·经验交流·

斜外侧腰椎椎间融合术中椎体骨折的原因和临床结果分析

曾忠友[1], 赵兴[2], 张珏[3], 陈平泉[4], 俞伟[1], 宋永兴[1], 范顺武[2], 裴斐[1], 范时洋[1], 宋国浩[1], 王海峰[1]
(1. 武警海警总队医院骨二科, 浙江　嘉兴　314000; 2. 浙江大学医学院附属邵逸夫医院骨科, 浙江　杭州　310016; 3. 皖南医学院戈矶山医院脊柱外科, 安徽　芜湖　241001; 4. 嘉兴市中医医院骨伤科, 浙江　嘉兴　314001)

【摘要】 目的: 分析斜外侧椎间融合(oblique lateral interbody fusion, OLIF)治疗腰椎病变术中椎体骨折的原因, 总结临床结果, 提出预防措施。**方法**: 回顾性分析 3 家医疗中心 2014 年 10 月至 2018 年 12 月采用斜外侧椎间融合治疗腰椎病变并出现椎体骨折的 8 例病例资料。8 例均为女性, 年龄 50~81 岁, 平均 66.4 岁; 腰椎退行性病变 1 例, 腰椎管狭窄症 3 例, 腰椎退行性滑脱 2 例, 腰椎退行性侧后凸 2 例; 术前双能 X 线骨密度检测, 2 例 T 值>−1 SD, 2 例 T 值−1~−2.5 SD, 4 例 T 值<−2.5 SD; 单节段融合 5 例, 双节段融合 1 例, 3 节段融合 2 例; 采用 Stand-alone OLIF 4 例, OLIF 联合后路椎弓根螺钉固定 4 例。术后影像检查均提示椎体骨折, 且均为单椎体骨折。表现为融合节段上椎体右下缘骨折 2 例, 融合节段下椎体骨折 6 例; 合并终板损伤且融合器部分嵌入椎体 6 例。3 例 Stand-alone OLIF 病例给予后路肌间隙入路椎弓根螺钉固定, 另 1 例 Stand-alone OLIF 病例和 4 例 OLIF 联合后路椎弓根螺钉固定病例未予特殊处理。**结果**: 未予特殊处理的 5 例与再次手术的 3 例均未出现切口皮肤坏死或切口感染, 随访时间 12~48 个月, 平均 22.8 个月。腰痛视觉模拟评分(visual analogue scale, VAS)由术前的 4~8 分(平均 6.3 分)下降至末次随访时的 1~3 分(平均 1.7 分), 腰痛明显改善; Oswestry 功能障碍指数(Oswestry disability index, ODI)由术前的 39.7%~52.4%(平均 40.2%)恢复至末次随访时的 7.9%~11.2%(平均 9.5%)。随访过程中未出现椎弓根螺钉系统松动或断裂现象, 发生椎体骨折节段的融合器均出现明显沉降, 融合器无横向移位。椎体骨折节段椎间隙高度由术前的 6.7~9.2 mm(平均 8.1 mm)恢复至术后的 10.5~12.8 mm(平均 11.2 mm), 术后与术前比较改善率为 37.98%; 末次随访时为 8.4~10.9 mm(平均 9.3 mm), 与术后比较丢失率为 16.71%; 说明腰椎融合节段术后椎间隙高度获得明显的恢复, 而在随访过程中出现了明显的丢失。末次随访时除 1 例不能明确外, 其余均获得椎间融合。**结论**: 斜外侧椎间融合治疗腰椎病变术中椎体骨折的发生率较低, 发生骨折的原因较多, 包括患者术前存在骨量减少或骨质疏松、终板损伤、终板形态不规则、融合器选择过大和病变节段骨赘增生等。椎体骨折只要发现及时, 处理得当, 多预后良好, 但仍需要加强预防。

【关键词】 腰椎; 内固定; 脊柱融合术; 并发症; 再手术
中图分类号: R683
DOI: 10.12200/j.issn.1003-0034.2023.05.003　　**开放科学(资源服务)标识码(OSID)**:

Analysis of the causes and clinical results of vertebral fracture during oblique lateral lumbar interbody fusion

ZENG Zhong-you[1], *ZHAO Xing*[2], *ZHANG Yu*[3], *CHEN Ping-quan*[4], *YU Wei*[1], *SONG Yong-xing*[1], *FAN Shun-wu*[2], *PEI Fei*[1], *FAN Shi-yang*[1], *SONG Guo-hao*[1], *WANG Hai-feng*[1] (*1. The Second Department of Orthopaedics, Hospital of Coast Guard General Corps of Armed Police Forces, Jiaxing* 314000, *Zhejiang, China*; *2. Department of Orthopaedics, Sir Run Run Shaw Hospital Affiliated to Zhejiang University School of Medicine, Hangzhou* 310016, *Zhejiang, China*; *3. Department of Spine Surgery, the First Affiliated Hospital of Wannan Medical College, Wuhu* 241001, *Anhui, China*; *4. Department of Orthopaedics and Traumatology, Jiaxing Hospital of Traditional Chinese Medicine, Jiaxing* 314001, *Zhejiang, China*)

ABSTRACT **Objective** To analyze the causes of vertebral fracture during oblique lateral interbody fusion in the treatment of lumbar spondylopathy, summarize the clinical results, and propose preventive measures. **Methods** Retrospective analysis was made on the data of 8 cases of lumbar spondylopathy and vertebral fracture treated by oblique lateral interbody fusion in three medical centers from October 2014 to December 2018. All were female, aged from 50 to 81 years with an average of 66.4 years. Disease types included 1 case of lumbar degenerative disease, 3 cases of lumbar spinal stenosis, 2 cases of lumbar degenerative spondylolisthesis and 2 cases of lumbar degenerative scoliosis. Preoperative dual energy X-ray bone mineral density test

基金项目: 浙江省医药卫生科技计划项目(编号: 2020KY968)
Fund program: Zhejiang Medical and Health Science and Technology Plan Project (No.2020KY968)
通讯作者: 曾忠友　E-mail: zjzengzy@126.com
Corresponding author: ZENG Zhong-you　E-mail: zjzengzy@126.com

showed that 2 cases had T-value >−1 SD, 2 cases had T−value −1 to −2.5 SD, and 4 cases had T−value <−2.5 SD. Single segment fusion was in 5 cases, two segment fusion in 1 case and three segment fusion in 2 cases. Four cases were treated with OLIF Stand-alone and 4 cases were treated with OLIF combined with posterior pedicle screw fixation. Postoperative imaging examination showed vertebral fracture, and all of them were single vertebral fracture. There were 2 cases of right lower edge fracture of upper vertebral body at fusion segment, 6 cases of lower vertebral body fracture at fusion segment, and 6 cases with endplate injury and fusion cage partially embedded in vertebral body. Three cases of OLIF Stand-alone were treated with pedicle screw fixation via posterior intermuscular approach, while one case of OLIF Stand-alone and four cases of OLIF combined with posterior pedicle screw fixation were not treated specially. **Results** The 5 cases of initial operation and 3 cases of reoperation did not show wound skin necrosis or wound infection. The follow-up time was from 12 to 48 months with an average of 22.8 months. Visual analogue scale (VAS) of low back pain was preoperative decreased from 4 to 8 points (averagely 6.3 points) and postoperative 1 to 3 points (averagely 1.7 points) at the final follow-up. Oswestry disability index (ODI) was preoperative 39.7% to 52.4% (averagely 40.2%), and postoperative 7.9% to 11.2% (averagely 9.5%) at the final follow-up. During the follow-up, there was no loosening or fracture of the pedicle screw system, and no lateral displacement of the fusion cage; however, the fusion cage at the vertebral fracture segment had obvious subsidence. The intervertebral space height of vertebral fracture segment was preoperaive 6.7 to 9.2 mm (averagely 8.1 mm), and postoperative 10.5 to 12.8 mm (averagely 11.2 mm). The improvement rate after operation was 37.98% compared to preoperative. The intervertebral space height at final follow-up was 8.4 to 10.9 mm (averagely 9.3 mm), and the loss rate was 16.71% compared with that after operation. At the final follow-up, interbody fusion was achieved in all cases except for one that could not be identified. **Conclusion** The incidence of vertebral fracture during oblique lateral interbody fusion in the treatment of lumbar spondylopathy is lower, and there are many reasons for fracture, including preoperative bone loss or osteoporosis, endplate injury, irregular shape of endplate, excessive selection of fusion cage, and osteophyte hyperplasia at the affected segment. As long as vertebral fracture is found in time and handled properly, the prognosis is well. However, it still needs to strengthen prevention.

KEYWORDS　Lumbar vertebrae;　Internal fixation;　Spinal fusion;　Complication;　Reoperation

近年来出现的斜外侧入路腰椎椎间融合术(oblique lateral interbody fusion, OLIF)[1-2],由于切口小、显露快捷、操作方便、创伤小、出血少、恢复快、融合率高、效果确切,而且不进行椎管的直接减压,不经椎管操作,同时具有良好的间接椎管减压效果,近年来获得快速而大量的应用[3-12]。但作为一项新兴的腰椎椎间融合技术,同样面临并发症的问题[8,13-18],而且报道的并发症发生率较高[8,13-18],特别是在技术开展的早期。在 OLIF 技术的并发症中包括一类较少发生的现象——椎体骨折[18]。椎体骨折作为后路腰椎间融合非常罕见的并发症[19-20],在 OLIF 技术中却偶有发生[18,21-24](具体文献见表 1)。OLIF 技术为什么会发生椎体骨折,椎体骨折有什么特点,临床结果如何,关于 OLIF 技术的椎体骨折尚未见专题报道。为了总结 OLIF 技术椎体骨折的发生特点、原因,从而进行有效的预防。武警海警总队医院、浙江大学医学院附属邵逸夫医院和皖南医学院戈矶山医院自 2014 年 10 月至 2018 年 12 月共采用 OLIF 技术治疗腰椎病变 1 421 例,出现腰椎骨折 8 例,发生率 0.56%。现对 8 例患者的临床资料进行回顾性分析,报告如下。

1　临床资料

1.1　病例选择

入选标准:在上述 3 家医疗中心接受 OLIF 手术的病例,包括 Stand-alone OLIF 或 OLIF 联合后路椎弓根螺钉固定;术中发现或术后通过影像检查明确椎体骨折。排除标准:失访或资料不全者。

1.2　一般资料

根据病例选择标准,本组共入选 8 例,均为女性,年龄 50~81 岁,平均 66.4 岁;腰椎退行性病变 1 例,腰椎管狭窄症 3 例,腰椎退行性滑脱 2 例,腰椎退行性侧后凸 2 例;术前双能 X 线骨密度检测,2 例 T 值>−1 SD,2 例 T 值−1~−2.5 SD,4 例 T 值<−2.5 SD。均采用 OLIF 技术,经腰椎左斜外侧入路,具体操作见文献[6,12]。融合节段数:单节段 5 例,双节段 1 例,3 节段 2 例。融合器内植骨:同种异体骨 6 例,人工骨(硫酸钙)加骨诱导蛋白(bone morphogenetic protein, BMP)2 例。采用 Stand-alone OLIF 4 例,Ⅰ期 OLIF 联合后路椎弓根螺钉固定 4 例。术后影像检查明确存在椎体骨折,且均为单椎体骨折,8 例患者的具体情况见表 2。其中发生于融合节段上位椎体 2 例,下位椎体 6 例;表现为椎体右下缘或右上方三角形骨块 7 例,椎体劈裂 1 例;合并终板损伤,融合器部分嵌入椎体 6 例。

2　治疗方法

4 例 OLIF 联合后路椎弓根螺钉固定病例未予特殊处理,于术后 3~5 d 佩戴胸腰支具下床活动。4 例 Stand-alone OLIF 病例中 3 例于术后 5~7 d 行后方肌间隙入路椎弓根螺钉固定,3 例再手术病例中 1 例椎体劈裂者予卧床 6 周后佩戴胸腰支具保护

表 1　OLIF 技术椎体骨折的相关文献资料

Tab.1　Related literature reports of vertebral fracture on OLIF

文献来源	总病例数	椎体骨折例数	椎体骨折原因	椎体骨折的处理方式
ZENG 等[18]	235	3	原因不明	1 例保守治疗，2 例辅加后路椎弓根螺钉固定
PATEL 等[21]	15	1	原因不明	保守治疗
KIM 等[22]	46	1	融合器移位	辅加后路椎弓根螺钉固定
PENNICOOKE 等[23]	1	1	骨赘增生	翻修
OH 等[24]	143	1	骨质疏松	翻修

表 2　椎体骨折 8 例患者的临床资料

Tab.2　Clinical data of 8 patients with vertebral fracture

病例序号	性别	年龄/岁	手术方式	融合部位	椎体发生部位	可能原因	处理方式
1	女	61	OLIF	$L_{2,3}$ $L_{3,4}$ $L_{4,5}$	L_2 椎体右下缘	骨质疏松+终板形态异常+骨赘增生	卧床 6 周
2	女	81	OLIF+PS	$L_{4,5}$	L_5 椎体右上缘	骨质疏松+骨赘增生	胸腰支具保护
3	女	53	OLIF	$L_{1,2}$ $L_{2,3}$ $L_{4,5}$	L_2 椎体右上缘	终板形态异常+骨赘增生+终板损伤	Ⅱ期予 PS
4	女	59	OLIF+PS	$L_{4,5}$	L_5 椎体右上缘	骨质疏松+融合器方向不正+终板损伤	胸腰支具保护
5	女	74	OLIF+PS	$L_{4,5}$	L_5 椎体右上缘	骨质疏松+融合器方向不正+终板损伤	胸腰支具保护
6	女	50	OLIF+PS	$L_{3,4}$ $L_{4,5}$	L_4 椎体右上缘	终板损伤	胸腰支具保护
7	女	78	OLIF	$L_{4,5}$	L_5 椎体劈裂	骨质疏松+终板损伤	Ⅱ期予 PS
8	女	75	OLIF	$L_{3,4}$	L_4 椎体右下缘	骨质疏松+融合器方向不正+终板损伤	Ⅱ期予 PS

注：OLIF 为斜外侧椎间融合，PS 为椎弓根螺钉固定

下下床活动，另 2 例于二次术后 3~5 d 佩戴胸腰支具下床活动；1 例 Stand-alone OLIF 病例未再次手术，予卧床 6 周后佩戴胸腰支具保护下下床活动。

3　结果

3.1　临床观察项目

（1）临床结果指标：对于初次或再次手术病例观察切口皮肤坏死或切口感染情况，分别采用 VAS（visual analogue scale，VAS）评分和 Oswestry 功能障碍指数（Oswestry disability index，ODI）评价术前、末次随访时的腰痛和腰椎功能。（2）影像学指标：术后 3~5 d（对于再次手术病例于再次手术后 3~5 d 重新检查 1 次，下同）及术后 1.5、3、6、12 个月行腰椎正侧位 X 线检查，术后 12 个月行腰椎过屈过伸位 X 线检查；术后 3~5 d、12 个月行 CT 平扫并二维、三维重建，观察融合器位置、随访过程中融合器沉降或移位情况、椎体骨折愈合情况和椎间融合情况；测量并对比术前、术后和末次随访时椎体骨折节段椎间隙高度的变化。椎间融合采用 COOK 等[25]提出的评价标准，即融合节段间有连续骨小梁形成的骨桥、椎弓根螺钉及融合器周围无硬化、透亮带，同时在动力位 X 线片上融合节段无相对位移。

3.2　临床结果

初次手术的 5 例与再次手术的 3 例均未出现切口皮肤坏死或切口感染，所有患者获得随访，时间 12~48 个月，平均 22.8 个月。末次随访时，腰痛明显改善，VAS 由术前的 4~8 分（平均 6.3 分）下降至末次随访时的 1~3 分（平均 1.7 分）；腰椎功能亦明显改善，ODI 由术前的 39.7%~52.4%（平均 40.2%）恢复至末次随访时的 7.9%~11.2%（平均 9.5%）。

3.3　影像学结果

随访过程中未出现椎弓根螺钉系统松动或断裂现象，椎体骨折节段均出现融合器的沉降（图 1、图 2），融合器无横向移位。椎体骨折节段椎间隙高度由术前的 6.7~9.2 mm（平均 8.1 mm）恢复至术后的 10.5~12.8 mm（平均 11.2 mm），术后与术前比较改善率 37.98%；末次随访时为 8.4~10.9 mm（平均 9.3 mm），与术后比较丢失率 16.71%。说明腰椎骨折节段术后椎间隙高度获得明显的恢复，而在随访过程中出现了明显的丢失。末次随访时除 1 例不能明确外（椎间融合器内骨质稀疏，并可见透亮线），其余均获得椎间融合（图 1、图 2），融合率为 87.5%。

4　讨论

4.1　椎体骨折的发生特点

椎间植骨作为最有效的手段广泛地应用于腰椎的融合治疗。后路椎间融合中，无论是单纯植骨或采用融合器植骨，椎体骨折极为罕见[19-20]。在前路腰椎椎间融合术（anterior lumbar interbody fusion，ALIF）、直接侧方椎间融合术（direct lateral interbody fusion，

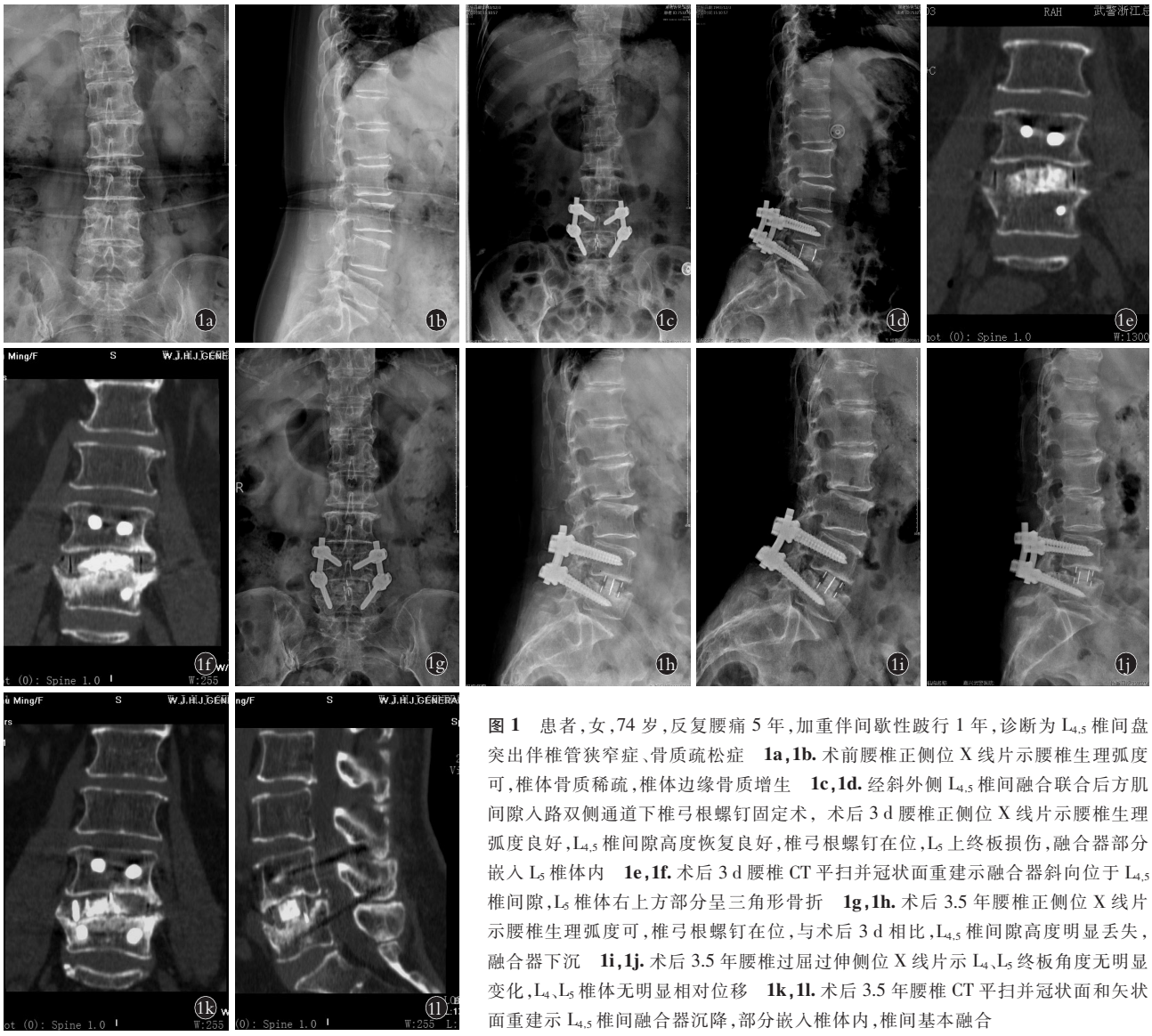

图 1　患者，女，74 岁，反复腰痛 5 年，加重伴间歇性跛行 1 年，诊断为 $L_{4,5}$ 椎间盘突出伴椎管狭窄症、骨质疏松症　**1a，1b.** 术前腰椎正侧位 X 线片示腰椎生理弧度可，椎体骨质稀疏，椎体边缘骨质增生　**1c，1d.** 经斜外侧 $L_{4,5}$ 椎间融合联合后方肌间隙入路双侧通道下椎弓根螺钉固定术，术后 3 d 腰椎正侧位 X 线片示腰椎生理弧度良好，$L_{4,5}$ 椎间隙高度恢复良好，椎弓根螺钉在位，L_5 上终板损伤，融合器部分嵌入 L_5 椎体内　**1e，1f.** 术后 3 d 腰椎 CT 平扫并冠状面重建示融合器斜向位于 $L_{4,5}$ 椎间隙，L_5 椎体右上方部分呈三角形骨折　**1g，1h.** 术后 3.5 年腰椎正侧位 X 线片示腰椎生理弧度可，椎弓根螺钉在位，与术后 3 d 相比，$L_{4,5}$ 椎间隙高度明显丢失，融合器下沉　**1i，1j.** 术后 3.5 年腰椎过屈过伸侧位 X 线片示 L_4、L_5 终板角度无明显变化，L_4、L_5 椎体无明显相对位移　**1k，1l.** 术后 3.5 年腰椎 CT 平扫并冠状面和矢状面重建示 $L_{4,5}$ 椎间融合器沉降，部分嵌入椎体内，椎间基本融合

Fig.1　A 74-year-old female patient with recurrent low back pain for 5 years, aggravated with intermittent claudication for 1 year, was diagnosed as $L_{4,5}$ disc herniation with spinal stenosis and osteoporosis　**1a, 1b.** Anterior and lateral X-ray films of the lumbar spine before operation showed that normal curvature of the lumbar spine was fair, the vertebral body was osteopenic, and the vertebral body was osteophytosis　**1c, 1d.** Three days after undergoing oblique lateral $L_{4,5}$ interbody fusion combined with posterior muscle space approach surgery, the lumbar AP and lateral X-ray films showed that the lumbar normal curvature was good, the height of $L_{4,5}$ intervertebral space was recovered well, the pedicle screws were in place, the upper endplate of L_5 was injury, and the fusion cage was partially embedded in L_5 vertebral body　**1e, 1f.** Three days after operation, plain CT scan and coronal reconstruction of the lumbar spine showed that the fusion cage was obliquely located in the $L_{4,5}$ intervertebral space, and the upper right part of the L_5 vertebral body was triangular fracture　**1g, 1h.** At 3.5 years after the operation, AP and lateral X-ray films of the lumbar spine showed that the normal curvature of the lumbar spine was fair, and the pedicle screws were in place. Compared with three days after the operation, the height of the $L_{4,5}$ intervertebral space had significantly decreased, and the fusion cage had become embedded　**1i, 1j.** At 3.5 years after operation, the lateral X-ray films on hyperflexion and hyperextension positions of the lumbar spine showed that no significant change in the endplate angle of L_4 and L_5, and no significant relative displacement at L_4 and L_5 vertebral body　**1k, 1l.** At 3.5 years after operation, the lumbar CT scan showed that the $L_{4,5}$ interbody fusion cage subsided, partially embedded in the vertebral body, and the interbody fusion had essentially occurred

DLIF）或 OLIF 技术中，亦偶有发生的报道[21-24,26-32]，本组发生 8 例，占 3 家医疗中心所开展 OLIF 病例中的 0.56%。分析本组病例的椎体骨折，有以下特点：(1)多发生于早期开展病例。(2)多发生于女性。(3)术前多合并骨量减少或骨质疏松，本组骨量减少 2 例，骨质疏松 4 例。(4)术中多存在终板损伤，本组术中终板损伤伴融合器部分嵌入椎体 6 例。(5)多发生于融合器植入的对侧，由于 3 家医疗中心的 OLIF 操作均采用左斜外侧入路，融合器自椎间隙左侧植入，因此均发生于椎体右侧，本组 7 例，另有椎体矢

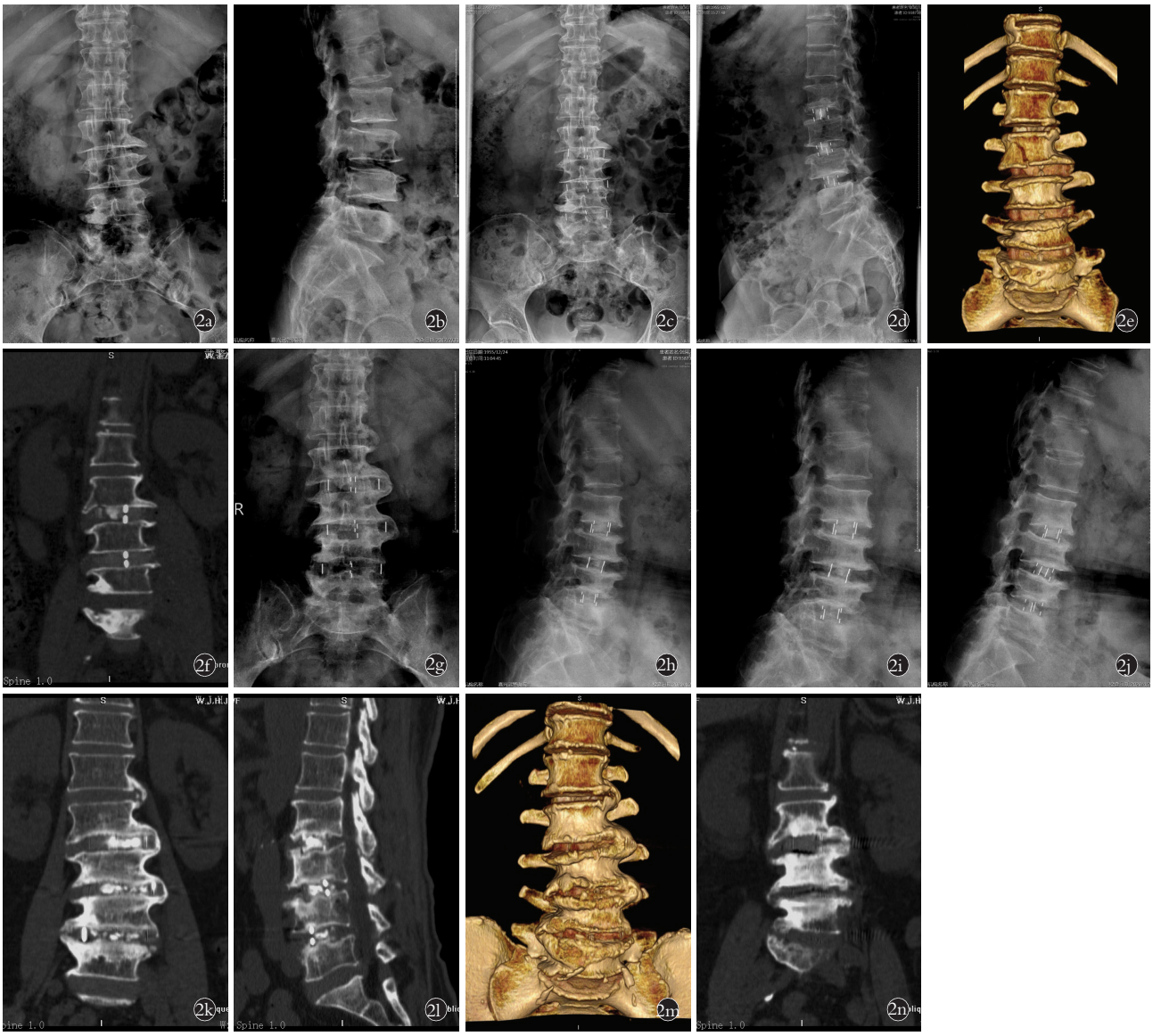

图 2　患者，女，61 岁，反复腰痛 7 年，加重伴双下肢放射 1.5 年，诊断为 $L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 椎管狭窄症　**2a，2b.** 术前腰椎正侧位 X 线片示腰椎轻度侧弯、旋转，椎体边缘骨质增生　**2c，2d.** 经斜外侧 $L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 椎间融合术，术后腰椎正侧位 X 线片示腰椎生理弧度可，$L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 椎间融合器在位　**2e，2f.** 术后腰椎 CT 平扫并三维和冠状面重建示 L_2 椎体前右下缘部分骨折　**2g，2h.** 术后 2 年 8 个月腰椎正侧位 X 线片示腰椎生理弧度可，与术后相比，$L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 椎间隙高度轻度丢失　**2i，2j.** 术后 2 年 8 个月腰椎过屈过伸侧位 X 线片示 $L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 终板角度无明显变化，$L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 椎体无明显相对位移　**2k，2l.** 术后 2 年 8 个月腰椎 CT 平扫并冠状面和矢状面重建示 $L_{2,3}$，$L_{3,4}$，$L_{4,5}$ 椎间隙轻度丢失，椎间融合　**2m，2n.** 术后 2 年 8 个月腰椎 CT 平扫并三维和冠状面重建示 L_2 椎体右下缘骨折部分已愈合

Fig.2　A 61-year-old female patient with recurrent low back pain for 7 years, worsened by radiaton of both lower limbs for 1.5 years, was diagnosed as lumbar spinal stenosis of $L_{2,3}$, $L_{3,4}$, $L_{4,5}$　**2a, 2b.** AP and lateral X-ray films of the lumbar spine before operation showed that the lumbar spine was slightly bent and rotated, with osteophytosis at the edge of the vertebral bodies　**2c, 2d.** After oblique lateral interbody fusion of $L_{2,3}$, $L_{3,4}$, $L_{4,5}$, AP and lateral X-ray films showed that the lumbar normal curvature was well, and the $L_{2,3}$, $L_{3,4}$, $L_{4,5}$ interbody fusion cages were on position　**2e, 2f.** Postoperative plain CT scan and 3D coronal reconstruction of lumbar spine showed that partial fractures at the front right lower edge of L_2 vertebral body　**2g, 2h.** Two years and eight months after operation, AP and lateral X-ray films showed that the normal ourvature of the lumbar spine was normal. Compared with that after operation, the height of the $L_{2,3}$, $L_{3,4}$, $L_{4,5}$ intervertebral space was slightly lost　**2i, 2j.** Two years and eight months after operation, the lumbar hyperflexion and hyperextension lateral X-ray films showed that the endplate angle of $L_{2,3}$, $L_{3,4}$, $L_{4,5}$ had no significant changes, and the lumbar vertebral body of $L_{2,3}$, $L_{3,4}$, $L_{4,5}$ had no significant relative displacement　**2k, 2l.** Two years and eight months after operation, plain CT scan of lumbar spine and reconstruction of coronal and sagittal planes showed that the $L_{2,3}$, $L_{3,4}$, $L_{4,5}$ intervertebral spaces were slightly lost, and the intervertebral fusion was well　**2m, 2n.** Two years and eight months after operation, plain CT scan and 3D coronal reconstruction of lumbar spine showed that the right lower edge fracture of L_2 vertebral body was partially healed

状面纵向劈裂 1 例。(7)多发生于融合节段的下位椎体，本组发生于融合节段下位椎体 6 例。(8)多表现为椎体部分骨折，即椎体右下方或右上方三角形骨块，较少侵及整个椎体，即完全骨折，本组完全骨折 1 例。(9)椎体骨折端均无明显移位。(10)部分病例椎体缘存在明显的骨赘增生。(11)部分病例存在终板形态异常，即终板表现为较深的穹隆状。

4.2 椎体骨折的发生原因

关于 OLIF 技术术中椎体骨折的原因，文献报道较少[18]。ZENG 等[18]报道了 235 例 OLIF 手术中出现 3 例椎体骨折，分析椎体骨折的原因考虑为骨质疏松、操作技术、所用试模和融合器太大等。当然，也有报道为融合器移位[22]或骨赘增生[23]等原因。与 OLIF 技术相比，虽然 DLIF 技术手术入路与进入椎间隙的位置稍有不同，但椎间隙内操作和所用融合器形状、容积基本相同。因而，DLIF 技术文献报道[26-28,30-32]中关于椎体骨折的原因可作为 OLIF 技术的参考与佐证：DUA 等[26]报道由经验丰富的高年资医师完成 13 例腰椎侧方椎间融合手术，同期进行了侧方钢板螺钉固定联合后方单侧椎弓根螺钉固定，术后明确 2 例椎体骨折，认为骨质疏松和侧方钢板螺钉切割可能是发生椎体骨折的原因。TENDER[28]通过分析 2 例腰椎侧方椎间融合术中的椎体骨折，认为腰椎侧方椎间融合术中椎体骨折可以发生于骨质条件正常的病例，原因可能有侧方钢板螺钉的放置、选择融合器太小、终板损伤、融合器斜向放置。BRIER-JONES 等[27]报道了腰椎侧方椎间融合术中的 4 例椎体骨折，认为即使在非骨质疏松病例中亦可能发生椎体骨折，原因主要有术中终板损伤、融合器切割陷入椎体、侧方钢板螺钉的切割、融合器的翻转等。

分析本组椎体骨折的原因，既有患者本身的因素，如骨量减少或骨质疏松、终板解剖异常、椎体缘明显的骨赘增生，也有术者的操作原因，如不规范或粗暴操作，以及融合器大小选择不当等，现就本组椎体骨折发生的可能主要原因分析如下。

4.2.1 患者骨量减少或骨质疏松　骨量减少或骨质疏松可能是术中发生椎体骨折的重要病理因素[33-36]，本组 8 例患者中术前检查提示存在骨量减少或骨质疏松 6 例，骨量减少或骨质疏松会增加椎体的脆性，降低椎体的承载能力，术中容易出现终板损伤或椎体骨折。

4.2.2 终板损伤　本组合并终板损伤 6 例，融合器部分嵌入椎体内。一旦终板损伤，椎体的完整性遭到破坏，必将进一步削弱椎体的承载能力，成为椎体骨折的始动因素。本组 1 例终板损伤合并椎体纵向劈裂即可能有此因素。

4.2.3 终板形态不规则　根据临床观察，国人腰椎终板多呈穹隆状，且多较浅平，但也可能出现变异，如终板表现为较深的穹隆状[37-38]，而 OLIF 所用融合器的前后向和左右侧角度固定，与终板形态不完全贴合。如此，在融合器的置入过程中，如选择融合器过大，加之敲击力量大，甚至粗暴用力，容易发生椎体的对向骨折。

4.2.4 融合器选择过大　如术前存在明显的椎间隙狭窄，加之病史长、椎间僵硬，如术中松解不充分、不彻底，椎间未能有效撑开，而使用的融合器又较大，特别是融合器高度明显超过椎间隙高度者[39]，融合器植入过程易偏离椎间隙方向而致椎体骨折，特别在终板穹隆状较深或对侧椎体缘骨赘增生者。

4.2.5 椎体缘骨赘增生　腰椎退变病例中，由于部分病例病史时间长，椎间存在不稳，长期的不良应力刺激，易出现椎体侧方的骨赘增生，特别是明显的增生，因 OLIF 技术要求融合器两侧与椎体左右缘平齐，即要求融合器架在两椎体之间，而不是含在终板之内。因此，在融合器置入过程中，对侧的骨赘必将成为较大的阻挡，从而出现椎体骨折。

当然，除上述主要原因外，术者对椎间隙方向把握不准、不规范操作也可能是导致椎体骨折的因素。

4.3 椎体骨折的处理与预后

由于椎体骨折发生较隐匿，多为部分骨折，且移位不甚明显，术中无论是直视下观察或使用 C 形臂 X 线机透视，多难于发现，本组均通过术后影像检查明确，而有的医院术后可能不常规进行腰椎的 CT、MRI 检查，椎体骨折易漏诊。椎体骨折一旦发生，势必降低椎体的承载能力，影响椎间应力传导和融合器的稳定。如处理不当可能出现融合器移位，甚至不融合或内固定松动等，因此，需要得到及时的诊断和有效的处理。当然，对于术中即发现的椎体骨折，如骨折端无明显移位，仍可使用融合器植骨，而骨折端明显移位者，建议行融合器取出，予结构性植骨。如椎体骨折明确，无论骨折端有无移位，均建议附加后路椎弓根螺钉固定。对于术中未发现而是通过术后检查明确者，如初次手术采用 Stand-alone 方式，则需要Ⅱ期加用后路椎弓根螺钉固定；如初次手术已联合后路椎弓根螺钉固定，且融合器位置良好，术后可适当延长卧床时间，加强随访观察。如融合器位置不良，或经严密观察术后出现内固定明显松动或融合器移位，需要考虑翻修。ZENG 等[18]报道的 3 例椎体骨折，1 例予保守治疗，2 例予Ⅱ期行后路椎弓根螺钉固定。TENDER[28]报道的 2 例腰椎侧方椎间融合，初次手术采用 Stand-alone 1 例，联合侧方钢板螺钉固定 1 例，术后影像检查发现下位椎体上方骨折，

2 例均再次手术，行后路椎弓根螺钉固定。BRIER-JONES 等[27]报道的 4 例腰椎侧方椎间融合术后的椎体骨折，其中 2 例接受了再手术（1 例经后路椎弓根螺钉固定并后外侧融合，另 1 例予椎体成形术），其余 2 例予保守治疗。所有出现椎体骨折的病例，即使附加了后路椎弓根螺钉固定或进行了其他方式的手术，均需要适当制动，根据骨折形态和局部稳定情况决定是否绝对卧床或延长卧床时间。下地活动时佩戴胸腰支具，加强胸腰部保护。由于椎体血液循环丰富且多为松质骨，只要发现及时、处理得当，均能获得较好的骨愈合，本组病例最后随访时椎体骨折均愈合良好。虽然随访中椎体骨折节段椎间融合器均出现较为明显的沉降，以及较为明显的椎间隙高度丢失，但未出现融合器移位或内固定松动、断裂现象，除 1 例融合不明确外，其余均获得椎间融合，且末次随访时腰痛和腰椎功能均获得明显的改善。

4.4　椎体骨折的预防

虽然 OLIF 技术椎体骨折发生率较低，却是较为严重的并发症，需要加强预防。建议：(1)严格病例选择，对于术前存在骨量减少或骨质疏松者，术中操作要仔细、规范，注意终板保护，而且建议常规联合后路椎弓根螺钉固定，以及术中、术后及时行影像检查。(2)术前仔细阅读影像资料，了解病变节段终板的形态和椎体缘骨赘增生情况，以指导术中的操作。(3)术中患者体位摆放标准、固定牢固，使用 C 形臂 X 线机引导和监视下操作。(4)对于病史时间长、骨赘增生明显、椎间隙狭窄、椎间僵硬者，需要做较大范围的椎间清理和较为彻底的椎间松解，必要时做前纵韧带、前方纤维环、对侧纤维环的松解。(5)准确地把握椎间隙方向，在使用试模和置入融合器时避免暴力。(6)融合器选用要适当，包括融合器长度和高度。

参考文献

[1] MAYER H M. A new microsurgical technique for minimally invasive anterior lumbar interbody fusion[J]. Spine (Phila Pa 1976), 1997, 22(6): 691-699.

[2] SILVESTRE C, MAC-THIONG J M, HILMI R, et al. Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients[J]. Asian Spine J, 2012, 6(2): 89-97.

[3] FUJIBAYASHI S, HYNES R A, OTSUKI B, et al. Effect of indirect neural decompression through oblique lateral interbody fusion for degenerative lumbar disease[J]. Spine (Phila Pa 1976), 2015, 40(3): E175-E182.

[4] OHTORI S, ORITA S, YAMAUCHI K, et al. Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for lumbar spinal degeneration disease[J]. Yonsei Med J, 2015, 56(4): 1051-1059.

[5] MOLLOY S, BUTLER J S, BENTON A, et al. A new extensile anterolateral retroperitoneal approach for lumbar interbody fusion from L_4 to S_1: a prospective series with clinical outcomes[J]. Spine J, 2016, 16(6): 786-791.

[6] 张建锋，范顺武，方向前，等. 斜外侧椎间融合术在单节段腰椎间盘退行性疾病中的应用[J]. 中华骨科杂志，2017，37(2)：80-88.
ZHANG J F, FAN S W, FANG X Q, et al. Clinical value of one-level oblique lateral interbody fusion in the treatment of degenerative lumbar disc diseases[J]. Chin J Orthop, 2017, 37(2): 80-88. Chinese.

[7] ZHANG Y H, WHITE I, POTTS E, et al. Comparison perioperative factors during minimally invasive pre-psoas lateral interbody fusion of the lumbar spine using either navigation or conventional fluoroscopy[J]. Global Spine J, 2017, 7(7): 657-663.

[8] SATO J, OHTORI S, ORITA S, et al. Radiographic evaluation of indirect decompression of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for degenerated lumbar spondylolisthesis[J]. Eur Spine J, 2017, 26(3): 671-678.

[9] KIM K T, JO D J, LEE S H, et al. Oblique retroperitoneal approach for lumbar interbody fusion from L1 to S1 in adult spinal deformity[J]. Neurosurg Rev, 2018, 41(1): 355-363.

[10] LIN G X, AKBARY K, KOTHEERANURAK V, et al. Clinical and radiologic outcomes of direct versus indirect decompression with lumbar interbody fusion: a matched-pair comparison analysis[J]. World Neurosurg, 2018, 119: e898-e909.

[11] BENG T B, KOTANI Y, SIA U, et al. Effect of indirect neural decompression with oblique lateral interbody fusion was influenced by preoperative lumbar lordosis in adult spinal deformity surgery[J]. Asian Spine J, 2019, 13(5): 809-814.

[12] 曾忠友，张建乔，宋永兴，等. 对比斜外侧椎间融合与后路融合治疗腰椎管狭窄症[J]. 中华骨科杂志，2020，40(11)：707-718.
ZENG Z Y, ZHANG J Q, SONG Y X, et al. Comparison of two different decompression and fusion methods in the treatment of lumbar spinal stenosis[J]. Chin J Orthop, 2020, 40(11): 707-718. Chinese.

[13] GRAGNANIELLO C, SEEX K. Anterior to psoas (ATP) fusion of the lumbar spine: evolution of a technique facilitated by changes in equipment[J]. J Spine Surg, 2016, 2(4): 256-265.

[14] JIN J, RYU K S, HUR J W, et al. Comparative study of the difference of perioperative complication and radiologic results: mis-DLIF (minimally invasive direct lateral lumbar interbody fusion) versus MIS-OLIF (minimally invasive oblique lateral lumbar interbody fusion)[J]. Clin Spine Surg, 2018, 31(1): 31-36.

[15] WOODS K R, BILLYS J B, HYNES R A. Technical description of oblique lateral interbody fusion at L_1-L_5 (OLIF25) and at L_5-S_1 (OLIF51) and evaluation of complication and fusion rates[J]. Spine J, 2017, 17(4): 545-553.

[16] ABE K, ORITA S, MANNOJI C, et al. Perioperative complications in 155 patients who underwent oblique lateral interbody fusion surgery: perspectives and indications from a retrospective, multicenter survey[J]. Spine (Phila Pa 1976), 2017, 42(1): 55-62.

[17] 王吉莹，周志杰，范顺武，等. 斜外侧椎间融合术治疗腰椎退行性疾病的早期并发症分析[J]. 中华骨科杂志，2017，37(16)：1006-1013.
WANG J Y, ZHOU Z J, FAN S W, et al. Early complications associated with oblique lateral interbody fusion in the treatment of degen-

erative lumbar diseases[J]. Chin J Orthop, 2017, 37(16): 1006-1013. Chinese.

[18] ZENG Z Y, XU Z W, HE D W, et al. Complications and prevention strategies of oblique lateral interbody fusion technique[J]. Orthop Surg, 2018, 10(2): 98-106.

[19] YASUHARA T, TAKAHASHI Y, KUMAMOTO S, et al. Proximal vertebral body fracture after 4-level fusion using l1 as the upper instrumented vertebra for lumbar degenerative disease: report of 2 cases with literature review[J]. Acta Med Okayama, 2013, 67(3): 197-202.

[20] SAVILLE P A, ANARI J B, SMITH H E, et al. Vertebral body fracture after TLIF: a new complication[J]. Eur Spine J, 2016, 25(Suppl 1): 230-238.

[21] PATEL R S, SUH S W, KANG S H, et al. The radiologic and clinical outcomes of oblique lateral interbody fusion for correction of adult degenerative lumbar deformity[J]. Indian J Orthop, 2019, 53(4): 502-509.

[22] KIM W J, LEE J W, KIM S M, et al. Precautions for combined anterior and posterior long-level fusion for adult spinal deformity: perioperative surgical complications related to the anterior procedure (oblique lumbar interbody fusion)[J]. Asian Spine J, 2019, 13(5): 823-831.

[23] PENNICOOKE B, GUINN J, CHOU D A. Symptomatic contralateral osteophyte fracture with migration causing lumbar plexopathy during oblique lumbar interbody fusion: illustrative case[J]. J Neurosurg Case Lessons, 2021, 2(1): CASE21210.

[24] OH B K, SON D W, LEE S H, et al. Learning curve and complications experience of oblique lateral interbody fusion: a single-center 143 consecutive cases[J]. J Korean Neurosurg Soc, 2021, 64(3): 447-459.

[25] COOK S D, SALKELD S L, STANLEY T, et al. Biomechanical study of pedicle screw fixation in severely osteoporotic bone[J]. Spine J, 2004, 4(4): 402-408.

[26] DUA, KEPLER C K, HUANG R C, et al. Vertebral body fracture after anterolateral instrumentation and interbody fusion in two osteoporotic patients[J]. Spine J, 2010, 10(9): e11-e15.

[27] BRIER-JONES J E, PALMER D K, İNCEOGLU S, et al. Vertebral body fractures after transpsoas interbody fusion procedures[J]. Spine J, 2011, 11(11): 1068-1072.

[28] TENDER G C. Caudal vertebral body fractures following lateral interbody fusion in nonosteoporotic patients[J]. Ochsner J, 2014, 14(1): 123-130.

[29] KWON Y K, JANG J H, LEE C D, et al. Fracture of the L_4 vertebral body after use of a stand-alone interbody fusion device in degenerative spondylolisthesis for anterior L_{3-4} fixation[J]. J Neurosurg Spine, 2014, 20(6): 653-656.

[30] TEMPEL Z J, GANDHOKE G S, BOLINGER B D, et al. Vertebral body fracture following stand-alone lateral lumbar interbody fusion (LLIF): report of two events out of 712 levels[J]. Eur Spine J, 2015, 24(Suppl 3): 409-413.

[31] DOMÍNGUEZ I, LUQUE R, NORIEGA M, et al. Extreme lateral lumbar interbody fusion. Surgical technique, outcomes and complications after a minimum of one year follow-up[J]. Rev Esp Cir Ortop Traumatol, 2017, 61(1): 8-18.

[32] TEMPEL Z J, MCDOWELL M M, PANCZYKOWSKI D M, et al. Graft subsidence as a predictor of revision surgery following stand-alone lateral lumbar interbody fusion[J]. J Neurosurg Spine, 2018, 28(1): 50-56.

[33] FORMBY P M, KANG D G, HELGESON M D, et al. Clinical and radiographic outcomes of transforaminal lumbar interbody fusion in patients with osteoporosis[J]. Global Spine J, 2016, 6(7): 660-664.

[34] OH K W, LEE J H, LEE J H, et al. The correlation between cage subsidence, bone mineral density, and clinical results in posterior lumbar interbody fusion[J]. Clin Spine Surg, 2017, 30(6): E683-E689.

[35] FIELDS A J, LEE G L, KEAVENY T M. Mechanisms of initial endplate failure in the human vertebral body[J]. J Biomech, 2010, 43(16): 3126-3131.

[36] CHO J H, HWANG C J, KIM H, et al. Effect of osteoporosis on the clinical and radiological outcomes following one-level posterior lumbar interbody fusion[J]. J Orthop Sci, 2018, 23(6): 870-877.

[37] WANG Y T, WANG H L, LV F Z, et al. Asymmetry between the superior and inferior endplates is a risk factor for lumbar disc degeneration[J]. J Orthop Res, 2018, 36(9): 2469-2475.

[38] ZHOU Q S, CHEN X, XU L, et al. Does vertebral end plate morphology affect cage subsidence after transforaminal lumbar interbody fusion[J]. World Neurosurg, 2019, 130: e694-e701.

[39] KIM W J, LEE J W, KIM S M, et al. Precautions for combined anterior and posterior long-level fusion for adult spinal deformity: perioperative surgical complications related to the anterior procedure (oblique lumbar interbody fusion)[J]. Asian Spine J, 2019, 13(5): 823-831.

（收稿日期：2022-12-09　本文编辑：王宏）