

不同入路微创经椎间孔腰椎间融合术治疗单节段腰椎管狭窄症的疗效比较



钟睿^{1,2}, 王润生¹, 刘建恒¹, 韩振川¹, 姜威¹, 刘庆祖¹, 毛克亚¹

1. 中国人民解放军总医院骨科(北京 100853)

2. 成都体育学院附属体育医院脊柱外科(成都 610041)

【摘要】 目的 比较微创经椎间孔入路腰椎间融合术(minimally invasive transforaminal lumbar interbody fusion, MIS-TLIF)中,单侧入路双侧减压和双侧入路双侧减压治疗单节段腰椎管狭窄症的临床疗效。方法 2015年2月–2017年1月,采用MIS-TLIF治疗单节段腰椎管狭窄症患者70例,其中采用单侧入路双侧减压(U组)36例,双侧入路双侧减压(B组)34例。两组患者年龄、性别、体质指数、病程、手术节段分布以及术前腰腿疼痛视觉模拟评分(VAS)、Oswestry功能障碍指数(ODI)比较,差异均无统计学意义($P>0.05$)。比较两组手术时间、术中出血量、术后住院时间、手术相关并发症及术后非症状侧根性症状发生情况;手术前后患者腰腿痛VAS评分、ODI评分;术后12个月摄腰椎X线片和CT判断椎间融合情况。结果 U组手术时间、术中出血量明显少于B组($P<0.05$),术后住院时间差异无统计学意义($t=-0.311, P=0.757$)。U组1例、B组2例术中硬脊膜撕裂,均未出现置钉相关神经损伤,术后无非症状侧根性症状发生。两组患者均获随访;U组随访时间24~38个月,平均32.8个月;B组为24~48个月,平均35.5个月。术后2d、3、6、12个月两组腰腿痛VAS评分均较术前明显降低($P<0.05$);各时间点两组间比较差异均无统计学意义($P>0.05$)。术后3、6、12个月两组ODI评分均较术前明显降低($P<0.05$);各时间点两组间比较差异无统计学意义($P>0.05$)。术后12个月影像学检查示两组椎间均骨性融合。结论 MIS-TLIF治疗单节段腰椎管狭窄症采用单侧入路双侧减压和双侧入路双侧减压均安全、有效,单侧入路双侧减压手术时间、术中出血量更少。

【关键词】 腰椎管狭窄症;微创手术;减压;脊柱融合术

Comparison of minimally invasive transforaminal lumbar interbody fusion between two approaches in treatment of single-segment lumbar spinal stenosis

ZHONG Rui^{1,2}, WANG Runsheng¹, LIU Jianheng¹, HAN Zhenchuan¹, JIANG Wei¹, LIU Qingzu¹, MAO Keya¹

1. Department of Orthopedics, Chinese PLA General Hospital, Beijing, 100853, P.R.China

2. Department of Spinal Surgery, Sport Hospital Affiliated to Chengdu Sport University, Chengdu Sichuan, 610041, P.R.China

Corresponding author: MAO Keya, Email: maokeya@sina.com

【Abstract】 Objective To compare the effectiveness of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) with bilateral decompression via unilateral approach and bilateral decompression via bilateral approaches in the treatment of single-segment lumbar spinal stenosis. **Methods** Between February 2015 and January 2017, 70 cases of single-segment lumbar spinal stenosis were treated with MIS-TLIF. The bilateral decompression via unilateral approach (group U) was performed in 36 cases and bilateral decompression via bilateral approaches (group B) in 34 cases. There was no significant difference in age, gender, body mass index, disease duration, distribution of responsibility segments, preoperative visual analogue scale (VAS) score of low back pain and leg pain and Oswestry disability index (ODI) score ($P>0.05$). The operation time, intraoperative blood loss, hospitalization stay after operation, complications related to operation, incidence of asymptomatic lateral root symptoms, VAS scores of low back pain and leg pain, and ODI score before and after operation were compared between the two groups. X-ray film and CT scan at 12 months after operation were used to assessed the intervertebral bony fusion. **Results** The operation time and

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通信作者: 毛克亚, Email: maokeya@sina.com

intraoperative blood loss in group U were significantly less than those in group B ($P < 0.05$). There was no significant difference in hospitalization stay after operation between the two groups ($t = -0.311$, $P = 0.757$). During the operation, 1 case in group U and 2 cases in group B had dural tear. No screw placement related nerve injury or asymptomatic lateral root symptoms occurred after operation. The patients were followed up 24 to 38 months, with an average of 32.8 months in group U and 35.5 months in group B. The VAS scores of low back pain and leg pain at 2 days, 3, 6, and 12 months after operation were significantly lower than that before operation in the two groups ($P < 0.05$), and there was no significant difference between the two groups ($P > 0.05$). The ODI scores at 3, 6 and 12 months after operation were significantly lower than that before operation in the two groups ($P < 0.05$), and there was no significant difference between the two groups ($P > 0.05$). Radiographic examination showed interbody fusion at 12 months after operation in the two groups. **Conclusion**

MIS-TLIF is safe and effective in the treatment of single-segment lumbar spinal stenosis with bilateral decompression via unilateral approach and bilateral decompression via bilateral approaches. Bilateral decompression via unilateral approach takes less operation time and has less intraoperative blood loss.

【Key words】 Lumbar spinal stenosis; minimally invasive surgery; decompression; spinal fusion

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腰椎管狭窄症继发于腰椎退变, 常见于中老年人群, 典型症状为腰痛和下肢疼痛, 以行走时症状更明显, 严重影响患者行走功能和生活质量^[1-2]。保守治疗无效患者需要手术治疗, 微创经椎间孔入路腰椎间融合术 (minimally invasive transforaminal lumbar interbody fusion, MIS-TLIF) 是临床治疗腰椎管狭窄症的常用术式, 该术式对脊柱后方结构损伤小, 疗效确切^[3-4]。标准 MIS-TLIF 为双侧切口双侧椎管减压, 随着手术器械和手术技术的改进, 有学者提出使用单侧入路, 同侧减压后再通过倾斜通道, 潜在给予对侧椎管、侧隐窝扩大减压, 并取得了较好疗效^[5]。为探讨上述两种不同入路方式疗效及优缺点, 为临床选择术式提供参考, 我们进行了一项回顾性比较研究。报告如下。

1 临床资料

1.1 患者选择标准

纳入标准: ① 严重腰痛伴单侧或双侧下肢疼痛、间歇性跛行; ② 正规保守治疗 3 个月以上无效或反复发作患者; ③ 单节段腰椎管狭窄症, 术前腰椎 CT 和 MRI 检查可见双侧侧隐窝狭窄及中央管狭窄, 腰椎 MRI 轴位提示马尾神经沉降征 (Schizas 分级^[6] C 级或 D 级), 症状体征与影像学资料相符; ④ 影像学检查提示多节段退变, 透视下经椎间孔腰神经阻滞检查明确责任节段为单一节段; ⑤ 术前动力位 X 线片提示腰椎节段性失稳或 I 度滑脱; ⑥ 接受 MIS-TLIF 治疗; ⑦ 临床资料完整。排除标准: ① 严重脊柱畸形, 关节突关节退变、增生包裹; ② 峡部裂型腰椎滑脱; ③ 椎

间盘突出伴后纵韧带骨化或者巨大后方骶环离断; ④ 严重骨质疏松。

2015 年 2 月—2017 年 1 月, 中国人民解放军总医院骨科脊柱病区收治的 70 例患者符合选择标准纳入研究。其中, 2016 年 1 月之前收治的 34 例采用双侧入路双侧减压 (B 组), 之后收治的 36 例采用单侧入路双侧减压 (U 组)。

1.2 一般资料

U 组: 男 19 例, 女 17 例; 年龄 40 ~ 83 岁, 平均 58.3 岁。体质指数 (body mass index, BMI) 为 $(25.0 \pm 3.3) \text{ kg/m}^2$ 。病程 3 ~ 360 个月, 平均 64.6 个月。手术节段: $L_{3,4}$ 3 例, $L_{4,5}$ 25 例, L_5 、 S_1 8 例。临床表现为单侧下肢症状 26 例, 双侧下肢症状 10 例。Schizas 分级: C 级 26 例、D 级 10 例。

B 组: 男 14 例, 女 20 例; 年龄 39 ~ 78 岁, 平均 56.5 岁。BMI 为 $(25.1 \pm 2.4) \text{ kg/m}^2$ 。病程 3 ~ 360 个月, 平均 66.2 个月。手术节段: $L_{3,4}$ 1 例, $L_{4,5}$ 22 例, L_5 、 S_1 11 例。临床表现为单侧下肢症状 27 例, 双侧下肢症状 7 例。Schizas 分级: C 级 23 例、D 级 11 例。

两组患者年龄、性别、BMI、病程、手术节段分布以及术前腰腿痛疼痛视觉模拟评分 (VAS)、Oswestry 功能障碍指数 (ODI) 比较, 差异均无统计学意义 ($P > 0.05$), 具有可比性。见表 1 ~ 3。

1.3 手术方法

两组手术均由同一组医生完成, MIS-TLIF 通道选用一次性可扩张通道 (北京中诺恒康生物科技有限公司)。

U 组: 患者全麻后取俯卧位, 腹部悬空。选择患侧或症状较重一侧, 以 9 号长针头在腰背部后正

中线旁开 2.5 ~ 3.0 cm 进行定位,以 C 臂 X 线机透视下正位针头位于责任间隙上、下椎弓根投影中心,侧位位于上、下椎弓根延长线为标准。以 2 枚针头连线为手术切口,切开皮肤分离软组织至峡部,逐级扩张并放置大小合适的通道后,对通道下方纵向撑开,清理局部残留软组织,显露上、下关节突关节和患侧椎板。采用横突定位法^[7],透视下确定螺钉位置后攻丝,制备钉道后骨蜡封填备用。长柄骨刀或超声骨刀沿棘突基底部切除患侧椎板、上位椎体下关节突及下位椎体上关节突反折部分,切除患侧增生肥厚的黄韧带,显露硬脊膜,脑棉片覆盖患侧硬膜。将手术床向对侧倾斜 20°,调整通道,用神经剥离子将对侧椎板与黄韧带之间进行分离,保留对侧黄韧带完整性以保护硬脊膜,将对侧椎板腹侧用长柄窄骨刀斜行凿除,咬除对侧下关节突腹侧直至显露对侧上关节突,根据术前影像学资料对侧隐窝狭窄者予以减压处理,将对侧黄韧带附着部咬除后整块去除黄韧带,显露对侧走行根,探查确认其松解后将手术床复位。常规切除椎间盘,处理椎间隙和软骨终板后植入切除的自体骨颗粒,斜行植入单枚合适高度的直行椎间融合器,敲击椎间融合器使其平放于椎间隙。沿钉道植入短尾万向椎弓根螺钉和钛棒,对侧单纯通道下植入短尾万向椎弓根螺钉和钛棒,适当加压固定,透视确定内固定物位置良好,切口周缘局部注射罗哌卡因后关闭切口^[8]。

B 组:参照本课题组报道的 MIS-TLIF 方法^[9],双侧置入通道后双侧减压,椎间融合器仍为单枚单侧植入,其余操作均与 U 组相同。见图 1。

1.4 术后处理

两组患者术后处理一致。常规预防性使用抗生素 48 h,术后 1 d 若患者无特殊不适,可在腰围保护下下床活动并复查腰椎正侧位 X 线片,术后佩

戴腰围 3 个月以上,3 个月内禁止剧烈活动及腰部负重活动。

1.5 疗效评价指标

记录手术时间、术中出血量、术后住院时间、手术相关并发症发生情况、非症状侧根性症状加重情况。术前及术后 2 d、3、6、12 个月,采用 VAS 评分评价腰腿痛情况。术前及术后 3、6、12 个月采用 ODI 评分评价患者功能恢复情况。术后 12 个月复查 X 线片及 CT 三维重建判断椎间融合情况,并按照 Bridwell 等^[10]的方法进行分级:Ⅰ级,椎间隙完全融合并伴有骨小梁重建;Ⅱ级,融合间隙无变化,未完全重建但无透明带出现;Ⅲ级,融合间隙无变化,但出现透明带;Ⅳ级,未融合,伴有椎间隙塌陷和吸收。Ⅰ、Ⅱ级定义为椎间融合。

1.6 统计学方法

采用 SPSS19.0 统计软件进行分析。计量资料以均数±标准差表示,组间比较采用独立样本 *t* 检验;组内各时间点间比较采用重复测量方差分析,术后各时间点与术前比较采用配对 *t* 检验;检验水准 $\alpha=0.05$ 。

2 结果

U 组手术时间、术中出血量分别为 (132.1±21.4) min、(133.6±39.1) mL,明显少于 B 组的 (149.3±21.2) min、(155.9±49.1) mL,差异有统计学意义 ($t=-3.372, P=0.001$; $t=-2.107, P=0.039$)。U 组术后住院时间为 (4.4±1.7) d,与 B 组 (4.5±2.0) d 比较差异无统计学意义 ($t=-0.311, P=0.757$)。U 组 1 例、B 组 2 例术中发生硬脊膜撕裂,均行一期硬脊膜缝合,术后未出现脑脊液漏及切口不愈合;两组均未出现置钉相关神经损伤,术后无非症状侧根性症状发生。

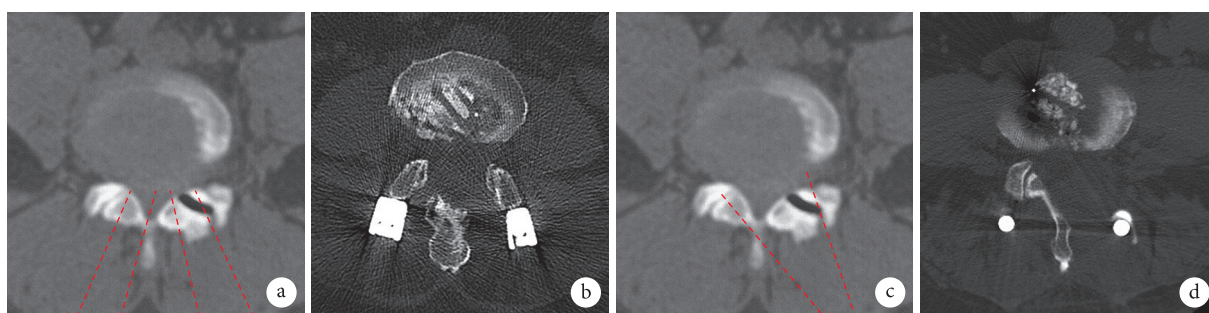


图 1 MIS-TLIF 不同入路减压方式 a、b. B 组双侧入路双侧减压示意图及术后 CT; c、d. U 组单侧入路双侧减压示意图及术后 CT

Fig.1 Different decompression approaches under MIS-TLIF a, b. Sketch and postoperative CT scan of bilateral decompression via bilateral approaches in group B; c, d. Sketch and postoperative CT scan of bilateral decompression via unilateral approach in group U

两组患者均获随访；U组随访时间24~38个月，平均32.8个月；B组为24~48个月，平均35.5个月。术后2d、3、6、12个月两组腰痛VAS评分和腿痛VAS评分均较术前明显降低，差异有统计学意义($P < 0.05$)；各时间点两组间比较差异均无统计学意义($P > 0.05$)。见表1、2。术后3、6、12个月两组ODI评分均较术前明显降低，差异有统计学意义($P < 0.05$)；各时间点两组间差异无统计学意义($P > 0.05$)。见表3。

术后12个月影像学检查示椎间均骨性融合，U组Bridwell I级19例、II级17例，B组I级19例、II级15例。两组随访期间均未出现螺钉松动、断裂与椎间融合器退入椎管等现象。见图2。

3 讨论

单节段腰椎管狭窄症常继发于腰椎间盘突出，椎间高度降低，引起局部失稳，关节突、黄韧带增生肥厚，引起腰腿痛及间歇性跛行，严重影响患者生活质量。经正规保守治疗3~6个月无效者，改行手术效果明显优于继续保守治疗^[11]。传统手术为椎板切除、神经和硬膜减压，随着内镜技术的发展，内镜下微创椎管减压治疗腰椎管狭窄症已逐渐用于临床，该术式在减小创伤的同时最大限度保留了后方结构^[12]。但对狭窄合并节段性失稳患者，内镜治疗可能加重失稳导致手术失败^[13]。为了减少远期节段性不稳和畸形的发生，有学者采取固定融合

表1 两组手术前后腰痛VAS评分比较 ($\bar{x} \pm s$)

Tab.1 Comparison of VAS score of low back pain between the two groups at pre- and post-operation ($\bar{x} \pm s$)

组别 Group	例数 n	术前 Preoperative	术后2d Two days after operation	术后3个月 Three months after operation	术后6个月 Six months after operation	术后12个月 Twelve months after operation	统计值 Statistic
U	36	4.9±1.5	3.7±1.6*	2.8±1.3*	2.0±1.2*	1.6±1.1*	F=47.936 P= 0.000
B	34	5.1±1.4	3.8±1.5*	2.9±1.3*	1.9±1.0*	1.4±1.1*	F=63.417 P= 0.000
统计值 Statistic		t=-0.642 P= 0.523	t=-0.421 P= 0.675	t=-0.254 P= 0.801	t=0.221 P=0.825	t=0.551 P=0.583	

*与术前比较 $P < 0.05$

*Compared with preoperative value, $P < 0.05$

表2 两组手术前后腿痛VAS评分比较 ($\bar{x} \pm s$)

Tab.2 Comparison of VAS score of leg pain between the two groups at pre- and post-operation ($\bar{x} \pm s$)

组别 Group	例数 n	术前 Preoperative	术后2d Two days after operation	术后3个月 Three months after operation	术后6个月 Six months after operation	术后12个月 Twelve months after operation	统计值 Statistic
U	36	7.0±1.8	2.9±1.3*	1.9±1.2*	1.9±1.1*	0.9±1.0*	F=143.376 P= 0.000
B	34	7.1±1.6	3.2±1.8*	2.1±1.2*	1.9±1.2*	0.7±0.9*	F=125.953 P= 0.000
统计值 Statistic		t=-0.363 P= 0.717	t=-0.788 P= 0.433	t=-0.494 P= 0.623	t=-0.093 P= 0.926	t=0.672 P=0.504	

*与术前比较 $P < 0.05$

*Compared with preoperative value, $P < 0.05$

表3 两组手术前后ODI评分比较 ($\bar{x} \pm s$)

Tab.3 Comparison of ODI score between the two groups at pre- and post-operation ($\bar{x} \pm s$)

组别 Group	例数 n	术前 Preoperative	术后3个月 Three months after operation	术后6个月 Six months after operation	术后12个月 Twelve months after operation	统计值 Statistic
U	36	40.7±12.5	23.7±9.4*	17.4±7.5*	15.5±8.3*	F=59.711 P= 0.000
B	34	43.6±12.4	24.7±9.3*	18.9±8.7*	15.5±7.4*	F=55.327 P= 0.000
统计值 Statistic		t=-0.977 P= 0.332	t=-0.456 P= 0.650	t=-0.768 P= 0.445	t=0.019 P=0.985	

*与术前比较 $P < 0.05$

*Compared with preoperative value, $P < 0.05$

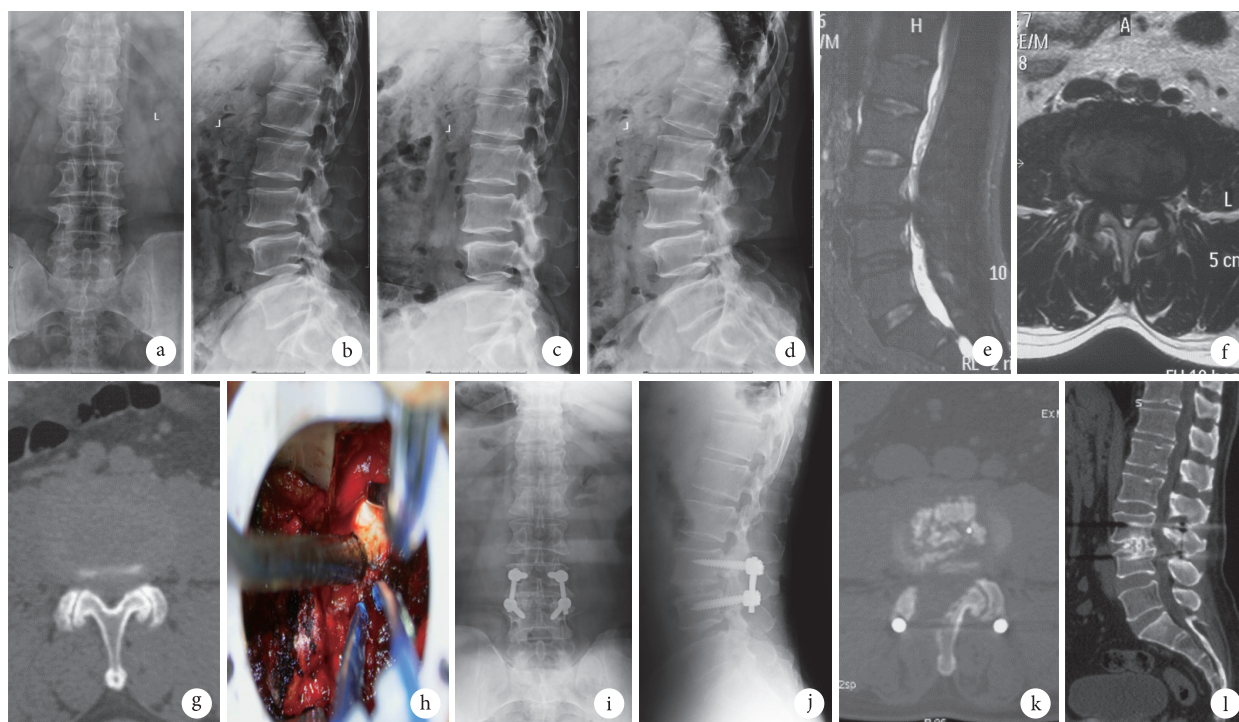


图2 U组患者,男,55岁,L_{3,4}腰椎管狭窄症 a, b. 术前腰椎正侧位X线片; c, d. 术前腰椎动力位X线片示L_{3,4}失稳; e, f. 术前腰椎MRI示L_{3,4}椎管狭窄; g. 术前CT示中央管、双侧侧隐窝狭窄; h. 术中通道内操作减压; i, j. 术后1年腰椎正侧位X线片; k, l. 术后1年CT示椎管容积明显增大, L_{3,4}椎间骨性融合

Fig.2 A 55-year-old male patient with lumbar spinal stenosis at L_{3,4} a, b. Anteroposterior and lateral X-ray films of lumbar spine before operation; c, d. Flexion and extension X-ray films showed the instability of L_{3,4}; e, f. MRI showed the spinal stenosis at L_{3,4} before operation; g. CT showed the central canal and bilateral recess stenosis before operation; h. Decompression under tube; i, j. Anteroposterior and lateral X-ray films at 1 year after operation; k, l. CT showed that the canal volume significantly increased and the interbody fusion at L_{3,4} obtained at 1 year after operation

治疗腰椎管狭窄症,尤其针对术前合并局部失稳患者^[14-15]。MIS-TLIF利用通道技术进行减压、椎间融合及固定,有效减少对椎旁肌肉和软组织的损伤,较传统后路减压椎间植骨融合术及开放TLIF出血更少、术后下地活动更早及并发症发生率更低^[16-18],尤其对于过度肥胖患者, MIS-TLIF优势更加明显^[19],但手术时间、放射线暴露时间可能增加。目前, MIS-TLIF已用于治疗各种单节段腰椎退行性疾病及术后翻修^[20-21]。刘超等^[22]总结了832例采用MIS-TLIF治疗的腰椎退行性疾病患者资料,认为MIS-TLIF治疗腰椎退行性疾病可获得良好的中远期疗效,对于复杂病例,如翻修、重度腰椎管狭窄症以及中重度滑脱症,未增加中远期并发症发生率。腰椎间盘突出症一般只需进行患侧减压,而腰椎滑脱症,尤其是峡部裂型滑脱,若术中需要复位,双侧入路双侧减压是更好的选择^[23]。对于腰椎管狭窄症,虽然部分患者仅表现为单侧下肢症状,但患侧减压的同时行对侧预防性减压,可降低术后非症状侧下肢根性症状发生率^[24],减压方式可采用双侧入路双侧减压,也可采取单侧入路双侧减压^[25]。

Kim等^[26]对66例中央管狭窄症单纯行主症状侧减压,利用椎间撑开也可达到对侧间接减压目的。Lin等^[5]认为对于重度中央管狭窄症,这种对侧间接减压方式效果可能不确切,他们采用经单侧入路同侧减压后再倾斜通道,潜行给予对侧椎管、侧隐窝扩大减压,实现了单侧入路双侧减压。莱龙等^[27]认为对于单侧症状的中央管狭窄症可行单侧入路双侧减压,而双侧症状的中央椎管狭窄症或需要复位的滑脱应行双侧入路双侧减压。我们认为对于无需复位的腰椎管狭窄症患者,双侧减压无论是经单侧还是双侧入路,均能达到满意减压效果。本研究中,两种减压术式均取得良好疗效,各时间点两组功能评分差异无统计学意义,无严重并发症发生,随访过程中均未出现椎间不融合。同时,单侧入路双侧减压未增加术后非症状侧根性症状发生率,也未增加损伤硬脊膜的风险。此外,U组因对侧椎板潜行减压,最大程度保留了对侧关节突关节、椎板后部骨性结构,手术时间、术中出血量也显著低于B组。

对于经单侧入路双侧减压的减压操作顺序,有

学者采取先减压主症状侧,再潜行减压对侧,最后进行椎间融合;也有学者先减压主症状侧,处理椎间隙后再进行对侧潜行减压。我们的经验是,根据硬脊膜前方的压迫情况,如果硬脊膜腹侧压迫严重,患侧减压后探查硬脊膜张力大,可先处理椎间隙,再潜行减压对侧;若硬脊膜背侧压迫严重,则先对侧潜行减压后再处理椎间隙。注意事项:①通道视野有限,一定要进行彻底止血,保持术野清晰,使减压操作更安全。②对侧潜行减压时,在黄韧带后方进行椎板及关节突骨性减压,可以降低损伤硬脊膜的风险。③对硬脊膜腹侧存在明显压迫患者,在先减压主症状侧后进行椎间植骨融合,可有效撑开椎间隙,增加椎间孔高度,也使对侧减压操作更安全。椎间植入椎间融合器和自体骨后,出血明显减少,填塞明胶海绵及速即纱后对术野无明显影响。④采用通道直视下置钉,放射线暴露时间与开放手术无明显差异,由于通道下操作空间有限,需先制备钉道,待减压和椎间融合后再行置钉固定。⑤椎间融合器植入方式为单侧经椎间孔斜行植入,借鉴香蕉型椎间融合器的植入方式^[28],在斜行敲入椎间融合器后,用自制捶骨棒敲击尾部,使其平放于椎间隙,以求达到更好的力学平衡。

单侧入路双侧减压 MIS-TLIF 是一种治疗单节段腰椎管狭窄症有效的微创手术方式,但该项操作对术者技术要求较高,学习曲线较长,连续 30 台手术后可将学习曲线变得平稳^[29],术中的辅助工具及术者的熟练程度对减压效果影响较大,操作不当不仅会造成减压不彻底,还容易在术中伤及硬脊膜和神经。通过显微镜录像资料、数字骨科、VR 技术等辅助学习可缩短学习曲线。但本研究观察例数有限,随访时间较短,对于其优缺点及远期疗效,有待前瞻性、大样本量、长期随访研究进一步验证。

作者贡献:钟睿负责手术实施、收集整理数据、文章撰写;王润生负责手术实施、收集整理数据;刘建恒负责手术实施、收集整理数据、统计分析;韩振川、姜威、刘庆祖负责随访、收集整理数据;毛克亚负责研究设计、手术实施、文章审核质控。

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参考文献

- Försth P, Ólafsson G, Carlsson T, *et al.* A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med*, 2016, 374(15): 1413-1423.
- Deyo RA, Mirza SK, Martin BI, *et al.* Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. *JAMA*, 2010, 303(13): 1259-1265.
- Zhao YZ, Zhu YJ, Zhang H, *et al.* Comparison of bilateral versus unilateral decompression incision of minimally invasive transforaminal lumbar interbody fusion in two-level degenerative lumbar diseases. *Int Orthop*, 2018, 42(12): 2835-2842.
- 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. *Clin Spine Surg*, 2018, 31(6): E302-E309.
- Lin JH, Chiang YH. Unilateral approach for bilateral foramen decompression in minimally invasive transforaminal interbody fusion. *World Neurosurg*, 2014, 82(5): 891-896.
- 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. *Spine (Phila Pa 1976)*, 2010, 35(21): 1919-1924.
- 王润生, 毛克亚, 黄承军, 等. 微创经椎间孔腰椎椎间融合术中横突定位法置钉的影像学评价. *中国脊柱脊髓杂志*, 2018, 28(4): 336-342.
- 韩振川, 毛克亚, 王博, 等. 微创经椎间孔腰椎椎体间融合术后切口注射罗哌卡因的镇痛效果. *脊柱外科杂志*, 2016, 14(2): 79-82.
- 毛克亚, 王岩, 肖嵩华, 等. 微创手术治疗单节段腰椎管狭窄症的疗效评价. *中国脊柱脊髓杂志*, 2011, 21(2): 113-117.
- Bridwell KH, Lenke LG, McEnery KW, *et al.* Anterior fresh frozen structural allografts in the thoracic and lumbar spine. Do they work if combined with posterior fusion and instrumentation in adult patients with kyphosis or anterior column defects? *Spine (Phila Pa 1976)*, 1995, 20(12): 1410-1418.
- Kovacs FM, Urrútia G, Alarcón JD. Surgery versus conservative treatment for symptomatic lumbar spinal stenosis: a systematic review of randomized controlled trials. *Spine (Phila Pa 1976)*, 2011, 36(20): E1335-E1351.
- 保国锋, 李卫东, 徐冠华, 等. 经皮椎板间隙入路 270° 椎管减压治腰椎管狭窄症. *中国矫形外科杂志*, 2017, 25(3): 264-269.
- 徐宝山, 常峰, 赵刘军, 等. 经皮椎间孔入路内镜下治疗腰椎管狭窄症术后手术的临床报告. *中华骨科杂志*, 2018, 38(8): 485-496.
- Bae HW, Rajae SS, Kanim LE. Nationwide trends in the surgical management of lumbar spinal stenosis. *Spine (Phila Pa 1976)*, 2013, 38(11): 916-926.
- Kim JE, Choi DJ. Biptoral endoscopic transforaminal lumbar interbody fusion with arthroscopy. *Clin Orthop Surg*, 2018, 10(2): 248-252.
- Ge DH, Stekas ND, Varlotta CG, *et al.* Comparative analysis of two transforaminal lumbar interbody fusion techniques: open TLIF versus Wiltse MIS TLIF. *Spine (Phila Pa 1976)*, 2019, 44(9): E555-E556.
- de Kunder SL, van Kuijk SMJ, Rijkers K, *et al.* Transforaminal lumbar interbody fusion (TLIF) versus posterior lumbar interbody fusion (PLIF) in lumbar spondylolisthesis: a systematic review and meta-analysis. *Spine J*, 2017, 17(11): 1712-1721.
- Hu W, Tang J, Wu X, *et al.* Minimally invasive versus open transforaminal lumbar fusion: a systematic review of complications. *Int Orthop*, 2016, 40(9): 1883-1890.
- Tan JH, Liu G, Ng R, *et al.* Is MIS-TLIF superior to open TLIF in

- obese patients?: A systematic review and meta-analysis *Eur Spine J*, 2018, 27(8): 1877-1886.
- 20 Khechen B, Haws BE, Patel DV, *et al.* Comparison of postoperative outcomes between primary MIS TLIF and MIS TLIF with revision decompression. *Spine (Phila Pa 1976)*, 2019, 44(2): 150-156.
- 21 刘新宇, 原所茂, 田永昊, 等. 微创经椎间孔腰椎椎间融合在腰椎退行性疾病翻修中的应用. *中华骨科杂志*, 2017, 37(3): 137-144.
- 22 刘超, 王建, 张正丰, 等. 微创经椎间孔腰椎椎间融合治疗腰椎退变性疾病的中远期疗效分析. *中华骨科杂志*, 2018, 38(20): 1266-1272.
- 23 Qin RQ, Liu B, Zhou P, *et al.* Minimally invasive versus traditional open transforaminal lumbar interbody fusion for the treatment of single-level spondylolisthesis grades 1 and 2: A systematic review and meta-analysis. *World Neurosurgery*, 2019, 122: 180-189.
- 24 迟成, 张建党, 邹德威, 等. 单侧症状的双侧腰椎神经根管狭窄行单、双侧减压的前瞻性研究. *中国脊柱脊髓杂志*, 2013, 23(4): 325-329.
- 25 张磊, 方向前, 赵兴, 等. 经椎间孔单侧入路双侧减压融合内固定术治疗腰椎管狭窄症的近期疗效观察. *中国修复重建外科杂志*, 2017, 31(5): 519-526.
- 26 Kim MC, Park JU, Kim WC, *et al.* Can unilateral-approach minimally invasive transforaminal lumbar interbody fusion attain indirect contralateral decompression? A preliminary report of 66 MRI analysis *Eur Spine J*, 2014, 23(5): 1144-1149.
- 27 英龙, 曾至立, 于研, 等. 固定通道下微创经椎间孔腰椎椎间融合术治疗单节段腰椎退行性疾病的临床疗效. *中华骨科杂志*, 2018, 38(20): 1258-1265.
- 28 Choi WS, Kim JS, Hur JW, *et al.* Minimally invasive transforaminal lumbar interbody fusion using banana-shaped and straight cages: radiological and clinical results from a prospective randomized clinical trial. *Neurosurgery*, 2018, 82(3): 289-297.
- 29 Sharif S, Afsar A. Learning curve and minimally invasive spine surgery. *World Neurosurgery*, 2018, 119: 472-478.

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