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• 专题报道 •

Lenke 5C 型青少年特发性脊柱侧凸置钉上棒矫形顺序的研究

林徐苗^{1△}, 陈 锴^{2△}, 邵 杰², 杨明园², 刘佳昊¹, 张国友², 石志才², 白玉树^{2*}

1. 海军军医大学(第二军医大学)第一附属医院麻醉学部疼痛治疗科, 上海 200433

2. 海军军医大学(第二军医大学)第一附属医院脊柱外科, 上海 200433

[摘要] **目的** 分析不同置钉上棒矫形顺序对 Lenke 5C 型青少年特发性脊柱侧凸(AIS)的手术效果。**方法** 选择 2013 年 1 月至 2020 年 12 月在我院行后路矫形植骨融合内固定术的 Lenke 5C 型 AIS 患者, 其中采用双侧置钉后先凸侧上棒矫形再行凹侧上棒矫形的患者 22 例(双侧组)、采用凸侧置钉上棒矫形后再行凹侧置钉上棒矫形的患者 20 例(凸侧组)。比较两组患者的手术相关指标(如手术时间等)、术前及术后 2 年时患者的影像学参数、生活质量评分, 同时分析并发症的发生情况。**结果** 双侧组的手术时间长于凸侧组, 差异有统计学意义[(232.8±13.1) min vs (198.4±16.5) min, $P<0.01$]。术后 2 年末次随访时凸侧组主弯 Cobb 角及其矫正率均优于双侧组[(8.0±2.3)° vs (9.9±3.2)°, $P=0.03$; (81.9±5.4)% vs (77.8±5.8)%, $P=0.02$]。双侧组和凸侧组的椎弓根螺钉破壁率分别为 5.4%(17/312)和 1.4%(4/280), 差异有统计学意义($P<0.01$)。术后 2 年末次随访时双侧组生活质量评估的治疗满意度为(4.61±1.38)分, 凸侧组为(4.50±1.44)分, 但两组间差异无统计学意义($P>0.05$)。两组患者术中均无电生理监测异常及手术相关并发症发生。**结论** 对于 Lenke 5C 型 AIS 患者, 采用凸侧置钉上棒矫形后再行凹侧置钉上棒矫形的手术效果更好。

[关键词] 青少年特发性脊柱侧凸; Lenke 5C 型; 脊柱侧凸矫形术; 矫形顺序; 矫形效果

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Orthopedic sequence of nailing on rods in patients with Lenke type 5C adolescent idiopathic scoliosis

LIN Xumiao^{1△}, CHEN Kai^{2△}, SHAO Jie², YANG Mingyuan², LIU Jiahao¹, ZHANG Guoyou², SHI Zhicai², BAI Yushu^{2*}

1. Department of Pain Medicine, Faculty of Anesthesiology, The First Affiliated Hospital of Naval Medical University (Second Military Medical University), Shanghai 200433, China

2. Department of Spinal Surgery, The First Affiliated Hospital of Naval Medical University (Second Military Medical University), Shanghai 200433, China

[Abstract] **Objective** To compare the surgical outcomes of the sequence of screw and rod placement for Lenke type 5C adolescent idiopathic scoliosis (AIS). **Methods** Lenke type 5C AIS patients who underwent posterior orthopedic fusion and fixation in our hospital from Jan. 2013 to Dec. 2020 were recruited. Based on surgical sequences, 22 cases were assigned to bilateral group (after bilateral screw placement, orthopedics was performed on the convex side and then on the concave side), and 20 cases were assigned to convex group (screws placed on the convex side and performed orthopedics, followed by the concave side). The operation-related indicators (including operation time), imaging parameters, quality of life scores were compared between the 2 groups before and 2 years after surgery. Complications of the 2 groups were analyzed. **Results** The operation time in the bilateral group was significantly longer than that in the convex group [(232.8±13.1) min vs (198.4±16.5) min, $P<0.01$]. At the last follow-up 2 years after operation, the Cobb angle and its correction rate in the convex group were better than those in the bilateral group [(8.0±2.3)° vs (9.9±3.2)°, $P=0.03$; (81.9±5.4)% vs (77.8±5.8)%, $P=0.02$]. The rate of pedicle screw breach rate was 5.4% (17/312) in the bilateral group and 1.4% (4/280) in the convex group, with significant difference ($P<0.01$). At the last follow-up 2 years after operation, the treatment satisfaction of quality of life assessment of the bilateral group was 4.61±1.38, and that of the convex group was 4.50±1.44, but there was no significant difference between the 2 groups ($P>0.05$). There were no abnormal electrophysiological monitoring or operation-related complications in the 2 groups. **Conclusion** For Lenke type 5C AIS, the convex side of pedicle screw placement and orthopedics followed by concave side of pedicle screw placement and

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[作者简介] 林徐苗, 博士, 主治医师. E-mail: superlin0426@163.com; 陈 锴, 硕士, 主治医师. E-mail: spine_kai@smmu.edu.cn

[△]共同第一作者(Co-first authors).

* 通信作者(Corresponding author). Tel: 021-31161695, E-mail: spinebaiys@163.com

orthopedics can achieve better surgical effect.

[Key words] adolescent idiopathic scoliosis; Lenke type 5C; scoliosis orthopedics; orthopedic sequence; orthopedic effects

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青少年特发性脊柱侧凸 (adolescent idiopathic scoliosis, AIS) 是一种原因不明的复杂脊柱畸形, 其患病率为 0.47%~5.20%^[1]。2001 年, Lenke 等^[2]提出一种新的 AIS 分型系统, 其中 Lenke 5C 型 AIS 定义为以胸腰弯/腰弯为结构性弯, 可伴有非结构性胸弯, 且骶骨中垂线 (center sacral vertical line, CSVL) 未触及顶椎的侧凸。目前, 后路椎弓根钉棒系统内固定已成为 Lenke 5C 型 AIS 患者最常用的矫形术式^[3-4]。已有许多文献报道, AIS 患者凸侧椎弓根较粗, 旋棒时的钉体力量朝向椎管外侧具有更好的脊髓神经安全性; 而凹侧椎弓根细小, 且脊髓贴近凹侧, 在凹侧置钉上棒进行矫形时损伤脊髓神经的风险较大^[5-6]。尽管目前节段复位平移矫形技术已较为常用, 但常规手术操作顺序仍为双侧先置钉后再行凸侧上棒矫形。因此, 目前对 Lenke 5C 型 AIS 的手术治疗常采用胸腰弯/腰弯双侧置钉后先凸侧上棒矫形再行凹侧上棒矫形, 且这已成为几乎所有脊柱畸形手术的操作步骤。然而, 有关术中置钉上棒矫形方式在 Lenke 5C 型 AIS 中的比较研究鲜见报道。本研究旨在比较 Lenke 5C 型 AIS 患者术中不同置钉上棒矫形顺序的手术效果。

1 资料和方法

1.1 病例资料 回顾性分析我院 2013 年 1 月至 2020 年 12 月收治的 Lenke 5C 型 AIS 患者的临床

资料。纳入标准: (1) 符合 Lenke 5C 型 AIS 诊断标准^[2]; (2) 行脊柱侧凸后路矫形植骨融合内固定术; (3) 随访 2 年以上; (4) 术前、术后影像学资料完整。排除标准: (1) 既往有脊柱手术史; (2) 有其他先天性脊柱疾病。共入选 42 例符合条件的 Lenke 5C 型 AIS 患者, 其中 2013 年 1 月至 2017 年 6 月采取双侧置钉后先凸侧上棒矫形再行凹侧上棒矫形的 22 例患者为双侧组, 2017 年 7 月至 2020 年 12 月采取凸侧置钉上棒矫形后再行凹侧置钉上棒矫形的 20 例患者为凸侧组。本研究经我院伦理委员会审批 (CHEC2024-143)。

1.2 手术方法 手术全程在体感诱发电位和运动诱发电位监护下完成。按照 Lenke 分型选择融合节段^[2]。患者全身麻醉后取俯卧位, 采用后正中切口, 于骨膜下剥离两侧椎旁肌, 显露棘突、椎板至小关节突外侧缘。(1) 双侧组: 分别于凸侧及凹侧置钉后, 根据胸腰弯/腰弯的曲度预弯矫形棒, 通过凸侧旋棒和椎体直接去旋转技术进行侧凸矫形, 凸侧适当行椎弓根螺钉间撑开。(2) 凸侧组: 先于凸侧置钉后, 根据胸腰弯/腰弯的曲度预弯凸侧矫形棒, 通过凸侧旋棒和椎体直接去旋转技术进行侧凸部分矫形, 暂时拧紧螺钉; 再行凹侧置钉, 根据胸腰弯/腰弯的曲度预弯凹侧矫形棒, 上棒后松开凸侧螺钉, 再行凸凹双侧同时去旋转矫形。见图 1。

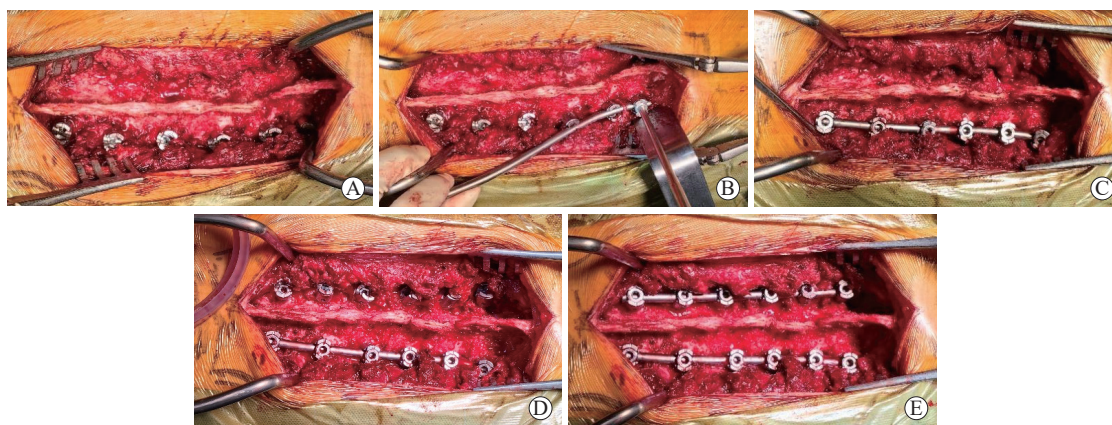


图 1 Lenke 5C 型 AIS 患者凸侧组手术操作顺序

Fig 1 Sequence of surgical operations in convex group of Lenke type 5C AIS patients

A: Placed screws in the convex side; B: Put rod in the convex side and perform orthopedic; C: Preload nuts; D: Placed screws in the concave side; E: Put rod in the concave side and lock double side nuts. AIS: Adolescent idiopathic scoliosis.

最后,依次拧紧螺帽,用咬骨钳咬除融合范围内的棘突、椎板去皮质、打磨小关节突后,行自体骨及同种异体骨的植骨融合,放置引流管,逐层关闭切口。

两组均采用强生胸腰椎后路内固定系统及其脊柱三维矫形工具。所有手术均由同一组医师完成,麻醉均由同一麻醉医师实施。

1.3 疗效评价

1.3.1 手术相关指标 包括手术时间、术中出血量、融合节段数量、置钉数量、住院天数。

1.3.2 影像学指标 术前拍摄站立位全脊柱正侧位 X 线片和 Bending 位 X 线片,术后 2 年随访时再次拍摄站立位全脊柱正侧位 X 线片,评估患者矫形效果: (1) 主弯 Cobb 角; (2) 术后 2 年随访时主弯矫正率 (%) = (术前主弯 Cobb 角 - 末次随访时主弯 Cobb 角) / 术前主弯 Cobb 角 × 100%; (3) 胸椎后凸角 (thoracic kyphosis, TK; T₅~T₁₂); (4) 腰椎前凸角 (lumbar lordosis, LL; L₁~S₁); (5) 顶椎偏距 (apical vertebral translation, AVT), 即胸腰弯/腰弯的顶椎(椎体或椎间盘)中点到 CSVL 的水平距离; (6) 冠状面平衡 (coronal balance, CB), 即 C₇ 铅垂线与 CSVL 的水平距离; (7) 矢状面平衡 (sagittal vertical axis, SVA), 即 C₇ 铅垂线与骶骨后上缘的水平距离; (8) 近端交界性后凸角 (proximal junctional angle, PJA), 即上固定椎的下终板与上固定椎上 2 个椎体的上终板形成的角度。

术后 1 周内通过 CT 平扫图像,根据 Gertzbein 和 Robbins^[7] 分级标准判断螺钉位置: A 级,椎弓根螺钉在椎弓根内; B 级,椎弓根螺钉穿破椎弓根皮质 ≤ 2 mm; C 级,椎弓根螺钉穿破椎弓根皮质 > 2 mm 且 ≤ 4 mm; D 级,椎弓根螺钉穿破椎弓根皮质 > 4 mm 且 ≤ 6 mm; E 级,椎弓根螺钉穿破椎弓

根皮质 > 6 mm。其中 A、B 级视为准确置钉,椎弓根螺钉破壁率 (%) = C、D、E 级椎弓根螺钉数量合计 / 总置钉数量 × 100%。

1.3.3 手术并发症 记录两组患者手术并发症的发生情况,包括血管神经损伤、断钉、断棒、螺钉松动、假关节及感染等。

1.3.4 生活质量评价 术前及术后 2 年末次随访时采用脊柱侧凸研究学会-22 (Scoliosis Research Society 22, SRS-22) 简明量表评估患者的生活质量。该量表包含 22 个条目,由功能/活动度、疼痛、自我形象、精神健康、治疗满意度 5 个维度组成。每个条目计分 1~5 分。

1.4 统计学处理 应用 SPSS 23.0 软件进行统计分析。计量资料以 $\bar{x} \pm s$ 表示,两组间比较采用独立样本 *t* 检验,采用重复测量方差分析评估术后不同随访时间点的差异。计数资料以例数和百分数表示,两组间比较采用 χ^2 检验。检验水准 (α) 为 0.05。

2 结果

2.1 患者基本资料 22 例 Lenke 5C 型 AIS 患者双侧组中,男 4 例、女 18 例,年龄为 10~15 (13.3 ± 1.6) 岁, BMI 为 (17.7 ± 1.7) kg/m², Risser 征为 2 级 2 例、3 级 3 例、4 级 13 例、5 级 4 例。20 例凸侧组患者中,男 3 例、女 17 例,年龄为 11~17 (13.5 ± 1.5) 岁, BMI 为 (18.8 ± 2.3) kg/m², Risser 征为 3 级 6 例、4 级 9 例、5 级 5 例。两组患者的性别、年龄、BMI 和 Risser 征差异均无统计学意义 (均 *P* > 0.05), 具有可比性。

2.2 手术相关指标比较 双侧组手术时间长于凸侧组,差异有统计学意义 (*P* < 0.01)。两组术中出血量、融合节段数量、置钉数量、住院天数差异均无统计学意义 (均 *P* > 0.05)。见表 1。

表 1 两组 Lenke 5C 型 AIS 患者的手术相关指标比较

Tab 1 Comparison of operation-related indicators between 2 groups of Lenke type 5C AIS patients

Index	Bilateral group <i>n</i> = 22	Convex group <i>n</i> = 20	<i>t</i> value	$\bar{x} \pm s$
				<i>P</i> value
Operative time/min	232.8 ± 13.1	198.4 ± 16.5	7.51	<0.01
Intraoperative blood loss/mL	538.6 ± 167.6	475.0 ± 89.6	1.51	0.14
Number of fused segments	6.4 ± 1.0	6.1 ± 1.2	0.91	0.37
Number of pedicle screws	14.4 ± 1.3	14.2 ± 1.0	0.60	0.55
Hospital stay/d	9.7 ± 1.6	8.7 ± 1.9	1.93	0.06

Bilateral group: After bilateral screw placement, orthopedics was performed on the convex side and then on the concave side; Convex group: Screws placed on the convex side and performed orthopedics, followed by the concave side. AIS: Adolescent idiopathic scoliosis.

2.3 矫形效果比较 两组患者均成功获得手术矫正。双侧组和凸侧组的术前主弯 Cobb 角比较差异无统计学意义 ($P=0.53$)，而术后 2 年末次随访时凸侧组主弯 Cobb 角及其矫正率均优于双侧组 ($P=0.03$ 、 0.02)；术前和术后 2 年末次随访

时 TK、LL、AVT、CB、SVA 及 PJA 组间比较差异均无统计学意义 (均 $P>0.05$)。双侧组和凸侧组的椎弓根螺钉破壁率分别为 5.4% (17/312) 和 1.4% (4/280)，差异有统计学意义 ($P<0.01$)。见表 2。

表 2 两组 Lenke 5C 型 AIS 患者术前和术后 2 年时影像学参数比较

Tab 2 Comparison of preoperative and 2-year postoperative imaging parameters between 2 groups of Lenke type 5C AIS patients				
Index	Bilateral group $N=22$	Convex group $N=20$	Statistic	P value
Main curve Cobb angle, $\bar{x}\pm s$				
Cobb angle before operation/(°)	44.3±4.1	43.7±2.1	$t=0.64$	0.53
Cobb angle 2 years after operation/(°)	9.9±3.2	8.0±2.3	$t=2.21$	0.03
Correction rate 2 years after operation/%	77.8±5.8	81.9±5.4	$t=2.36$	0.02
TK/(°), $\bar{x}\pm s$				
Preoperative	20.2±2.9	22.1±3.6	$t=-1.89$	0.67
2 years after operation	29.7±3.0	30.3±4.7	$t=-0.49$	0.62
LL/(°), $\bar{x}\pm s$				
Preoperative	45.3±8.5	51.3±9.3	$t=-2.13$	0.11
2 years after operation	56.4±7.2	57.7±10.8	$t=-0.71$	0.75
AVT/mm, $\bar{x}\pm s$				
Preoperative	31.8±5.7	33.1±3.7	$t=-0.87$	0.39
2 years after operation	16.0±6.8	17.1±5.1	$t=-0.59$	0.60
CB/mm, $\bar{x}\pm s$				
Preoperative	21.7±5.9	20.2±4.0	$t=0.98$	0.33
2 years after operation	15.7±3.7	13.9±2.7	$t=1.84$	0.07
SVA/mm, $\bar{x}\pm s$				
Preoperative	22.6±8.1	31.0±9.6	$t=-3.23$	0.30
2 years after operation	21.5±6.0	26.0±7.8	$t=-1.25$	0.75
PJA/(°), $\bar{x}\pm s$				
Preoperative	6.3±3.6	6.2±3.6	$t=0.13$	0.97
2 years after operation	11.8±6.0	14.6±5.7	$t=0.97$	0.22
Pedicle screw breach rate 1 week after operation, % (n/N) ^a	5.4 (17/312)	1.4 (4/280)	$\chi^2=6.97$	<0.01

^a: The total number of nails in the bilateral group and convex group was 312 and 280, respectively. Bilateral group: After bilateral screw placement, orthopedics was performed on the convex side and then on the concave side; Convex group: Screws placed on the convex side and performed orthopedics, followed by the concave side. AIS: Adolescent idiopathic scoliosis; TK: Thoracic kyphosis; LL: Lumbar lordosis; AVT: Apical vertebral translation; CB: Coronal balance; SVA: Sagittal vertical axis; PJA: Proximal junctional angle.

2.4 手术并发症分析 两组患者术中均无电生理监测异常及手术相关并发症发生。

2.5 生活质量比较 术后 2 年末次随访时，所有患者均完成了 SRS-22 量表调查。与术前相比，两组患者末次随访时 SRS-22 量表各维度得分均有所提高，

在自我形象和心理状况方面差异均有统计学意义(均 $P<0.01$)。双侧组治疗满意度为 (4.61±1.38) 分，凸侧组治疗满意度为 (4.50±1.44) 分，两组间差异无统计学意义 ($P>0.05$)。见表 3。

表 3 两组 Lenke 5C 型 AIS 患者术前和术后 2 年时 SRS-22 量表各维度得分比较

Tab 3 Comparison of preoperative and 2-year postoperative SRS-22 scores on each dimension between 2 groups of Lenke type 5C AIS patients					
Group	Function/activity	Pain	Self-image/appearance	Mental health	$\bar{x}\pm s$ Satisfaction
Bilateral group $n=22$					
Preoperative	4.32±1.17	4.45±1.10	3.27±0.70	3.23±0.75	2.03±0.72
2 years after operation	4.55±2.06	4.68±1.21	4.36±0.90	4.55±1.34	4.61±1.38
t value	-0.45	-0.65	-4.48	-4.04	-7.79
P value	0.66	0.52	<0.01	<0.01	<0.01
Convex group $n=20$					
Preoperative	4.35±1.27	4.10±1.21	3.20±0.95	3.20±0.70	2.08±0.83
2 years after operation	4.55±1.36	4.85±1.31	4.35±1.31	4.55±1.40	4.50±1.44
t value	-0.48	-1.88	-3.18	-3.87	-6.52
P value	0.63	0.07	<0.01	<0.01	<0.01

Bilateral group: After bilateral screw placement, orthopedics was performed on the convex side and then on the concave side; Convex group: Screws placed on the convex side and performed orthopedics, followed by the concave side. AIS: Adolescent idiopathic scoliosis; SRS-22: Scoliosis Research Society 22.

3 讨论

随着椎弓根螺钉技术及平移矫形技术的发展,后路矫形融合内固定术已成为 Lenke 5C 型 AIS 矫形的标准术式。对于包括 Lenke 5C 型在内的所有脊柱侧凸,手术常规的操作顺序是先双侧分别置钉,再行矫形侧上棒及对侧上棒。Lenke 5C 型 AIS 由于弯曲畸形发生在胸腰交界或腰椎,有柔韧度较好、椎体旋转度较大、术中操作时椎体活动幅度更明显等特征。我们在长期大量的 AIS 矫形手术中发现,Lenke 5C 型脊柱侧凸患者凹侧置钉时由于椎体旋转向对侧,因此在椎弓根螺钉开口开路置钉时,操作器械的内倾角度是各类型 AIS 患者中最大的,容易出现螺钉向椎弓根外侧突破椎弓根皮质骨的情况,在体重较大或术区伤口较深的病例中甚至会出现椎旁肌软组织阻挡开路器和椎弓根螺钉螺丝刀内倾的情况。此外,在凹侧置钉开口开路时,开路器对椎弓根开口开路处的压力会加重椎体旋转,这在旋转度、柔韧度都很大的 Lenke 5C 型脊柱侧凸行凹侧置钉时尤为明显,不利于准确、高效、方便的开路和置钉。

对于 Lenke 5C 型 AIS 患者如果先在凸侧置钉后行凸侧上棒矫形,然后再行凹侧置钉,这样在凸侧上棒矫形后腰椎弯曲的旋转已被大部分去旋转至近中立位,有利于接下来的凹侧开路和置钉。同时,凸侧上棒矫形固定后,凹侧开口开路置钉时的压力也不会造成腰椎弯曲旋转进一步向凸侧加重。这既有利于凹侧开口开路置钉,降低凹侧置钉难度和置钉破壁率,同时也能减少对 Lenke 5C 型 AIS 患者腰弯凹侧置钉时的旋转的外力加重。这种置钉和上棒顺序的步骤顺序调整,对于整个手术策略和其他步骤没有影响。

本研究对 Lenke 5C 型 AIS 患者不同置钉上棒顺序的手术效果进行了比较,结果也显示凸侧组在手术时间和置钉准确度上都更有优势,而其余主要结果不受影响。脊柱侧凸由于椎弓根解剖结构异常及椎体旋转,致使此类手术损伤脊髓、血管、神经的风险大大增加^[8]。有研究报道,脊柱侧凸患者的凹侧椎弓根直径小于凸侧^[9-10],且椎弓根相对窄而硬化^[11],具有较高的椎弓根破壁率及并发症的发生率^[12]。从理论上而言,凸侧椎弓根较凹侧椎弓根粗且相对凹侧而言远离脊髓和硬膜囊,因此,本研究结果显示凸侧置钉先上棒矫形固定再行凹侧置钉,对于凹侧椎体而言,其更贴近正常矢状面且在加压置钉过程中柔韧度降低,可以抵抗开口开路过程中椎体旋转,使凹侧置钉过程中螺钉偏出椎体外壁的可能性大大降低,同时也减少了置钉过程中对凹侧硬膜囊造成干扰的可能,增加了手术安全性。

综上所述,对于 Lenke 5C 型 AIS,凸侧置钉先上棒矫形再行凹侧置钉上棒矫形是一种安全、有效的方法。本研究也存在不足之处,如样本量较小、随访时间短,拟在后续研究中扩大样本量、延长随访时间,以进一步观察长期疗效。

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