

## · 临床研究 ·

# 腰椎两种不同椎间融合方式终板损伤的病例对照研究

曾忠友<sup>1</sup>, 吴宏飞<sup>1</sup>, 范时洋<sup>1</sup>, 范顺武<sup>2</sup>, 方向前<sup>2</sup>, 赵兴<sup>2</sup>, 宋永兴<sup>1</sup>, 俞伟<sup>1</sup>, 裴斐<sup>1</sup>, 宋国浩<sup>1</sup>

(1. 武警部队骨科医学中心 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)

**【摘要】** 目的: 总结并比较肌间隙入路通道下经椎间孔椎间融合联合椎弓根螺钉固定方式与斜外侧椎间融合联合椎弓根螺钉固定方式治疗腰椎病变终板损伤的特点与临床结果。方法: 回顾性分析 2016 年 1 月至 2019 年 6 月收治的 213 例腰椎病变患者, 男 73 例, 女 140 例; 年龄 24~81(54.9±10.5) 岁; 病程 6~180(40.30±28.71) 个月; 腰椎间盘退行性病变 35 例, 巨大型腰椎间盘突出症 22 例, 椎间盘源性腰痛 15 例, 炎症转归期原发性腰椎间隙炎 9 例, 腰椎管狭窄症 52 例, 腰椎退行性滑脱 47 例, 腰椎椎弓峡部裂伴或不伴椎体滑脱 33 例; 单节段 191 例(L<sub>2,3</sub> 5 例、L<sub>3,4</sub> 24 例、L<sub>4,5</sub> 162 例), 双节段 22 例(L<sub>2,3</sub> 和 L<sub>3,4</sub> 3 例、L<sub>3,4</sub> 和 L<sub>4,5</sub> 19 例)。采用后方肌间隙入路通道下双侧椎弓根螺钉固定并椎间融合术 110 例(后路融合组), 斜外侧椎间融合联合后方肌间隙入路通道下双侧椎弓根螺钉固定术 103 例(斜外侧融合组)。观察两组患者终板损伤的发生特点, 并比较两组患者的临床和影像结果及并发症情况。结果: 后路融合组发生终板损伤 8 例 9 个节段, 发生率 7.27%(8/110), 男 1 例, 女 7 例, 年龄(63.22±3.51) 岁; 8 例中术前存在骨量减少或骨质疏松 7 例; 使用香蕉型融合器 5 例, 解剖型融合器 3 例; 发生于椎体上终板 3 个节段, 椎体下终板 6 个节段。斜外侧融合组发生终板损伤 21 例 24 个节段, 发生率 20.39%(21/103), 男 4 例, 女 17 例, 年龄(62.50±5.02) 岁; 21 例中术前存在骨量减少或骨质疏松 16 例; 使用融合器偏大(指融合器高度) 5 例, 终板解剖形态异常 4 例, 豁嵴过高 3 例; 发生于椎体上终板 20 个节段, 椎体下终板 4 个节段; 21 例终板损伤中合并椎体骨折 2 例。后路融合组终板损伤发生率低于斜外侧融合组。两组患者均未发生切口感染, 随访时间 12~48 个月, 中位数 12 个月。随访中后路融合组出现融合器沉降 22 例, 斜外侧融合组 43 例, 两组各发生 1 例融合器移位, 均无内固定松动、移位或断裂。斜外侧融合组并发症发生率 33.98%(35/103), 高于后路融合组 23.64%(26/110), 两组比较差异有统计学意义( $P=0.039$ )。两组患者术后椎间隙高度均获得良好的恢复, 但在随访时出现不同程度的丢失。融合率后路融合组为 94.5%(104/110), 斜外侧融合组为 96.1%(99/103), 两组差异无统计学意义( $P=0.083$ )。末次随访时两组患者临床症状均得到明显改善。结论: 两种方法治疗单或双节段腰椎病变均能获得良好的临床效果。两种融合方式终板损伤的特点不完全相同。虽然两种固定融合方式的终板损伤没有影响最终的临床结果, 但仍需要加以重视, 做好终板损伤的预防和有效处理, 尤其是对于斜外侧椎间融合方式。

**【关键词】** 腰椎; 脊柱融合术; 手术后并发症; 终板损伤

中图分类号: R681.5

DOI: 10.12200/j.issn.1003-0034.2022.10.006

开放科学(资源服务)标识码(OSID):



**Case-control study on endplate injury of lumbar spine with two different intervertebral fusion methods** ZENG Zhong-you\*, WU Hong-fei, FAN Shi-yang, FAN Sun-wu, FANG Xiang-qian, ZHAO Xing, SONG Yong-xing, YU Wei, PEI Fei, and SONG Guo-hao. \* The Second Department of Orthopaedics, Hospital of Coast Guard General Corps of Armed Police Forces, Jiaxing 314000, Zhejiang, China

**ABSTRACT Objective:** To summarize and compare the endplate injury occurrence characteristics and clinical results of transforaminal intervertebral fusion combined with pedicle screw fixation through intermuscular approach and oblique lateral intervertebral fusion combined with pedicle screw fixation in the treatment of lumbar disease. **Methods:** A retrospective analysis of 213 cases of lumbar disease admitted from January 2016 to June 2019, including 73 males and 140 females. The age ranged from 24 to 81 years old, with an average of (54.9±10.5) years old. The courses of disease ranged from 6 to 180 months, with an average of (40.30±28.71) months. There were 35 cases of degenerative lumbar intervertebral disc disease, 22 cases of

基金项目: 浙江省医药卫生科技计划项目(编号: 2020KY968)

Fund program: Zhejiang Provincial Medical Science and Technology Program (No. 2020KY968)

通讯作者: 曾忠友 E-mail: zjzengzy@126.com

Corresponding author: ZENG Zhong-you E-mail: zjzengzy@126.com

giant lumbar disc herniation, 15 cases of discogenic low back pain, 9 cases of primary lumbar intervertebral inflammation at the turn of inflammation, 52 cases of lumbar spinal stenosis, 47 cases of lumbar degenerative spondylolisthesis, 33 cases of lumbar spondylolysis with or without spondylolisthesis. There were 191 cases of single-segment lesions, including 5 cases on L<sub>2,3</sub>, 24 cases on L<sub>3,4</sub>, 162 cases on L<sub>4,5</sub>. And there were 22 cases of two-segment lesions, including 3 cases on L<sub>2,3</sub> and L<sub>3,4</sub>, and 19 cases on L<sub>3,4</sub> and L<sub>4,5</sub>. One hundred and ten cases were taken by bilateral pedicle screw fixation and interbody fusion under the posterior muscle space approach (abbreviated as posterior fusion group), and 103 cases were taken by oblique lateral interbody fusion combined with bilateral pedicle screw fixation under the posterior muscle space approach (oblique lateral fusion group). Observed the characteristics of endplate injury in the two groups, and compared the clinical and imaging results and complications of the two groups. **Results:** There were 8 cases of endplate injury occurred in 9 segments in the posterior fusion group. According to the number of cases, the incidence rate was 7.27% (8/110), 1 case was male, 7 cases were female, with an average age of (63.22±3.51) years old. Among the 8 cases, there were 7 cases of bone loss or osteoporosis before the operation, 5 cases using banana fusion cages, 3 cases using anatomical fusion cages. Three cases occurred in the upper endplate of the vertebral body and 6 cases in the inferior endplate of the vertebral body. In the oblique lateral fusion group, there were 21 cases of endplate injury in 24 segments, and the incidence rate was 20.39% (21/103). There were 4 males and 17 females, with an average age of (62.50±5.02) years old. Among the 21 cases, 16 cases were bone loss or osteoporosis before operation. There were 5 cases used large fusion cages, 4 cases had abnormal endplate anatomy, and 3 cases had iliac crest hypertrophy. It occurred in 20 segments of the upper endplate of the vertebral body, and 4 segments of the lower endplate of the vertebral body. Two of the 21 cases of endplate injury combined with vertebral body fractures. The incidence of endplate injury of the posterior fusion group was significantly lower than that of the oblique lateral fusion group. No incision infection occurred in the two groups, the follow-up time was ranged from 12 to 48 months, and the median follow-up period was 12 months. In the follow-up, 22 cases occurred fusion cage subsidence in the posterior fusion group, 43 cases in the oblique lateral fusion group, and 1 case in each group occurred fusion cage displacement. There was no loosening, displacement or breakage of the internal fixation. The incidence of complications in the oblique lateral fusion group 33.98% (35/103) was significantly higher than that in the posterior fusion group 23.64% (26/110),  $P=0.039$ . The height of the intervertebral space in both groups recovered well after the operation, but it was lost to varying degrees during follow-up. The fusion rate of the posterior fusion group was 94.5% (104/110), and 96.1% (99/103) in the oblique lateral fusion group ( $P=0.083$ ). At the latest follow-up, the clinical symptoms of the two groups of patients were significantly improved. **Conclusion:** Two methods in treating single or two-segment lumbar spine lesions obtained good clinical effects. The characteristics of endplate injury in the two fusion methods are not completely the same. Although the endplate injury did not affect the final clinical results of the two fixed fusion methods, it still needs to be paid attention to and emphasize the prevention and effective treatment of endplate injury, especially for oblique lateral intervertebral fusion.

**KEYWORDS** Lumbar vertebrae; Spinal fusion; Postoperative complications; Endplate injury

后方经椎间孔入路椎间融合(transforaminal lumbar interbody fusion, TLIF)作为成熟而标准的手术方式广泛地应用于腰椎的固定融合治疗<sup>[1-7]</sup>。随着认识的深入、理论的提升、技术的进步,以及解剖、生物力学和材料的进展,出现了很多不同椎间融合方式的应用<sup>[6,8-18]</sup>。其中,腰椎斜外侧椎间融合(oblique lateral interbody fusion, OLIF)作为一项新兴的椎间融合技术,近年来出现了大量的报道<sup>[8,10-14,17-18]</sup>。但作为椎间融合最为常见的并发症,无论是 TLIF 或 OLIF 技术,术中终板损伤均无法避免<sup>[17,19-26]</sup>。终板损伤的发生可能需要改变椎间植骨方式,如由融合器植骨改为单纯性植骨,也可能需要改变手术方式,以加强固定节段的稳定性,如由 Stand-alone 而 I 期或分期附加椎弓根螺钉固定。部分病例可能因终板损伤致术后融合器的持续沉降,甚至移位、脱出、不融合或内固定失败,面临着翻修手术。而且不同的椎间融合方式,终板损伤后的临床结果亦可能不同。为了

对比 TLIF 联合椎弓根螺钉固定与 OLIF 联合椎弓根螺钉固定治疗腰椎病变术中终板损伤的发生特点和临床结果,笔者对 2016 年 1 月至 2019 年 6 月分别采用上述两种固定融合方式治疗的 213 例腰椎病变的临床资料进行回顾性分析,报告如下。

## 1 资料与方法

### 1.1 病例选择

**1.1.1 纳入标准** (1)腰椎间盘退行性病变,巨大型腰椎间盘突出症,椎间盘源性腰痛,炎症转归期原发性腰椎间隙炎,腰椎管狭窄症(根据 Schizas 等<sup>[27]</sup>腰椎管狭窄程度分级为 A-C 级),腰椎退行性滑脱 I-II 度(Meyerding 分度法,下同),腰椎椎弓峡部裂伴或不伴椎体滑脱(如有滑脱,滑脱程度为 Meyerding I-II 度)。(2)单节段或双节段病变。(3)病变部位为 L<sub>2</sub>-L<sub>5</sub>。(4)获得≥1 年的随访,且资料完整。

**1.1.2 排除标准** (1)如骨性中央管或侧隐窝狭窄(包括发育性椎管狭窄),或非包容性椎间盘突出等

需要直接椎管减压者。(2) 固定节段腰椎关节突融合。(3) 既往有腰椎后路手术史或腹膜外手术史, 或髂血管鞘与腰大肌间隙消失。(4) 合并基础疾病无法耐受手术者。

**1.2 临床资料** 本研究根据病例选择标准, 选择后方肌间隙入路通道下双侧椎弓根螺钉固定并椎间融合术(TLIF 术式)110 例(后路融合组), 斜外侧椎间融合联合后方肌间隙入路通道下双侧椎弓根螺钉固定术 103 例(斜外侧融合组)。本组 213 例中男 73 例, 女 140 例; 年龄 24~81 (54.9±10.5) 岁; 病程 6~180 (40.30±28.71) 个月; 腰椎间盘突出退行性病变 35 例, 巨大型腰椎间盘突出症 22 例, 椎间盘源性腰痛 15 例, 炎症转归期原发性腰椎间隙炎 9 例, 腰椎管狭窄症 52 例, 腰椎退行性滑脱 47 例, 腰椎椎弓峡部裂伴或不伴椎体滑脱 33 例; 单节段 191 例(L<sub>2,3</sub> 5 例、L<sub>3,4</sub> 24 例、L<sub>4,5</sub> 162 例), 双节段 22 例(L<sub>2,3</sub> 和 L<sub>3,4</sub> 3 例、L<sub>3,4</sub> 和 L<sub>4,5</sub> 19 例)。后路融合组 110 例中男 38 例, 女 72 例; 年龄 25~78 (55.10±10.23) 岁; 病程 6~180 (40.70±29.14) 个月; 腰椎间盘突出退行性病变 20 例, 巨大型腰椎间盘突出症 10 例, 椎间盘源性腰痛 8 例, 炎症转归期原发性腰椎间隙炎 5 例, 腰椎管狭窄症 27 例, 腰椎退行性滑脱 24 例(均为 I 度滑脱), 腰椎椎弓峡部裂伴或不伴椎体滑脱 16 例(I 度滑脱 3 例, II 度滑脱 13 例); 单节段 98 例(L<sub>2,3</sub> 3 例、L<sub>3,4</sub> 13 例、L<sub>4,5</sub> 82 例), 双节段 12 例(L<sub>2,3</sub> 和 L<sub>3,4</sub> 2 例、L<sub>3,4</sub> 和 L<sub>4,5</sub> 10 例)。斜外侧融合组 103 例中男 35 例, 女 68 例; 年龄 24~81 (54.60±11.08) 岁; 病程 8~156 (39.80±

27.91) 个月; 腰椎间盘突出退行性病变 15 例, 巨大型腰椎间盘突出症 12 例, 椎间盘源性腰痛 7 例, 炎症转归期原发性腰椎间隙炎 4 例, 腰椎管狭窄症 25 例, 腰椎退行性滑脱 23 例(均为 I 度滑脱), 腰椎峡部裂伴或不伴椎体滑脱 17 例(I 度滑脱 2 例, II 度 15 例); 单节段 93 例(L<sub>2,3</sub> 2 例、L<sub>3,4</sub> 11 例、L<sub>4,5</sub> 80 例), 双节段 10 例(L<sub>2,3</sub> 和 L<sub>3,4</sub> 1 例、L<sub>3,4</sub> 和 L<sub>4,5</sub> 9 例)。两组患者一般资料比较差异无统计学意义, 有可比性, 见表 1。

两组患者均有慢性腰痛, 其中伴双下肢神经症状 31 例, 伴一侧下肢神经症状 156 例。入院后常规行腰椎 X 线正侧位和过屈过伸位检查(如有腰椎滑脱或椎弓峡部裂, 同时行腰椎双斜位 X 线检查), 行 CT 及 MRI 检查。术前双能 X 线骨密度检测, 93 例 T 值 -1~-2.5 SD, 51 例 T 值 < -2.5 SD。

**1.3 治疗方法**

所有病例完成手术操作, 且由同一组医生完成。后路所用通道由山东威高医疗器械有限公司提供的 Mispine 系统, 后路融合器(其中植入 1 枚解剖型融合器 25 例, 经一侧植入 2 枚解剖型融合器 37 例, 植入香蕉型融合器 48 例)由北京富乐医疗器械有限公司生产的 poster 融合器(解剖型, Peek 材料)62 例, 由美国枢法模公司提供的 Crescent 融合器(香蕉型, Peek 材料)48 例, 椎间融合器内植骨均为自体骨, 椎间隙深部植骨采用自体骨 19 例, 同种异体骨和自体骨混合 91 例。斜外侧融合所用通道和融合器由美国枢法模公司提供, 融合器为 Peek 材料 Clydesdale 系统, 融合器内植骨均为同种异体骨。同种异体骨由北

表 1 两组腰椎病变患者术前一般资料比较

Tab.1 Comparison of preoperative general data of patients with lumbar disease between two groups

组别	例数 (例)	年龄 ( $\bar{x}\pm s$ , 岁)	性别(例)		病程 ( $\bar{x}\pm s$ , 月)	疾病类型(例)						
			男	女		1	2	3	4	5	6	7
后路融合组	110	55.10±10.23	38	72	40.70±29.14	20	10	8	5	27	24	16
斜外侧融合组	103	54.60±11.08	35	68	39.80±27.91	15	12	7	4	25	23	17
检验值		$t=0.837$	$\chi^2=0.729$		$t=1.146$	$\chi^2=1.563$						
P 值		0.725	0.179		0.423	0.095						

组别	例数 (例)	疾病部位(例)					融合节段数(例)	
		L <sub>2,3</sub>	L <sub>3,4</sub>	L <sub>4,5</sub>	L <sub>2,3</sub> 和 L <sub>3,4</sub>	L <sub>3,4</sub> 和 L <sub>4,5</sub>	单节段	双节段
后路融合组	110	3	13	82	2	10	98	12
斜外侧融合组	103	2	11	80	1	9	93	10
检验值		$\chi^2=1.372$					$\chi^2=1.125$	
P 值		0.129					0.108	

注: 疾病类型中 1, 2, 3, 4, 5, 6, 7 分别表示腰椎间退行性病变, 巨大型腰椎间盘突出症, 椎间盘源性腰痛, 炎症转归期原发性腰椎间隙炎, 腰椎管狭窄症, 腰椎退行性滑脱, 腰椎椎弓峡部裂伴或不伴椎体滑脱

Note: 1, 2, 3, 4, 5, 6, and 7 of the disease types indicate lumbar intervertebral degeneration, giant lumbar disc herniation, discogenic low back pain, primary lumbar intervertebral interstitial inflammation, and lumbar spinal stenosis, lumbar degenerative spondylolisthesis, lumbar spondylolysis with or without spondylolisthesis

京鑫康辰医学科技发展有限公司提供。椎弓根螺钉为山东威高医疗器械有限公司提供的 UPASS II 型钛合金系统 183 例,台湾国扬医疗器械有限公司 Stone 系统 30 例。

**1.3.1 后路融合组手术方法** 全麻下患者取俯卧位,保持腹部悬空,以病变节段为中心,旁开棘突 2~3 cm,做棘突两旁纵行切口,锐性切开腰背筋膜,于多裂肌纤维间做钝性分离达椎板和关节突表面。插入扩张套管,逐级扩张。于两侧先后置入带光源的通道并纵向撑开,同时使其底部呈喇叭状张口,将通道保持外倾并头倾方向固定。清除椎板、关节突表面残余软组织,充分显露病变节段椎板间隙及关节突关节。在 C 形臂 X 线机监视下完成病变节段两侧经椎弓根置入定位针。采用单侧经椎间孔入路,具体为:切除关节突关节(取下骨质备用),做髓核摘除、终板软骨清除、椎间隙深部植骨、融合器植入。如为双节段融合,则将通道向上或向下移至另一节段,依上述步骤再行标准的经 TLIF 术式减压、椎间隙深部植骨、融合器植入。融合器植入完成后,取出椎弓根定位针,分别拧入螺钉,于两侧装棒,如有滑脱将滑脱椎体做提拉复位,适当椎间压缩后紧固螺栓。大量生理盐水冲洗切口,探查切口内无活动性出血,逐层缝合切口,于减压侧放置 1 根引流管接负压引流。

**1.3.2 斜外侧融合组手术方法** 全麻下患者取标准右侧卧位,保持屈髋,腋下及髋部分别用宽布胶固定。C 形臂 X 线机定位并规划切口,切口定位如下:沿病变椎间隙体表投影椎体前缘向前延伸 2 cm,向后延伸 1 cm,做斜行切口。如为双节段融合,切口定位如下:做两节段病变中部平行椎间隙的斜切口,仍然是椎体前缘向前延伸 2~3 cm,向后延伸 2 cm。分别沿腹外斜肌、腹内斜肌纤维走行方向做钝性分离,切开腹横肌,向腹侧推开腹膜外脂肪和腹内脏器。显露腰大肌,用骨膜剥离器将腰大肌稍向背侧推开,用牵开器将腰大肌牵向背侧,将腹内脏器连同腹膜外脂肪牵向腹侧,显露病变节段椎间隙。于椎间隙前中 1/3 斜向插入导针,C 形臂 X 线机透视确定无误后逐级放置扩张套管和带光源的通道。移除套管,扩张通道并予以固定(保持通道斜向方向),做椎间盘开窗切除,顺椎间隙垂直插入钝性绞刀,透视确定椎间隙位置和终板方向。用融合器试模做椎间隙的逐级撑开,进一步清除残余髓核和终板软骨,制作融合器床。C 形臂 X 线机透视确定所用融合器的高度和长度。将填入骨块的融合器(融合器填入骨块后用可吸收缝线予以跳跃性捆绑,以防止融合器在植入椎间隙过程骨块脱落)垂直植入椎间隙,透视确定融合器位置良好后冲洗切口,探查切口内无活动性出

血,撤除通道。如为双节段融合,则依上述步骤重新定位另一椎间隙、植入融合器。再次探查并确认切口内无活动性出血,予逐层缝合切口。将患者改为俯卧位,保持腹部悬空,以病变节段为中心,旁开棘突 2~3 cm,做棘突两旁纵行切口。锐性切开腰背筋膜,于多裂肌和最长肌间隙做钝性分离达椎板和关节突表面。插入扩张套管,逐级扩张。于两侧同时置入带光源的通道并纵向撑开,同时使其底部呈喇叭状张口,将通道保持外倾并头倾方向固定。清除关节突表面残余软组织,显露病变节段关节突关节。在 C 形臂 X 线机监视下完成病变节段两侧经椎弓根置入螺钉,于两侧装棒,如有滑脱将滑脱椎体做进一步提拉复位,适当椎间压缩后紧固螺栓。大量生理盐水冲洗切口,探查切口内无活动性出血,逐层缝合切口,3 个切口内均未放置引流管。

**1.3.3 术后处理** 术后常规予预防感染、脱水、小剂量激素等治疗,并卧床休息。麻醉苏醒后,嘱患者主动进行双侧踝关节背伸运动、被动进行双下肢直腿抬高运动。后路融合组根据引流量,于术后 48~72 h 拔除切口引流管。两组病例均于术后 3~5 d 佩戴腰围下床活动,6 周后渐进性腰背肌、腹肌锻炼。

#### 1.4 观察项目与方法

**1.4.1 一般情况观察** 记录两组患者的手术时间和术中出血量,其中斜外侧融合组术中更换体位、术野消毒、铺巾所用时间不包括在手术时间中。

**1.4.2 影像学评价** 于术后 3~5 d、3、6、12 个月,随后每隔 12 个月行腰椎 X 线正侧位检查,术后 12 个月行腰椎 X 线过屈过伸位检查;术后 3~5 d 行腰椎 CT 平扫,术后 12 个月行腰椎 CT 平扫并矢状面、冠状面重建。测量并对比两组患者手术前后不同时期的椎间隙高度、腰椎冠状面和矢状面 Cobb 角,观察有无终板损伤、终板损伤部位、椎体骨折、融合器沉降或移位、内固定松动或断裂、椎间融合情况。

椎间融合评价标准:(1)椎间融合器无移位,融合器内无透亮线。(2)椎间融合器前方有骨小梁通过。(3)融合器与椎体终板间无透亮线并有骨小梁通过。(4)过屈过伸位 X 线片提示融合节段椎体无相对移位及终板角度变化 $<5^{\circ}$ 。其中符合(1)、(2)、(4),或者(1)、(3)、(4)项认为椎间融合良好。

**1.4.3 临床疗效评价** 分别采用视觉模拟评分法<sup>[2]</sup>(visual analogue scale, VAS), Oswestry 功能障碍指数<sup>[2]</sup>(Oswestry Disability Index, ODI)评估术后腰痛和腰椎功能的情况。

#### 1.5 统计学处理

应用 SPSS 20.0 统计软件进行数据处理,两组患者性别、疾病类型、病变部位、并发症发生率等定性

资料的比较采用 $\chi^2$ 检验;两组年龄、病史、手术时间、术中出血量、VAS、腰椎冠状面和矢状面 Cobb 角、椎间隙高度、ODI 的比较采用成组设计定量资料  $t$  检验;同组手术前后不同时期定量资料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

2.1 一般情况及临床疗效

手术时间后路融合组(96.80±13.11) min,斜外侧融合组(97.30±14.05) min,两组差异无统计学意义 ( $t=1.72, P=0.069$ )。术中出血量后路融合组(288.30±56.61) ml,斜外侧融合组(91.30±31.24) ml,斜外侧融合组少于后路融合组( $t=9.43, P < 0.000 1$ )。

所有患者随访 1 年以上,时间 12~48 个月,中位数 12 个月。腰痛 VAS 评分,后路融合组由术前的(5.52±0.87)分降至末次随访时的(0.71±0.64)分,斜外侧融合组由术前的(5.37±0.91)分降至末次随访时的(0.66±0.58)分,两组末次随访时腰痛评分与术前比较差异均有统计学意义 ( $t=14.815, P < 0.000 1; t=14.481, P < 0.000 1$ ),两组间术前和末次随访时对比差异无统计学意义 ( $t=2.712, P=0.109; t=1.926, P=0.153$ )。ODI 指数方面:后路融合组由术前的(43.50±5.78)%恢复至末次随访时的(9.7±3.69)%,斜外侧融合组由术前的(42.80±5.46)%恢复至末次随访时的(9.40±3.21)%,末次随访时 ODI 指数与术前比较差异有统计学意义 ( $t=9.164, P < 0.000 1; t=8.957, P < 0.000 1$ ),两组间术前和末次随访时比较差异无统计学意义( $t=1.925, P=0.096; t=1.744, P=0.102$ )。

2.2 影像学观察

典型病例的影像学资料见图 1-2。

2.2.1 椎间隙高度 两组患者手术前后病变节段椎间隙高度比较,结果见表 2。所有患者椎间隙高度术后较术前有明显恢复,末次随访时出现不同程度的丢失。手术前后不同时期组间比较差异均无统计学意义( $P > 0.05$ )。

2.2.2 腰椎冠状面和矢状面 Cobb 角变化 两组患者术前和末次随访时腰椎冠状面、矢状面 Cobb 角变

表 2 两组腰椎病变患者手术前后病变节段椎间隙高度比较 ( $\bar{x} \pm s, \text{mm}$ )

Tab.2 Comparison of lesion segmental intervertebral space height of patients with lumbar disease between two groups before and after operation ( $\bar{x} \pm s, \text{mm}$ )

组别	例数	术前	术后 3~5 d	末次随访
后路融合组	110	9.29±2.16	12.31±1.86 <sup>□</sup>	10.72±1.93 <sup>■</sup>
斜外侧融合组	103	9.23±2.10	12.42±1.79 <sup>△</sup>	10.39±2.02 <sup>▲</sup>
$t$ 值		0.428	0.136	0.247
$P$ 值		0.754	1.051	0.912

注:与术前比较,  $\square t=9.152, P < 0.000 1; \triangle t=9.672, P < 0.000 1$ 。  $\square$ 与 $\blacksquare$ 比较,  $t=7.163, P < 0.000 1; \triangle$ 与 $\blacktriangle$ 比较,  $t=7.845, P < 0.000 1$

Note: Compared with preoperative data,  $\square t=9.152, P < 0.000 1; \triangle t=9.672, P < 0.000 1$ .  $\square$  vs  $\blacksquare, t=7.163, P < 0.000 1; \triangle$  vs  $\blacktriangle, t=7.845, P < 0.000 1$

化见表 3, 术后腰椎冠状面和矢状面平衡均获得了较好改善。组间比较, 术前及术后 3~5 d 腰椎冠状面、矢状面 Cobb 角差异均无统计学意义( $P > 0.05$ )。

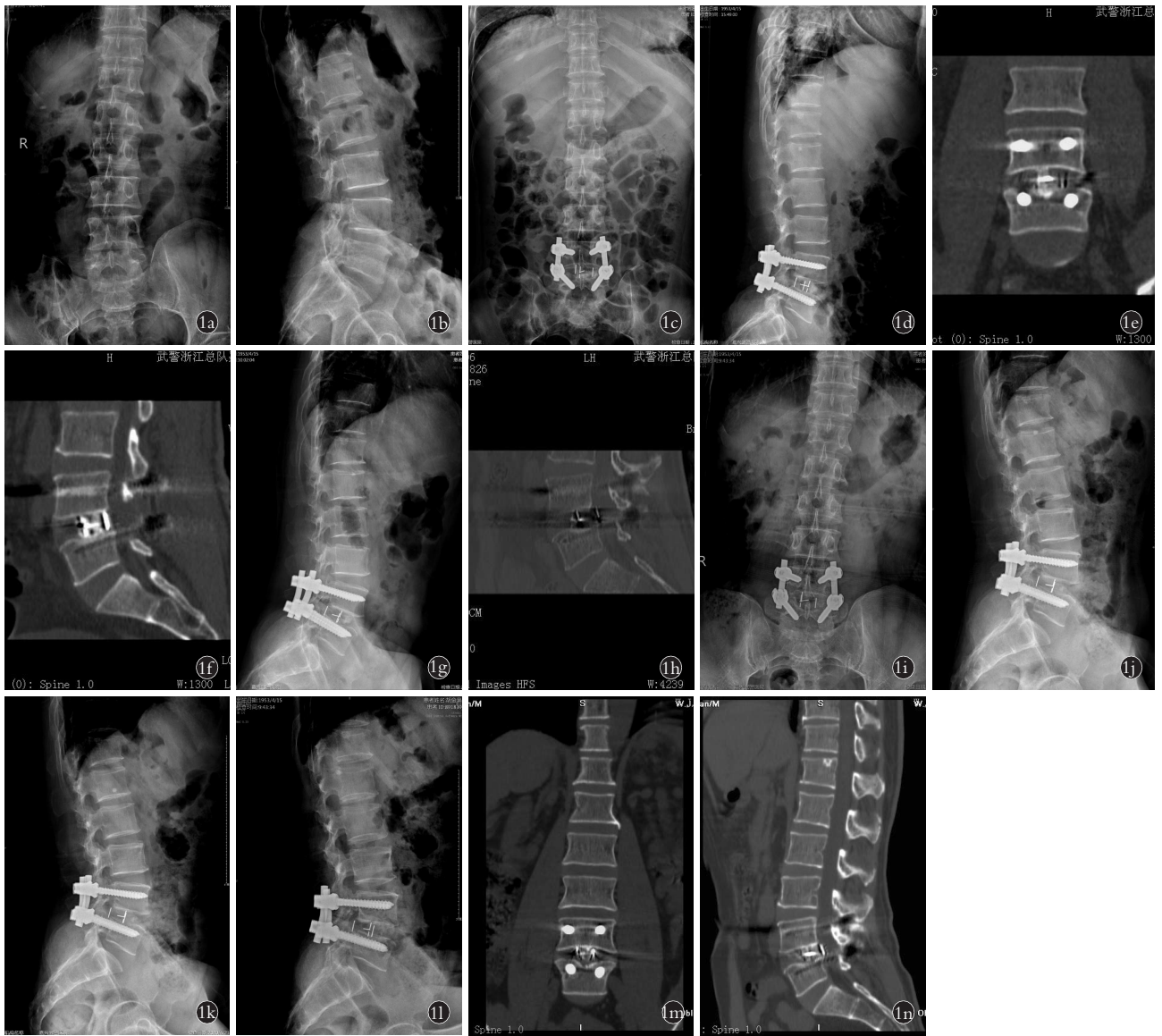
2.2.3 融合情况 根据评价标准,除 10 例(后路融合组 6 例,斜外侧融合组 4 例)不能明确(椎间融合器内骨质稀疏,并可见透亮线)外,其余均获得椎间融合,后路融合组融合率为 94.5%(104/110),斜外侧融合组融合率为 96.1%(99/103),两组比较差异无统计学意义( $\chi^2=2.794, P=0.083$ )。

2.2.4 终板损伤情况 后路融合组发生终板损伤 8 例 9 个节段,发生率为 7.27%(8/110);其中男 1 例,女 7 例;年龄(63.22±3.51)岁;术前存在骨量减少或骨质疏松 7 例,使用香蕉型融合器 5 例,解剖型融合器 3 例;发生于椎体上终板 3 个节段,发生于椎体下终板 6 个节段。斜外侧融合组发生终板损伤 21 例 24 个节段,发生率为 20.39%(21/103);其中男 4 例,女 17 例;年龄(62.50±5.02)岁;术前存在骨量减少或骨质疏松 16 例;使用融合器偏大(指融合器高度)5 例,存在终板解剖形态异常 4 例,髂嵴过高 3 例;发生于椎体上终板 20 个节段,发生于椎体下终板 4 个节段,21 例终板损伤中合并椎体骨折

表 3 两组腰椎病变患者手术前后腰椎冠状面和矢状面 Cobb 角比较

Tab.3 Comparison of coronal plane and sagittal plane Cobb angle of patients with lumbar disease between two groups before and after operation

组别	例数	冠状面 Cobb 角( $\bar{x} \pm s, ^\circ$ )		$t$ 值	$P$ 值	矢状面 Cobb 角( $\bar{x} \pm s, ^\circ$ )		$t$ 值	$P$ 值
		术前	术后 3~5 d			术前	术后 3~5 d		
后路融合组	110	2.53±1.03	1.05±0.62	9.37	<0.000 1	37.29±9.24	43.73±7.91	3.21	0.016
斜外侧融合组	103	2.66±1.15	1.38±0.79	8.92	<0.000 1	38.10±10.17	43.92±8.25	2.87	0.038
$t$ 值		1.48	1.53			1.76	1.51		
$P$ 值		0.126	0.061			0.921	1.042		



**图 1** 患者,男,63 岁,L<sub>4,5</sub> 椎管狭窄症 **1a,1b**. 术前腰椎正侧位 X 线片示腰椎生理弧度可,L<sub>4,5</sub> 椎间隙高度下降 **1c,1d**. 经后方肌间隙入路双侧通道下椎弓根螺钉固定并椎间融合术,术后腰椎正侧位 X 线片示腰椎生理弧度可,L<sub>4,5</sub> 椎间隙高度部分恢复,椎弓根螺钉及椎间融合器在位良好 **1e,1f**. 术后腰椎 CT 平扫并冠状面、矢状面重建示 L<sub>5</sub> 椎体上终板损伤,融合器平椎体后缘 **1g**. 术后 2 个月腰椎侧位 X 线片示腰椎生理弧度良好,椎弓根螺钉在位良好,椎间融合器向后移位 **1h**. 术后 4 个月腰椎 CT 平扫并矢状面重建示椎间融合器向后移位 **1i,1j**. 术后 32 个月腰椎正侧位 X 线片示腰椎生理弧度良好,L<sub>4,5</sub> 椎间隙高度维持良好,椎弓根螺钉在位良好,椎间融合器无进一步移位 **1k,1l**. 术后 32 个月腰椎过屈过伸侧位 X 线片示 L<sub>4,5</sub> 终板角度无明显变化,L<sub>4,5</sub> 椎体无明显相对位移 **1m,1n**. 术后 32 个月腰椎 CT 平扫并冠状面和矢状面重建示 L<sub>4,5</sub> 椎间融合良好

**Fig.1** A 63-year-old male patient with L<sub>4,5</sub> spinal stenosis **1a,1b**. Preoperative AP and lateral X-rays showed a physiological curvature of the lumbar spine, with a decrease on the height of L<sub>4,5</sub> spinal space **1c,1d**. The pedicle screw fixation and interbody fusion under the bilateral channel through the posterior muscle space approach. Postoperative lumbar spine AP and lateral X-rays showed that lumbar vertebra was physiologically curved, and the height of L<sub>4,5</sub> intervertebral spaces was partially restored. The pedicle screws and the cage was on good position **1e,1f**. Postoperative lumbar spine CT scan with coronal and sagittal plane reconstruction showed the injury of the upper endplate of the L<sub>5</sub> vertebral body, and the cage leveled the posterior edge of vertebral body **1g**. At 2 months after operation, lateral X-ray of lumbar spine showed that lumbar spine had a good physiological curvature, the pedicle screws were well on place, and the interbody cage was displaced backwards **1h**. At 4 months after operation the lumbar spine CT plain scan and sagittal reconstruction showed the posterior displacement of the intervertebral cage **1i,1j**. At 32 months after operation, AP and lateral X-rays showed lumbar spine had a good physiological curvature, the height of L<sub>4,5</sub> intervertebral spaces was well maintained, the pedicle screws were well on place, and there was no further displacement of the intervertebral cage **1k,1l**. At 32 months after operation, lateral X-rays of lumbar spine hyperflexion and hyperextension showed that no significant changes on L<sub>4,5</sub> endplate angles, and no significant relative displacement of L<sub>4,5</sub> vertebral bodies **1m,1n**. At 32 months after operation, CT scan with coronal plane and sagittal plane reconstruction showed good fusion of L<sub>4,5</sub> intervertebral vertebrae



图 2 患者,女,56 岁,L<sub>4</sub> 退行性滑脱 2a,2b. 术前腰椎正侧位 X 线示 L<sub>4</sub> 椎体向前滑移 I 度,L<sub>4,5</sub> 椎间隙高度下降 2c,2d. 经 I 期行斜外侧 L<sub>4,5</sub> 椎间融合联合后方肌间隙入路通道下双侧椎弓根螺钉固定术,术后 3 d 腰椎正侧位 X 线片示 L<sub>4</sub> 椎体复位良好,L<sub>4,5</sub> 椎间高度恢复良好,融合器部分位于椎体外侧,内固定在位 2e. 术后 3 d 腰椎 CT 平扫并冠状面重建示 L<sub>4,5</sub> 椎间融合器偏斜,且未完全进入椎间隙,L<sub>5</sub> 上终板损伤 2f. 术后 2 个月腰椎正位 X 线片示 L<sub>4,5</sub> 椎间融合器向左侧移位 2g. 术后 4 个月腰椎正位 X 线片 L<sub>4,5</sub> 椎间融合器无进一步移位 2h,2i. 术后 20 个月腰椎正侧位 X 线片示 L<sub>4,5</sub> 椎间融合器无进一步移位,椎间隙

高度部分丢失,融合器轻度沉降,内固定在位 2j,2k. 术后 20 个月腰椎过屈过伸侧位 X 线片示 L<sub>4</sub>、L<sub>5</sub> 终板角度无明显变化,L<sub>4</sub>、L<sub>5</sub> 椎体无相对位移 2l,2m. 术后 20 个月腰椎 CT 平扫并冠状面和矢状面重建示 L<sub>4,5</sub> 椎间基本融合

**Fig.2** A 56-year-old female patient with L<sub>4</sub> degenerative spondylolisthesis 2a,2b. Preoperative AP and lateral X-rays showed that L<sub>4</sub> vertebral body slipped forward for I degree, and the height of L<sub>4,5</sub> intervertebral spaces decreased 2c,2d. At 3 days after one-stage oblique, lateral L<sub>4,5</sub> interbody fusion combined with bilateral pedicle screw fixation under the posterior intermuscular approach channel, AP and lateral X-rays showed that L<sub>4</sub> vertebral body was well reset, and L<sub>4,5</sub> intervertebral body was well reduced. The height has recovered well, the cage was partially located outside the vertebral body, and the internal fixation is in place 2e. At 3 days after the operation, lumbar spine CT scan with coronal plane reconstruction showed L<sub>4,5</sub> interbody cages were deflected and did not fully enter the intervertebral space, and the upper end plate of L<sub>5</sub> was injured 2f. At 2 months after operation, AP X-ray of lumbar spine showed that the L<sub>4,5</sub> interbody cage was displaced to the left 2g. At 4 months after the operation the AP X-ray showed that no further displacement of the L<sub>4,5</sub> interbody cage 2h,2i. At 20 months after operation, AP and lateral X-rays showed no further displacement of L<sub>4,5</sub> interbody cage, the height of intervertebral space was partially lost, the cage was slightly subsided, and the internal fixation was on place 2j,2k. At 20 months after operation, lateral X-ray of lumbar spine hyperflexion and hyperextension showed that no significant changes in the angles of L<sub>4</sub> and L<sub>5</sub> endplates, and no relative displacement of L<sub>4</sub> and L<sub>5</sub> vertebral bodies 2l,2m. At 20 months after operation, lumbar spine CT scan with coronal plane and sagittal reconstruction showed basic fusion of L<sub>4,5</sub> intervertebral vertebrae

2 例。终板损伤的发生率后路融合组低于斜外侧融合组( $\chi^2=6.351, P=0.007$ )。

### 2.3 并发症情况

后路融合组术中发生硬脊膜撕裂和脑脊液漏

3 例,椎弓根入点处骨折 6 例,终板损伤 8 例。术后出现神经根损伤 2 例,1 例考虑为椎弓根螺钉进入椎管顶压所致,予螺钉调整术,另 1 例考虑为术中神经松解所致;出现切口皮肤部分坏死 5 例,切口愈合

不良 1 例。

斜外侧融合组术中出现节段血管损伤 2 例,终板损伤 21 例,交感链损伤 2 例,术后一过性髂腰肌无力 5 例,左大腿前外侧疼痛麻木伴股四头肌无力 3 例、神经根损伤 1 例,其中神经根损伤原因考虑为椎弓根螺钉进入椎管顶压所致,予螺钉调整术。

两组病例均未发生切口感染,随访过程中出现融合器沉降 65 例(后路融合组 22 例,斜外侧融合组 43 例),融合器移位两组各 1 例,2 例均有终板损伤,经佩戴胸腰支具加强外保护后,融合器无进一步移位。两组病例均无内固定松动或断裂,亦未观察到固定部位邻近节段的明显退变(包括椎间盘突出、椎间隙高度明显下降、明显的骨质增生和局部畸形)。融合器沉降不计入并发症,两组并发症发生率后路融合组 23.64%(26/110),斜外侧融合组为 33.98%(35/103),后者高于前者( $\chi^2=4.272, P=0.039$ )。

### 3 讨论

#### 3.1 两种固定融合方式临床结果的对比

TLIF 联合椎弓根螺钉固定是腰椎固定融合效果最为确切的手术方式之一<sup>[1-4,6]</sup>,具有技术成熟、稳定性好、融合率高等优点,而且通过肌间隙入路通道显露下的操作,进一步减小了切口、减少了创伤、减少了出血,加速了恢复<sup>[3,5,7]</sup>。OLIF 联合后方肌间隙入路通道下椎弓螺钉固定方式作为腰椎固定融合的最新应用<sup>[8,10-14,17-18]</sup>,不仅具有上述优点,且干扰椎管、出血更少。两组病例的手术时间对比基本一致,而斜外侧融合组出血量明显少于后路融合组。所有患者术后椎间隙高度获得明显的恢复,随访过程中出现较为明显的丢失。两组间椎间隙高度的对比,无论是术后或末次随访时差异均无统计学意义。两组患者均获得良好的椎间融合,末次随访时腰痛和腰椎功能均获得很好的改善,组间比较差异无统计学意义。综上对比,两种固定融合方式治疗单节段和两节段腰椎病变均能获得良好的临床结果,且斜外侧融合方式临床优势更为明显。

#### 3.2 两种融合方式终板损伤的特点和原因分析

后路融合组发生终板损伤 8 例 9 个融合节段,斜外侧融合组终板损伤 21 例 24 个融合节段,斜外侧融合发生率明显高于后路融合。分析两种融合方式终板损伤的特点,既有相同之处,如多发生于老年女性病例,且术前较多存在骨量减少或骨质疏松,其中后路融合组男 1 例,女 7 例,年龄(63.22±3.51)岁,术前存在骨量减少或骨质疏松 7 例;斜外侧融合组男 4 例,女 17 例,年龄(62.50±5.02)岁,术前存在骨量减少或骨质疏松 16 例。当然,两组患者终板损伤的特点也有不同之处,后路融合组表现为多发生于

使用香蕉型融合器病例,终板损伤部位多位于椎体下终板。斜外侧融合组表现为发生于使用过大的融合器 5 例,发生于 L<sub>4,5</sub> 节段融合髂嵴过高的病例 3 例。终板解剖形态存在异常病例 4 例。终板损伤多发生于椎体上终板。根据两组病例终板损伤的特点,分析后路融合和斜外侧融合终板损伤的原因,亦存在共同之处,如患者骨量减少或骨质疏松<sup>[21,28-30]</sup>、终板形态不规则<sup>[31-32]</sup>、术者的粗暴或不规范操作、融合器选择过大。但由于椎间具体操作、融合器形态和面积,以及融合器所要求放置的位置不同,终板损伤的发生与上述因素也可能具有相关性。大致上看,两种椎间融合方式的操作步骤基本一致,均包含髓核摘除、终板软骨清理、椎间松解和撑开、融合器植入。但细究仍有区别:TLIF 术式是在通道下切除关节突,经椎间孔入路行椎管减压和椎间操作,虽然通道可以通过纵向和不对称撑开,口小底大,实现最大化显露,但由于椎间孔骨性窗口较小,加之脊膜和神经根的阻挡,以及椎间位置较深,椎间隙操作基本在盲视下完成,因此,进行髓核摘除、终板软骨清除时存在终板损伤的风险。但 TLIF 技术使用的融合器体积较小,如子弹头型、矩形、长方形,且融合器多放置于椎体的 III-IV 区<sup>[32]</sup>,因而融合器植入过程中出现终板损伤的可能性较小。当然,如使用香蕉型融合器,加之椎间隙清理不彻底,未逐级使用融合器试模预制做融合器植入轨迹,则香蕉型融合器在植入过程中易偏离椎间隙方向而致终板损伤,后路融合组 8 例终板损伤中 5 例使用了香蕉型融合器。OLIF 技术采用腹部前外侧经腹壁肌纤维间,再经腰大肌与血管鞘天然间隙进入,行髓核摘除、终板软骨清除、椎间逐级撑开和松解、融合器植入。虽然斜外侧椎间操作基本在直视下完成,但由于所用融合器体积和面积较大,且融合器要求尽量架在两椎体之间,而不是含在终板之内,因而椎间清理空间更大、松解更彻底。另外,由于入路和解剖原因<sup>[33-34]</sup>,融合器多要求放置于椎间的 II-III 区。有研究表明<sup>[35-36]</sup>:无论是骨密度或骨矿含量,椎体前部分低于后部分。因而,腰椎终板前部分是相对薄弱的部位,容易出现损伤。而且所用融合器体积较大,如终板形态不规则或椎间隙过窄,或行 L<sub>4,5</sub> 节段融合时患者存在高髂嵴,均是斜外侧融合导致终板损伤的重要因素。因此,斜外侧融合术中终板损伤的风险明显高于后路融合,而且两种融合方式终板损伤特点亦不完全相同。文献<sup>[19-21]</sup>报道 TLIF 技术术中出现终板损伤较少,而且,微创显露亦不增加终板损伤的风险<sup>[37]</sup>,但对于 OLIF 技术来讲,术中终板损伤的发生率较高,而且是 OLIF 技术最为常见的并发症<sup>[22-26]</sup>。



### 3.3 两种手术方式终板损伤的处理

虽然两种手术均采用了椎弓根螺钉固定,但由于两种技术所用融合器的体积和面积不一、融合器所要求放置的位置不一,加之 TLIF 技术所用的融合器是含在终板之内,而 OLIF 技术是要求融合器“架”在两椎体之间。以上的不同,决定了两种融合器与终板接触面积和力学传导的差异。从手术设计和技术特点来看,TLIF 技术要求融合器接触面终板的完整性,而斜外侧融合更强调终板环的完整性,理论上讲,局部的终板损伤对于斜外侧融合器的承载和力学传导的影响应该不大。因而,两种技术对于终板损伤的处理亦不同:TLIF 术中如终板损伤面积不大,可做局部植骨填充后继续使用融合器;如果损伤面积较大,超过融合器接触面积,则需要放弃使用融合器,改用结构性植骨。OLIF 技术终板的局部损伤可不予处理,除非终板环的完整性受损,如椎体骨折,一方面需要放弃使用融合器,改用结构性植骨,另外要强化局部稳定,如附加椎弓根螺钉固定。本研究中,OLIF 组出现 2 例椎体骨折,由于是术后发现,且不影响融合器的稳定,因而未进行再次手术,仅予严密随访观察。需要指出的是,部分病例的终板损伤可能术中无法确定,需要通过术后影像检查明确。当然,通过术后检查明确的终板损伤,如融合器位置和稳定性良好,亦无须特殊处理,可以适当延长卧床时间,下床活动时加强胸腰部外保护、严密随访。

### 3.4 终板损伤对治疗结果的影响和预防

本研究中,TLIF 技术和 OLIF 技术均有终板损伤的发生,且 OLIF 技术合并 2 例椎体骨折。虽然随访中椎间隙高度有不同程度的丢失和融合器沉降,但两组仅各出现 1 例融合器移位,无内固定松动、断裂,均获得良好的椎间融合,末次随访时两组病例腰椎功能亦获得很好的恢复。但是,需要强调的是:虽然两组病例的终板损伤未导致严重并发症的发生,仍应重视终板损伤的预防,包括术前严格的病例选择、患者骨质条件的评估、病变节段终板形态的观察、术中的细致规范操作、重要步骤的影像监测,以减少终板损伤的发生。

### 3.5 本研究的不足

本研究为回顾性分析,而且两种融合技术不仅椎间操作不完全相同,所用融合器体积和面积、融合器所放置的位置亦不同,上述多方面的差异可能在一定程度上影响结果的可比性。两组病例的随访时间不够长,亦有待加强随访观察。

#### 参考文献

- [1] Houten JK, Post NH, Dryer JW, et al. Clinical and radiographically/neuroimaging documented outcome in transforaminal lumbar interbody fusion[J]. *Neurosurg Focus*, 2006, 20(3): E8.
- [2] Chastain CA, Eck JC, Hodges SD, et al. Transforaminal lumbar interbody fusion: a retrospective study of long-term pain relief and fusion outcomes[J]. *Orthopedics*, 2007, 30(5): 389-392.
- [3] Dhall SS, Wang MY, Mummaneni PV. Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up[J]. *J Neurosurg Spine*, 2008, 9(6): 560-565.
- [4] Xu H, Tang H, Li Z. Surgical treatment of adult degenerative spondylolisthesis by instrumented transforaminal lumbar interbody fusion in the Han nationality[J]. *J Neurosurg Spine*, 2009, 10(5): 496-499.
- [5] Rouben D, Casnellie M, Ferguson M. Long-term durability of minimal invasive posterior transforaminal lumbar interbody fusion: a clinical and radiographic follow-up[J]. *J Spinal Disord Tech*, 2011, 24(5): 288-296.
- [6] Lee N, Kim KN, Yi S, et al. Comparison of outcomes of anterior, posterior, and transforaminal lumbar interbody fusion surgery at a single lumbar level with degenerative spinal disease[J]. *World Neurosurg*, 2017, 101: 216-226.
- [7] Kim JS, Jung B, Lee SH. Instrumented minimally invasive spinal-transforaminal lumbar interbody fusion (MIS-TLIF): minimum 5-year follow-up with clinical and radiologic outcomes[J]. *Clin Spine Surg*, 2018, 31(6): E302-E309.
- [8] Mayer HM. A new microsurgical technique for minimally invasive anterior lumbar interbody fusion[J]. *Spine (Phila Pa 1976)*, 1997, 22(6): 691-699.
- [9] Hsieh PC, Koski TR, O'Shaughnessy BA, et al. Anterior lumbar interbody fusion in comparison with transforaminal lumbar interbody fusion: implications for the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance[J]. *J Neurosurg Spine*, 2007, 7(4): 379-386.
- [10] Silvestre C, Mac-Thiong JM, 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.
- [11] Fujibayashi S, Hynes RA, 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): E175-182.
- [12] Mobbs RJ, Phan K, Malham G, et al. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF[J]. *J Spine Surg*, 2015, 1(1): 2-18.
- [13] Molloy S, Butler JS, Benton A, et al. A new extensile anterolateral retroperitoneal approach for lumbar interbody fusion from L1 to S1: a prospective series with clinical outcomes[J]. *Spine J*, 2016, 16(6): 786-791.
- [14] Kim JS, Choi WS, Sung JH. 314 minimally invasive oblique lateral interbody fusion for L4-5: clinical outcomes and perioperative complications[J]. *Neurosurgery*, 2016, 63(Suppl 1): 190-191.
- [15] Hozumi T, Orita S, Inage K, et al. Successful salvage surgery for failed transforaminal lumbosacral interbody fusion using the anterior-transperitoneal approach[J]. *Clin Case Rep*, 2016, 4(5): 477-480.

- [16] Fujibayashi S, Kawakami N, Asazuma T, et al. Complications associated with lateral interbody fusion: nationwide survey of 2998 cases during the first two years of its use in Japan [J]. *Spine (Phila Pa 1976)*, 2017, 42(19): 1478–1484.
- [17] Hah R, Kang HP. Lateral and oblique lumbar interbody fusion—current concepts and a review of recent literature [J]. *Curr Rev Musculoskelet Med*, 2019, 22: 305–310.
- [18] 曾忠友, 张建新, 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 ZY, ZHANG JQ, SONG YX, et al. Comparison of two different decompression and fusion methods in the treatment of lumbar spinal stenosis [J]. *Zhonghua Gu Ke Za Zhi*, 2020, 40(11): 707–718. Chinese.
- [19] Schwender JD, Holly LT, Rouben DP, et al. Minimally invasive transforaminal lumbar interbody fusion (TLIF): technical feasibility and initial results [J]. *J Spinal Disord Tech*, 2005, 18(Suppl): S1–S6.
- [20] Holly LT, Schwender JD, Rouben DP, et al. Minimally invasive transforaminal lumbar interbody fusion: indications, technique, and complications [J]. *Neurosurg Focus*, 2006, 20(3): E6.
- [21] Formby PM, Kang DG, Helgeson MD, et al. Clinical and radiographic outcomes of transforaminal lumbar interbody fusion in patients with osteoporosis [J]. *Global Spine J*, 2016, 6(7): 660–664.
- [22] Woods KR, Billys JB, Hynes RA. Technical description of oblique lateral interbody fusion at L<sub>4</sub>–L<sub>5</sub> (OLIF25) and at L<sub>5</sub>–S<sub>1</sub> (OLIF51) and evaluation of complication and fusion rates [J]. *Spine J*, 2017, 17(4): 545–553.
- [23] Zeng ZY, Xu ZW, He DW, et al. Complications and prevention strategies of oblique lateral interbody fusion technique [J]. *Orthop Surg*, 2018, 10(2): 98–106.
- [24] Lin GX, Kotheeranurak V, Zeng TH, et al. A longitudinal investigation of the endplate cystic lesion effect on oblique lumbar interbody fusion [J]. *Clin Neurol Neurosurg*, 2019, 184: 105407.
- [25] Kim WJ, Lee JW, Kim SM, 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.
- [26] 曾忠友, 方向前, 马维虎, 等. 腰椎斜外侧椎间融合术中终板损伤原因分析 [J]. *中华骨科杂志*, 2020, 40(17): 1135–1143. ZENG ZY, FANG XQ, MA WH, et al. Analysis the causes of endplate injury in oblique lateral interbody fusion [J]. *Zhonghua Gu Ke Za Zhi*, 2020, 40(17): 1135–1143. Chinese.
- [27] Schizas C, Theumann N, Burn A, et al. Qualitative grading of severity of lumbar spinal stenosis based on the morphology of the dural sac on magnetic resonance images [J]. *Spine (Phila Pa 1976)*, 2010, 35(21): 1919–1924.
- [28] Oh KW, Lee JH, Lee JH, 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.
- [29] Fields AJ, Lee GL, Keaveny TM. Mechanisms of initial endplate failure in the human vertebral body [J]. *J Biomech*, 2010, 43(16): 3126–3131.
- [30] Cho JH, Hwang CJ, 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.
- [31] Wang Y, Wang H, Lv F, 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.
- [32] Zhou QS, 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.
- [33] Moro T, Kikuchi S, Konno S, et al. An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery [J]. *Spine (Phila Pa 1976)*, 2003, 28(5): 423–428.
- [34] Hu WK, He SS, Zhang SC, et al. An MRI study of psoas major and abdominal large vessels with respect to the X/DLIF approach [J]. *Eur Spine J*, 2011, 20(4): 557–562.
- [35] 赵凤东, 范顺武, Patricia Dolan, 等. 腰椎终板骨折特点及相关因素的实验研究 [J]. *中华外科杂志*, 2006, 44(16): 1132–1135. ZHAO FD, FAN SW, Patricia D, et al. The feature of experimental endplate fracture in lumbar spine and its related factors [J]. *Zhonghua Wai Ke Za Zhi*, 2006, 44(16): 1132–1135. Chinese.
- [36] 赵凤东, 范顺武, 丁献军, 等. 中老年人腰椎椎体区域性骨密度差异与力学特性关系 [J]. *中华物理与康复杂志*, 2006, 28(7): 473–477. ZHAO FD, FAN SW, DING XJ, et al. Bone mineral density and bone mineral content in the lumbar vertebrae and the vertebra's biomechanical properties [J]. *Zhonghua Wu Li Yu Kang Fu Za Zhi*, 2006, 28(7): 473–477. Chinese.
- [37] Rihn JA, Gandhi SD, Sheehan P, et al. Disc space preparation in transforaminal lumbar interbody fusion: A comparison of minimally invasive and open approaches [J]. *Clin Orthop Relat Res*, 2014, 472(6): 1800–1805.

(收稿日期:2022-01-21 本文编辑:王宏)