

临床论著

锥束 CT 拼接成像联合工形测量仪在青少年特发性脊柱侧凸矫形术中冠状位平衡评估的应用

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【摘要】目的:探讨锥束 CT 拼接成像联合工形测量仪在青少年特发性脊柱侧凸(adolescent idiopathic scoliosis, AIS)患者矫形术中冠状位平衡评估的应用价值。**方法:**收集 2019 年 1 月~2021 年 1 月在北部战区总医院接受脊柱后路矫形手术且术中均应用锥束 CT 拼接成像技术联合工形测量仪评估冠状位平衡情况的 48 例 AIS 患者的相关资料, 患者年龄 12~18 岁(14.9±1.8 岁), 随访时间 1~2 年(1.8±0.2 年)。根据冠状位平衡情况进行分型:A 型为冠状位平衡距离(coronal balance distance, CBD)<20mm, B 型为 CBD≥20mm 且 C7 铅垂线位于主弯的凹侧, C 型为 CBD≥20mm 且 C7 铅垂线在主弯的凸侧, 将 CBD≥20mm 定义为冠状位失平衡。记录所有患者术前、术中、术后 1 周、末次随访时的主弯 Cobb 角、CBD、骨盆冠状倾角(pelvic coronal obliquity angle, PCOA)以及术前、末次随访时疼痛视觉模拟评分(visual analogue scale, VAS)及 Oswestry 功能障碍指数(Oswestry disability index, ODI), 比较不同时间点的冠状位平衡情况及临床矫形效果。**结果:**48 例患者术前、术中、术后 1 周及末次随访时主弯 Cobb 角分别为 58.45°±12.81°、14.13°±5.86°、14.48°±5.98°、14.39°±5.74°, 术中及术后 1 周较术前均有明显改善($P<0.05$), 末次随访与术后 1 周差异无统计学意义($P>0.05$); 术前、术中、术后 1 周及末次随访时 PCOA 分别为 3.72°±2.75°、1.25°±0.97°、1.25°±0.96°、1.28°±0.96°, 其中术中及术后 1 周较术前均有明显差异($P<0.05$), 末次随访与术后 1 周差异无统计学意义($P>0.05$)。所有患者术前冠状位失平衡率为 47.91%(23/48), 末次随访时冠状位失平衡率为 10.42%(5/48)。A 型组 25 例患者术前、术中、术后 1 周及末次随访时的 CBD 分别为 12.53±4.46mm、8.06±3.15mm、8.37±3.13mm、8.66±3.77mm, 术中与术后 1 周较术前均有明显改善($P<0.05$), 末次随访与术后 1 周差异均无统计学意义($P>0.05$); B 型组 15 例及 C 型组 8 例患者术前、术中、术后 1 周及末次随访时的 CBD 分别为 24.57±4.60mm、14.91±4.62mm、14.95±4.49mm、15.06±3.98mm 及 26.46±6.78mm、16.58±4.00mm、16.94±4.12mm、16.58±3.97mm, 两组患者术中与术后 1 周较同组术前均有明显改善($P<0.05$), 末次随访与同组术后 1 周差异均无统计学意义($P>0.05$)。所有患者末次随访时 VAS 评分(3.98±0.57 分)及 ODI[(21.82±3.12)%]较术前[(7.68±0.64)分、(46.51±4.79)%]均有明显改善($P<0.05$)。**结论:**锥束 CT 拼接成像联合工形测量仪是一种有效且整体平衡评估能力强的术中冠状位平衡评估方法, 能够更好地辅助脊柱外科医生在 AIS 患者脊柱侧凸矫形术中进行冠状位平衡的评估, 及时调整矫形程度, 有效减少术后冠状位失平衡发生。

【关键词】 青少年特发性脊柱侧凸; 后路矫形术; 冠状位平衡; 锥束 CT; 拼接脊柱全长片

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Application of cone-beam CT mosaic imaging combined with I-shaped measurement instrument in assessing the coronal balance during corrective surgery for adolescent idiopathic scoliosis/LI Linyang, ZHANG Haocong, WANG Hongwei, et al//Chinese Journal of Spine and Spinal Cord, 2023, 33(3): 244-250

【Abstract】Objectives: To investigate the values of cone-beam CT(CBCT) mosaic imaging combined with I-shaped measurement instrument in assessing coronal balance during the correction surgery for patients with adolescent idiopathic scoliosis (AIS). **Methods:** Clinical data of 48 AIS patients treated with posterior spinal correction surgery and assessed for coronal balance by CBCT mosaic imaging an I-shaped measurement instrument in the General Hospital of Northern Theater Command from January 2019 to January 2021 were

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retrospectively analyzed. The patients aged 14.9 ± 1.8 (12–18) years and were followed up for 1.8 ± 0.2 (1–2) years. They were classified based on the conditions of coronal balance as follows: Type A, coronal balance distance(CBD) <20 mm; Type B, $CBD \geq 20$ mm and C7 plumb line(C7PL) shifted to the concave side of the main curve; Type C, $CBD \geq 20$ mm and C7PL shifted to the convex side of the main curve. $CBD \geq 20$ mm was defined as coronal imbalance. The main curve Cobb angle, CBD and pelvic coronal obliquity angle (PCOA) before and during surgery, at 1 week after the surgery and the last follow-up visit were recorded. In addition, visual analogue scale(VAS) scores and Oswestry disability index(ODI) before operation and at the last follow-up were recorded. Parameters reflecting the coronal balance and clinical orthopedic effect at each time point were compared. **Results:** The main curve Cobb angles of 48 AIS patients before operation, during operation, at 1 week after operation and the last follow-up were $58.45^\circ \pm 12.81^\circ$, $14.13^\circ \pm 5.86^\circ$, $14.48^\circ \pm 5.98^\circ$ and $14.39^\circ \pm 5.74^\circ$, respectively, which were significantly reduced during operation and at 1 week after operation compared with that before surgery($P < 0.05$), and which were not significantly different between postoperative 1 week and the last follow-up($P > 0.05$). The PCOAs before operation, during operation, at 1 week after surgery and the last follow-up were $3.72^\circ \pm 2.75^\circ$, $1.25^\circ \pm 0.97^\circ$, $1.25^\circ \pm 0.96^\circ$ and $1.28^\circ \pm 0.96^\circ$, respectively. A significant difference was detected in intraoperative PCOA and postoperative PCOA ($P < 0.05$); While no significant difference was detected between the PCOA at 1 week after surgery and the last follow-up visit($P > 0.05$). The coronal imbalance rate was 47.91%(23/48) before operation and 10.42%(5/48) at final follow-up. The CBDs of the type A 25 patients before surgery, during surgery, at 1 week after surgery and the last follow-up were 12.53 ± 4.46 mm, 8.06 ± 3.15 mm, 8.37 ± 3.13 mm and 8.66 ± 3.77 mm, respectively. The intraoperative and postoperative 1 week CBDs were significantly reduced compared with before surgery ($P < 0.05$), and no significant difference was found between those of postoperative 1 week and the last follow-up ($P > 0.05$). The CBDs of type B 15 patients before surgery, during surgery, at 1 week after surgery and the last follow-up were 24.57 ± 4.60 mm, 14.91 ± 4.62 mm, 14.95 ± 4.49 mm and 15.06 ± 3.98 mm, which in type C 8 patients were 26.46 ± 6.78 mm, 16.58 ± 4.00 mm, 16.94 ± 4.12 mm and 16.58 ± 3.97 mm, respectively. CBDs during surgery and at 1 week after surgery in both type B and C patients were significantly reduced compared with those before the surgery($P < 0.05$), and no significant difference was detected between those at 1 week after surgery and the last follow-up($P > 0.05$). VAS score(3.98 ± 0.57 vs. 7.68 ± 0.64) and ODI[(21.82 ± 3.12)% vs. (46.51 ± 4.79)%] at the last follow-up were significantly improved than preoperative ones($P < 0.05$). **Conclusions:** The CBCT mosaic imaging combined with I-shaped measurement instrument can be an effective and powerful tool to assess the coronal balance intraoperatively, which can assist spinal surgeons to assess the coronal balance conditions during the corrective surgery for scoliosis in AIS patients, and to timely adjust the correction degree and therefore effectively reduce the incidence of postoperative coronal imbalance.

【Key words】 Adolescent idiopathic scoliosis; Posterior orthopedic; Coronal balance; Cone-beam CT; Mosaic full-spine X-ray

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冠状位失平衡(coronal imbalance, CIB)是青少年特发性脊柱侧凸(adolescent idiopathic scoliosis, AIS)患者主要表现之一,常表现为外观改变、脊柱倾斜,严重时甚至影响心肺功能^[1,2]。相关研究表明^[3],术前 CIB 发生率为 7%~34.8%,所以 AIS 患者手术的主要目的是在保留最大非融合节段数量的同时恢复冠状位平衡。但进行矫形术后仍有 10%~40.30%的 CIB 发生率,其原因可能与缺乏良好术前规划有关,更多的是术中无法对 CIB 的纠正程度进行准确、即刻的评估所致,后因长节段固定后的脊柱代偿能力较差,故术后 CIB

的情况多见^[4-9]。为了避免术后 CIB 的发生,选择适当的方法对术中脊柱侧凸矫形效果进行评估是近些年脊柱矫形领域研究热点。

目前,国内大部分医疗单位仍通过 C 型臂 X 线透视局部术区进行冠状面平衡评估,但此方法准确性较差,且放射线暴露次数较多。2012 年 Andras 等^[10]首次报告“T 形测量仪”在术中冠状面平衡评估中的应用,该方法将“T 形测量仪”水平杆与骨盆保持同一水平,垂直杆经过骶骨正中线(CSVL),用以观察 C7 铅垂线与 CSVL 之间的距离(C7-CSVL),但经常发生 C 型臂 X 线透视无法

包含双侧用于定位的解剖结构,且当上胸弯为代偿性弯曲时,不需要进行固定融合,在术中透视时垂直杆无法通过 T1 椎体。2019 年,盛伟斌教授^[1]提出“点线法”用于术中冠状位平衡的评估,但该方法仅在下固定椎位于 L3 及其以下的患者中进行了评估,最佳适应证为胸腰段、腰段或(和)腰骶部存在结构性畸形。对其他类型侧凸应用效果仍未知。因此,急需寻求一种适应证广且简单、有效的冠状位平衡评估方法,以便及时调整术中矫正情况,减少术中辐射暴露剂量,降低术后 CIB 发生率。我科结合现有技术设备,经多年实践,提出了一种新型术中冠状位平衡评估方法,即锥束 CT (cone beam computed tomography, CBCT) 拼接成像联合工形测量仪评估法。本研究旨在探讨 CBCT 拼接成像联合工形测量仪评估法进行矫形术中冠状面序列评估的可行性及有效性,并探讨其在 AIS 矫形术中的应用价值。

1 资料与方法

1.1 一般资料

纳入标准:①符合 AIS 诊断;②术中均应用 CBCT 拼接成像联合工形测量仪评估冠状位平衡;③主要观察指标数据随访完整。排除标准:①因心肺功能异常不能耐受手术者;②随访周期中出现脊柱外伤,或脊柱二次手术患者;③因四肢患有相关疾病导致 CIB。

2019 年 1 月~2021 年 1 月于北部战区总医院接受脊柱后路矫形术且符合上述纳入与排除标准的 AIS 患者共有 48 例,男 17 例,女 31 例,患者年龄 12~18(14.9±1.8)岁,包括胸弯 15 例,双胸弯 10 例,胸腰弯 10 例,腰弯 13 例。

1.2 CBCT 拼接成像联合工形测量仪评估法

所有患者均全身麻醉下行脊柱后路矫形手术。术中矫形完成后将工形测量仪(工形金属杆,头尾端等长度的水平杆,在两端水平杆的中心由一个垂直杆连接)的水平杆放置在与髂骨顶端平行的位置,垂直杆与骶骨中心线平行(图 1),如果脊柱与骨盆平衡良好,透视图像显示工形测量仪的垂直结构顶端穿过上固定椎椎体中点,应用 Artis Zeego 系统(西门子公司)行 CBCT 扫描(CBCT 是锥形束投照计算机重组断层影像设备,其原理是 X 线发生器以较低的射线量围绕患者做环形数字式投照,然后将围绕患者多次投照得

到的 X 线片经计算机进行重组进而获得三维图像,本组患者不进行环形投照,仅从患者单侧进行一次投照且不经计算机进行重组,即可得到一张 X 线片)。扫描结束后通过 ADviewer 视图工具将图像进行拼接(一般进行 3~4 次投照,即可拼接成一张脊柱全长像),并对冠状位平衡进行评估。测量时只需要将术中矫形后获取的脊柱全长 X 线片导入至 Surgimap 软件中,测量时间大概在 2min 左右,并不会明显延长手术时间。如果矫形效果满意,则手术完成;若矫形效果未达到预期,则由手术医师再次进行矫正(直接对矫形钉棒内固定进行调整)直至患者获得良好的冠状位平衡。

1.3 评价指标

1.3.1 影像学指标 在患者术前、术中、术后 1 周、末次随访时的脊柱全长 X 线片上由两名主治医师使用 Surgimap(version 2.2.9.7, Nemaris Inc, New York, NY)进行测量。测量参数:(1)主弯 Cobb 角,头侧端椎上缘垂线与尾侧端椎下缘垂线的交角。(2)冠状位平衡距离(coronal balance distance, CBD), C7 铅垂线与 CSVL 之间的距离, $CBD \geq 20\text{mm}$ 时定义为 CIB;根据冠状位平衡情况分为 A 型 25 例($CBD < 20\text{mm}$);B 型 15 例($CBD \geq 20\text{mm}$, C7 铅垂线位于主弯的凹侧);C 型 8 例($CBD \geq 20\text{mm}$, C7 铅垂线在主弯的凸侧)。(3)骨盆冠状倾角(pelvic coronal obliquity angle, PCOA),连接两侧髂骨顶部连线与水平线之间的夹角。

1.3.2 临床疗效指标 所有患者均在术前及末次随访时进行疼痛视觉模拟评分(visual analogue scale, VAS)^[12]和 Oswestry 功能障碍指数(Oswestry disability index, ODI)^[13]评定。

1.4 统计学分析

对 48 例患者术前、术中、术后 1 周及末次随访时的主弯 Cobb 角、CBD、PCOA 进行分析,对冠状位分型的各型患者术前、术中、术后 1 周及末次随访时的主弯 Cobb 角、CBD 进行分析,数据以均数±标准差表示,采用 IBM SPSS Statistics 23.0 (SPSS Inc, IL, USA)统计学软件对数据进行统计分析,经过配对 *t* 检验对术前、术中、术后即刻及末次随访检测结果进行对比, $P < 0.05$ 表示有统计学差异。

2 结果

根据术前冠状位平衡情况分型,48 例 AIS 患者中,A 型 25 例,B 型 15 例,C 型 8 例,术前 CIB 发生率为 47.91%(23/48)。48 例患者经过 1~2 年(1.8 ± 0.2 年)的随访,末次随访时 CIB 共 5 例,发生率为 10.42%。

2.1 影像学测量

48 例 AIS 患者术前、术中、术后 1 周及末次随访时冠状位影像学参数见表 1。所有患者术中、术后主弯 Cobb 角、CBD、PCOA 较术前均有明显改善($P<0.05$),且末次随访时与术后 1 周比较均无统计学差异($P>0.05$)。

2.2 根据冠状位平衡情况分型的分析

术前 A 型患者 25 例,术前、术中、术后 1 周及末次随访时相关参数见表 2。术中及术后 1 周主弯 Cobb 角与术前差异有统计学意义($P<0.05$,图 2),末次随访时主弯 Cobb 角与术后 1 周差异无统计学意义($P>0.05$);术中及术后 1 周 CBD 与

术前差异有统计学意义($P<0.05$),末次随访与术后 1 周差异无统计学意义($P>0.05$)。

术前 B 型患者 15 例,术前、术中、术后 1 周及末次随访时相关参数见表 2。术中及术后 1 周主弯 Cobb 角与术前差异有统计学意义($P<0.05$),末次随访时主弯 Cobb 角与术后 1 周差异无统计学意义($P>0.05$);术中及术后 1 周 CBD 与术前差异有统计学意义($P<0.05$),末次随访与术后 1 周差异无统计学意义($P>0.05$)。

术前 C 型患者 8 例,术前、术中、术后 1 周及末次随访时相关参数见表 2。术中及术后 1 周主弯 Cobb 角与术前差异有统计学意义($P<0.05$,图 3),末次随访时主弯 Cobb 角与术后 1 周差异无统计学意义($P>0.05$);术中及术后 1 周 CBD 与术前差异有统计学意义($P<0.05$),末次随访与术后 1 周差异无统计学意义($P>0.05$)。

2.3 临床效果

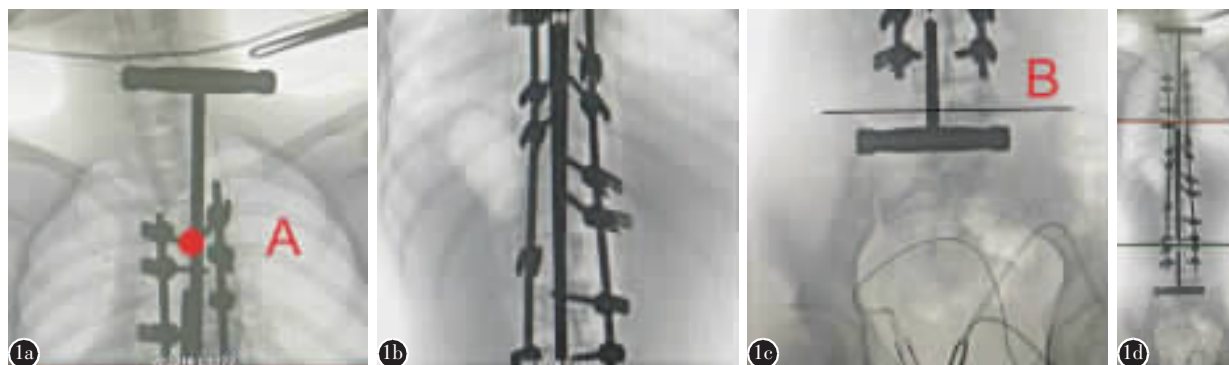


图 1 工形测量仪如图所示,术中矫形完成后,通过锥束 CT 进行分段透视获得图像 a、b、c,使用 ADviewer 视图工具将图 a、b、c 拼接获得脊柱全长像图 d,若工形杆的垂直杆通过点 A(上固定椎中点),且工形杆的下水平杆与线段 B(双侧髂骨最高点连线)平行,则冠状位平衡良好

Figure 1 The I-shaped measuring instrument. After the correction for AIS, images a, b and c were captured by the CBCT mosaic imaging. The full-length image d was obtained by splicing images a, b and c with ADviewer. If the vertical rod of the I-shaped measurement instrument passed through the point A (midpoint of UIV), and the lower horizontal rod of the I-shaped measuring instrument was parallel to the B-line that connected the highest points of the bilateral iliac, then the coronal balance was well

表 1 48 例患者术前、术中、术后 1 周、末次随访时影像学指标比较

Table 1 Comparison of imaging indexes of 48 patients at different time points

	术前 Preoperative	术中 Intraoperative	术后 1 周 Postoperative 1 week	末次随访时 Final follow-up
Cobb 角(°) Cobb angle	58.45±12.81	14.13±5.86 ^①	14.48±5.98 ^①	14.39±5.74 ^②
冠状位平衡距离(mm) Coronal balance distance	18.61±8.05	11.61±5.31 ^①	11.85±5.24 ^①	12.12±5.05 ^②
骨盆冠状倾角(°) Pelvic coronal obliquity angle	3.72±2.75	1.25±0.97 ^①	1.25±0.96 ^①	1.28±0.96 ^②

注:①与同指标术前比较 $P<0.05$;②与同指标术后 1 周比较 $P>0.05$

Note: ①Compared with preoperative, $P<0.05$; ②Compared with postoperative 1 week, $P>0.05$

表 2 术前冠状位失衡各分型患者术前、术中、术后和末次随访时各影像学指标比较

Table 2 Comparison of imaging indexes at different time points of patients of various preoperative coronal imbalance types

	A型组 (n=25) Type A group		B型组 (n=15) Type B group		C型组 (n=8) Type C group	
	Cobb角(°) Cobb angle	CBD(mm)	Cobb角(°) Cobb angle	CBD(mm)	Cobb角(°) Cobb angle	CBD(mm)
术前 Preoperative	49.14±7.50 (32-63)	12.53±4.46 (1.92-18.81)	67.13±7.34 (57-83)	24.57±4.60 (20.11-29.82)	71.34±11.86 (56-91)	26.46±6.78 (20.14-38.53)
术中 Intraoperative	10.50±4.46 ^① (0-14)	8.06±3.15 ^① (1.22-14.02)	17.09±2.34 ^① (13-21)	14.91±4.62 ^① (9.21-21.43)	19.93±6.92 ^① (12-35)	16.58±4.00 ^① (12.47-22.12)
术后 1 周 Postoperative 1 week	10.58±4.49 ^① (0-14)	8.37±3.13 ^① (1.23-15.49)	17.18±2.35 ^① (13-21)	14.95±4.49 ^① (9.34-20.84)	20.02±6.81 ^① (12-35)	16.94±4.12 ^① (12.91-22.70)
末次随访 Final follow-up	10.74±4.32 ^② (1-15)	8.66±3.77 ^② (2.51-16.44)	17.57±2.29 ^② (13-22)	15.06±3.98 ^② (10.18-21.85)	19.83±6.62 ^② (11-32)	16.58±3.97 ^② (11.33-24.43)

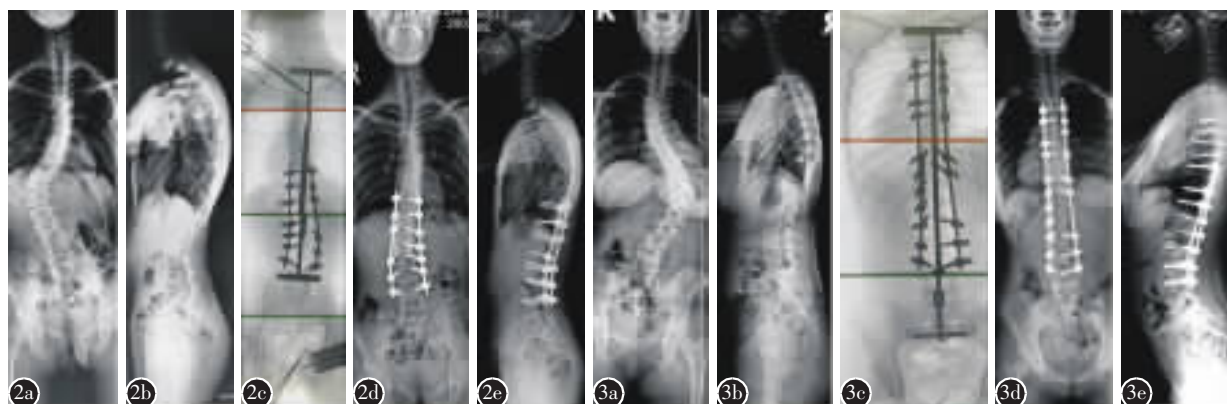
注:①与同组术前比较 $P<0.05$;②与同组术后 1 周比较 $P>0.05$ Note: ①Compared with preoperative, $P<0.05$; ②Compared with postoperative 1 week, $P>0.05$ 

图 2 患者男,17 岁,青少年特发性脊柱侧凸(lenke 5,C),发现脊柱侧凸 8 年 a,b 术前站立位脊柱全长正侧位 X 线片示主弯 Cobb 角 50°,CBD 为 19.76mm c 行胸腰椎后路脊柱侧凸矫形、T10~L4 钉棒系统内固定术,术中应用 CBCT 拼接成像(术中脊柱全长正位 X 线片)联合工形测量仪评估冠状位平衡良好 d,e 术后 1 周复查站立位脊柱全长正侧位 X 线片示主弯 Cobb 角 13°,CBD 为 7.94mm 图 3 患者女,12 岁,青少年特发性脊柱侧凸(Lenke 6,C),发现脊柱侧凸 2 年 a,b 术前站立位脊柱全长正侧位 X 线片示主弯 Cobb 角 66°,CBD 为 36.64mm c 行胸腰椎后路脊柱侧凸矫形、T4~L4 钉棒系统内固定术,术中应用 CBCT 拼接成像(术中脊柱全长正位 X 线片)联合工形测量仪评估冠状位平衡良好 d,e 术后 1 周复查站立位脊柱全长正侧位 X 线片示主弯 Cobb 角 6°,CBD 为 15.36mm

Figure 2 A 17-year-old male patient with Lenke 5 C AIS, scoliosis for 8-year a, b Preoperative full-length frontal and lateral X-rays of the spine at the standing position showed the main curve Cobb angle and CBD of 50° and 19.76mm, respectively c The patient was treated with posterior correction of thoracolumbar scoliosis with pedicle screw-rod fixation at T10-L4. An acceptable coronal balance was intraoperatively assessed by the CBCT mosaic imaging(Intraoperative full-length anteroposterior image of the spine) combined with the measurement using an I-shaped measuring instrument d, e Full-length frontal and lateral X-rays of the spine at the standing position one week after the surgery, showed the main curve Cobb angle and CBD of 13° and 7.94mm, respectively **Figure 3** A 12-year-old female patient with Lenke 6 C AIS, scoliosis for 2-year a, b Preoperative full-length frontal and lateral X-rays of the spine at the standing position, showed the main curve Cobb angle and CBD of 66° and 36.64 mm, respectively c The patient was treated with posterior correction of thoracolumbar scoliosis with pedicle screw-rod fixation at T4-L4. An acceptable coronal balance was intraoperatively assessed by the CBCT mosaic imaging (Intraoperative full-length anteroposterior image of the spine) combined with the I-shaped measuring instrument d, e Full-length frontal and lateral X-rays of the spine at the standing position one week after the surgery showed the main curve Cobb angle and CBD of 6° and 15.36mm, respectively

48例患者术前及末次随访时的VAS评分及ODI见表3,末次随访时的VAS评分及ODI与术前比较均明显改善($P<0.05$)。

3 讨论

CBCT最早被应用于口腔科^[14],后逐渐应用于骨科脊柱手术中,辅助术者评估内置物的位置。随着CBCT技术的发展,CBCT已经可以做到将术中获得的影像进行拼接,从而获得术者需要的任何部位的全长片。因此,我们可以通过术中CBCT拼接成像技术评估脊柱局部和整体的冠状位平衡。与传统的多层螺旋CT相比,CBCT可以在消耗更少的资源、更低的成本下更快的产生3D图像,而且CBCT产生辐射剂量更低,是传统CT的51%~96%^[15]。CBCT相比于C型臂X线透视可以在术中更直观地看到内置物的位置。有研究^[16]表明,随着CBCT在脊柱手术中的应用,因术中定位错误的手术减少了0.5%,使椎弓根外置钉的发生率降低了10倍,并且减少了49%的置钉时间,每例手术时间减少了20~40min,有效减少了因内置物位置不良而进行翻修的手术次数。由于我们的研究内容是AIS矫形术中冠状位平衡的评估,仅需要患者术中的脊柱全长像,因此在本文中并未放置患者的3D图像。

重建冠状位平衡是脊柱侧凸手术成功的关键,在进行矫形手术时,患者在术中俯卧位时没有办法得到如同站立位脊柱全长X线片相同的影像学数据,为了避免术后CIB的发生,所以应该选择适当的方法对脊柱侧凸矫形效果进行评估。Kurra等^[17]在一项研究中将应用一种不透过射线的T形金属杆(T square shaped device, TSSD)与未应用TSSD的患者进行比较,虽然这两者术后平均冠状位错位(coronal malalignment, CM)的差异无统计学意义,但术中使用TSSD的患者(70%)比未使用TSSD的患者(18%)可以获得更好的CM矫正,且应用TSSD患者的Cobb角矫正率可以达到68%,与未应用TSSD的患者(44%)相比优势更明显。盛伟斌教授团队^[18]应用点线法对46例脊柱侧凸患者进行了为期2年的随访,46例患者术前主弯Cobb角为 $17^{\circ}\sim 109^{\circ}$ ($57.24^{\circ}\pm 26.51^{\circ}$),术后即刻主弯Cobb角为 $1^{\circ}\sim 63^{\circ}$ ($14.71^{\circ}\pm 10.17^{\circ}$),矫正率为21%~96%,在末次随访时CIB的发生率为10.87%(5/46)。在临床治疗过程中,

表3 48例患者术前和末次随访时临床效果评分比较

Table 3 Comparison of clinical effects between preoperation and final follow-up in 48 patients

	VAS[分(point)]	ODI(%)
术前 Preoperative	7.68±0.64	46.51±4.79
末次随访 Final follow-up	3.98±0.57 ^①	21.82±3.12 ^①

注:①与同指标术前比较 $P<0.05$

Note: ①Compared with preoperative, $P<0.05$

当我们给上胸弯为代偿性侧弯的AIS患者制订手术方案时,上胸弯并不需要进行矫形固定,只需要将胸腰段、腰段或/和腰骶部存在结构性侧凸进行固定融合即可,因此我们在术中矫形完成后进行冠状位平衡评估时应用工形测量仪,将其垂直部分穿过上固定椎中心定义为术中的冠状位平衡。

本研究显示,通过在术中和术后即刻的脊柱全长X线片中用C7-CSVL进行冠状位平衡的评估,两者的测量结果存在一定误差,而出现这种误差的患者往往在术前脊柱柔韧性评估中有良好的脊柱柔韧性,在那些术前评估脊柱柔韧性较差的AIS患者中,这种误差的发生率较低。然而这种误差的出现不排除一些其他原因。研究^[18]表明,使用C7-CSVL作为术中评估冠状位平衡的指标时是不够准确的,在术中患者取俯卧位时,由于失去重力影响,很难通过C7-CSVL来评估冠状位平衡情况,因此提出用骶骨骨盆中心线(CSPL)来代替CSVL。Hey等^[19]将C7-CSPL和C7-CSVL进行了对比并阐述了髂臼上缘连线的三个优点,首先,骨盆可以分为承重部分(如髂臼顶)和非承重部分(如髂骨翼),非承重部分并不会影响整个脊柱的排列,因此,从这些部分获得的测量值没有意义;第二,髂臼顶的位置使其成为确定骨盆水平轴的合适的解剖标志,它们在旋转的骨盆中不容易出现高度差异,因为它们比髂嵴更居中;第三,双下肢长度相等的患者站立时可以得到一条水平的髂臼线,使得髂臼上缘连线成为评估站立后冠状位平衡的更好参考标志,因为其受下肢长度的影响。

我们还发现了有一些AIS患者会出现术后即刻CIB,常表现为双肩不等高,在术后随访中,这种现象会自发矫正。既往一些学者也发现了这类问题,他们将这种自发矫正的现象归因于肩部、未融合的节段、骨盆、双下肢相互代偿的结果^[20-22]。而我们在对这些患者既往生活习惯的调查研究

中, 这些患者术前为了让身体趋于冠状位的平衡稳定, 会通过调整双肩倾斜度来代偿脊柱的冠状位不平衡以获得姿势上的平衡。

本研究存在一些局限性。首先我们没有将脊柱侧凸研究学会-22 简明量调查问卷 (scoliosis research society questionnaires-22, SRS-22) 纳入本研究作为临床疗效的评估; 其次本研究的样本量相对较小, 随访时间较短, 而且所有的病例均由同一团队医生完成, 如果是由多个团队的脊柱外科医生参与的多中心研究可能更有助于 CBCT 拼接成像联合工形测量仪的广泛应用。

综上所述, CBCT 拼接成像联合工形测量仪的方法是一种不需要过度辐射就可以评估术中整体的冠状位平衡的方法, 能够在术中获得一个整体的影像对患者矫形后的冠状位平衡进行评估, 及时调整矫形程度, 减少术后 CIB 的发生率。

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