论著·临床医学

Dolenc入路较之传统翼点入路夹闭更能改善复杂后交通动脉瘤预后:一项非随机对照研究

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[摘要] **目的** 后交通动脉瘤(posterior communicating artery aneurysm,PCoAA)解剖关系复杂,部分大型或向后内侧指向病变显微夹闭难度大且术后致残风险仍较高,如何选择更有利的手术入路仍是临床关注的重点。本研究比较Dolenc入路与传统翼点入路夹闭大型或向后内侧指向的PCoAA的疗效、安全性及综合表现。**方法** 采用前瞻性非随机对照研究设计,纳入2019年9月至2025年9月在重庆医科大学附属第一医院梁平医院神经外科收治的79例大型或向后内侧指向PCoAA患者,按入院顺序交替分配至Dolenc入路组41例与传统翼点入路组38例。主要终点为术后3个月预后良好率,预后评估采用格拉斯哥预后评分量表(Glasgow outcome scale,GOS),GOS 4~5分定义为预后良好,GOS 1~3分定义为预后不佳。次要终点包括手术时间、术后住院天数、GOS评分分布及术后3个月CTA/DSA评估的瘤颈残留(影像示瘤颈造影剂充盈定义为残留)。采用Firth偏倚校正的惩罚似然Logistic回归评估手术方式与预后不佳的关联(以年龄分层为协变量),并报告*OR*、95%*CI*与*P*值;同时构建技术-安全-效率三维度标准化得分及综合得分用于描述性比较,并进行成本效果与亚组分析。**结果** 主要终点方面,Dolenc组预后良好率为97.6%(40/41),高于传统组78.9%(30/38),2组差值为18.6%(95%*CI*:4.8%~32.4%,*P*=0.009)。术后住院天数Dolenc组较传统组更短[(13.46±2.43) *vs* (16.05±2.46) d],均值差为−2.59 d(95%*CI*:−3.69~−1.49,*P*<0.001)。2组手术时间相近(3.98±0.60 h *vs* 3.97±0.62 h),均值差为0.01 h(95%*CI*:−0.26~0.28,*P*=0.944)。临床功能结局方面,Dolenc组GOS为5分的比例更高(61.0% *vs* 18.4%),差值为42.6%(95%*CI*:23.2%~61.9%,*P*<0.001),且Dolenc组GOS分布更偏向高分,4分和3分比例低于传统翼点组(χ^2=14.96,*P*<0.001)。影像随访方面,瘤颈残留率在Dolenc组更低(2.4% *vs* 13.2%),差值为−10.8%(95%*CI*:−22.5%~1.0%,*P*=0.072)。多变量分析显示,传统翼点入路与预后不佳相关(*OR*=10.20,95%*CI*:1.20~87.04,*P*=0.034);模型总体显著(χ^2=7.56,*df*=2,*P*=0.02),校准度良好(Hosmer-Lemeshow检验*P*=0.82),判别能力中等(AUC=0.75,95%*CI*:0.61~0.86)。三维度得分及综合得分均显示Dolenc组更高(综合得分0.873 *vs* 0.739)。亚组分析提示Dolenc入路在高危/复杂亚组中优势更明显,例如Hunt-Hess Ⅲ~Ⅳ级差值0.256(95%*CI*:0.056~0.475,*P*=0.025),大型动脉瘤差值0.157(95%*CI*:0.016~0.305,*P*=0.049);部分亚组样本量有限,需谨慎解读。**结论** 对于大型或向后内侧指向PCoAA显微夹闭,Dolenc入路与更高的术后3个月预后良好率及更短住院时间相关,且未观察到手术时间延长;其三维度综合得分亦呈现更有利的方向。

[关键词] 后交通动脉瘤;Dolenc入路;翼点入路;显微外科夹闭;预后

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Dolenc approach improves outcomes compared with traditional pterional approach for clipping complex posterior communicating artery aneurysms: a nonrandomized controlled study

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[**Abstract**] **Objective** Posterior communicating artery aneurysm(PCoAA) exhibit complex anatomical relationships, and microsurgical clipping of large or posteromedially projecting aneurysms remains technically challenging with considerable postoperative morbidity. Therefore, selecting optimal surgical approach has become a key clinical concern. This study compares the efficacy, safety, and overall performance of the Dolenc approach versus the conventional pterional approach for clipping large or posteromedially projecting PCoA aneurysms. **Methods** A prospective nonrandomized controlled study design was adopted. A total of 79 patients with large or posteromedially projecting PCoA aneurysms consecutively treated in Department of Neurosurgery, Liangping Hospital of the First Affiliated Hospital of Chongqing Medical University between September 2019 and September 2025 were enrolled, and alternatively assigned to the Dolenc approach group (n=41) or conventional pterional approach group (n=38) based on admission sequence. The primary endpoint was the favorable outcome rate at 3 months postoperatively, assessed using Glasgow Outcome Scale (GOS), with GOS score of 4 to 5 defined as a favorable outcome and score of 1 to 3 as an unfavorable outcome. Secondary endpoints included operative time, postoperative length of hospital stay, distribution of GOS scores, and aneurysm neck residual on digital subtraction angiography (DSA)/CT angiography (CTA) at 3 months postoperatively (defined as contrast filling of the aneurysm neck). Firth's bias-reduced penalized likelihood logistic regression analysis was used to evaluate the association between surgical approach and unfavorable outcome (with age stratification as covariate), reporting odds ratio (*OR*), 95% confidence interval (*CI*), and P value. In addition, a standardized three-domain (technical-safety-efficiency) scoring system and a composite score were constructed for descriptive comparison, along with cost-effectiveness and subgroup analyses. **Results** For the primary endpoint, the favorable outcome rate was 97.6% (40/41) in the Dolenc group and 78.9% (30/38) in the conventional group, with an absolute difference of 18.6% (95%*CI*: 4.8% to 32.4%, P=0.009). Postoperative length of hospital stay was shorter in the Dolenc group (13.46±2.43 *vs* 16.05±2.46 d), with a mean difference of −2.59 d (95%*CI*: −3.69 to −1.49, P<0.001). Operative time was comparable between groups (3.98±0.60 *vs* 3.97±0.62 h), with a mean difference of 0.01 h (95%*CI*: −0.26 to −0.28, P=0.944). Regarding functional outcomes, the Dolenc group had a greater proportion of patients achieving a GOS score of 5 than the conventional group (61.0% *vs* 18.4%), with an absolute difference of 42.6% (95%*CI*: 23.2% to 61.9%, P<0.001), and the distribution of GOS scores in the Dolenc group was shifted toward better outcomes, with lower proportions of patients having GOS scores of 4 and 3 than the conventional pterional group (χ^2=14.96, P<0.001). For imaging follow-up, the neck remnant rate was lower in the Dolenc group (2.4% *vs* 13.2%), with an absolute difference of −10.8% (95%*CI*: −22.5% to −1.0%, P=0.072). Multivariable analysis showed that the conventional pterional approach was associated with unfavorable outcome (*OR*=10.20, 95%*CI*: 1.20 to 87.04, P=0.034). The model was significant overall (χ^2=7.56, *df*=2, P=0.02), with good calibration (Hosmer-Lemeshow test P=0.82), and moderate discrimination (AUC=0.75, 95%*CI*: 0.61 to 0.86). Both the three-domain scores and the composite score were higher in the Dolenc group (composite score: 0.873 *vs* 0.739). Subgroup analyses suggested the Dolenc approach demonstrated greater advantage in high-risk/complex subgroups, with difference of 0.256 for Hunt-Hess grade Ⅲ－Ⅳ

(95%*CI*: 0.056 to 0.475, *P*=0.025) and 0.157 for large aneurysms (95%*CI*: 0.016 to 0.305, *P*=0.049); however, these findings should be interpreted with caution given the limited sample sizes in some subgroups. **Conclusion** In this cohort, for microsurgical clipping of large or posteromedially projecting PCoA aneurysms, the Dolenc approach is associated with a higher rate of 3-month favorable postoperative outcomes and a shorter length of hospital stay, without an apparent increase in operative time.

[**Key words**] posterior communicating artery aneurysms; Dolenc approach; pterional approach; microsurgical clipping; prognosis

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后交通动脉瘤(posterior communicating artery aneurysm,PCoAA)是最常见的颅内动脉瘤类型,占所有颅内动脉瘤的25%~53%[1]。当前外科治疗以血管内介入与开颅显微夹闭术为主[2-3]。近年来,随着术前影像评估、显微外科技术及围术期管理的进步,总体疗效有所提升。然而,对于部分解剖关系复杂的PCoAA,尤其是大型或向后内侧指向、穿支血管变异多见者,显微夹闭术后仍存在较高的并发症风险与功能结局不确定性[4]。此外,动脉瘤破裂所致动脉瘤性蛛网膜下腔出血(aneurysmal subarachnoid hemorrhage, aSAH)的围术期并发症(如急性脑积水、迟发性脑缺血)仍是影响神经功能结局的重要因素[5]。因此,如何在保证夹闭彻底性的同时,降低手术相关并发症、改善患者预后并减少疾病负担,仍是脑血管外科领域亟待解决的问题。

目前,血管内介入治疗因其创伤小、恢复快、颅内感染风险低等优点而被各大医院甚至基层医院广泛应用,但其存在动脉瘤复发率较高、费用昂贵等局限[6]。开颅夹闭术虽创伤较大、恢复周期长,但具有复发率低、无需长期抗板治疗以及费用相对较低等优势[7],随着材料科学与操作技术的发展,介入治疗的应用范围逐渐扩大;然而对于合并颅内血肿、瘤体巨大、血管解剖复杂或经济条件受限的患者,开颅夹闭手术仍具有不可替代的地位[8]。因此,针对开颅夹闭术的术式优化与技术创新具有重要的临床意义。

在临床实践中,传统翼点经侧裂入路在处理大型或向后内侧指向的PCoAA时[9],常面临载瘤动脉无法控制、瘤颈暴露困难、周围结构辨识度低及理想夹闭角度难以获取等问题,易遭遇术中动脉瘤破裂、穿支血管误夹、闭塞不全或载瘤动脉狭窄等风险,进而影响患者预后。Dolenc入路通过向前外侧扩大视野、增加硬膜外操作空间,有助于提升复杂动脉瘤的显露质量与操作安全性,有望降低上述手术风险[10]。

为进一步明确Dolenc入路在大型或向后内侧指向的PCoAA治疗中的实际效果与优势,本研究开展一项单中心前瞻性非随机对照试验,采用多变量Logistic回归分析方法,系统评估其对患者预后的影响,以期为该病的外科治疗提供更可靠的理论依据和临床策略。

1 资料与方法

1.1 一般资料

本研究采用前瞻性非随机对照研究设计,纳入2019年9月至2025年9月期间于重庆医科大学附属第一医院梁平医院神经外科就诊的符合纳入标准的连续入院的大型或向后内侧指向的后交通动脉瘤患者,与患者家属沟通后自愿选择行显微夹闭术治疗PCoAA病例79例,按照入院顺序被交替分配至Dolenc手术组或传统手术组。Dolenc入路41例,传统翼点入路38例。纳入标准:① 根据血管影像(CTA、MRA或DSA)诊断为大型或向后内侧指向的后交通动脉瘤的患者;② 自愿接受动脉瘤夹闭或者血管条件不允许介入的患者;③ 术前GCS 8分以上;④ Hunt-Hess分级Ⅳ级及以下。排除标准:① 合并严重心肺基础疾病,不能耐受开颅手术者;②伴有严重凝血功能障碍性疾病;③动脉瘤严重钙化,不适合夹闭手术者;本研究经重庆医科大学附属第一医院梁平医院伦理委员会审核批准(LDYYLL2025-2087)。

1.2 手术方法

2组手术均由同一位具有丰富动脉瘤夹闭经验的高年资副主任医师主刀手术。2组在术前均常规放置腰池引流;若术前脑室内积血较多,或者开颅后仍有颅内高压,则术中行潘氏点穿刺脑室。2组开始时均采用翼点入路开颅,腰池引流缓慢、间断、分次释放脑脊液10~30 mL,充分磨除蝶骨嵴至眶脑膜带。Dolenc入路组剪开眶脑膜带,沿圆孔外侧至床突尖内侧分离

眶颞硬膜壁层与脏层;海绵窦外侧壁静脉出血时用倍绣胶(广州倍绣生物技术有限公司)止血。经硬膜外磨除前床突:先用大号、后用小号金刚砂钻头逐步磨除视神经管顶壁及视柱,蛋壳化前床突尖后,以显微剥离子自硬膜逐步剥离,完整取出;或酌情以显微咬骨钳分块咬除。操作中须避免向下、向后暴力分离床突尖,以防损伤或刺破颈内动脉,并尽量减少硬膜撕裂。Dolenc三角骨质断端以骨蜡封闭。若术前CT示视柱明显气化并与蝶窦相通,和/或前床突上脚(视神经管顶壁)与筛窦相通,则尽量保护窦腔黏膜完整;若已破损,以脂肪或肌肉联合倍绣胶严密修补,防止脑脊液漏[11-12]。显微镜下沿侧裂行倒"T"型剪开硬膜——内侧至同侧视神经内侧缘,外侧至动眼神经上方。打开颈内动脉池,缓慢释放脑脊液进一步降颅压;酌情逆行和/或顺行解剖外侧裂,将颞叶连同硬膜向后牵拉。传统翼点入路组朝向前外侧弧形剪开硬膜,分离外侧裂,轻抬额叶。2组均充分显露载瘤动脉近心端以备临时阻断,以显微剪配合神经剥离子分离暴露动脉瘤颈,至瘤颈近、远心端可置入动脉瘤夹叶片即可,无需完整显露瘤体。

1.3 结局指标定义与随访方案

本研究的主要终点指标为术后3个月的临床预后良好率。预后评估采用格拉斯哥预后评分量表(Glasgow outcome scale,GOS),将GOS 5分(恢复良好)和4分(中度残疾但能独立生活)定义为预后良好,GOS 1~3分(死亡、植物生存或重度残疾)定义为预后不良。次要终点指标包括手术时间(定义为从切皮至切口缝合结束的时长)、术后住院天数及动脉瘤闭塞情况。其中,动脉瘤闭塞程度通过术后3个月复查的CTA或DSA影像进行判定,若影像显示瘤颈部存在造影剂充盈则定义为瘤颈残留。所有患者在出院后通过门诊复查或电话访谈形式完成随访(术后3个月)。临床结局数据由2名对具体手术分组不知情的独立神经外科医师进行盲法评估,以减少测量偏倚;影像学结果由2名评估者独立判读,若存在分歧则经讨论后达成一致。

1.4 术前记录和术后观察指标

术前记录2组患者的性别、年龄、体质量、Hunt-Hess评分、GCS评分、改良Fisher分级、动脉瘤瘤体朝向、动脉瘤形状和动脉瘤大小等特征,以便后续的分析、研究。将年龄分为<60岁和≥60岁2个亚组,将体质量分为<60 kg、60~75 kg和>75 kg 3个亚组,将GCS评分按评分值分为轻度意识障碍分、中度意识障碍分和重度意识障碍分。术后记录各组患者的手术时间、术后住院天数、GOS评分、术后3月复查瘤颈是否残留等预后相关情况。

1.5 多变量分析与变量选择策略

本研究以术后3个月预后情况为因变量(预后不佳=1,预后良好=0)进行回归分析。候选自变量包括手术方式及患者基线临床/影像学特征(年龄、性别、体质量、Hunt-Hess分级、GCS分级、改良Fisher分级等)。为减少自由度消耗,部分变量按临床意义进行分层/合并编码,例如:Hunt-Hess评分(Ⅰ~Ⅱ *vs* Ⅲ~Ⅳ),改良Fisher分级(1~2级 *vs* 3~4级)。鉴于预后不佳事件数较少且可能存在分离,采用Firth偏倚校正的惩罚似然Logistic回归获得更稳健的估计。变量控制遵循"临床优先+统计约束"原则:单因素分析(P<0.10)仅作为候选变量进入的参考,为避免过拟合,最终多变量模型预先限制参数数目(≤2~3个)。模型整体显著性以似然比检验评估;校准度以Hosmer-Lemeshow检验评价(小样本下仅作参考);ROC曲线用于评估判别能力。多重共线性通过VIF评估(VIF>5提示需进一步处理)。

1.6 三维度评分与综合得分计算

为便于对2种术式在技术-安全-效率三维度进行整体展示,本研究基于可量化结局指标构建三维度得分体系。各指标按方向性划分为效益型(越大越好)与成本型(越小越好)。首先对各指标进行0~1标准化,成本型指标按同向转换后进入计算;随后在每个维度内对标准化指标采用等权平均得到维度得分;综合得分为三维度得分的等权平均,取值为0~1,分值越高表示整体表现越优。本综合得分用于描述性比较,不进行排序推断。

1.7 成本效果分析

基于关键临床指标(预后良好率、住院天数、手术时间及A线距离),从资源投入-健康产出角度进行成本效果分析。分析思路为:将预后良好率作为主要效果指标,将住院天数与手术时间作为主要资源消耗,并对2组均值/比例差异进行增量比较,计算增量成本效果比(incremental cost-effectiveness ratio, ICER):

$$ICER=\frac{\Delta Cost}{\Delta Effect}$$

其中ΔCost为2组在某项资源指标上的差值(传统翼点 *vs* Dolenc入路),ΔEffect为预后良好率差值。ICER解释为每额外获得1例良好预后所需付出的额

外资源。当出现ΔCost<0且ΔEffect>0时,表示Dolenc入路相对传统翼点入路具有优势方案特征(更省资源且效果更好);若ΔCost>0且ΔEffect>0,则需结合ICER数值判断是否可接受。

1.8 统计学分析

所有统计分析使用R软件(版本号4.4.3),符合正态分布的连续变量以$\bar{x}\pm s$表示,采用独立样本t检验进行比较;否则以$M(P_{25}, P_{75})$表示,采用Mann-Whitney U检验。计数资料以频数(%)表示,亚组间比较采用χ^2检验或Fisher精确检验,以P<0.05为差异具有统计学意义。

2 结果

2.1 2组患者临床特征及结局比较

本研究共纳入79例患者,其中Dolenc入路组41例,传统翼点入路组38例。基线特征比较显示,2组在性别、年龄分层、体质量分层、Hunt-Hess分级、入院GCS分级、改良Fisher分级、动脉瘤瘤体朝向、动脉瘤形状及动脉瘤大小分层等方面差异均无统计学意义,提示2组总体基线具有可比性。此外,A线距离Dolenc入路组为(6.82±0.87) mm,大于传统翼点入路组(5.11±0.83) mm(t=8.93,P<0.001,表1)。

在围手术期及结局指标方面,主要终点术后3个月预后良好率在2组间差异有统计学意义,Dolenc入路组预后良好率为97.6%(40/41),高于传统翼点入路组的78.9%(30/38),2组差值为18.6%(95%*CI*:4.8%~32.4%,P=0.009);2组手术时间相近[(3.98±0.60) *vs* (3.97±0.62) h,t=0.07,P=0.944];Dolenc入路组术后住院天数更短[(13.46±2.43) *vs* (16.05±2.46) d,t=4.70,P<0.001];GOS评分分布在2组间存在显著差异(χ^2=14.96,P<0.001),其中Dolenc入路组GOS=5分比例更高(61.0% *vs* 18.4%),而传统翼点入路组GOS=4分比例更高(36.6% *vs* 73.7%);术后3个月影像随访显示,瘤颈残留发生率在2组间差异未达统计学意义,见表2。

2.2 多变量逻辑回归分析

多变量回归结果显示,手术方式与预后不佳发生具有统计学相关性:在调整年龄分层后,与Dolenc入路组相比,传统翼点入路组发生预后不佳的*OR*为10.20(95%*CI*:1.20~87.04,P=0.034)。该结果提示,在本研究样本中,Dolenc入路可能与较低的预后不佳发生风险相关。年龄分层与预后不佳的关联未达到统计学意义(*OR*=1.33,95%*CI*:0.29~6.18,P=0.712)。模型整体拟合优于零模型(似然比检验:χ^2=7.65,df=2,P=0.02),Hosmer-Lemeshow检验提示模型校准度良好(P=0.82),见表3。基于最终模型预测概率绘制ROC曲线,AUC为0.75(95%*CI*:0.61~0.86),表明模型对预后不佳具有中等区分能力(图1)。鉴于样本量及事件数限制,部分效应估计的置信区间仍相对较宽,相关结果仍需在更大样本研究中进一步验证。

2.3 三维度得分及综合得分比较

基于技术-安全-效率三维度标准化评分体系,Dolenc入路组在技术得分、安全得分与效率得分以及综合得分方面均高于传统翼点入路组,提示在本研究所选指标框架下,Dolenc入路整体表现更优(表4)。

2.4 关键临床指标的成本效果分析

Dolenc入路组虽手术时间与对照组相近,但平均住院日缩短2.6 d,且预后良好率提高18.7%。从卫生经济学角度分析,该入路在初始资源投入(住院时间)降低的同时,产出的"健康效益"(预后良好率)更高,提示其具有更优的成本-效果比,具备临床推广价值。此外,Dolenc入路在手术操作空间方面亦显示出优势,见表5。

2.5 不同亚组中手术方式效果比较

结果表明,在不同分组中,Dolenc入路手术组相较于传统翼点入路手术组在多数情况下显示出更优的预后良好率,尤其在部分高危或复杂亚组中差异具有统计学意义。在Hunt-Hess评分III~IV级的患者中,Dolenc入路手术组的预后良好率为96%(24/25),显著高于传统翼点入路手术组的70.4%(19/27)(95%*CI*:0.056~0.475,P=0.025);同样,在大型动脉瘤患者中,Dolenc入路手术组达到97.0%(32/33)的预后良好率,高于对照组的81.2%(26/32)(95%*CI*:0.016~0.305,P=0.049);中小型动脉瘤中,Dolenc组预后良好率亦高于对照组,但差异未达统计学意义;在中度意识障碍(GCS评分)及瘤体朝向后内侧的亚组中,Dolenc入路手术组亦显著优于传统翼点入路手术组(P<0.05);此外,在年龄<60岁、瘤体朝向后外侧/后下、囊状动脉瘤及改良Fisher分级Ⅰ~Ⅱ级等亚组中,虽未达到统计学显著性,但Dolenc入路手术组仍呈现较高的预后良好率及有利的数值趋势。本研究同时发现,在Hunt-Hess评分Ⅰ~Ⅱ级、体质量<60 kg亚组中,2种手术方式均表现优异,预后良好率均达100%。

表1 2组患者基线特征比较[例(%),$\bar{x}\pm s$]

Table 1 Baseline characteristics of the participants in the Dolenc and conventional pterional groups [n(%),$\bar{x}\pm s$]

Variables	Dolenc group (n=41)	Conventional pterional group (n=38)	χ^2/t	P value
Gender			1.10	0.295
Female	21(51.2)	15(39.5)		
Male	20(48.8)	23(60.5)		
Age /years			2.25	0.134
≥60	19(46.3)	24(63.2)		
<60	22(53.7)	14(36.8)		
Weight /kg			0.90	0.639
<60	4(9.8)	2(5.3)		
60 to 75	14(34.1)	16(42.1)		
>75	23(56.1)	20(52.6)		
Hunt-Hess grade			2.18	0.536
Ⅰ	4(9.8)	1(2.6)		
Ⅱ	12(29.3)	10(26.3)		
Ⅲ	19(46.3)	22(57.9)		
Ⅳ	6(14.6)	5(13.2)		
Admission GCS score			0.27	0.875
Mild impairment of consciousness	25(61.0)	21(55.3)		
Moderate impairment of consciousness	15(36.6)	16(42.1)		
Severe impairment of consciousness	1(2.4)	1(2.6)		
Modified Fisher grade			1.61	0.657
Grade Ⅰ	4(9.8)	2(5.3)		
Grade Ⅱ	21(51.2)	20(52.6)		
Grade Ⅲ	15(36.6)	16(42.1)		
Grade Ⅳ	1(2.4)	0(0.0)		
Aneurysm projection			0.19	0.665
Posterolateral/Posteroinferior	33(80.5)	32(84.2)		
Posteromedial	8(19.5)	6(15.8)		
Aneurysm morphology			1.54	0.463
Saccular	35(85.4)	29(76.3)		
Lobulated	5(12.2)	6(15.8)		
Fusiform	1(2.4)	3(7.9)		
Aneurysm size/mm			0.40	0.939
<5	5(12.2)	3(7.9)		
5 to 10	3(7.3)	3(7.9)		
<10 to 25	29(70.7)	28(73.7)		
>25	4(9.8)	4(10.5)		
A-line distance/mm	6.82±0.87	5.11±0.83	8.93	<0.001

表2 大型或向后内侧指向后交通动脉瘤患者Dolenc入路组与传统翼点入路组围手术期指标及术后3个月功能与影像学结局指标[例(%),$\bar{x}\pm s$]

Table 2 Perioperative variables and 3-month functional and imaging outcome indicators in patients with large or posteromedially projecting posterior communicating artery (PCoA) aneurysms in the Dolenc and conventional pterional groups[n(%),$\bar{x}\pm s$]

Variable	Dolenc group (n=41)	Conventional pterional group (n=38)	χ^2/t	P value
Outcome status (primary endpoint)			6.77	0.009
Favorable	40(97.6)	30(78.9)		
Unfavorable	1(2.4)	8(21.1)		
Operative time/h	3.98±0.60	3.97±0.62	0.07	0.944
Postoperative length of hospital stay/d	13.46±2.43	16.05±2.46	4.70	<0.001
GOS score			14.96	<0.001
5	25(61.0)	7(18.4)		
4	15(36.6)	28(73.7)		
3	1(2.4)	3(7.9)		
Aneurysm neck remnant			3.23	0.072
None	40(97.6)	33(86.8)		
Present	1(2.4)	5(13.2)		

表3 大型或向后内侧指向后交通动脉瘤患者术后3个月预后不良影响因素的多因素Logistic回归分析

Table 3 Multivariable logistic regression analysis of factors associated with 3-month unfavorable outcomes in patients with large or posteromedially projecting PCoA aneurysms

Variable	*OR*	95%*CI*	P value
Surgical approach(conventional pterional group *vs* Dolenc group)	10.20	1.20 - 87.04	0.034
Age(≥60 *vs* <60 years)	1.33	0.29 - 6.18	0.712

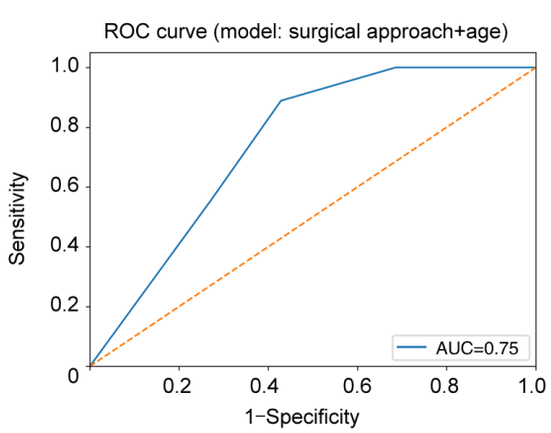


图1 大型或向后内侧指向后交通动脉瘤患者术后3个月预后不佳预测模型的受试者工作特征曲线

Figure 1 Receiver operating characteristic curve of the predictive model for 3-month unfavorable outcomes in in patients with large or posteromedially projecting PCoA aneurysms

表4 大型或向后内侧指向后交通动脉瘤患者Dolenc入路组与传统翼点入路组三维度得分及综合得分

Table 4 Three-domain scores and composite score in patients with large or posteromedially projecting PCoA aneurysms in the Dolenc and conventional pterional groups

Surgical approach	Technical score	Safety score	Efficiency score	Composite score
Dolenc group	0.930	0.912	0.587	0.873
Conventional pterional group	0.775	0.707	0.451	0.739

3 讨论

3.1 Dolenc入路与更佳短期结局及更短住院时间相关

本研究显示,与传统翼点入路相比,Dolenc入路组术后3个月预后良好率更高,术后住院天数更短,而手术时间未见明显延长。住院时间差异可能与Dolenc入路改善手术暴露、提升操作效率有关,同时亦可能受到围术期并发症预防与处理策略的影响;近

表5 大型或向后内侧指向后交通动脉瘤患者Dolenc入路组与传统翼点入路组术后3个月预后、住院时间、手术时间及A线距离的增量成本效果比

Table 5 Incremental cost-effectiveness ratios for 3-month favorable outcome, length of hospital stay, operative time, and a-line distance in patients with large or posteromedially projecting PCoA aneurysms in the Dolenc and conventional pterional groups

	Dolenc group	Conventional pterional group	Incremental cost-effectiveness ratio	Interpretation
Favorable outcome rate/%	97.6	78.9	-	Dolenc approach favored
Mean length of hospital stay/d	13.5	16.1	-2.6	Dolenc approach favored
Operative time/h	3.98	3.97	+0.01	Acceptable
A-line distance /mm	6.8	5.1	+1.7	Dolenc approach favored

表6 大型或向后内侧指向后交通动脉瘤患者不同亚组中Dolenc入路组与传统翼点入路组术后3个月预后良好率及率差

Table 6 Three-month favorable outcome rates and rate differences between the Dolenc and conventional pterional groups across subgroups of patients with large or posteromedially projecting PCoA aneurysms

Subgroup	Favorable outcome rate/% (Dolenc group)	Favorable outcome rate/% (Conventional pterional group)	Rate difference/% (95% *CI*)	*P* value
Age <60 years	100.0(22/22)	78.6(11/14)	21.4(3.80—0.491)	0.051
Age ≥60 years	94.7(18/19)	79.2(19/24)	15.6(-3.5—34.7)	0.205
Hunt-Hess grade Ⅰ~Ⅱ	100.0(16/16)	100.0(11/11)	0	1.000
Hunt-Hess grade Ⅲ~Ⅳ	96.0(24/25)	70.4(19/27)	25.6(5.6—47.5)	0.025
Small-to-medium aneurysms	100.0(8/8)	66.7(4/6)	33.3(-4.4—71.1)	0.165
Large aneurysms	97.0(32/33)	81.2(26/32)	15.7(1.6—30.5)	0.049
Weight/kg				
<60	100(4/4)	100(2/2)	0	1.000
60 to 75	100.0(14/14)	81.2(13/16)	18.8(-0.4—37.9)	0.228
>75	95.7(22/23)	75.0(15/20)	20.7(-0.1—41.4)	0.081
Admission GCS score				
Mild impairment of consciousness	100.0(25/25)	95.2(20/21)	4.8(-4.3—13.9)	0.457
Moderate impairment of consciousness	100.0(15/15)	62.5(10/16)	37.5(11.0—64.0)	0.018
Severe impairment of consciousness	0(0/1)	0(0/1)	0	1.000
Aneurysm orientation				
Posterolateral/Posteroinferior	97.0(32/33)	81.2(26/32)	15.7(1.0—30.5)	0.054
Posteromedial	100.0(8/8)	66.7(4/6)	33.3(3.5—71.1)	0.046
Aneurysm morphology				
Saccular	97.1(34/35)	82.8(24/29)	14.4(-0.1—33.4)	0.083
Lobulated	100.0(5/5)	66.7(4/6)	33.3(-4.4—71.1)	0.455
Fusiform	100.0(1/1)	66.7(2/3)	33.3(-20.0—86.7)	1.000
Modified Fisher grade				
Grade Ⅰ~Ⅱ	100.0(25/25)	90.9(20/22)	9.1(-2.9—21.1)	0.214
Grade Ⅲ~Ⅳ	93.8(15/16)	62.5(10/16)	31.2(4.7—57.8)	0.083

年研究提示腰池持续引流可改善aSAH合并急性脑积水患者预后,并有研究建立了夹闭术后迟发性脑缺血的早期识别模型,为优化围术期管理、降低不良结局提供了补充证据[13]。为进一步降低潜在混杂因素的影响,在事件数有限的前提下采用Firth偏倚校正的惩罚似然Logistic回归进行多变量分析,结果提示在调整年龄分层后,手术方式与预后不佳仍存在统计学相关性;与Dolenc入路相比,传统翼点入路与预后不佳发

生呈更高的优势比(*OR*=10.20,95%*CI*:1.20~87.04),提示在本研究队列中Dolenc入路可能与更低的预后不佳发生概率相关。

3.2 硬膜外前床突磨除可能通过提升暴露质量并降低牵拉相关风险带来获益

Dolenc入路获得更优结局的潜在机制可能与其关键步骤-硬膜外磨除前床突[14]相关,从而实现对颈内动脉近端更充分、更加前向外侧的显露,并建立相对更宽阔的显微操作通道。在这一通道下,术中对脑组织的牵拉需求可能降低,为肿胀脑组织提供更充分的缓冲空间,从而有助于降低牵拉相关的医源性损伤风险;同时,视野的外侧与前方扩展更有利于辨认载瘤动脉、动脉瘤、穿支血管与周围颅神经的空间关系,便于夹闭角度与夹闭位置的精细调整,从而在理论上减少误夹穿支、夹闭不全或载瘤动脉狭窄等问题[15]。本研究中Dolenc入路组瘤颈残留率呈更低的数值趋势,且暴露距离(A线)更具优势,这些现象从侧面支持了"暴露质量改善-操作精度提升-结局获益"这一可能路径,但仍需结合更充分的并发症谱与长期随访数据进一步印证。

3.3 亚组分析提示:复杂解剖与高危状态下获益更突出

亚组分析显示,Dolenc入路的获益趋势在病情更重或解剖更具挑战性的患者中更为明显,尤其体现在大型动脉瘤、Hunt-Hess Ⅲ~Ⅳ级、瘤体朝向后内侧以及中度意识障碍等亚组。这一差异可能归因于该入路在脑水肿与颅内压增高等情况下更有利于最小化脑组织牵拉、优化手术空间,从而使暴露与近端控制优势更易转化为临床结局的改善。相对而言,在Hunt-Hess Ⅰ~Ⅱ级等条件较理想的亚组中,2种入路的疗效差异可能不显著,提示在低风险患者中术式选择更具弹性。需要强调的是,部分亚组样本量较小、统计效能不足,相关结果更适合作为探索性线索,不宜作确定性推断,仍需更大样本研究进一步验证。

3.4 复杂解剖与高危状态下Dolenc入路的优势更为突出

本研究对2种术式从"技术-安全-效率"三维度得分及综合得分进行了比较[16]。结果显示,Dolenc入路组在三维度得分及综合得分方面总体更高,其变化方向与主要临床结局及资源利用指标基本一致:在未明显延长手术时间的情况下,Dolenc入路组住院天数更短且预后良好率更高,提示其在"健康产出-资源消耗"维度上可能具有一定优势。需要说明的是,综合得分主要用于提高呈现的直观性与可读性,临床解释仍应回归到预后、住院日、影像残留及并发症谱等具体终点的逐项评估与实际可行性判断。

本研究采用按入院顺序交替分配的前瞻性非随机对照设计,与随机对照试验相比缺乏随机化及分配隐藏,仍可能引入选择偏倚,并可能受到时间趋势或学习曲线影响,因此更应将结论理解为在本队列中的关联性与提示性证据。尽管通过统一的纳排标准、报告并比较基线特征、实施盲法结局评估以及采用Firth校正回归以降低分离风险等措施尽可能减少偏倚,但残余混杂仍难以完全排除。此外,预后不佳事件数较少可能导致效应估计精度受限,部分亚组样本量不足使亚组结论更偏探索性;随访时间以术后3个月为主,也限制了对长期神经功能恢复、复发/再干预及迟发并发症的评估。

综上,在本研究队列中,针对大型或向后内侧指向的PCoAA显微夹闭,Dolenc入路与更佳的短期神经功能结局及更短住院时间相关,尤其在病情较重或解剖更复杂的患者中更为突出。未来仍需更大样本、多中心研究与更长期随访进一步验证疗效差异,并系统评估特定并发症谱及远期获益,从而为不同风险分层患者提供更精细化的手术策略支持。

利益冲突 本文所有作者声明不存在利益冲突

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