

临床论著

儿童 SDSG 5/6 型发育不良性腰椎滑脱患者
手术治疗后骨盆平衡情况变化郭 东,姚子明,张学军,李承鑫,祁新禹,白云松,孙保胜
(国家儿童医学中心 首都医科大学附属北京儿童医院骨科 100045 北京市)

【摘要】目的:探讨在儿童重度发育不良性腰椎滑脱伴不平衡型骨盆[即脊柱畸形研究学组(Spinal Deformity Study Group,SDSG)分型 5 和 6 型]患者中手术复位及重建腰骶前凸对骨盆平衡的影响。方法:回顾性分析 2015 年 2 月~2019 年 2 月手术治疗的 23 例儿童重度发育不良性腰椎滑脱患者,男 2 例,女 21 例,年龄 9.6 ± 2.4 岁。均为 L5 滑脱,术前均伴有骨盆后倾。SDSG 分型 5 型 21 例,6 型 2 例。均行减压复位腰骶后凸矫正内固定融合术。测量术前及术后 1 年随访时脊柱骨盆矢状面相关参数,包括骨盆入射角(pelvic incidence,PI)、骨盆倾斜角(pelvic tilt,PT)、骶骨倾斜角(sacral slope,SS)、L5 倾斜角(L5 slope,L5S)、腰椎前凸角(lumbar lordosis,LL)、滑脱程度(slip percentage,SP)、SDSG 发育不良腰骶角(SDSG dysplastic lumbosacral angle,SDSG-dys LSA)、Boxall's 滑脱角(Boxall's slip angle,BSA)、Dubousset's 腰骶角(Dub-LSA)、腰骶后凸角(kyphotic Cobb angle,k-Cobb)。根据术后 1 年时骨盆旋转情况分为术后平衡型骨盆组和不平衡型骨盆组,对比两组患者后凸改善、滑脱复位率及近端固定椎的差异。结果:随访 26 ± 11 个月(13~48 个月),术后 1 年时 PI 无显著性改变($P>0.05$),SS 及 Dub-LSA 较术前均有显著性增加($P<0.05$);PT、L5S、LL、SP、SDSG dys-LSA 及 BSA 较术前均有显著性减少($P<0.05$);k-Cobb 由术前 $11.6^\circ\pm 12.8^\circ$ 改善至 $-11.5^\circ\pm 16.3^\circ$ ($P<0.05$);滑脱复位率为 $(85.5\pm 16.4)\%$ 。术后 1 年时 23 例患者中有 5 例(22%)骨盆改善为平衡型,骨盆平衡组患者滑脱复位率显著性高于不平衡组(90.9% vs. 76.2% , $P<0.05$),两组腰骶后凸改善及近端固定椎位置无显著性差异($P>0.05$)。结论:手术治疗儿童 SDSG 5/6 型发育不良性腰椎滑脱可有效改善脊柱-骨盆矢状位序列,部分患者可从不平衡型骨盆改善为平衡型骨盆,且骨盆平衡的改善与滑脱复位相关。

【关键词】腰椎滑脱;发育不良;骨盆参数;不平衡骨盆;儿童

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The pelvic balance after surgical treatment for pediatric SDSG 5/6 developmental spondylolisthesis/
GUO Dong, YAO Ziming, ZHANG Xuejun, et al//Chinese Journal of Spine and Spinal Cord, 2020, 30
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【Abstract】Objectives: To investigate the effect of surgical reduction and reconstruction of lumbosacral lordosis on the improvement of pelvic balance in children with high-grade developmental spondylolisthesis of type 5 and 6 according to Spinal Deformity Study Group(SDSG) classification. Methods: 23 children with high-grade developmental spondylolisthesis treated by operation from February 2015 to February 2019 were analyzed retrospectively. There were 2 males and 21 females, aged 5.3 to 13.8 years(9.6 ± 2.4 years). All patients with retroverted pelvis before operation were classified into type 5 and 6 according to SDSG classification. All patients underwent decompression, reduction, lumbosacral kyphosis correction and internal fixation. The related parameters of sagittal plane of spine and pelvis were measured before operation and at one year follow-up, including pelvic incidence(PI), pelvic tilt(PT), sacral slope(SS), L5 slope(L5S), lumbar lordosis(LL), slip percentage(SP), SDSG dysplastic lumbosacral angle(SDSG-dysLSA), Boxall's slip angle(BSA), Dubousset's lumbosacral angle(Dub-LSA), and kyphotic Cobb angle(k-Cobb). All patients were divided into two groups according to postoperative pelvic rotation, group balanced pelvis and group unbalanced pelvis. Comparison of lumbosacral

第一作者简介:男(1980-),副主任医师,医学硕士,研究方向:脊柱外科

电话:(010)59616412 E-mail:drguodong@vip.163.com

通讯作者:张学军 E-mail:zhang-x-j04@163.com

kyphosis, slippage reduction rate and proximal anchoring level was made between two groups. **Results:** The patients were followed up for 26 ± 11 months(13–48 months). There was no significant change in PI($P>0.05$). SS and Dub–LSA increased significantly($P<0.05$). PT, L5S, LL, SP, SDSG dys–LSA and BSA decreased significantly($P<0.05$). The k–Cobb was improved from $11.6^\circ\pm 12.8^\circ$ to $-11.5^\circ\pm 16.3^\circ$. The reduction rate of spondylolisthesis was $(85.5\pm 16.4)\%$. Of the 23 patients, 5(22%) had pelvic improvement to balanced type. Group of balanced pelvis had a higher reduction rate than group of unbalanced pelvis(90.9% vs. 76.2%, $P<0.05$). There was no significant difference on lumbosacral kyphosis and proximal anchoring level between two groups.

Conclusions: Surgical reduction of spondylolisthesis and reconstruction of lumbosacral lordosis can improve the sagittal balance of spine–pelvis in children with dysplastic severe spondylolisthesis. 22% of the patients could be improved from unbalanced pelvis to balanced pelvis.

【Key words】 Lumbar spondylolisthesis; Dysplasia; Pelvic parameters; Unbalanced pelvis; Children

【Author's address】 Department of Orthopaedics, Beijing Children's Hospital, Capital Medical University, National Center for Children's Health, China, Beijing, 100045, China

发育不良性腰椎滑脱是儿童期常见的脊柱畸形,由腰骶交界区发育异常所致,随青少年期高速增长发育,滑脱进展迅速,腰骶后凸逐渐加重,从而引起骨盆后倾、姿势异常和神经损害等,严重影响患者的身心健康和生长发育^[1,2]。脊柱畸形研究学组(Spinal Deformity Study Group,SDSG)提出了 L5 腰椎滑脱的脊柱–骨盆矢状位平衡分型,在重度滑脱中根据骨盆旋转分为平衡型骨盆和不平衡型(后倾型)骨盆,伴有后倾型骨盆的重度滑脱即 SDSG 5/6 型^[3]。既往有研究指出重建腰骶前凸对脊柱骨盆矢状位平衡至关重要,但是少有文献报道手术复位术后患者骨盆平衡改善情况及影响骨盆平衡改善的相关因素。本研究旨在探讨儿童重度发育不良性腰椎滑脱伴不平衡型骨盆患者中,手术复位及重建腰骶前凸对骨盆平衡改善的影响及相关因素。

1 资料和方法

1.1 一般资料

收集 2015 年 2 月~2019 年 2 月我院骨科收治的发育不良性腰椎滑脱病例,纳入标准:(1)滑脱节段为 L5;(2)SDSG 分型 5 型及 6 型腰椎滑脱;(3)根据 Hresko 等^[4]提出的骨盆矢状位平衡标准,术前为不平衡型骨盆;(4)行减压复位内固定加椎间植骨融合术。排除标准:(1)资料不全;(2)随访时间不足 1 年;(3)合并脊柱创伤、感染、肿瘤及代谢性疾病等。共 23 例患者符合纳排标准,其中男 2 例,女 21 例。术前均表现为不同程度的腰痛,弯腰受限,间歇性跛行或步态异常。

1.2 手术方法

所有患者均行后路 L5/S1 椎间盘切除,神经

根减压,滑脱复位、后凸矫正,椎弓根螺钉内固定术,其中 18 例患者仅行 L5~S1 短节段内固定,2 例患者行 L4~S1 内固定,1 例患者行 L4~S2 固定,2 例患者行 L4~S2AI 固定。20 例患者行 S1 上终板拱顶样改变部分切除,15 例行 L5 弧形下终板部分切除。所有患者均行椎间植骨融合,术后支具保护 3 个月。

1.3 影像学测量及评估

影像学评估和测量均利用 Surgimap 软件(Nemaris,纽约,美国)测量完成,隔周测量两次取平均值,角度测量精确度为 0.1° ,百分比精度为 1%。影像学测量参数包括:(1)骨盆入射角(pelvic incidence,PI);(2)骨盆倾斜角(pelvic tilt,PT);(3)骶骨倾斜角(sacral slope,SS);(4)L5 倾斜角(L5 slope,L5S),L5 上终板与水平线夹角;(5)腰椎前凸角(lumbar lordosis,LL),L1 上终板和 L5 下终板夹角;(6)SDSG 发育不良腰骶角(SDSG dysplastic lumbosacral angle,SDSG –dys LSA),L5 椎体上终板和 S1 上终板夹角,前凸时为负值,后凸时为正值;(7)Boxall's 滑脱角(Boxall's slip angle,BSA),L5 椎体下终板和 S1 椎体后缘垂线的夹角;(8)Dubousset's 腰骶角(Dub–LSA),L5 椎体上终板和 S1 椎体后缘的夹角;(9)腰骶后凸角(kyphotic Cobb angle,k–Cobb),L5 椎体上终板和 S1 椎体下终板的矢状位 Cobb 角;(10)滑脱程度(slip percentage,SP),L5 滑移距离所占 S1 上终板长度的百分比,滑脱复位率=(术前滑脱程度–术后滑脱程度)/术前滑脱程度 $\times 100\%$ 。

术后 1 年随访时,根据 Hresko 等^[4]提出的骨盆矢状位平衡标准将患者分为平衡型骨盆组及不平衡型骨盆组,对比两组患者以上影像学参数。

1.4 统计学方法

采用 SPSS 19.0 软件对数据进行统计学分析。定量数据以均数 $\pm$ 标准差表示,术前与术后各参数比较采用配对 t 检验。采用独立样本 t 检验和 χ^2 检验对术后骨盆平衡组和不平衡组的参数进行对比, $P < 0.05$ 为差异有统计学意义。

2 结果

患者手术时年龄 9.6 ± 2.4 岁 (5.3~13.8 岁)。术前骨骼成熟度:Risser 征 0 级 21 例,4 级 2 例;Y 软骨开放状态 8 例,正在闭合 13 例,完全闭合 2 例。SDSG 分型 5 型 21 例,6 型 2 例。Meyerding 法分类:Ⅲ度滑脱 19 例,Ⅳ度滑脱 3 例,Ⅴ度滑脱 1 例。手术时间 226 ± 68 min,术中出血量 458 ± 126 ml。术后随访 26 ± 11 个月 (13~48 个月),共 8 例患者出现并发症,其中 2 例近端固定于 L5,术后 6 个月时出现 L4 轻度滑脱,随访观察中;6 例术后出现神经根牵拉症状,给予营养神经药物,术后 2 周至 9 个月恢复;1 例伤口浅层感染,换药后愈合良好。

术前及术后 1 年随访时的影像学参数见表 1。术后 1 年,PI 无显著性改变 ($P > 0.05$),PT、SS、L5S、LL、dys-LSA、SDSG LSA、Dub-LSA、k-Cobb 与术前比较均有显著性差异 ($P < 0.05$)。滑脱复位率为 $49\% \sim 110\% [(85.5 \pm 16.4)\%]$ 。术后 1 年随访时,5 例 (22%) 患者恢复为平衡型骨盆 (图 1),18 例仍为不平衡型骨盆。两组患者术前影像学参数见表 2。两组患者术前 SS、PT、LL、SP、Dub-LSA 及术后 k-Cobb 和 Dub-LSA 改善无显著性差异 ($P > 0.05$);平衡型骨盆组患者滑脱复位率显著性高于不平衡型组 ($90.9\% \text{ vs. } 76.2\%, P < 0.05$)。两组患者的近端固定椎分布情况无显著性差异 ($P > 0.05$)。

3 讨论

发育不良性腰椎滑脱患儿与正常儿童的骨盆形态不同。既往研究表明,PI 随年龄的增长不断增加^[5]。Zhou 等^[9]发现无症状中国儿童及青少年 12 岁以下随生长发育 PI 值与年龄的关系为 $PI = 26.243 + 1.153 \times \text{年龄}$ 。与其他国家发表的青少年研究相比,我国儿童 PI、PT 和 SS 更低^[6-9]。本研究中发育不良性腰椎滑脱患儿的 PI 明显高于正常儿童。为避免年龄增加对 PI 值的影响,本研究选取

术后 1 年随访为观察期。此外,由于 L5 下终板弧形变及 S1 上终板穹窿样变,使传统局部后凸测量不准确,因此本研究采用了 k-Cobb 角和 Dub-LSA 来描述局部后凸畸形^[10]。

重度发育不良性滑脱是否进行手术复位目前仍有争议,一方面复位操作本身具有一定的挑战,另一方面会造成较多的神经系统并发症^[11-13]。Petraco 等^[14]报道,滑脱复位与 L5 神经根张力的增加有关。而 Bourassa-Moreau 等^[15]认为手术复位后患者生活质量有明显改善。有研究发现,与原位融合相比,复位并不增加神经功能障碍的风险^[16,17],增加融合率^[18,19]。本组患者中均进行了滑脱复位,平均复位率达 85.5%,术后骨盆平衡组的患者滑脱复位率更高,证实滑脱复位可能是术后骨盆平衡改善的重要因素。

Roussouly 等^[20]的研究中,对病理状态的骨盆进行生物力学分析,指出脊柱、骨盆、下肢均参与病理后凸状态下矢状位平衡机制,腰骶后凸的矫正理论上可以改善骨盆平衡,后凸矫正按照髋关节-骨盆-脊柱,顺序恢复矢状位平衡,重建腰骶前凸后脊柱骨盆会形成新的平衡状态,在髋关节

表 1 23 例患者手术前后脊柱-骨盆矢状位参数

Table 1 Variations of sagittal spine-pelvic parameters pre- and post-operatively

	术前 Pre-op	术后 1 年 1 year post-op	改变 Change	P 值 P value
PI (°)	70.1 $\pm$ 12.7	71.5 $\pm$ 10.7	1.5 $\pm$ 5.1	0.186
PT (°)	38.3 $\pm$ 9.3	30.2 $\pm$ 6.6	8.1 $\pm$ 8.5	<0.05
SS (°)	31.8 $\pm$ 11.5	41.5 $\pm$ 10.1	9.7 $\pm$ 7.4	<0.05
L5S (°)	39.2 $\pm$ 9.7	25.2 $\pm$ 13.3	13.9 $\pm$ 10.1	<0.05
LL (°)	62.5 $\pm$ 13.4	51.6 $\pm$ 13.8	10.9 $\pm$ 13.5	<0.05
SDSG dys-LSA (°)	11.6 $\pm$ 15.0	-16.2 $\pm$ 13.2	27.9 $\pm$ 15.2	<0.05
BSA (°)	25.2 $\pm$ 18.5	-1.4 $\pm$ 10.3	26.6 $\pm$ 19.9	<0.05
Dub-LSA (°)	67.6 $\pm$ 14.6	97.1 $\pm$ 14.0	29.5 $\pm$ 13.9	<0.05
k-Cobb (°)	11.6 $\pm$ 12.8	-11.5 $\pm$ 16.3	24.5 $\pm$ 15.6	<0.05
SP (%)	62 $\pm$ 15	9 $\pm$ 17	53 $\pm$ 15	<0.05

注:PI,骨盆入射角;PT,骨盆倾斜角;SS,骶骨倾斜角;L5S,L5 倾斜角;LL,腰椎前凸角;SDSG dys-LSA,SDSG 发育不良腰骶角;BSA,Boxall's 滑脱角;Dub-LSA,Dubouset's 腰骶角;k-Cobb,腰骶后凸角;SP,滑脱程度

Note: PI, Pelvic incidence; PT, Pelvic tilt; SS, Sacral slope; L5S, L5 slope; LL, Lumbar lordosis; SDSG dys-LSA, SDSG dysplastic lumbosacral angle; BSA, Boxall's slip angle; Dub-LSA, Dubouset's lumbosacral angle; k-Cobb, kyphotic Cobb angle; SP, slip percentage

代偿恢复后,骨盆的回旋和 L5 后倾会相继出现。周艺等^[21]观察了 10 例伴有不平衡型骨盆的发育不良性重度滑脱患者,滑脱复位和后凸矫正后,2 例(20%)转变为平衡型骨盆。而 Martikos 等^[22]的研究表明,滑脱部分复位后,最初不平衡的骨盆在手术后仍可能为不平衡型骨盆。Alzakri 等^[23]的一项多中心研究发现,手术复位从重度滑脱变为轻度滑脱时,对术后维持和恢复正常骨盆平衡更为有效;27 例患者中 11 例(40%)术后恢复骨盆平



图 1 患者女,8 岁,发育不良性 L5 重度滑脱,SDSG 5 型
a 术前 X 线片示 L5 椎体 IV 度滑脱,PI 62.6°,PT 31.2°,SS 31.4°,LL 60.2°,k-Cobb 8.2°,Dub-LSA 81.4°,SP 88% b 术后 1 年随访 X 线片,PI 62.4°,PT 19.2°,SS 43.2°,LL 61.6°,k-Cobb -20.5°,Dub-LSA 107.8°,滑脱程度为 12%;腰骶后凸矫正 28.7°,PT 恢复 12.0°,SS 增加 11.8°,滑脱复位率 86%,术后恢复为平衡型骨盆

Figure 1 Female, 8 years old, with high-grade developmental spondylolisthesis, unbalanced pelvis and balanced spine-SDSG type 5 a Preoperative radiograph showing grade IV developmental spondylolisthesis, PI 62.6°, PT 31.2°, SS 31.4°, LL 60.2°, k-Cobb 8.2°, Dub-LSA 81.4°, and SP 88% b Postoperative radiograph, 1 yr follow-up, with PI 62.4°, PT 19.2°, SS 43.2°, LL 61.6°, k-Cobb -20.5°, Dub-LSA 107.8°, and SP 12%. Lumbosacral kyphosis was corrected by 28.7°, PT improved 12°. After the operation, the patient returned to balanced pelvis, SS increased by 11.8°, and slippage reduction rate was 86%

衡状态。在本研究中 23 例伴有不平衡型骨盆的重度发育不良性腰椎滑脱,术后有 5 例转变为平衡型骨盆。提示重度发育不良性滑脱伴不平衡型骨盆的患儿仍有较强的骨盆平衡改善能力。

本研究结果显示,尽管术后骨盆平衡型患者的后凸改善平均值更大一些,但差异无统计学意义。理论上,腰骶前凸的重建与滑脱复位是相互影响的过程,骨盆平衡的改善需要 L5 和 S1 之间的相对平移和旋转来改善,造成两组无统计学差异的结果,可能是由于样本量较小所致。

在本研究中还发现 5 例术后恢复平衡骨盆的患者均为近端固定节段在 L5 的短节段固定患者,可能与保留 L4/5 椎间活动有一定的代偿能力有关。

总之,手术治疗儿童 SDSG 5/6 型发育不良性腰骶滑脱可有效改善脊柱-骨盆矢状位序列,部分患者可从不平衡型骨盆改善为平衡型骨盆,且骨盆平衡的改善与滑脱复位相关。但本研究随访时间短,取 1 年随访的结果虽可避免年龄增长带来的儿童 PI 值变化,却无法确定长期随访结果;另外本研究样本量不足,在进行分析时有可能

表 2 术后平衡和不平衡骨盆患者相关参数比较

Table 2 Comparison of parameters between patients with postoperative balanced and unbalanced pelvis

	术后平衡型骨盆(n=5) Balanced pelvis post-op	术后不平衡型骨盆(n=18) Unbalanced pelvis post-op	P值 P value
术前骶骨倾斜(°) Pre-op SS	38.7±8.1	30.0±11.4	0.129
术前骨盆倾斜角(°) Pre-op PT	32.6±2.8	40.4±10.2	0.113
术前腰椎前凸角(°) Pre-op LL	71.6±13.1	56.0±15.3	0.138
术前滑脱程度(°) Pre-op SP	63.4±14.3	59.3±16.3	0.615
术前腰骶角(°) Pre-op Dub-LSA	69.9±13.7	66.9±13.1	0.663
腰骶后凸角改善(°) Improvement of k-Cobb	26.4±6.0	25.0±16.0	0.845
Dubousset's 腰骶角改善(°) Improvement of Dub-LSA	32.7±11.2	28.6±14.7	0.517
滑脱复位率(°) Slippage reduction rate	90.9±7.4	76.2±22.8	0.030
近端固定椎 Proximal anchoring segment			
L4	0	5	0.545
L5	5	13	

会出现偏倚。在未来的研究中有待进一步改进。

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(英文编审 谭 啸)

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