临床论著

椎间融合器的置入方式对腰椎融合效果的影响

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【摘要】**目的**:探讨椎间融合器置入方向和位置对腰椎椎间融合术患者临床疗效的影响。**方法**:回顾性分析 2010 年 6 月~2014 年 6 月在我院行 L4/5 或 L5/S1 单节段腰椎融合术患者的临床资料,依据融合器置入方式分为斜向置入组(斜向组,100 例)和横向置入组(横向组,100 例)。记录两组患者年龄、性别、骨密度、体重指数(body mass index,BMI)及手术节段,术前和末次随访时行 Oswestry 功能障碍指数(Oswestry disability index,ODI)及疼痛视觉模拟(visual analog scale,VAS)评分。术后 1 周、6 个月、12 个月及末次随访时行 X 线片、CT 检查,测量术前、术后 1 周和末次随访时融合节段的椎间隙高度,术后 1 周和末次随访时的植骨面积、椎间融合器距离椎体边缘的距离;术后 6 个月、12 个月和末次随访时采用改良 Brantigan 评分评估椎间融合情况。统计随访过程中内固定断裂和再发生腰背部疼痛情况。**结果**:两组患者年龄、性别、骨密度、BMI 及手术节段均无统计学差异(P>0.05),术前手术节段椎间隙高度、ODI 及 VAS 评分无统计学差异(P>0.05);两组患者均获得 24 个月以上随访,术后 1 周和末次随访时的 ODI 和 VAS 评分较术前均有显著性改善(P<0.05);两组患者术中使用融合器的高度无统计学差异(P>0.05),术后融合节段椎间隙高度较术前增加无统计学差异(P>0.05);术后 1 周椎间隙平均植骨面积横向组(322.26±32.36mm^2)大于斜向组(198.40±22.08mm^2)(P<0.05);斜向组椎间融合器距离椎体左右侧距离分别为 8.5±1.2mm、21.2±1.5mm,距椎体后缘距离 4.2±0.5mm,横向组椎间融合器距离椎体左右侧距离分别为 13.1±1.8mm、14.2±1.4mm,距椎体后缘距离 9.8±0.8mm,两组比较有统计学差异(P<0.05)。术后 6 个月融合率横向组(90%)大于斜向组(71%)(P<0.05),12 个月、24 个月两组融合率比较无统计学差异(P>0.05);末次随访椎间隙高度丢失度横向组(1.8±1.6mm)低于斜向组(2.6±1.7mm)(P<0.05),植骨面积横向组(423.56±23.29mm^2)大于斜向组(299.64±21.68mm^2)(P<0.05);随访过程中斜向组 4 例出现断钉,5 例再发生腰背部疼痛;横向组无断钉,2 例再发生腰背部疼痛,两组比较有统计学差异(P<0.05)。**结论**:腰椎融合手术采取斜向和横向置入椎间融合器均能取得满意的疗效,但椎间融合器横向置入能更好地维持椎间隙高度,早期融合率更高,可减少术后钉棒断裂、腰背部疼痛再发生等并发症的发生。

【关键词】腰椎融合术;融合器置入方式;椎弓根螺钉内固定系统;椎间隙植骨;融合率
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【**Abstract**】**Objectives:** To explore the influence of the cage implantation methods on lumbar fusion. **Methods:** Two-hundred patients underwent the L4/5 or L5/S1 single-level lumbar interbody fusion from June 2010 to June 2014 were reviewed. According to the cage implanted methods, the patients were divided into oblique implantation group(100 cases) and transverse implantation group(100 cases). The age, sex, bone mineral density(BMD), body mass index(BMI) and operative level of the two groups were recorded. Oswestry disability index (ODI) and visual analog scale(VAS) score were recorded before operation, postoperation and at the last follow-up. The X-ray and CT examinations were performed at 1 week, 6 months, 12 months and last follow-up after operation. The height of intervertebral space was measured preoperatively, 1 week after operation and at the last follow-up. The area of bone graft and the distance between the cage and the edge of the vertebral body were measured at 1 week and the last follow-up after operation. Reform Brantigan scores were used to evaluate intervertebral fusion at 6 months, 12 months and the last follow-up after operation. The breakage of

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screws and rods and recurrent back pain during follow-up were recorded. **Results:** There were no statistical differences in age, gender, BMD, BMI index and surgical segments between the two groups(P>0.05). Preoperative intervertebral space height, ODI and VAS scores were not significantly different between the two groups (P>0.05). All patients were followed up for more than 24 months. In both group, the ODI and VAS scores at the last follow-up were significantly improved compared with those before the operation(P<0.05). There was no statistical difference in the height of cage between the two groups(P>0.05), and there was no statistical difference in the height of intervertebral space after operation compared with that before operation (P>0.05). One week after operation, the average area of bone graft in transverse implantation group(322.26±32.36mm^2) was larger than that in oblique implantation group(198.40±22.08mm^2)(P<0.05). In oblique implantation group, the distance between the fusion cage and the left and right sides of the vertebral body were 8.5±1.2mm and 21.2±1.5mm respectively, and the distance from the posterior margin of the vertebral body was 4.2±0.5mm. In transverse implantation group, the distance between the fusion cage and the left and right sides of the vertebral body were 13.1±1.8mm and 14.2±1.4mm, and the distance from the posterior margin of the vertebral body was 9.8±0.8mm. There was significant difference between the two groups (P<0.05). The fusion rate in transverse implantation group(90%) was higher than that in oblique implantation group(71%) at 6 months after operation (P<0.05), but there was no significant difference between the two groups at 12 and 24 months follow-up(P>0.05). At the last follow-up, the loss of intervertebral space height in transverse implantation group (1.8±1.6mm) was lower than that in oblique implantation group(2.6±1.7mm), the bone graft area in transverse implantation group(423.56±23.29mm^2) was larger than in oblique implantation group(299.64±21.68mm^2), and there was significant difference between the two groups(P<0.05). During follow-up, 4 patients in the oblique group had screw and rods breakage, 5 patients had back pain recurred; there was no screw or rods breakage in the transverse group, and 2 cases had back pain recurred. There was significant difference between the two groups (P<0.05). **Conclusions:** Both transverse and oblique implantation methods of cage in posterior lumbar interbody fusion can achieve satisfactory clinical results. However, transverse implantation can better maintain the height of the intervertebral space, and the early fusion rate is higher, which can reduce postoperative screw or rods breakage, recurrence of back pain and other complications.

【Key words】 Lumbar interbody fusion; Cage implantation methods; All pedicle screw system; Intervertebral bone graft; Fusion rate

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腰椎退变性疾病是脊柱外科常见的一类疾病，影响患者生活质量，部分患者经长期保守治疗效果不佳时，往往需要采取手术治疗。目前椎弓根螺钉固定加椎间隙融合术式为临床普遍应用，早期椎间隙融合采用双侧平行置入 2 枚融合器的术式，因双侧置入创伤较大、效费比低，已被单枚椎间融合器斜向置入术式所取代[1,2]。单枚椎间融合器斜向置入可以减少对椎体终板的损伤及脊柱后柱稳定结构的破坏，增加植骨空间，提高融合率，减小创伤，但斜向置入因选用融合器与终板接触面积大小、融合器置入位置偏一侧或偏后、椎间植骨量少等因素，易导致术后椎间隙塌陷、椎间融合效果差甚至不融合、钉棒断裂等[3~5]。有学者通过将子弹形椎间融合器形状设计为更符合椎间隙解剖结构的肾形，将肾形融合器横向居中置入，并通过生物力学测试试验，提出肾形椎间融合器在腰椎融合及维持腰椎稳定性较单枚子弹头形椎间融合器斜向置入更有优势[6]。我们模拟肾形椎间融合器置入方式将子弹头形椎间融合器横向置入，可能能够在一定程度上解决单枚子弹头形椎间融合器的上述不足。本研究回顾性分析 2010 年 6 月~2014 年 6 月在我院采取不同方式置入椎间融合器的腰椎间融合手术患者的临床资料，分析椎间融合器置入方式对椎间融合效果的影响。

1 资料与方法

1.1 一般资料

病例纳入标准：(1)患者存在长期反复的腰腿痛，经保守治疗症状缓解不佳；(2)腰椎间盘突出或腰椎管狭窄伴腰椎不稳、椎间隙下沉、上下终板

严重退变等;(3)相关影像学检查证实病变节段与体征和症状相符，骨密度正常或伴骨量减少;(4)手术均在充分减压基础上行减压节段的单枚子弹头形椎间融合器置入并附加椎弓根螺钉系统内固定;(5)获得 24 个月以上的术后随访。排除标准:(1)腰椎其他退变性病变如退变性侧凸、原发性或继发性滑脱,伴糖尿病、骨质疏松、肥胖等;(2)合并肿瘤、感染、类风湿疾病、强直性脊柱炎及长期服用激素的代谢性或内分泌系统疾病。

收集 2010 年 6 月~2014 年 6 月在我院行腰椎椎间融合术的患者 200 例，均为 L4/5 或 L5/S1 单节段行单侧减压融合手术，使用子弹头形椎间融合器,其中融合器斜向置入 100 例(斜向组),融合器横向入 100 例(横向组),两组患者的年龄、性别、骨密度及手术节段见表 1,两组间比较均无显著性差异(P>0.05)。

表 1 两组患者基线资料比较

Table 1 Baseline date comparsion of two groups

	斜向组 Oblique (n=100)	横向组 Transverse (n=100)	P值 P value
年龄(岁) Age(year)	47.6±12.3	48.2±11.8	>0.05
性别(男/女,例) Gender(male/famale)	53/47	59/41	>0.05
骨密度(g/cm^2) BMD	1.115±0.181	1.121±0.177	>0.05
手术节段(例) Operated levels(case)			
L4/5	51	52	>0.05
L5/S1	49	48	
体重指数(kg/m^2) Body mass index	24.1±2.1	23.9±2.3	>0.05

1.2 手术方法要点及术后处理

所有患者均行腰椎后路融合术+椎弓根螺钉内固定，减压侧行手术椎间隙上位椎板下 2/3 和下位椎板上 1/2,关节突关节内侧 1/2 以及棘突部分基底切除[7](整块切除的下关节突骨块留用)。

融合器均采用四川纳米科技公司生产的纳米羟基磷灰石/聚酰胺 66(n-HA/PA66)融合器,宽度及长度为 2.6×1.0cm,高度根据患者邻近椎间隙高度和术中减压后试模测量决定，对椎间隙明显狭窄者,术中予以适当撑开。

融合器置入方式:斜向组,将切除的椎板及关节突修剪成碎骨,一部分填入融合器,余碎骨植入椎间隙前方压实，融合器于矢状面向对侧斜向约 45°置入，直至融合器位于椎间隙中心前中 1/2 处,用髓核钳清除融合器后方移位碎骨,填塞明胶海绵;C 型臂 X 线机正位透视椎间融合器显影点三点较聚集,融合器位置偏一侧,侧位透视融合器显影标志一显影点较另外两点相距较远 (图 1)。横向组,融合器里填入碎骨,整块切除的下关节突骨块及余下碎骨植入椎间隙前方压实，融合器于矢状面向对侧斜向约 45°置入，融合器约进 2/3 时,于尾端行水平向对侧打入,融合器尾端进入椎间后，打入器于尾端斜向外打至与椎间隙冠状平行,融合器横向位于椎间隙中间,用髓核钳清除融合器后方移位碎骨，填塞明胶海绵;C 型臂 X 线机透视正位椎间融合器一显影点较另外两点相距较远,侧位透视融合器显影标志三点靠近,融合器位置居中(图 2)。

术后应用抗生素预防感染、地塞米松和甘露

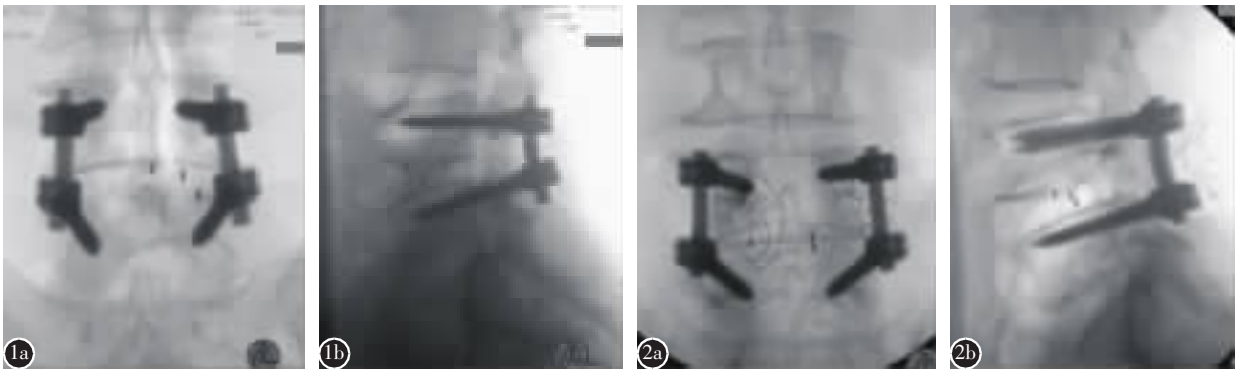

图 1 a、b 椎间融合器斜向置入,正侧位透视融合器三个显影标志点位置 **图 2 a、b** 椎间融合器横向置入,正侧位透视融合器三个显影标志点位置

Figure 1 a, b On anteroposterior and lateral films showing the three markers on the intervertebral cage when it was positioned obliquely **Figure 2 a, b** On anteroposterior and lateral films showing the three marker on the intervertebral cage when it was positioned transversely

醇预防神经根水肿 3d，第 2~3 天拔除引流管，第 4~5 天鼓励患者佩戴好支具下地行走；3 个月内佩戴保护支具适当活动，避免腰部过屈过伸运动及负重，术后 2~3 周行腰背肌功能锻炼，半年内避免重度体力劳动及剧烈运动。

1.3 观察指标及疗效评估

所有患者术前、术后 1 周及末次随访时均进行视觉模拟（visual analogue scale/score，VAS）评分及 Oswestry 功能障碍指数（Oswestry disability index，ODI）；术前，术后 1 周、3 个月、6 个月、12 个月和末次随访时行腰椎 X 线片及 CT 扫描加三维重建，在 X 线片上测量两组患者术前、术后 1 周及末次随访时融合节段的椎间隙高度（前、中、后的平均高度）；在 CT 片上观察椎弓根螺钉是否进入椎管、穿透椎体及破坏椎弓根，是否存在椎弓根螺钉断钉及植骨融合情况；测量术后 1 周及末次随访时椎体间隙自体碎骨面积（使用我院 iMedPACS 影像系统自带不规则图像面积测量工具测量椎体横断面总面积和融合器的横断面面积，椎体横断面总面积减去融合器的横断面面积即为植骨面积，图 3）；测量椎间融合器与椎间隙两侧及后缘距离；采用改良 Brantigan 评分[8]（0~4 分）评价椎间融合情况：完全融合，塑形良好为 4 分；融合良好，但仍有少量透亮线为 3 分；上下部分（50%）连接，但仍有大量透亮线为 2 分；上下部分未连接，但骨量较术后即刻植骨量增多为 1 分；上下部分未连接，高度丢失、植骨吸收为 0 分。≥3 分者视为融合。

1.4 统计学分析

运用 SPSS 19.0 处理和分析数据，计量资料用均数±标准差（$\bar{x}\pm s$）表示，组间比较用独立样本 t 检验，或配对 t 检验；计数资料比较采用 χ^2/Fisher 检验。P<0.05 为差异有统计学意义。

2 结果

两组术前、术后 1 周和末次随访时的 ODI 及 VAS 见表 2，术前两组间比较无统计学差异（P>0.05）；术后 1 周和末次随访时与术前比较均有统计学差异（P<0.05），两组同时间点比较均无显著性差异（P>0.05）。两组患者术中使用融合器的高度、术后即刻椎间隙平均高度无统计学差异（P>0.05，表 3）；术后 1 周椎间隙植骨面积横向组明显高于斜向组（P<0.05），末次随访时两组椎间隙平均高度变化、植骨面积有统计学差异（P>0.05，表 3）。两组融合器距离椎体左右侧及后缘距离见表 4，两组间比较均有统计学差异（P<0.05）。术后 6 个月，横向组融合率高于斜向组（P<0.05），术后 12 个月及末次随访，两组融合率比较无统计学差异（P>0.05，表 5）。随访期间，斜向组术后腰背部疼痛再发生 5 例，断钉 4 例，腰背部再疼痛及断钉的发生率为 9%（图 4）；横向组术后腰背部疼痛再发生 2 例，无断钉发生，腰背部再疼痛及断钉的发生率为 2%（图 5）；两组比较具有统计学意义（P<0.05）。

图 3 植骨面积的测量：横断面总面积减去融合器的横断面面积

Figure 3 Measurement of bone graft area: the total cross-sectional area minus the cross-sectional area of cage

3 讨论

本研究通过对两组患者术后至末次随访的影像学资料的分析对比，发现术后 6 个月随访时两组患者融合率及椎间隙变化均存在差异，横向组椎间融合率高于斜向组，椎间隙变化小于斜向组，并发症发生的例数也小于斜向组，分析原因在于腰椎融合术后椎间隙未完全融合期间内固定系统起短暂稳定作用，持续的稳定还依赖于腰椎自身结构的恢复和愈合，完全的植骨融合可使腰椎长期稳定并能承载脊柱负荷，减轻椎弓根螺钉的固定作用。相关文献报告指出，断钉的原因主要在于椎间融合率低或未融合，融合节段间隙下沉，椎弓根螺钉受力不均，椎弓根螺钉刚性疲劳等；术后腰背部再疼痛的原因是椎间隙稳定丢失、内固定系统松动，导致上下关节突的磨损刺激及椎体医源

表 2 两组患者术前、术后 1 周和末次随访时的 ODI 及 VAS 评分 ($\bar{x}\pm s$, n=100)

Table 2 ODI and VAS of the two group at preoperation, postoperation and last follow-up

	ODI			VAS评分/VAS score		
	术前 Pre-operation	术后 1 周 Postoperation	末次随访 Last follow-up	术前 Pre-operation	术后 1 周 Postoperation	末次随访 Last follow-up
斜向组 Oblique group	67.7±12.6	16.5±12.2①	14.1±10.1①	6.52±1.61	2.41±0.52①	1.63±0.62①
横向组 Transverse group	68.5±12.8	17.0±11.8①	13.9±9.7①	6.21±1.42	2.34±0.58①	1.33±0.70①

注:①与同组术前比较 P<0.05

Note: ①Compared with preoperative value, P<0.05

表 3 两组患者术前和术后不同时间点的椎间隙高度、植骨面积及融合器高度 ($\bar{x}\pm s$, n=100)

Table 3 Comparison of intervertebral space height, bone graft area and average height of cage

	椎间隙高度(mm) Intervertebral space height				植骨面积(mm^2) Bone graft area		融合器高度(mm) Cage average height
	术前 Pre-operation	术后 1 周 Postoperation	末次随访 Last follow-up	丢失度 Loss degree	术后 1 周 Postoperation	末次随访 Last follow-up	
斜向组 Oblique group	9.2±1.1	13.9±1.9①	10.8±1.5①	2.6±1.7	198.40±22.08	299.64±21.68	11.5±1.4
横向组 Transverse group	10.4±1.3	13.2±1.8①	11.1±1.2①②	1.8±1.6②	322.26±32.36②	423.56±23.29②	11.6±1.3

注:①与同组术前比较 P<0.05;②与同时间点斜向组比较 P<0.05

Note: ①Compared with preoperative value, P<0.05; ②Compared with oblique group at the same time, P<0.05

表 4 两组患者椎间融合器距离椎体边缘距离 (mm)

Table 4 The intervertebral fusion cage is away from the vertebral edge

	斜向组 Oblique group (n=100)	横向组 Transverse group (n=100)	P值 P value
置入侧与椎体边缘距离 The implantation side is away from the vertebral edge	8.5±1.2	13.1±1.8	<0.05
非置入侧与椎体边缘距离 The distance between the implantation side and the vertebral edge	21.2±1.5	14.2±1.4	<0.05
与椎体后缘距离 Distance from posterior vertebral body	4.2±0.5①	9.8±0.8	<0.05

性骨折等[3~5]。因此,融合率对腰椎融合手术至关重要,椎间融合器、自体碎骨植骨量、植骨空间的稳定性等是提高融合率的重要影响因素。

3.1 椎间融合器对腰椎融合的影响

传统的椎间隙植骨多采用自体骨, 术后早期不能有效支撑椎体的前中柱, 因此容易导致后柱应力载荷过于集中,出现椎间隙塌陷、移位,假关节形成等并发症,植骨融合率低,为克服自体骨植骨的缺陷,椎间融合器得到了广泛应用。椎间融合器结合椎弓根螺钉内固定系统减少了椎间隙下沉及融合器移位的发生, 早期双融合器平行置入有较强的椎间隙支撑作用,减少椎间隙塌陷[9~11];但

表 5 两组患者不同随访时间点的 Brantigan 评分及融合率

Table 5 X-ray and CT Brantigan score and fusion rate at follow-up

	斜向组(n=100) Oblique group			横向组(n=100) Transverse group		
	术后 6 个月 Postoperation 6 months	术后 12 个月 Postoperation 12 months	末次随访 Last follow-up	术后 6 个月 Postoperation 6 months	术后 12 个月 Postoperation 12 months	末次随访 Last follow-up
Brantigan评分 Brantigan score	2.59±1.19	2.82±1.12	2.85±1.12	2.89±1.18①	3.21±1.14	3.26±1.13
融合 fusion	71(71%)	98(98%)	98(98%)	90(90%)①	100(100%)	100(100%)
未融合 Not fusion	29(22%)	2(2%)	2(2%)	6(6%)①	0(0%)	0(0%)

注:①与同时间点斜向组比较P<0.05

Note: ①Compared with oblique group at the same time, P<0.05

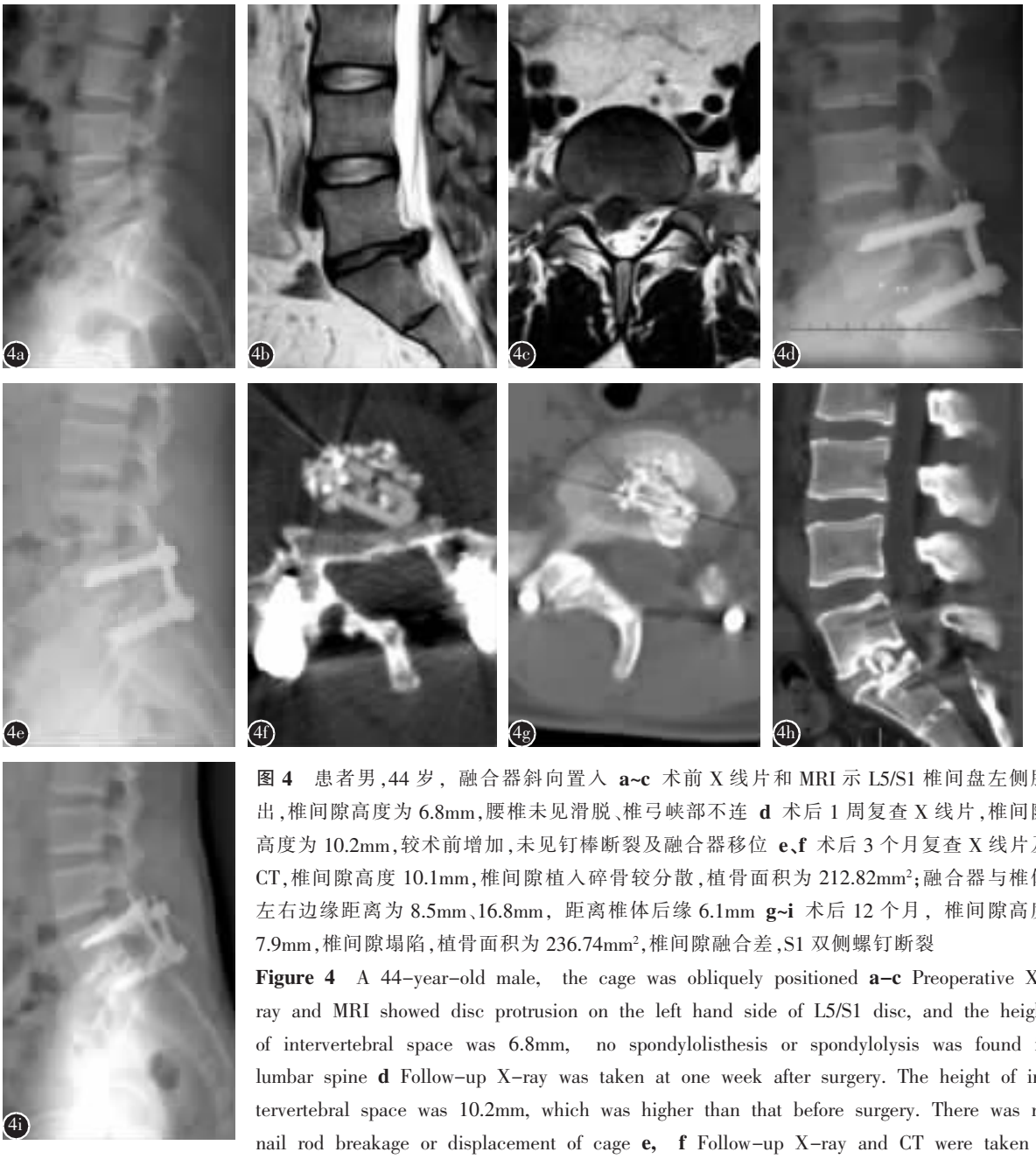

图 4 患者男，44 岁，融合器斜向置入 **a~c** 术前 X 线片和 MRI 示 L5/S1 椎间盘左侧脱出，椎间隙高度为 6.8mm，腰椎未见滑脱、椎弓峡部不连 **d** 术后 1 周复查 X 线片，椎间隙高度为 10.2mm，较术前增加，未见钉棒断裂及融合器移位 **e、f** 术后 3 个月复查 X 线片及 CT，椎间隙高度 10.1mm，椎间隙植入碎骨较分散，植骨面积为 212.82mm²；融合器与椎体左右边缘距离为 8.5mm、16.8mm，距离椎体后缘 6.1mm **g~i** 术后 12 个月，椎间隙高度 7.9mm，椎间隙塌陷，植骨面积为 236.74mm²，椎间隙融合差，S1 双侧螺钉断裂

Figure 4 A 44-year-old male, the cage was obliquely positioned **a–c** Preoperative X-ray and MRI showed disc protrusion on the left hand side of L5/S1 disc, and the height of intervertebral space was 6.8mm, no spondylolisthesis or spondylolysis was found in lumbar spine **d** Follow-up X-ray was taken at one week after surgery. The height of intervertebral space was 10.2mm, which was higher than that before surgery. There was no nail rod breakage or displacement of cage **e, f** Follow-up X-ray and CT were taken 3 months after the operation, the height of the intervertebral space was 10.1mm, the bone fragments were scattered, the area of bone graft was 212.82mm²; distances from the cage to the lateral edges of vertebral body were 8.5mm and 16.8mm respectively, and 6.1mm to the posterior edge of the vertebral body **g–i** 12 months after the operation, the height of L5/S1 intervertebral space was 6.8mm, intervertebral space collapsed and the area of bone graft was 236.74mm². With a poor intervertebral fusion, S1 screw broke on both sides

该术式需广泛切除双侧小关节突及椎板，严重破坏了脊柱后方稳定结构，增加了手术创伤及并发症[12]。Brodke 等[13]、Oxland 等[14]的研究证明单枚融合器可以提供足够的椎间刚度。单枚椎间融合器与上下椎体的接触面积与传统的双枚融合器比较并无明显减少，后期的融合率也无明显差异[15]，也能取得满意的融合效果，且单枚融合器的置入术式简化了手术操作，减少了腰椎后柱稳定结构的破坏。因此双枚融合器平行置入术式逐渐被单枚椎间融合器植入术式所取代，目前融合器经过几代更新，临床疗效良好，早期融合率可达 96%[16]；但临床应用中仍存在椎间隙下沉、椎间融合率不

图 5 患者男,48 岁, 融合器横向置入 **a~c** 术前 X 线片和 MRI 示 L4/5 椎间盘左侧脱出,椎间隙高度为 9.6mm,腰椎未见滑脱、椎弓峡部不连 **d** 术后 1 周复查 X 线片,椎间隙高度为 12.3mm 较术前增加,未见钉棒断裂及融合器移位 **e、f** 术后 3 个月复查 X 线片及 CT,椎间隙高度 12.3mm,椎间隙植入碎骨集聚椎间前方,植骨面积为 283.21mm^2;融合器与椎体左右边缘距离为 9.5mm、10.7mm, 距离椎体后缘 9.2mm **g~i** 术后 12 个月,椎间隙高度 12.0mm,植骨面积为 286.84mm^2,未见明显塌陷,椎间隙融合良好,钉棒无断裂

Figure 5 A 48-year-old male, the cage was positioned in atransverse direction **a-c** Preoperative X-ray and MRI showed disc protrusion on the left hand side of L4/5 disc, and the height of intervertebral space was 9.6mm, without spondylolisthesis or spondylolysis **d** Another X-ray was taken at one week after surgery. The height of intervertebral space was 12.3mm higher than that before surgery, and no nail rod breakage or displacement of cage was found **e, f** X-ray and CT were taken again at 3 months after the operation, the height of the intervertebral space was 12.3mm, the intervertebral space was replaced with bone fragments that gathered in front of the intervertebral space, the area of bone graft was 283.21mm^2; distances from the cage to the lateral edges of vertebral body was 9.5mm and 10.7mm respectively, and 9.2mm to the posterior edge of the vertebral body **g-i** 12 months after the operation, the height of intervertebral space at L4/5 was 12.0mm, the area of bone graft was 286.84mm^2, vertebar space fusion was good and without looseness or screw breakage

满意及钉棒断裂的情况, 学者们逐渐关注到术中融合器位置和形态对融合术后的影响[17]。

3.2 融合器置入方式对植骨量及融合率的影响

Chin 等[18]认为,融合器的接触面在融合节段形成了一个类似“杠杆支点”效应,融合器相对面积与终板接触面积较小,导致融合节段的不稳定,在融合器融合基础上进行相应的植骨融合非常必要。Park 等[19]提出融合的效果与坚强稳定的内固定及充分的植骨相关。相关文献[20]报告植骨量过低容易出现不融合或融合率低,并主张大量植骨。但单侧椎板间开窗所获局部自体骨量最少, 临床采用局部自体骨结合自体髂骨、异体骨、异种骨和

骨形态发生蛋白等增大植骨量。杨勇等[7]提出单侧椎板间扩大开窗术式可以获得大于 2.5cm³ 的局部自体骨粒，联合单枚融合器能够满足椎间融合植骨量的要求。我们在临床实践中发现，椎间隙前方植入的碎骨，有部分因植入融合器后溢出，说明融合器前方的空间对植骨量也有一定的影响。通过影像分析发现，融合器平行横向置入较斜向置入可在椎间隙正前方预留更大的植骨空间，保证了椎间隙前方能容纳足够的骨量，同时可容纳关节突或椎板的整骨块，使整骨块与椎间融合器提供双支撑作用，同时水平横向打入融合器时可对前方植骨提供一个水平均匀的推压，减少因打入融合器时对前方已压实的植骨造成松动或移位到融合器的背侧，造成侧隐窝的狭窄及神经根的卡压。而斜向置入椎间融合器时，为保证椎间融合器尾端与椎体后缘保持足够的安全距离，需将椎间融合器打入更深，更靠前，导致了椎间隙正前方预留的植骨空间减小，同时椎间隙前方的碎骨因打入融合器时挤压而向融合器两侧移位，在融合器背侧的碎骨，因担心对后方侧隐窝、神经根的挤压，在置入融合器后常规给予取出，导致了植骨量的减少；椎间隙前方预留的空间减小，避免整块切除的下关节突骨块对融合器置入的影响，需将切除的整骨块咬碎后植入。Ha 等[21]发现椎间隙内植骨颗粒随时间延长会发生自我吸收溶解。植入碎骨致密性不好时，延长骨粒之间、骨粒与终板之间形成纤维连接的时间，增加重建融合时间[22]。椎间隙未完全融合时腰椎的稳定性需内固定的辅助，内固定应力的长期集中，导致内固定刚性疲劳，出现断钉断棒的风险，对骨质疏松的患者，椎间隙稳定丢失，内固定系统松动，造成节段上下关节突的磨损刺激及椎体医源性骨折，可能也是患者术后腰背部再疼痛的原因之一。

3.3 椎间融合器置入位置的影响

Tye 等[23]和 Priyan 等[24]认为椎间融合器尽量放置靠前，利于腰椎生理曲度的恢复和稳定。Grant 等[25] 对 62 个椎体的 27 个位置进行压痕试验，试验结果表明腰椎中心区域的强度是最弱的，椎体后方强度大于前方，椎体后外侧的强度最高。Santoni 等[26]认为，植骨环境稳定差，增加了融合器与终板的局部应力，导致融合器沉降、椎体间不融合或融合差。椎间融合器的置入位置不能太偏外，否则可能影响神经根孔，相关文献提出间隙中线两侧各约 5mm 的空间为椎间融合器置入“安全区域”[27]。因此，在椎间融合中，融合器位置应位于椎间隙中 1/3 或略向前，其后缘应距椎体后缘 3~4mm 以上[24]。本研究中横向组融合器位置居中，与椎体两侧及椎体后缘距离保持足够的安全距离，融合器横向阻挡作用，避免碎骨块卡压神经，同时在椎间隙前方预留了充裕的植骨空间，便于在椎间隙前方植入整块切除的下关节突骨块，其与椎间融合器提供双支撑作用，增加了椎间隙前方的支撑作用，“三点支撑”使得椎间隙受到的应力更均匀，提供了一个稳定的植骨融合环境。而融合器斜向置入，位置偏减压置入侧，这使得椎间隙非置入侧的支撑力较弱，椎间隙受到的应力不平衡，术后早期融合节段间隙的应力传导主要集中于上下终板与椎间融合器，椎间隙不稳，融合器下沉，终板破坏，最终延长融合时间；同时斜向置入为保证椎间融合器尾端与椎体后缘保持足够的安全距离，需将椎间融合器打入得更深，更靠前，增加融合器打出椎间隙、掉落到椎体前方的风险。

综上所述，椎间融合器横向置入能在椎间隙前方预留更大的植骨空间，提供一个较稳定的融合环境，提高融合率、减少后期椎间隙下沉及椎弓根螺钉断裂的风险，对临床融合器置入方向和位置有一定的参考价值。但本研究为回顾性随访研究，术中切除的关节突及椎板骨均植入融合器中空部分及椎间隙前方，因置入融合器时，部分碎骨溢出，因此对术中椎间隙植入的骨量无法进行准确对比，只能通过 CT 横断面扫描计算植骨面积及椎间隙高度初步判断植骨量；另外，患者的 BMI 差异及部分患者过早的体力劳动也会造成研究节段融合的差异。有待进一步研究。

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