅内动脉瘤的安全性和有效性。**方法** 回顾性连续纳入我科 2010 年 8 月至 2017 年 12 月应用血流导向装置治疗的 99 例患者共 101 个复杂颅内动脉瘤的临床资料, 其中 91 个为首次治疗, 10 个为复发动脉瘤。动脉瘤平均最大径为 (19.6 ± 6.6) mm, 94 个位于前循环, 7 个位于后循环。61 例患者的 61 个动脉瘤应用 Tubridge 血流导向装置治疗, 38 例患者的 40 个动脉瘤应用 Pipeline 血流导向装置治疗。术后予以临床随访与影像学随访。**结果** 99 例患者的 101 个动脉瘤共置入血流导向装置 116 枚 (Tubridge 74 枚、Pipeline 42 枚), 均成功输送并释放。术后 1 例患者发生迟发性出血并死亡, 2 例发生缺血性并发症。88 个动脉瘤获得了影像学随访, 其中短期随访 (0~6 个月) 完全闭塞率为 66.7% (42/63)、中长期随访 (7~18 个月) 完全闭塞率为 73.5% (36/49)、长期随访 (>18 个月) 完全闭塞率为 89.3% (25/28)。全部动脉瘤末次影像学随访完全闭塞率为 72.7% (64/88), Tubridge 组和 Pipeline 组分别为 73.6% (39/53) 和 71.4% (25/35), 差异无统计学意义 ($P > 0.05$)。**结论** 应用 Tubridge 血流导向装置与 Pipeline 血流导向装置治疗复杂颅内动脉瘤均安全有效, 但也存在一定的并发症风险。

[关键词] 颅内动脉瘤; 血流导向装置; 安全性; 有效性**[中图分类号]** R 651.22 **[文献标志码]** A **[文章编号]** 0258-879X(2019)03-0304-07

Flow diverters in treatment of complex intracranial aneurysms: a single-center experience

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[Abstract] **Objective** To evaluate the safety and efficacy of Tubridge and Pipeline embolization devices in the treatment of complex intracranial aneurysms. **Methods** The clinical data of 99 patients harboring 101 complex intracranial aneurysms, who underwent embolization device treatment between Aug. 2010 and Dec. 2017 in our department, were retrospectively collected and analyzed. Among them, 91 aneurysms were treated for the first time and 10 were recurrent lesions. The mean maximum diameter of the aneurysms was (19.6 ± 6.6) mm. Ninety-four lesions were located in anterior circulation and 7 in posterior circulation. Sixty-one aneurysms of 61 patients were treated with Tubridge embolization device, and 40 of 38 patients were treated with Pipeline embolization device. Clinical and angiographic follow-up were preformed conventionally. **Results** A total of 116 embolization devices (74 Tubridge and 42 Pipeline) were delivered and implanted successfully. One patient died of delayed hemorrhage, and 2 patients suffered from ischemic events after operation. Angiographic follow-up data was available in 88 aneurysms. The complete occlusion rates of short-term (0-6 months), mid-term (7-18 months) and long-term (>18 months) were 66.7% (42/63), 73.5% (36/49) and 89.3% (25/28), respectively. The complete occlusion rate of all aneurysms was 72.7% (64/88) at the last imaging follow-up, and there was no significant difference between the Tubridge and Pipeline groups (73.6% [39/53] vs 71.4% [25/35], $P > 0.05$). **Conclusion** Both Tubridge and Pipeline embolization devices are safe and effective in treatment of complex intracranial aneurysms. However, the complications shall not be ignored after implantation of embolization device.

[Key words] intracranial aneurysm; embolization device; safety; efficacy

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随着介入治疗技术与器具的快速发展,血管内治疗已成为颅内动脉瘤的主要治疗方式。血流导向装置的问世进一步颠覆了传统血管内治疗的理念,它通过改变动脉瘤瘤腔及其载瘤动脉的血流动力学,促进瘤内血栓的形成,最终达到治愈动脉瘤的目的。在临床应用经验不断积累和机制研究不断深入的基础上,各家介入器具厂商也相继推出了自己的血流导向装置产品,目前多见 Pipeline 血流导向装置(美国 Medtronic 公司)的相关临床报道^[1]。由我国自主研发的 Tubridge 血流导向装置[微创神通医疗科技(上海)有限公司]也已获准上市,其性能与疗效已得到多中心临床研究证实^[1-2]。本研究回顾性分析我科应用上述两种血流导向装置治疗复杂颅内动脉瘤的单中心数据,进一步探讨其安全性与有效性。

1 资料和方法

1.1 病例资料 回顾性连续纳入 2010 年 8 月至 2017 年 12 月我科应用血流导向装置治疗的复杂颅内动脉瘤病例,收集其临床及影像学资料进行分析。纳入标准:(1)最大径 ≥ 10.0 mm 或既往治疗后复发的颅内动脉瘤;(2)应用血流导向装置进行治疗。排除标准:(1)合并其他颅内血管性疾病;(2)严重肝肾功能不全;(3)临床及影像资料不完整;(4)拒绝签署手术知情同意书。本研究通过我院伦理委员会审批。

最终纳入 99 例患者共 101 个复杂颅内动脉瘤。其中男 26 例(26.3%),女 73 例(73.7%);患者年龄为 20~78 岁,平均年龄为(53.9 \pm 11.9)岁。89 例(89.9%)患者为首次行动脉瘤治疗,10 例(10.1%)患者因既往治疗后复发而行再治疗。首次治疗的 89 例患者中,首发症状为头痛者 20 例(22.5%)、头晕者 22 例(24.7%)、复视或视力下降者 31 例(34.8%)、短暂性脑缺血或缺血性脑卒中症状者 5 例(5.6%)、意外发现 11 例(12.4%)。

1.2 动脉瘤特征 101 个颅内动脉瘤中未破裂动脉瘤 91 个(90.1%),其中囊性动脉瘤 87 个(86.1%)、夹层动脉瘤 4 个(4.0%);其余 10 个(9.9%)为复发动脉瘤再治疗。动脉瘤最大径范围为 10.1~32.2 mm,平均最大径为(19.6 \pm 6.6) mm,其中 10.0~14.9 mm 者共 31 个(30.7%)、15.0~24.9 mm 者共 44 个(43.6%)、 ≥ 25.0 mm 者共 26 个(25.7%)。在

动脉瘤部位分布上,94 个(93.1%)位于前循环,包括颈内动脉海绵窦段 50 个(49.5%)、颈内动脉眼动脉段 17 个(16.8%)、颈内动脉床突段 19 个(18.8%)、颈内动脉末段 8 个(7.9%);其余 7 个(6.9%)位于后循环。

1.3 治疗策略 所有手术操作均在气管插管全身静脉麻醉下经股动脉穿刺入路进行。穿刺成功后予以全身肝素化。行常规旋转数字减影血管造影(digital subtraction angiography, DSA)检查并进行三维重建,测量动脉瘤和载瘤动脉远端及近端直径,依此制定治疗策略,选择合适的血流导向装置(Tubridge 血流导向装置或 Pipeline 血流导向装置)及弹簧圈。在血流导向装置释放过程中,以 6 F 或 7 F 导引导管为支撑,在微导丝辅助下将支架微导管[T-track 微导管,微创神通医疗科技(上海)有限公司;Marksman 微导管,美国 Medtronic 公司]超选至载瘤动脉远端,通过“Y”形阀将血流导向装置置入微导管内,将支架输送至微导管头端,在 X 线透视下定位。固定输送导丝,并缓慢回撤微导管释放血流导向装置,通过推送血流导向装置和回撤微导管的配合,增加瘤颈处的金属覆盖率,并促进支架的充分打开及贴壁。释放完成后使用 Artis Zee Biplane VC 14 医用血管造影机(德国西门子医疗系统有限公司)行动态计算机断层扫描(Dyna computed tomography, DynaCT)或使用 Allura Xper FD20 Biplane 造影机(荷兰 Philips 公司)行 VasoCT,评估血流导向装置打开及贴壁情况。对于血流导向装置打开欠满意或贴壁不良者,采用微导丝成襻技术或高顺应性球囊(Hyperform 或 Scepter 球囊,美国 Medtronic 公司)予以扩张。对于拟行血流导向装置结合弹簧圈栓塞治疗者,须在释放血流导向装置前将输送弹簧圈的微导管提前置于瘤内,应用支架后释放技术进行辅助栓塞。最后进行工作角度及标准正侧位造影,评估支架打开及远端血流的情况。

1.4 抗血小板聚集方案 患者于术前常规口服阿司匹林(300 mg 1 次/d)+氯吡格雷(75 mg 1 次/d),不少于 3 d。术中对患者行全身肝素化,术后肝素自然中和。术后 6 周内继续口服阿司匹林(100 mg、1 次/d)+氯吡格雷(75 mg 1 次/d)。3 个月后停用氯吡格雷,继续口服阿司匹林(100 mg、1 次/d),建议终身服用。

1.5 术后评估及临床和影像学随访 术后即刻,由 2 名高年资的神经外科医师共同评价手术效果。

对于合并使用弹簧圈的动脉瘤采用 Raymond 分级对动脉瘤栓塞情况进行评估: Raymond I 级为致密栓塞, Raymond II 级为瘤颈残留, Raymond III 级为瘤体残留。将单纯行血流导向装置支架成形术的动脉瘤根据支架置入后造影剂滞留情况分为有明显滞留和无明显滞留^[3]。本研究中复发动脉瘤在既往治疗中均合并使用弹簧圈,即刻结果以 Raymond 分级进行评价。

治疗前、治疗后及出院时均采用改良 Rankin 量表(modified Rankin scale, mRS)对患者临床症状进行评分,并记录新发的神经系统症状,之后对患者进行门诊或电话随访。建议所有患者术后3个月行头部磁共振血管造影(magnetic resonance angiography, MRA),6、12个月行 DSA 检查,以后每年定期行头部 MRA 检查。通过与前次影像学结果比较,将动脉瘤影像学结果判定为完全闭塞、进一步血栓形成、稳定、复发4类情况^[2]。

1.6 统计学处理 采用 SPSS 18.0 软件进行统计学分析。计量资料以 $\bar{x} \pm s$ 表示,两组间比较采用非参数检验;计数资料以例数和百分数表示,组间比较采用 χ^2 检验或其校正公式。检验水准(α)为0.05。

2 结果

2.1 手术情况 对 99 例患者 101 个动脉瘤共置入 116 枚血流导向装置(Tubridge 74 枚、

Pipeline 42 枚),均成功输送并释放。其中,61 个(60.4%)动脉瘤应用 Tubridge 血流导向装置治疗(Tubridge 组),40 个(39.6%)应用 Pipeline 血流导向装置治疗(Pipeline 组)。Tubridge 组共 61 例患者 61 个动脉瘤,平均年龄为(52.3±12.8)岁,男 18 例、女 43 例;Pipeline 组共 38 例患者 40 个动脉瘤,男 8 例、女 30 例,平均年龄为(56.8±10.1)岁。两组性别和年龄差异均无统计学意义(P 均>0.05)。

在治疗策略上,71 个(70.3%)动脉瘤行血流导向装置合并使用弹簧圈治疗(图 1),20 个(19.8%)行单纯血流导向装置置入治疗(图 2),10 个(9.9%)复发动脉瘤再次行血流导向装置合并使用弹簧圈治疗。4 个颈内动脉海绵窦段动脉瘤行 Pipeline 血流导向装置治疗时为进一步改善支架在血管迂曲处的贴壁情况行高顺应性球囊扩张,扩张后支架贴壁情况良好,载瘤动脉通畅。81 个行血流导向装置合并使用弹簧圈治疗的动脉瘤(含复发动脉瘤),术后即刻评估 2 个(2.5%)达到 Raymond I 级,4 个(4.9%)达到 Raymond II 级,75 个(92.6%)为 Raymond III 级;20 个行单纯血流导向装置置入治疗的动脉瘤中,17 个(85.0%)在血流导向装置置入后动脉瘤腔内造影剂明显滞留,3 个(15.0%)未见造影剂明显滞留。详见表 1。

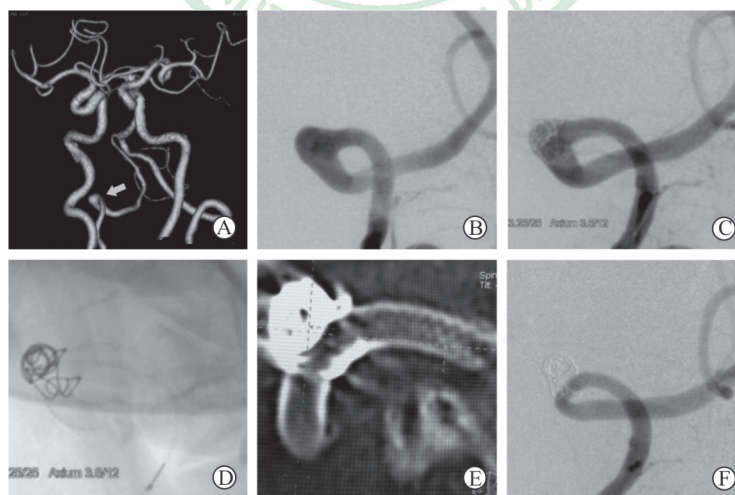


图 1 1 例行血流导向装置合并使用弹簧圈治疗的颅内动脉瘤患者影像学资料

Fig 1 Imaging data of a patient with intracranial aneurysm treated by embolization device with adjunctive coil

Male, 69 years old, dizziness and headache for 3 months and hypertension for 10 years. Computed tomography angiography showed an aneurysm (arrow) in right vertebral artery (A), and intraoperative angiography confirmed the right vertebral artery dissecting aneurysm (B), with proximal vascular diameter of 3.3 mm and distal vascular diameter of 3.2 mm. After a Pipeline embolization device was successfully deployed with 1 adjunctive coil, aneurysm body remained and the parent artery was unobstructed immediately (C), and the shapes of stent and coils were satisfactory (D, E). At 8 months after operation, the aneurysm was completely undetected and the parent artery was unobstructed (F). There was no new neurological dysfunction after operation

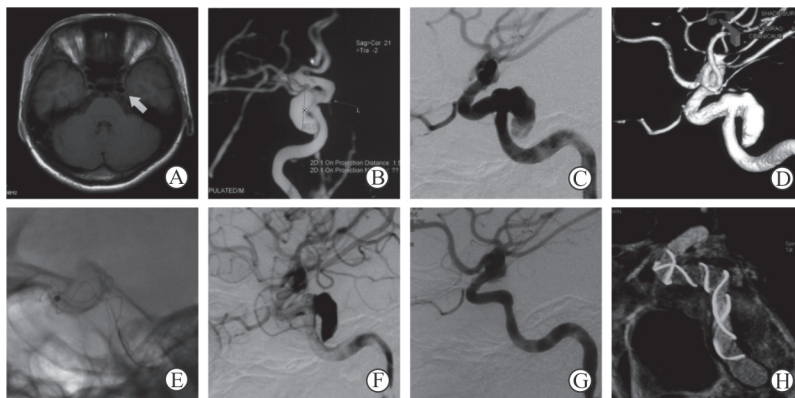


图2 1例单纯血流导向装置治疗的颅内动脉瘤患者影像学资料

Fig 2 Imaging data of a patient with intracranial aneurysm treated with embolization device alone

Female, 24 years old, blurred vision for 2 months. Magnetic resonance angiography showed a large aneurysm (arrow) of internal carotid artery cavernous segment (A, B). Left internal carotid artery angiography confirmed the cavernous sinus aneurysm of the left internal carotid artery (C). The maximum diameter of the aneurysm was 15.4 mm, with a wide neck of 6.7 mm. The proximal and distal diameters of the parent artery were 4.5 mm and 4.8 mm, respectively (D). A Tubridge embolization device was deployed successfully (E). Immediately after operation, the contrast agent was obviously retained and the parent artery was unobstructed (F). At 12 months after operation, the aneurysm was completely occluded (G), and the shape of stent was satisfactory (H)

表1 颅内动脉瘤一般资料及患者血流导向装置治疗情况

Tab 1 Baseline characteristics of intracranial aneurysms and treatment outcomes of the patients treated by embolization devices

Index	Total N=101	Tubridge N=61	Pipeline N=40	χ^2 value	<i>n</i> (%) <i>P</i> value
Aneurysm type				0.372	0.830
Saccular	87 (86.1)	52 (85.2)	35 (87.5)		
Dissecting	4 (4.0)	3 (4.9)	1 (2.5)		
Pre-treated	10 (9.9)	6 (9.8)	4 (10.0)		
Size <i>d</i> /mm				2.998	0.223
10.0-14.9	31 (30.7)	15 (24.6)	16 (40.0)		
15.0-24.9	44 (43.6)	30 (49.2)	14 (35.0)		
≥ 25.0	26 (25.7)	16 (26.2)	10 (25.0)		
Location				1.655	0.799
ICA-cavernous	50 (49.5)	28 (45.9)	22 (55.0)		
ICA-ophthalmic	17 (16.8)	11 (18.0)	6 (15.0)		
ICA-paraclinoid	19 (18.8)	11 (18.0)	8 (20.0)		
ICA-terminal	8 (7.9)	6 (9.8)	2 (5.0)		
Posterior circulation	7 (6.9)	5 (8.2)	2 (5.0)		
Treatment strategy				4.101	0.129
Embolization device alone	20 (19.8)	16 (26.2)	4 (10.0)		
Adjunctive coiling	71 (70.3)	39 (63.9)	32 (80.0)		
Pre-treated	10 (9.9)	6 (9.8)	4 (10.0)		
Immediate result					
Embolization device alone ^a				0.323	0.570
Stagnant flow	17 (85.0)	14 (87.5)	3 (75.0)		
Unchanged flow	3 (15.0)	2 (12.5)	1 (25.0)		
Adjunctive coiling ^b				0.662	0.718
Raymond I	2 (2.5)	1 (2.2)	1 (2.8)		
Raymond II	4 (4.9)	3 (6.7)	1 (2.8)		
Raymond III	75 (92.6)	41 (91.1)	34 (94.4)		
Complication ^c	3 (3.0)	1 (1.6)	2 (5.3)	0.947	0.331
Hemorrhagic	1 (1.0)	0 (0)	1 (2.6)		
Ischemic	2 (2.0)	1 (1.6)	1 (2.6)		
Mortality ^c	1 (1.0)	0 (0)	1 (2.6)	0.046	0.831

^a: Twenty intracranial aneurysms were treated by embolization devices alone; ^b: Eighty-one intracranial aneurysms were treated by embolization devices with adjunctive coils, including 10 recurrent lesions; ^c: A total of 99 patients in this study. ICA: Internal carotid artery

2.2 临床随访结果 围手术期内 Pipeline 血流导向装置组 1 例患者于置入术后 2 d 发生致死性动脉瘤破裂后死亡。2 例发生术后缺血性并发症,其中 1 例左侧海绵窦段动脉瘤在 Pipeline 血流导向装置置入术后 2 h 突发言语含糊,磁共振成像(magnetic resonance imaging, MRI)检查示左侧基底节区新鲜梗死灶,5 d 后发生肢体无力,头颅计算机断层扫描(computed tomography, CT)示

梗死区域出血转化,出院时 mRS 评分为 3 分;另 1 例为颈内动脉眼动脉段动脉瘤患者行 Tubridge 血流导向装置治疗,脉络膜前动脉发生闭塞,出院时 mRS 评分为 2 分,随访过程中功能缺损进一步恢复。98 例患者治疗前、出院时及末次随访 mRS 评分见表 2, Tubridge 组和 Pipeline 组各时间点 mRS 评分差异均无统计学意义(P 均 >0.05)。

表 2 颅内动脉瘤治疗前、出院时及随访时改良 Rankin 量表评分

Tab 2 Clinical outcomes of patients treated by embolization devices

Modified Rankin scale score	Total N=98	Tubridge N=61	Pipeline N=37	χ^2 value	P value
<i>n</i> (%)					
Pre-operative				0.144	0.930
0-1	91 (92.9)	57 (93.4)	34 (91.9)		
2	5 (5.1)	3 (4.9)	2 (5.4)		
≥ 3	2 (2.0)	1 (1.6)	1 (2.7)		
At discharge				1.134	0.576
0-1	89 (90.8)	56 (91.8)	33 (89.2)		
2	6 (6.1)	4 (6.6)	2 (5.4)		
≥ 3	3 (3.1)	1 (1.6)	2 (5.4)		
Last follow-up ^a				1.057	0.590
0-1	83 (91.2)	52 (92.9)	31 (88.6)		
2	5 (5.5)	3 (5.4)	2 (5.7)		
≥ 3	3 (3.3)	1 (1.8)	2 (5.7)		

^a: Seven patients were lost during follow-up

共 91 例患者获得临床随访,随访时间为 6~74 个月,平均(28.7±12.2)个月。7 例患者失访。随访过程中无新发出血及缺血事件。以复视或视力下降为首发症状的 31 例患者中,23 例(74.2%)症状缓解,8 例(25.8%)症状稳定,无一例患者症状进一步加重。

2.3 影像学随访结果 在 101 个颅内动脉瘤中,共 88 个(87.1%)获得了影像学随访,失访(含死亡病例)13 个(12.9%)。63 个动脉瘤获得了短期随访(0~6 个月),其中 42 个(66.7%)动脉瘤完全闭塞,15 个(23.8%)进一步血栓形成,5 个(7.9%)稳定,1 个(1.6%)复发;49 个动脉

瘤获得了中长期随访(7~18 个月),其中 36 个(73.5%)动脉瘤完全闭塞,11 个(22.4%)进一步血栓形成,1 个(2.0%)稳定,1 个(2.0%)复发;28 个动脉瘤获得了长期随访(>18 个月),其中 25 个(89.3%)动脉瘤完全闭塞,2 个(7.1%)进一步血栓形成,1 个(3.6%)稳定,无动脉瘤复发。全部动脉瘤末次影像学随访动脉瘤完全闭塞率为 72.7%(64/88),Tubridge 组和 Pipeline 组末次随访动脉瘤完全闭塞率差异无统计学意义($\chi^2=0.049$, $P=0.824$;表 3)。载瘤动脉及覆盖分支均保持通畅,远端血流未受影响,无相关临床症状。

表 3 血流导向装置治疗颅内动脉瘤影像学随访动脉瘤完全闭塞率

Tab 3 Complete occlusion rate of intracranial aneurysms treated by embolization devices during follow-up

Group	Short-term (0-6 months)	Mid-term (7-18 months)	Long-term (>18 months)	Last follow-up
Total	66.7 (42/63)	73.5 (36/49)	89.3 (25/28)	72.7 (64/88)
Tubridge	64.9 (24/37)	67.7 (21/31)	91.3 (21/23)	73.6 (39/53)
Pipeline	69.2 (18/26)	83.3 (15/18)	80.0 (4/5)	71.4 (25/35)

3 讨论

血流导向装置的临床应用改变了颅内动脉瘤介入治疗的传统理念,随着临床经验的不断积累,

已成为复杂颅内动脉瘤的重要治疗手段^[5-6]。相较于常规颅内支架,血流导向装置通过重塑颅内动脉瘤及其载瘤动脉的血流动力学环境,促进瘤内血栓的形成,并为新生血管内膜提供附着,从而最终

实现颅内动脉瘤的治愈性闭塞^[7]。既往研究显示,应用血流导向装置治疗大型、巨大型等复杂颅内动脉瘤,其完全闭塞率显著高于常规弹簧圈辅助栓塞治疗^[8]。Kallmes等^[1]报道应用 Pipeline 血流导向装置治疗 1 221 例颅内动脉瘤,随访显示 6 个月完全闭塞率达 75%,1 年完全闭塞率达 85.5%;而 Liu 等^[2]应用 Tubridge 血流导向装置治疗复杂动脉瘤的前瞻性多中心随机对照研究结果显示,Tubridge 治疗组术后 6 个月的完全闭塞率达 75.3%,显著高于支架辅助弹簧圈栓塞组的 24.5%。

除了具有较高的治愈率外,血流导向装置相较于载瘤动脉闭塞、弹簧圈辅助栓塞等常规介入治疗方法能够有效缓解大型、巨大型动脉瘤产生的占位效应。Zanaty 等^[9]比较了应用血流导向装置、支架辅助栓塞、单纯栓塞及载瘤动脉闭塞 4 种方法治疗颈内动脉海绵窦段动脉瘤的临床疗效,结果显示接受血流导向装置治疗的患者症状缓解率(92.16%)显著高于其他治疗方案组。Puffer 等^[10]报道使用 Pipeline 血流导向装置治疗 44 例颈内动脉海绵窦段动脉瘤患者,随访时 90% 的患者症状改善。而在本组病例中以复视或视力下降为首发症状的 31 例患者,在临床随访过程中 23 例(74.2%)症状缓解,8 例(25.8%)症状稳定,均未出现症状加重。

虽然血流导向装置对于治疗复杂颅内动脉瘤较常规介入治疗方法更具优势,但仍有部分病例在接受血流导向装置治疗后未能实现动脉瘤的有效闭塞。Brasiliense 等^[11]研究显示,动脉瘤的大小与部位会影响血流导向装置治疗闭塞率,体积较小、位于颈内动脉近端的动脉瘤其闭塞率较高。除了动脉瘤本身的特征,Rouchaud 等^[12]应用兔动脉瘤模型对影响血流导向装置闭塞率的因素进行了研究,结果显示血流导向装置支架的贴壁情况是影响动脉瘤闭塞的关键因素;Aquarius 等^[13]应用大鼠动脉瘤模型也得到了相似结论,认为提高血流导向装置支架贴壁性比提高金属覆盖率更重要。在本组病例中,有 2 例患者在血流导向装置释放过程中发生支架贴壁不良,因此应用球囊对支架进行了后扩张,后期也取得了良好的治疗效果。合并应用弹簧圈被认为能够加快瘤内血栓的形成,提高血流导向装置的远期疗效^[14];但一项基于 Pipeline 血流导向装置的前瞻性研究显示,合并应用弹簧圈治疗较单独血流导向装置治疗的平均手术时间增加,同时其死亡率也较高,仍需进一步研究^[15]。目前仍多主张在硬膜环内,特别是对大型、巨大型动脉瘤的治疗应合并应用弹簧圈^[6]。

血流导向装置治疗颅内动脉瘤整体上是安全的,但仍存在一定的并发症风险。一项 meta 分析

显示血流导向装置治疗颅内动脉瘤的总体并发症率为 17%,其中永久性致残率为 3.7%,致死率为 2.8%^[16]。动脉瘤迟发性出血是血流导向装置置入后最严重的并发症之一^[17],在本组病例中,亦有 1 例患者在 Pipeline 血流导向装置置入后 2 d 发生致死性的动脉瘤破裂出血。Cebal 等^[18]应用流体力学模拟技术对血流导向装置置入后的血流动力学变化进行分析,结果显示血流导向装置置入后会引肿瘤内压力增高,这可能是导致动脉瘤发生破裂的原因之一。同时,Ikeda 等^[19]通过对血流导向装置术后动脉瘤破裂的患者进行尸体解剖发现,虽然动脉瘤的流出道已形成血栓,但在流入道仍有入射血流的存在,也提示血流导向装置置入后动脉瘤血流动力学环境的变化与动脉瘤破裂有关。相较于血流导向装置术后动脉瘤破裂,迟发性的脑实质出血发生率可能更高,文献报道其发生率为 4.0%~8.5%,但其发生原因尚不明确^[20-21]。本组病例中也有 1 例患者发生实质性脑出血,但其术后早期 MRI 检查有明确的缺血性脑卒中证据,提示缺血性脑卒中后出血转化可能是血流导向装置术后脑实质出血的机制之一。由于血流导向装置的金属覆盖率较常规颅内支架更高,其发生缺血性事件的风险不容忽视,缺血性事件主要由支架内血栓、载瘤动脉或分支血管闭塞所致^[16]。本组病例中有 1 例患者血流导向装置覆盖的脉络膜前动脉发生闭塞导致缺血性事件。文献报道血流导向装置覆盖分支在随访中发生血流减少或闭塞的比例为 15.8%~20%,其是否会导致相关缺血性并发症仍需进一步的长期随访数据^[22-23]。

由于血流导向装置为编织支架,其释放技术有别于以往的激光雕刻支架,在操作过程中应注重推拉技术的配合,以使血流导向装置在精确定位的同时能够充分打开和贴壁。血流导向装置释放后建议常规进行 DynaCT 或 VasoCT 重建,以准确判断其打开及贴壁情况。如果血流导向装置打开不满意,可以使用“J”形导丝技术进行支架内按摩或应用球囊进行扩张。本研究中应用的两种血流导向装置在安全性与有效性上相似,但在支架特性和实际操作中又略有不同,其根本在于两种血流导向装置采用的金属材质不同。Pipeline 血流导向装置为钴铬合金材料,具有较好的径向支撑力,打开后远端可提供较好的锚定,在长直血管中贴壁性良好,也正是因为较大的径向支撑力,Pipeline 血流导向装置第 1 代的 Classic 和第 2 代的 Flex 均设计了头端保护装置,避免在输送过程中对血管造成损伤。而 Tubridge 为镍钛合金材料,能提供良好的柔顺性,通过推拉技术的配合在弯曲血管甚至是“S”形血管均能获得良好的贴壁,整体操作简单。以上支架性能及操作技巧上的不同在病例选择过程中应

予以考虑。

综上所述,本研究结果显示应用 Tubridge 和 Pipeline 两种血流导向装置治疗复杂颅内动脉瘤均能取得良好的疗效,但也存在一定的并发症风险。其有效性和安全性的进一步提升有赖于更深入的临床研究和机制研究。

[参考文献]

- [1] KALLMES D F, BRINJIKJI W, CEKIRGE S, FIORELLA D, HANEL R A, JABBOUR P, et al. Safety and efficacy of the Pipeline embolization device for treatment of intracranial aneurysms: a pooled analysis of 3 large studies[J]. *J Neurosurg*, 2017, 127: 775-780.
- [2] LIU J M, ZHOU Y, LI Y, LI T, LENG B, ZHANG P, et al. Parent artery reconstruction for large or giant cerebral aneurysms using the Tubridge flow diverter: a multicenter, randomized, controlled clinical trial (PARAT)[J]. *AJNR Am J Neuroradiol*, 2018, 39: 807-816.
- [3] RAYMOND J, GUILBERT F, WEILL A, GEORGANOS S A, JURAVSKY L, LAMBERT A, et al. Long-term angiographic recurrences after selective endovascular treatment of aneurysms with detachable coils[J]. *Stroke*, 2003, 34: 1398-1403.
- [4] QUINN T J, DAWSON J, WALTERS M R, LEES K R. Reliability of the modified Rankin scale: a systematic review[J]. *Stroke*, 2009, 40: 3393-3395.
- [5] WALCOTT B P, STAPLETON C J, CHOUDHRI O, PATEL A B. Flow diversion for the treatment of intracranial aneurysms[J]. *JAMA Neurol*, 2016, 73: 1002-1008.
- [6] BRINJIKJI W, MURAD M H, LANZINO G, CLOFT H J, KALLMES D F. Endovascular treatment of intracranial aneurysms with flow diverters: a meta-analysis[J]. *Stroke*, 2013, 44: 442-447.
- [7] LI Z F, FANG X G, YANG P F, HUANG Q H, ZHAO W Y, LIANG C, et al. Endothelial progenitor cells contribute to neointima formation in rabbit elastase-induced aneurysm after flow diverter treatment[J]. *CNS Neurosci Ther*, 2013, 19: 352-357.
- [8] ZHANG Y, ZHOU Y, YANG P, LIU J, XU Y, HONG B, et al. Comparison of the flow diverter and stent-assisted coiling in large and giant aneurysms: safety and efficacy based on a propensity score-matched analysis[J]. *Eur Radiol*, 2016, 26: 2369-2377.
- [9] ZANATY M, CHALOUHI N, STARKE R M, BARROS G, SAIGH M P, SCHWARTZ E W, et al. Flow diversion versus conventional treatment for carotid cavernous aneurysms[J]. *Stroke*, 2014, 45: 2656-2661.
- [10] PUFFER R C, PIANO M, LANZINO G, VALVASSORI L, KALLMES D F, QUILICI L, et al. Treatment of cavernous sinus aneurysms with flow diversion: results in 44 patients[J]. *AJNR Am J Neuroradiol*, 2014, 35: 948-951.
- [11] BRASILIENSE L B C, AGUILAR-SALINAS P, MILLER D A, TAWK R G, SAUVAGEAU E A, HANEL R A. Analysis of predictors and probability of aneurysm occlusion in the internal carotid artery after treatment with Pipeline embolization device[J]. *World Neurosurg*, 2017, 107: 641-648.
- [12] ROUCHAUD A, RAMANA C, BRINJIKJI W, DING Y H, DAI D, GUNDERSON T, et al. Wall apposition is a key factor for aneurysm occlusion after flow diversion: a histologic evaluation in 41 rabbits[J]. *AJNR Am J Neuroradiol*, 2016, 37: 2087-2091.
- [13] AQUARIUS R, DE KORTE A, SMITS D, GOUNIS M, VERRIJP K, DRIESSEN L, et al. The importance of wall apposition in flow diverters[J]. *Neurosurgery*, 2019, 84: 804-810.
- [14] BENDER M T, JIANG B, CAMPOS J K, LIN L M, BEATY N, VO C D, et al. Single-stage flow diversion with adjunctive coiling for cerebral aneurysm: outcomes and technical considerations in 72 cases[J]. *J Neurointerv Surg*, 2018, 10: 843-850.
- [15] PARK M S, KILBURG C, TAUSSKY P, ALBUQUERQUE F C, KALLMES D F, LEVY E I, et al. Pipeline embolization device with or without adjunctive coil embolization: analysis of complications from the IntrePED Registry[J]. *AJNR Am J Neuroradiol*, 2016, 37: 1127-1131.
- [16] ZHOU G, SU M, YIN Y L, LI M H. Complications associated with the use of flow-diverting devices for cerebral aneurysms: a systematic review and meta-analysis[J/OL]. *Neurosurg Focus*, 2017, 42: E17. doi: 10.3171/2017.3.FOCUS16450.
- [17] ROUCHAUD A, BRINJIKJI W, LANZINO G, CLOFT H J, KADIRVEL R, KALLMES D F. Delayed hemorrhagic complications after flow diversion for intracranial aneurysms: a literature overview[J]. *Neuroradiology*, 2016, 58: 171-177.
- [18] CEBRAL J R, MUT F, RASCHI M, SCRIVANO E, CERATTO R, LYLYK P, et al. Aneurysm rupture following treatment with flow-diverting stents: computational hemodynamics analysis of treatment[J]. *AJNR Am J Neuroradiol*, 2011, 32: 27-33.
- [19] IKEDA H, ISHII A, KIKUCHI T, ANDO M, CHIHARA H, ARAI D, et al. Delayed aneurysm rupture due to residual blood flow at the inflow zone of the intracranial paraclinoid internal carotid aneurysm treated with the Pipeline embolization device: histopathological investigation[J]. *Interv Neuroradiol*, 2015, 21: 674-683.
- [20] WHITE A C, KUMPE D A, ROARK C D, CASE D E, SEINFELD J. Patterns, predictors, and outcomes of postprocedure delayed hemorrhage following flow diversion for intracranial aneurysm treatment[J/OL]. *World Neurosurg*, 2018, 115: e97-e104. doi: 10.1016/j.wneu.2018.03.190.
- [21] CRUZ J P, CHOW M, O'KELLY C, MAROTTA B, SPEARS J, MONTANERA W, et al. Delayed ipsilateral parenchymal hemorrhage following flow diversion for the treatment of anterior circulation aneurysms[J]. *AJNR Am J Neuroradiol*, 2012, 33: 603-608.
- [22] RANGEL-CASTILLA L, MUNICH S A, JALEEL N, CRESS M C, KRISHNA C, SONIG A, et al. Patency of anterior circulation branch vessels after Pipeline embolization: longer-term results from 82 aneurysm cases[J]. *J Neurosurg*, 2017, 126: 1064-1069.
- [23] BHOGAL P, GANSLANDT O, BÄZNER H, HENKES H, PÉREZ M A. The fate of side branches covered by flow diverters—results from 140 patients[J]. *World Neurosurg*, 2017, 103: 789-798.