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椎体和椎间盘矢状面形态学改变对退变性脊柱后凸畸形的影响

何守玉, 李海东, 闵继康, 罗盛昌, 戴季林

(湖州师范学院附属第一医院脊柱外科, 浙江 湖州 313000)

【摘要】 目的: 探讨椎体楔形变和椎间盘退变(塌陷)等形态学改变对成人退变性胸腰椎/腰椎后凸畸形的影响。方法: 回顾性分析 2015 年 8 月至 2020 年 12 月收治的 32 例脊柱退变性胸腰椎/腰椎后凸畸形患者, 其中男 8 例, 女 24 例, 年龄 48~75(60.3±12.4)岁。在站立位全脊柱正侧位 X 线片上测量脊柱冠状面侧凸 Cobb 角和矢状面胸腰椎/腰椎后凸角(kyphosis angle, KA), 评估顶椎(apex vertebral, AV)及顶椎上下各 2 个椎体(AV-1, AV-2, AV+1, AV+2)与椎间盘(AV-1D, AV-2D, AV+1D, AV+2D)的高度及楔变参数, 包括椎体前缘高度(anterior vertebral body height, AVH), 椎体后缘高度(posterior vertebral body height, PVH), 椎体楔变角(vertebral wedge angle, VWA), 椎体楔变率(ratio of vertebral wedging, RVW); 椎间盘前缘高度(anterior disc height, ADH), 椎间盘后缘高度(posterior disc height, PDH), 椎间盘楔变角(disc wedge angle, DWA), 椎间盘楔变率(ratio of disc wedging, RDW), 椎间盘贡献率(DWA/KA)。结果: 所纳入患者 KA 为(44.2±19.1)°, 后凸节段内椎体前缘高度均显著低于椎体后缘高度($P < 0.05$), 提示椎体发生不同程度楔形变; 而后凸节段内椎间盘前后缘高度差异无统计学意义。后凸节段内椎体楔变率/贡献率分别为 AV-2(14.98±10.95)%/(14.21±8.08)%, AV-1(21.08±12.39)%/(18.09±7.38)%, AV(26.94±11.94)%/(25.52±8.64)%, AV+1(24.19±8.42)%/(20.82±8.69)%, AV+2(20.56±7.80)%/(15.60±9.71)%, 椎体总贡献率为(94.23±22.25)%; 后凸节段内椎间盘楔变率/贡献率分别为 AV-2D(2.88±2.57)%/(5.27±4.11)%, AV-1D(1.98±1.41)%/(2.29±2.16)%, AV+1D(-5.54±3.75)%/(-0.57±0.46)%, AV+2D(-8.27±4.62)%/(-1.22±1.11)%, 椎间盘总贡献率(5.77±4.79)%, 且顶椎贡献率明显大于邻近椎体贡献率($P < 0.05$)。结论: 椎体楔形变及椎间盘塌陷共同构成了成人退变性胸腰椎/腰椎后凸畸形状态。就对后凸贡献率而言, 椎体形态改变对后凸的贡献要远超椎间盘的贡献, 且顶椎的楔形变对胸腰椎/腰椎后凸的贡献尤为明显。

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通讯作者: 闵继康 E-mail: mjk@medmail.com

Corresponding author: MIN Ji-kang E-mail: mjk@medmail.com

【关键词】 退变性后凸畸形； 胸腰椎； 腰椎； 椎体楔形变； 椎间盘退变

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Effect of morphological changes in the sagittal plane of vertebrae and discs on degenerative kyphodeformity

HE Shou-yu, LI Hai-dong, MIN Ji-kang, LUO Sheng-chang, DAI Ji-lin (Spine Surgery, the First Affiliated Hospital of Huzhou Teachers College, Huzhou 313000, Zhejiang, China)

ABSTRACT Objective To explore the effects of morphological changes such as vertebral wedge deformation and disc degeneration (collapse) on adult thoracolumbar/lumbar degenerative kyphosis (TL/LDK) deformity. **Methods** A retrospective analysis of 32 patients with spinal TL/LDK deformity admitted from August 2015 to December 2020, including 8 males and 24 females, aged 48 to 75 (60.3±12.4) years old. On the long-cassette standing upright lateral radiographs, the coronal Cobb angle, sagittal thoracic lumbar/lumbar kyphosis angle (KA) of spine were measured, and the height and wedge parameters of apex vertebral (AV) and two vertebrae (AV-1, AV-2, AV+1, AV+2) above and below AV and the intervertebrae and the intervertebral disc (AV-1D, AV-2D, AV+1D, AV+2D) were evaluated, involving anterior vertebral body height (AVH), posterior vertebral body height (PVH), vertebral wedge angle (VWA), ratio of vertebral wedging (RVW), anterior disc height (ADH), posterior disc height (PDH), disc wedge angle (DWA), ratio of disc wedging (RDW), and DWA/KA. **Results** The average angle of kyphosis was (44.2±19.1)°. A significant decrease in anterior height of vertebral was observed compared to the posterior height of vertebral ($P<0.005$). There was no significant difference in anterior and posterior height of discs. The vertebral wedging ratio/contribution ratio: AV-2 (14.98±10.95)%/(14.21±8.08)%, AV-1 (21.08±12.39)%/(18.09±7.38)%, AV (26.94±11.94)%/(25.52±8.64)%, AV+1 (24.19±8.42)%/(20.82±8.69)%, AV+2 (20.56±7.80)%/(15.60±9.71)%, total contribution (94.23±22.25)%, the disc wedging ratio/contribution ratio: AV-2D (2.88±2.57)%/(5.27±4.11)%, AV-1D (1.98±1.41)%/(2.29±2.16)%, AV+1D (-5.54±3.75)%/(-0.57±0.46)%, AV+2D (-8.27±4.62)%/(-1.22±1.11)%, total contribution (5.77±4.79)%. And the contribution rate of AV was significantly higher than that of adjacent vertebral ($P<0.05$). **Conclusion** The vertebral body and intervertebral disc shape both have influence on thoracolumbar kyphosis. However, the contribution of vertebral morphometry to the angle of TL/LDK deformity is relatively more important than the disc. The contribution of the wedge change of the AV to the TL/LDK deformity is particularly significant.

KEYWORDS Degenerative kyphosis; Thoracolumbar vertebrae; Lumbar vertebrae; Vertebral wedging; Disc degeneration

退变性胸腰椎/腰椎后凸畸形(thoracolumbar/lumbar degenerative kyphosis, TL/LDK)是由于椎体、椎间盘等退变性改变所引起的脊柱畸形,主要表现为脊柱矢状面上胸腰椎或腰椎生理性前凸减少或丢失,并逐步进展为胸腰椎或腰椎后凸畸形,且常合并有不同程度的脊柱冠状面畸形。其发病与不良的生活方式、长期低头弯腰负重和重体力劳动等有关。既往研究表明 TL/LDK 系由于脊柱退变诱发,病程的发展和加剧也都与脊柱退变存在一定的相关性^[1],但具体的发病机制目前仍不清楚。有研究者进行了一项长达 12 年的前瞻性研究发现 TL/LDK 可因无症状的椎间盘退行性改变而加剧,如椎间盘高度降低>20%或单侧椎间盘高度降低>5 mm, TL/LDK 的发生率可明显增加^[2]。在正常人群胸椎生理性后凸的构成要素中,椎体和椎间盘的楔形变共同参与其中^[3]。脊柱退行性改变在椎间盘高度丢失的同时,通常伴有椎体楔形变,二者在脊柱后凸构成要素中的权重及贡献如何鲜有报道,笔者对 2015 年 8 月至 2020 年 12 月收治的 32 例成人脊柱退变性胸腰椎/腰椎后凸畸形患者进行回顾性分析,旨在探讨椎体

楔形变和椎间盘退变(塌陷)等形态学改变对 TL/LDK 的贡献,以期对 TL/LDK 的发病机制研究及临床治疗提供参考。

1 资料与方法

1.1 病例选择

纳入标准:(1)成人退变性胸腰椎段/腰段后凸畸形, TL/LDK 后凸 Cobb 角>10°。(2)年龄 45~75 岁。(3)脊柱冠状面侧凸 Cobb 角<20°。

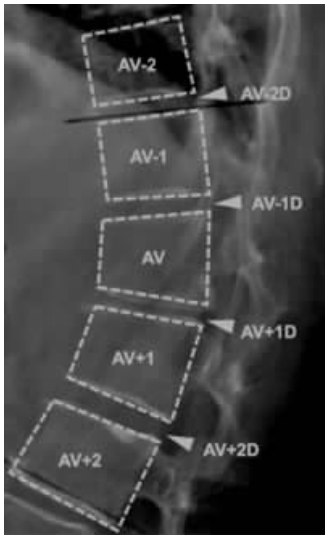
排除标准:(1)陈旧性胸腰椎骨折致脊柱后凸畸形及其他包括强直性脊柱炎、脊柱肿瘤、结核、骨质疏松性椎体压缩性骨折等病理原因导致的胸腰椎后凸畸形患者。(2)既往有脊柱及髋关节手术史者。

1.2 临床资料

回顾性分析 2015 年 8 月至 2020 年 12 月就诊的成人 TL/LDK 患者 32 例,其中男 8 例,女 24 例,年龄 48~75 (60.3±12.4)岁,单纯腰背痛患者 21 例,腰痛伴有下肢放射痛患者 11 例,其中 13 例患者接受手术治疗,19 例患者进行保守治疗。本研究经本院医学伦理委员会批准[伦(审)第 2019088 号]审批通过。

1.3 观察项目与方法

在站立位全脊柱正侧位 X 线片测量冠状面侧凸 Cobb 角,胸腰段/腰段后凸 Cobb 角(kyphosis angle, KA), 确定后凸顶椎(apex vertebral, AV)并评估顶椎上下位椎体、椎间盘的矢状面形态。评估顶椎及顶椎上下各 2 个椎体(AV-1, AV-2, AV+1, AV+2)与椎间盘(AV-1D, AV-2D, AV+1D, AV+2D)节段(图 1)的矢状面形态学参数^[3],具体如下。



注:AV 为顶椎,AV-1,AV-2,AV+1,AV+2 分别为顶椎上下各 2 个椎体,AV-1D,AV-2D,AV+1D,AV+2D 分别为顶椎上下各 2 个椎间盘

图 1 顶椎及上下各 2 个椎体与椎间盘示意图

Fig.1 Illustration of apex vertebral and two upper and lower vertebral and discs

(1)椎体矢状面形态学评估指标:椎体前缘高度(anterior vertebral body height, AVH), 椎体后缘高度(posterior vertebral body height, PVH), 椎体楔变角(vertebral wedge angle, VWA) 即矢状面上椎体上终板与下终板的夹角。根据椎体前后缘高度的差异计算椎体楔变率(ratio of vertebral wedging, RVW), $RVW=(1-AVH/PVH) \times 100\%$, 根据椎体楔变角计算椎体贡献率, 椎体贡献率= $(VWA/KA) \times 100\%$ 。

(2)椎间盘矢状面形态学评估指标:椎间盘前缘高度(anterior disc height, ADH), 椎间盘后缘高度(posterior disc height, PDH), 椎间盘楔变角(disc wedge angle, DWA) 即矢状面上所测椎间盘上位椎体下终板与下位椎体上终板的夹角。根据椎间盘前后缘高度的差异计算椎间盘楔变率(ratio of disc wedging, RDW), $RDW=(1-ADH/PDH) \times 100\%$, 根据椎间盘楔变角计算椎间盘贡献率, 椎间盘贡献率= $(DWA/KA) \times 100\%$ 。

1.4 统计学处理

采用 SPSS 19.0 软件进行统计学分析。患者年龄、冠状面侧凸角度、脊柱后凸角度、椎体及椎间盘高度、楔变角等符合正态分布的定量资料以均数±标准差($\bar{x} \pm s$)表示。椎体前后高度差异、椎间盘前后缘高度差异以及各节段椎体、椎间盘楔变角差异的比较采用 *t* 检验。不同节段椎体与椎间盘楔变率及贡献率的差异比较, 采用单因素方差分析。以 $P < 0.05$ 为差异有统计学意义。

2 结果

本研究所纳入 TL/LDK 患者冠状面侧凸 Cobb 角为 $(23.3 \pm 12.4)^\circ$, 后凸 Cobb 角 KA 为 $(44.2 \pm 19.1)^\circ$ 。通过测量发现后凸节段内椎体(AV-2, AV-1, AV, AV+1, AV+2)前缘高度与椎体后缘高度比较, 差异有统计学意义($P < 0.05$), 提示椎体发生不同程度楔形变; 而后凸节段椎间盘(AV-2D, AV-1D, AV+1D, AV+2D)前后缘高度比较, 差异无统计学意义($P > 0.05$)。见表 1。进一步测量椎体及椎间盘楔变角并计算相应楔变率及贡献率发现, 椎体楔变角度均为正向(与后凸方向一致), 椎体对后凸的总贡献率达到 $(94.23 \pm 22.25)\%$; 椎间盘楔变角度部分(AV+1D, AV+2D)为负向(与后凸方向相反), 提示椎间盘节段对后凸的贡献存在“抵消”现象, 其对后凸总贡献率仅为 $(5.77 \pm 4.79)\%$ 。进一步比较发现顶椎椎体的贡献率显著大于上下邻近椎体及椎间盘($P = 0.005$), 顶椎上位椎间盘 AV-2D 对后凸的贡献显著大于其余椎间盘节段($P = 0.001$)。见表 2。

表 1 胸腰椎/腰椎后凸畸形 32 例患者椎体与椎间盘节段前后缘高度比较($\bar{x} \pm s$)

Tab.1 Comparison of anterior and posterior height of disc and vertebral in 32 patients with TL/LDK($\bar{x} \pm s$)

单位:mm

项目	AV-2	AV-1	AV	AV+1	AV+2	AV-2D	AV-1D	AV+1D	AV+2D
前缘高度	17.77±2.49	16.92±2.65	16.47±2.68	17.31±3.25	17.45±2.66	4.06±1.37	4.73±1.52	5.25±1.31	5.69±1.43
后缘高度	21.12±3.46	21.64±2.86	22.68±2.72	22.76±3.22	22.16±3.79	4.67±1.82	5.07±1.57	5.21±1.09	5.49±1.60
<i>t</i> 值	5.105	5.934	8.056	10.64	8.152	1.113	0.870	0.163	0.625
<i>P</i> 值	0.000	0.000	0.000	0.000	0.000	0.285	0.399	0.872	0.542

注:TL/LDK 为退变性胸腰椎/腰椎后凸畸形。AV 为顶椎,AV-1、AV-2、AV+1、AV+2 分别为顶椎上下各 2 个椎体,AV-1D、AV-2D、AV+1D、AV+2D 分别为顶椎上下各 2 个椎间盘。下同

表 2 胸腰椎/腰椎后凸畸形 32 例患者椎体与椎间盘节段楔变角、楔变率与贡献率 ($\bar{x} \pm s$)Tab.2 Wedge angle, wedging ratio and contribution ratio of disc and vertebral in 32 patients with TL/LDK ($\bar{x} \pm s$)

项目	椎体节段					椎间盘节段			
	AV-2	AV-1	AV	AV+1	AV+2	AV-2D	AV-1D	AV+1D	AV+2D
楔变角/ $^{\circ}$	5.96 \pm 2.39	8.42 \pm 4.37	10.95 \pm 3.18	8.53 \pm 1.99	6.92 \pm 3.75	2.70 \pm 3.81	1.54 \pm 2.27	-0.26 \pm 1.92	0.57 \pm 3.37
楔变率/%	14.98 \pm 10.95	21.08 \pm 12.39	26.94 \pm 11.94	24.19 \pm 8.42	20.56 \pm 7.80	2.88 \pm 2.57	1.98 \pm 1.41	-5.54 \pm 3.75	-8.27 \pm 4.62
贡献率/%	14.21 \pm 8.08	18.09 \pm 7.38	25.52 \pm 8.64	20.82 \pm 8.69	15.60 \pm 9.71	5.27 \pm 4.11	2.29 \pm 2.16	-0.57 \pm 0.46	-1.22 \pm 1.11

注:椎体节段贡献率组间比较,顶椎(AV)贡献率最高, $F=4.039, P=0.005$;椎间盘节段贡献率组间比较,顶椎上位椎间盘 AV-2D 节段贡献率最高, $F=5.886, P=0.001$

3 讨论

脊柱退变性后凸是由于脊柱及邻近组织退变而导致的脊柱矢状面畸形,最常发生于脊柱腰段或胸腰段,是平背综合征的一种亚型,早期表现为平背或腰椎前凸,后期逐步进展为 TL/LDK,引起下腰痛和腰背部畸形^[4]。流行病学调查发现 TL/LDK 多见于亚洲人群,中老年女性多发,男女比例约 1:4.5,发病年龄为 63.0~70.4 岁,ZAPPALA 等^[5]研究认为,脊柱后凸在性别间无显著差异,而与年龄、种族存在显著相关性,随着年龄增加脊柱后凸逐渐增大,尤其是 60 岁以上人群脊柱后凸明显大于 40 岁以下人群。

3.1 TL/LDK 发病原因

TL/LDK 的发病原因至今未明确,但有研究表明 TL/LDK 的发病是多种因素共同作用的结果,其畸形的发生和进展与椎间盘退变、椎旁肌肉退变、椎体楔形变等密切相关^[6]。随着年龄的增长,椎间盘高度随着水分的减少而逐渐丢失,一般表现为椎间盘前缘高度的丢失,随着椎间盘楔形变程度的增加,后凸畸形逐渐加重^[1]。XIA 等^[7]观察了 58 例 TL/LDK 患者的 928 节椎间盘终板退变情况,发现有 51.7% 的患者出现终板 Modic 改变,其中有高达 58.6% 的软骨终板出现了 II 级以上的改变;并认为 Modic 改变与椎间盘退变、腰椎前凸丢失、骨盆倾斜等密切相关。既往研究显示,腰背肌的萎缩或退变与脊柱冠状面、矢状面畸形的发生发展密切相关^[8-9]。通过功能训练等改善腰背肌强度的方法可有效延缓脊柱后凸进展、提高生活质量^[10]。KATZMAN 等^[11]纳入 103 例老年脊柱后凸患者,通过为期 3 个月的后凸纠正训练和体态、姿态训练等干预措施,在随后 3 年的随访中,脊柱后凸无明显加重,生活质量也获得一定程度的改善。提示改善椎旁肌肉强度能够一定程度上预防后凸进展并减轻患者腰痛状况。

3.2 TL/LDK 椎体楔形变的病理机制与椎间盘“抵消”现象

本研究结果表明,椎体楔形变对 TL/LDK 后凸的贡献尤为明显,而椎体楔形变的病理机制值得进

一步研究。GUO 等^[12]研究发现,绝经后骨质疏松患者在无胸腰椎压缩性骨折情况下依然会出现胸腰椎后凸畸形,究其原因考虑为椎体骨量降低、骨微结构改变,导致椎体尤其是椎体前柱生物力学强度降低,脊柱纵向应力载荷破坏椎体终板及骨小梁,导致椎体前缘皮质塌陷,从而出现椎体楔形变。多个楔形变椎体的叠加则促成了脊柱胸腰段/腰段后凸畸形的出现。本研究中,在后凸节段多个楔形变椎体中,顶椎椎体楔形变最为明显,分析原因为顶椎椎体的前方应力最为集中、椎体前缘皮质塌陷最明显,因此对后凸畸形的贡献也最突出。YUKAWA 等^[13]研究表明,正常人群腰椎前凸(T_{12} - S_1)构成要素中 L_4 - S_1 的前凸贡献占比最大(站立位时为 85.1%,仰卧位时为 70.8%), L_1 - L_3 在腰椎前凸的贡献占比不足 15%(站立位),可见以 L_4 为腰椎前凸顶椎情况下,其上方椎体及椎间盘对前凸的贡献小于下方椎体和椎间盘的贡献。本研究中顶椎区上方椎间盘对后凸的贡献大于顶椎区下方椎体和椎间盘的贡献,究其原因考虑为顶椎区下方椎间盘存在前方张开情况,该节段椎间盘楔变方向与脊柱后凸方向相反,即该节段椎间盘对后凸的贡献存在“抵消”现象。

3.3 椎体及椎间盘形态对 TL/LDK 手术治疗指导意义

在评估 TL/LDK 患者矢状面形态时,不仅要着眼于后凸节段,还需要重视其脊柱-骨盆的代偿性改变,周恒才等^[14]通过对比研究发现,与陈旧性胸腰骨折伴后凸畸形患者相比,TL/LDK 患者由于诸多退变因素,矢状面不仅表现为胸腰段后凸畸形、腰椎前凸减小,还同时伴有骨盆后旋转、躯干前倾的失代偿模式,而腰椎前凸丢失及矢状面失平衡是引起成人机械性腰痛的重要因素^[15]。对于出现脊柱矢状面失代偿的 TL/LDK 患者,保守治疗常难以奏效,往往需要手术干预,手术治疗的目的在于恢复脊柱序列、改善脊柱失平衡状态、重建脊柱稳定性。手术治疗的主要途径主要是基于改变后凸节段内椎体尤其是后凸顶椎椎体的楔形变状态,以达到矫正脊柱后凸、恢复

矢状面平衡的目的。RAJASEKARAN 等^[16]根据脊柱后凸矢状面形态提出了不同等级的截骨矫形手术方案: I 型, 脊柱后凸节段前后柱均完整, 其中 I A 型为后凸节段柔韧性良好、椎间盘前方可张开, 一般采用 Ponte 截骨; I B 型为后凸节段僵硬, 椎间盘不能张开, 常需要采用经椎弓根椎体截骨 (pedicle subtraction osteotomy, PSO); II 型, 后凸节段前柱 (II A) 或后柱 (II B) 存在缺陷, 一般可采用 Ponte 截骨, PSO 截骨, 或包括椎间盘切除的 PSO 截骨 (disc bone osteotomy, DBO); III 型为后凸节段内前后柱均有不同程度缺陷 (III A 型为后凸 $\leq 60^\circ$, III B 型为后凸 $> 60^\circ$, III C 型为屈曲塌陷、折叠), 对此类患者往往需要单节段或多节段全椎体截骨, 部分患者术前需行 4~6 周 Halo 牵引。BAO 等^[17]比较 PSO 与多节段经关节突“V”形截骨 (Smith-Petersen osteotomy, SPO) 对退变性侧后凸畸形冠矢状面平衡重建的影响, 结果发现虽然两种术式适应证不相同, 但均可通过纠正顶椎区椎体及椎间盘矢状面形态达到矫形畸形目的。

总之, TL/LDK 的出现是脊柱多种退变性因素综合作用的结果, 就矢状面形态而言, 椎体的楔形变及椎间盘塌陷共同构成了成人 TL/LDK 矢状面畸形状态。就对后凸贡献率而言, 椎体的贡献要远远超过椎间盘的贡献, 并且顶椎的楔形变对后凸的贡献要明显大于邻近椎体对后凸的贡献。这对于 TL/LDK 的病理机制的深入研究及手术治疗具有一定的参考意义。

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