



在线全文

椎体骨质量及椎旁肌变化与经椎间孔腰椎椎间融合术后邻近节段退变的相关性研究*

郑俊勇¹, 王松², 张鑫³, 肖萧⁴, 彭松林^{1,4△}

1. 暨南大学第二临床医学院(深圳 518020); 2. 暨南大学第一临床医学院(广州 510632); 3. 普宁市人民医院 骨科(普宁 515300);
4. 深圳市人民医院 脊柱外科(深圳 518020)

【摘要】目的 通过回顾性分析因腰椎退行性疾病(lumbar degenerative disease, LDD)行经椎间孔腰椎椎间融合术(transforaminal lumbar interbody fusion, TLIF)的患者,探讨椎体骨质量(vertebral bone quality, VBQ)及椎旁肌变化与TLIF术后邻近节段退变(adjacent segment degeneration, ASD)的相关性。**方法** 选取2016年1月–2022年12月在深圳市人民医院因LDD行TLIF手术治疗并具有完善的随访影像学资料的患者共98例,根据ASD判定标准,分为ASD组43例, N-ASD组55例,收集两组患者的基本特征,并通过术前及末次随访时的腰椎核磁共振成像测量相关参数,包括VBQ,腰大肌(psoas major, PM)、竖脊肌(erector spinae, ES)及多裂肌(multifidus, MF)的总横截面积(total cross-section area, TCSA)、功能横截面积(functional cross-section area, FCSA),计算出相对脂肪浸润(relative fat infiltration, RFI)。运用logistic回归分析研究ASD发生的危险因素。**结果** 末次随访时ASD发生率为43.9%(43例),平均随访时间为(27.23±4.15)个月,两组的年龄,体质指数(body mass index, BMI),术前骨密度(bone mineral density, BMD),术前VBQ、 ΔRFI_{PM} 、 ΔRFI_{ES+MF} 的差异有统计学意义($P<0.05$)。logistic回归分析结果显示BMI[比值比(odds ratio, OR)=1.450, 95%置信区间(confidence interval, CI): 1.081~1.945, $P=0.013$]、术前VBQ(OR=6.191, 95%CI: 1.692~22.657, $P=0.006$)、 ΔRFI_{ES+MF} (OR=1.117, 95%CI: 1.007~1.238, $P=0.037$)为TLIF术后发生ASD的独立危险因素。**结论** 因LDD行TLIF的患者术后ASD与较高的BMI、术前VBQ和术后竖脊肌与多裂肌的相对脂肪浸润程度增加相关。因此,强调在手术过程中对椎旁肌群的保护至关重要,并且术后加强腰背部肌肉锻炼,优化骨质量和体质量管理,有利于降低术后ASD的发生风险。

【关键词】 腰椎椎间融合术 椎间盘退行性变 椎体骨质量 椎旁肌

Correlation of Vertebral Bone Quality and Paraspinal Muscle Changes With Adjacent Segment Degeneration After Transforaminal Lumbar Interbody Fusion Operation ZHENG Junyong¹, WANG Song², ZHANG Xin³, XIAO Xiao⁴, PENG Songlin^{1,4△}. 1. The Second Clinical Medical College, Jinan University, Shenzhen 518020, China; 2. The First Affiliated Hospital of Jinan University, Guangzhou 510632, China; 3. Department of Orthopedic Surgery, Puning People's Hospital, Puning 515300, China; 4. Department of Spine Surgery, Shenzhen People's Hospital, Shenzhen 518020, China

△ Corresponding author, E-mail: songlin824@gmail.com

【Abstract】 Objective To investigate the correlation of vertebral bone quality (VBQ) and paraspinal muscle changes with adjacent segment degeneration (ASD) after transforaminal lumbar interbody fusion (TLIF) through a retrospective analysis of patients who have undergone TLIF for lumbar degenerative diseases (LDD). **Methods** A total of 98 patients who underwent TLIF surgical treatment for LDD between January 2016 and December 2022 at Shenzhen People's Hospital were selected. Well-established follow-up imaging data were available for all subjects who were divided into two groups, the ASD group ($n=43$) and the non-ASD (N-ASD) group ($n=55$), according to whether they met the ASD evaluation criteria. Data on the basic characteristics of the patients in both groups were collected, and the relevant parameters, including VBQ and the total cross-sectional area (TCSA) and the functional cross-sectional area (FCSA) of psoas major (PM), erector spinae (ES), and multifidus (MF), were measured by magnetic resonance imaging of the lumbar spine performed preoperatively and at the last follow-up. Then, the relative fat infiltration (RFI) was calculated from the above metrics accordingly. Logistic regression analysis was conducted to investigate the risk factors for ASD. **Results** The incidence of ASD was 43.9% ($n=43$) at the final follow-up. The mean follow-up time was (27.23±4.15) months. The age, body mass index (BMI), preoperative bone mineral density (BMD), preoperative VBQ, ΔRFI_{PM} , and ΔRFI_{ES+MF} showed significant differences between the ASD and N-ASD groups ($P<0.05$). According to the results of the logistic regression analysis, BMI (odds ratio [OR]=1.450, 95% confidence interval [CI]: 1.081-1.945, $P=0.013$), preoperative VBQ (OR=6.191, 95% CI: 1.692-22.657, $P=0.006$), and ΔRFI_{ES+MF} (OR=1.117, 95% CI: 1.007-1.238, $P=0.037$) were independent risk factors for ASD. **Conclusion** The incidence of postoperative ASD in patients who have undergone TLIF for LDD was found to be associated with higher BMI, preoperative VBQ, and increased postoperative

* 国家自然科学基金(No.82272488)资助

△ 通信作者, E-mail: songlin824@gmail.com

出版日期: 2024-09-20

relative fat infiltration of the ES and MF muscles. Consequently, it is advisable to prioritize the intraoperative protection of the paraspinal muscles during TLIF. In the postoperative period, it is essential to strengthen exercises of the lower back muscles and to optimize bone mass and weight management, which is conducive to reducing the risk of ASD in the postoperative period.

【Key words】 Lumbar interbody fusion Intervertebral disc degeneration Vertebral bone quality
Paraspinal muscles

随着社会人口老龄化的加速进程,腰椎退行性疾病(lumbar degenerative disease, LDD)的发病率持续呈上升趋势,然而对于退行性疾病而言,保守治疗效果有限,随着年龄增长与病程延长,许多患者的症状也在不断加重,手术是最终治疗方法^[1]。腰椎椎间融合手术作为一项成熟的外科技术,已成为LDD手术治疗的主要术式^[2]。虽然大多数患者在术后早期症状得到缓解、生活质量提高,但腰椎椎间融合所致的脊柱生物力学性质改变,可能会促使患者腰椎邻近节段退行性改变(adjacent segment degeneration, ASDeg),从而对患者的远期治疗效果产生不利影响^[3]。当ASDeg引起腰腿部再次出现神经根性症状如疼痛、麻木等,进而进展为邻近节段退行性疾病(adjacent segment disease, ASDis)时,患者可能面临再次手术,这不仅对患者的身心造成严重打击,同时也显著增加了家庭的经济负担^[4]。骨质量的好坏对脊柱椎间融合术后的疗效存在影响,是术后不良结果的已知预测因素^[5-6]。由双能X线吸收检测法(dual energy x-ray absorptiometry, DEXA)衍生的骨密度(bone mineral density, BMD)是反映骨强度的一个重要参数,但其测定结果受骨骼内部有机成分、骨小梁微结构以及骨髓组织特性等多重因素的影响^[7-8]。近期,有研究提出一种基于核磁共振成像技术的新指标——椎体骨质量(vertebral bone quality, VBQ),并将其作为评估骨质量的全新参数^[9],且与BMD相关^[10]。另外已有研究发现,VBQ可用于独立预测脊柱椎间融合术后并发症的发生^[11-12]。此外发挥重要功能性运动的脊柱椎旁肌在术中受到的破坏可进一步影响肌肉的力量和耐力,从而影响脊柱的节段性稳定^[13]。

因此,本研究通过回顾性分析接受经椎间孔入路腰椎椎间融合术(transforaminal lumbar interbody fusion, TLIF)的患者的临床资料,探讨VBQ及椎旁肌的变化与术后ASD的相关性,旨在探究ASD的危险因素并为临床预防术后ASD提供可靠依据。

1 资料与方法

1.1 纳入和排除标准

纳入标准:①确诊LDD并具备手术指征,且已接受了TLIF手术治疗。②具有完整的病历,术前及术后末次随

访均行腰椎磁共振成像(magnetic resonance imaging, MRI)扫描,无任何对比度增强。③有2年及以上的随访资料的患者。

排除标准:①既往曾行腰椎手术或融合椎体的邻近节段已行减压手术。②合并脊柱侧弯、脊柱旋转等严重脊柱畸形。③合并脊柱或脊髓损伤、脊柱感染、脊柱肿瘤、强直性脊柱炎等其他脊柱疾病;合并异常骨代谢疾病,如库欣综合征、甲状旁腺亢进症等。④随访时间不足2年或缺乏相关术前、术后随访影像学资料。

1.2 ASD诊断标准及分组

1.2.1 ASD诊断标准^[14-16]

依据末次随访的MRI与术前MRI对比,①融合椎体邻近节段椎间盘突出加重、椎管狭窄分级^[17]加重;②融合椎体邻近节段Pfirrmann分级加重至少1级;③融合椎体邻近节段椎间盘高度塌陷>10%;④融合椎体存在>3 mm的滑脱;⑤融合节段邻近椎体压缩性骨折;⑥TLIF术后半年再次出现腰腿疼痛、麻木等临床症状及体征,且经影像学证实为邻近节段退变所致。

上述各项影像学判定标准中,与术前对比的任一改变均可视作术后发生ASDeg,若引起患者出现腰痛或下肢根性症状显著加剧,则判定为ASDis。

1.2.2 分组

TLIF术后邻近节段退变加重(影像学)或发生ASDis(影像学+症状学)的患者纳入ASD组,反之纳入非ASD组(N-ASD组)。

1.3 数据来源

年龄、性别、体质质量指数(body mass index, BMI)、手术节段、疾病类型、高血压史、糖尿病史、随访时间等一般资料均来自于深圳市人民医院病历系统资料,术前BMD结果为腰椎整体T值且均由深圳市人民医院脊柱外科Horizon TM骨密度检测系统计算所得,腰椎MRI影像学资料均由深圳市人民医院脊柱外科Philips Multiva 1.5T磁共振成像系统进行成像及图像处理,最终形成图像保存于深圳市人民医院影像科PACS系统,影像学测量数据由2名脊柱外科医生对影像学资料进行独立测量所得。本研究方案获得我院伦理委员会批准(LL-KY-2024094-02),因为回顾性研究,故无需签署相关知情同

意书。

1.4 VBQ及椎旁肌横截面积测量方法

测量VBQ所使用的图像均为腰椎T1加权MRI矢状面影像, 通过将感兴趣区(region of interest, ROI)放置在L1至L5髓质部分和L3水平的脑脊液(cerebrospinal fluid, CSF)的矢状面非对比T1加权MRI图像上获取两者的平均信号强度(mean signal intensity, MSI), 即 MSI_{L1-L5} 和 MSI_{L3-CSF} ,

以 MSI_{L1-L5} 与 MSI_{L3-CSF} 的比值计算VBQ评分。若L3水平的CSF信号被其他混杂因素(如狭窄性病变、神经根)遮挡, 则使用L3水平以上的L2或L4水平的CSF信号。图1中A、B图是来自同1例行TLIF手术的患者, 分别为术前及术后末次随访T1加权MRI矢状面影像, 该例患者术前、术后末次随访T1加权MRI矢状面影像, 该例患者术前、术后VBQ分别为3.410、3.963。则术后与术前VBQ差值即 $\Delta VBQ = 0.553$ 。

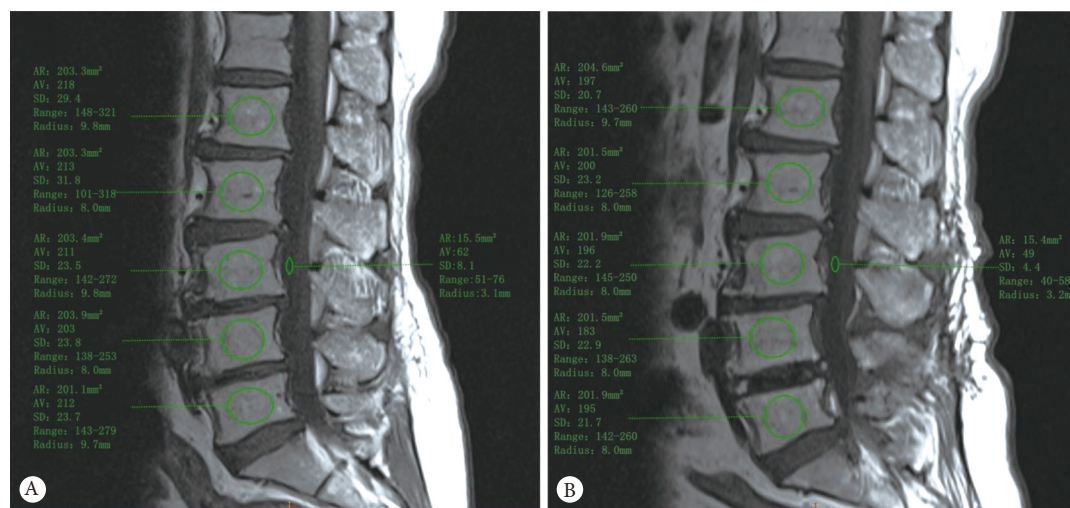


图1 VBQ测量方法示意及案例图

Fig 1 VBQ score measurement method illustration and case diagrams

A, Preoperation; B, postoperative final follow-up.

测量椎旁肌横截面积(cross-section area, CSA)所用的图像均为腰椎T2加权MRI横断面影像, 均选取L4椎体终板上缘为测量层面, 分别勾勒腰大肌(psoas major, PM)、竖脊肌(erector spinae, ES)及多裂肌(multifidus, MF)的总横截面积(total cross-section area, TCSA)、功能横截面积(functional cross-section area, FCSA), 并计算其平均值分别代表 $TCSA_{PM}$ 、 $FCSA_{PM}$ 、 $TCSA_{ES+MF}$ 、 $FCSA_{ES+MF}$ 。图2为1例

拟行TLIF的患者的术前腰椎T2加权MRI横断面影像, A、B图分别勾勒出TCSA、FCSA, 可得出该例患者 $TCSA_{PM}$ 为 9.77 cm^2 , $TCSA_{ES+MF}$ 为 27.15 cm^2 , $FCSA_{PM}$ 为 8.43 cm^2 , $FCSA_{ES+MF}$ 为 19.05 cm^2 。双侧测量后求其平均值, 通过计算公式 $(TCSA - FCSA) / TCSA$ 得出相对脂肪浸润(relative fat infiltration, RFI); $RFI_{PM} = 0.14$, $RFI_{ES+MF} = 0.30$ 。通过计算术后与术前的数据差值即可得出 $\Delta TCSA$ 、 $\Delta FCSA$ 、 ΔRFI 。

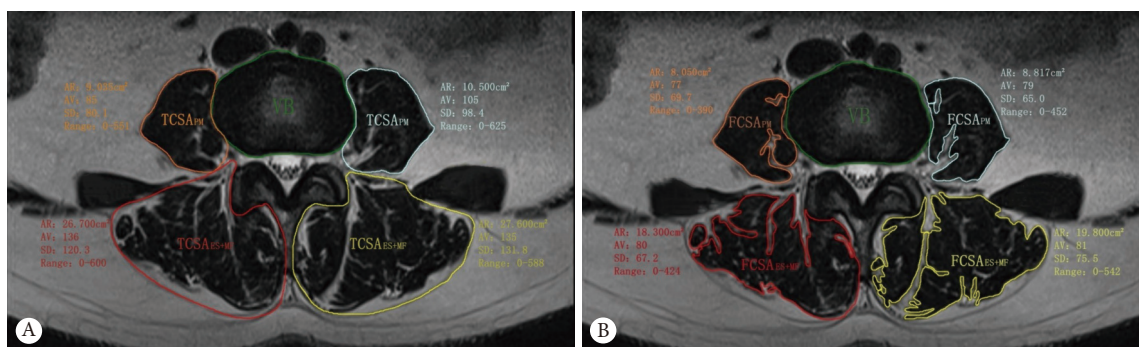


图2 椎旁肌CSA测量方法示意及案例图

Fig 2 Illustration and case diagram for the paraspinal muscles CSA measurement method

AR: area; AV: average; SD: standard deviation; TCSA: total cross-section area; FCSA: functional cross-section area; PM: psoas major; ES: erector spinae; MF: multifidus.

1.5 统计学方法

数据分析采用SPSS 27.0统计软件包(Version 27.0, International Business Machines公司, 美国)进行统计学分析, $P < 0.05$ 为差异有统计学意义。对于计量资料先进行正态性检验, 正态分布的数据以 $\bar{x} \pm s$ 的形式呈现, 非正态分布的数据以中位数(四分位间距)进行描述, 符合正态分布的数据采用独立样本 t 检验, 不符合正态分布的数据采用Mann-Whitney U 检验。计数资料采用例数(%)的形式表示, 采用卡方检验。以上单因素分析结果提示差异有统计学意义的变量纳入二元logistic 回归分析, 计算比值比(odds ratio, OR)及 95%置信区间(confidence interval, CI)。

2 结果

2.1 人群统计学特征

结果见表1。总共有43.9%(43/98)的患者在随访中表现出ASD, 平均随访时间为 (27.23 ± 4.15) 个月, 平均年龄 (61.38 ± 11.57) 岁。ASD组的年龄大于N-ASD组($P < 0.05$), BMI亦较高($P < 0.05$)。在性别、疾病类型、融合节段、有无合并高血压病史、有无合并糖尿病病史等资料均未见明显差异($P > 0.05$)。

2.2 两组患者影像学资料的单因素分析

单因素分析结果见表2。ASD组和N-ASD组的术前BMD、术前VBQ、 ΔRFI_{PM} 、 ΔRFI_{ES+MF} 的差异有统计学意义

表 1 样本人群统计学特征
Table 1 Statistical characteristics of the sample population

Variable	ASD group (n=43)	N-ASD group (n=55)	χ^2/t	P
Sex/case (%)			0.136	0.712
Male	18 (41.86)	21 (38.18)		
Female	25 (58.14)	34 (61.82)		
Age/yr.	64.70 $\pm$ 11.09	58.78 $\pm$ 11.37	2.584	0.011
BMI/(kg/m ²)	25.77 $\pm$ 1.74	24.42 $\pm$ 2.19	3.298	0.001
Type of disease/case (%)			0.868	0.648
LSS	19 (44.19)	24 (43.64)		
LSL	15 (34.88)	23 (41.82)		
LDH	9 (20.93)	8 (14.55)		
Fusion segment/case (%)			0.539	0.463
Single segment	30 (69.77)	42 (76.36)		
Double segment	13 (30.23)	13 (23.64)		
Specific single segment/case (%)			1.004	0.605
L3/4	1 (3.33)	3 (7.14)		
L4/5	25 (83.33)	31 (73.81)		
L5/S1	4 (13.33)	8 (19.05)		
Specific double segment/case (%)			0.154	0.695
L3/4, L4/5	6 (46.15)	7 (53.85)		
L4/5, L5/S1	7 (53.85)	6 (46.15)		
Hypertension/case (%)			0.437	0.509
Yes	24 (55.81)	27 (49.09)		
No	19 (44.19)	28 (50.91)		
Diabetes/case (%)			0.117	0.733
Yes	9 (20.93)	10 (18.18)		
No	34 (79.07)	45 (81.82)		

BMI: body mass index; LSS: lumbar spinal stenosis; LSL: lumbar spondylolisthesis; LDH: lumbar disc herniation.

表 2 相关影像学资料分析
Table 2 Analysis of the relevant imaging data

Variable	ASD group (n=43)	N-ASD group (n=55)	t	P
Preop BMD	-2.10±0.78	-1.35±1.18	-3.769	<0.001
Preop VBQ	3.66±0.47	3.11±0.54	5.286	<0.001
ΔVBQ	0.14±0.50	0.08±0.55	0.516	0.607
PM				
Preop TCSA _{PM} /cm ²	10.17±3.19	10.06±3.53	0.158	0.875
Preop FCSA _{PM} /cm ²	9.53±3.19	9.33±3.60	0.294	0.769
Postop TCSA _{PM} /cm ²	10.53±3.72	10.19±3.78	0.451	0.653
Postop FCSA _{PM} /cm ²	9.67±3.71	9.40±3.81	0.349	0.728
ΔTCSA _{PM} /cm ²	0.36±1.69	0.13±1.31	0.778	0.438
ΔFCSA _{PM} /cm ²	0.14±1.70	0.07±1.34	0.203	0.839
ΔRFI _{PM} /%	2.24±2.46	0.31±2.83	3.556	<0.001
ES+MF				
Preop TCSA _{ES+MF} /cm ²	21.62±5.61	22.77±4.48	-1.130	0.261
Preop FCSA _{ES+MF} /cm ²	20.20±5.40	20.84±4.33	-0.652	0.516
Postop TCSA _{ES+MF} /cm ²	21.29±5.01	22.90±4.56	-1.656	0.101
Postop FCSA _{ES+MF} /cm ²	18.08±4.84	19.76±4.86	-1.696	0.093
ΔTCSA _{ES+MF} /cm ²	-0.33±2.34	0.12±2.17	-0.990	0.325
ΔFCSA _{ES+MF} /cm ²	-2.11±2.55	-1.08±2.82	-1.877	0.064
ΔRFI _{ES+MF} /%	8.82±4.19	5.76±7.62	2.534	0.013

Preop: preoperative; Postop: postoperative; VBQ: vertebral bone quality; ΔVBQ: the variation of VBQ; BMD: bone mass quality; ΔCSA: the variation of CSA; ΔRFI: the variation of relative fat infiltration; the other abbreviations are explained in the note to Fig 2.

($P < 0.05$), 而ΔVBQ、术前TCSA_{PM}、术前FCSA_{PM}、术后TCSA_{PM}、术后FCSA_{PM}、术前TCSA_{ES+MF}、术前TCSA_{ES+MF}、术后TCSA_{ES+MF}、术后FCSA_{ES+MF}以及ΔTCSA_{PM}、ΔFCSA_{PM}、ΔTCSA_{ES+MF}、ΔFCSA_{ES+MF}的差异均无统计学意义。

2.3 TLIF术后发生ASD危险因素的logistic回归分析

将单因素分析结果中差异有统计学意义的参数进行二元logistic回归分析。表3结果显示BMI(OR= 1.450, 95%CI: 1.081 ~ 1.945, $P = 0.013$)、术前VBQ(OR= 6.191, 95%CI: 1.692 ~ 22.657, $P = 0.006$)和ΔRFI_{ES+MF}(OR= 1.117,

95%CI: 1.007 ~ 1.238, $P = 0.037$)为TLIF术后发生ASD的独立危险因素。

3 讨论

ASD是腰椎融合术的术后并发症之一,同时也是导致术后再次翻修手术的主要原因之一,既往报道发现腰椎融合术后ASDeg的发生率为4% ~ 80%、ASDis发生率为0 ~ 35%,翻修手术率约为0 ~ 25%^[18-19]。本研究中ASD的整体发生率为43.9%,由于不同研究选取的目标人群不同且评价ASD所用方法的不同,发生率变化范围较大。ASD的发生具有隐匿性特征,患者在早期可能临床症状不明显。然而,随着疾病进展至中后期,相关临床症状显现,对患者的生活质量产生显著影响,部分患者甚至不得不接受翻修手术治疗。即便在成功进行二次手术的情况下,其长期预后仍有可能因ASD复发而受影响,鉴于此,对ASD的预防显得尤为重要,深入了解与其发病相关的危险因素,不仅有助于更准确地评估和识别ASD的发生风险,而且对延缓ASDeg的发生、阻止其进展为ASDis具有重要的临床意义。

既往研究中发现ASD的发生与患者年龄、性别和BMI有关^[20]。体质量的增加使椎体的机械负荷增大,并一

表 3 TLIF术后发生ASD危险因素的logistic回归分析结果
Table 3 Results of logistic regression analysis of risk factors for the development of ASD after TLIF

Variable	β	Wald	OR	95% CI	P
Age	0.016	0.355	1.016	0.965-1.069	0.551
BMI	0.371	6.141	1.450	1.081-1.945	0.013
Preop BMD	-0.260	0.849	0.771	0.443-1.341	0.357
Preop VBQ	1.823	7.585	6.191	1.692-22.657	0.006
ΔRFI _{PM}	0.144	2.107	1.155	0.951-1.403	0.147
ΔRFI _{ES+MF}	0.110	4.373	1.117	1.007-1.238	0.037

β: partial regression coefficient; OR: odds ratio; CI: confidence interval; the other abbreviations are explained in the note to Table 1 and Table 2.

定程度上影响椎间盘的减震性能;而随年龄增长,LDD发病率及严重程度随之增加,且对腰椎融合术后生物力学改变的适应度也随之下降;女性患者绝经后雌激素水平下降带来的骨质疏松又进一步加速椎间盘的老化。在本研究中,年龄和BMI在ASD组与N-ASD组间的差异均有统计学意义($P < 0.05$),且较高的BMI是ASD发生的独立危险因素,因此适当地减重有利于预防术后ASD的发生。但年龄在回归分析中的差异无统计学意义,可能与本研究中样本人群的年龄分布比较集中有关,目前接受腰椎融合手术的患者仍以老年患者为主。另外ASD组中的女性患者占较大比例,但两组间未见明显差异,这可能需要更多的样本来进一步观察性别对ASD的影响。

VBQ作为评价椎体骨质量的一个新指标参数,在近来开展了许多相关研究,如HU等^[21]通过回顾性研究发现VBQ对于TLIF术后融合器下沉具有一定的预测能力;CHEN^[22]等通过横断面研究提出VBQ为腰椎融合术后螺钉松动的独立危险因素,为评估骨质量提供了一种新的无创方案。还有研究发现ASD的发生与融合术后椎体的应力改变、椎体内的微骨折、血管化减少影响椎间盘的营养供应等相关,可进一步诱发椎间盘的退化^[23]。而VBQ不仅包含了椎体内的脂肪浸润信号,间接反映了椎体骨密度,同时还包含了椎体内有机成分、骨小梁结构、骨髓性质所反映的信号,正如学者研究发现的,VBQ涵盖了不局限于骨密度的脊柱信息^[24]。本研究采用并改进了EHRESMAN等^[9]描述的方法对TLIF术前及术后的整体腰椎椎体骨质量进行测量,相比既往VBQ仅测量腰1椎体至腰4椎体的方法,改良测量腰椎的所有椎体能更好地代表腰椎整体的骨质量。

本研究结果表明,在两组术前资料的比对中不仅BMD的差异有统计学意义($P < 0.05$),VBQ亦存在明显差异,同时经过回归分析可见术前较高的VBQ是ASD发生的一个独立危险因素,但BMD却未能被纳入影响ASD发生的独立危险因素中。这可能是因为在患者的BMD发生实质性变化之前,松质骨已发生了早期、不呈比例的重塑,并出现骨小梁密度下降等^[25],而MRI可比双能X线成像更加敏感地检出此征象,表现出VBQ与ASD的相关性更强。另外本研究还分析了患者VBQ在随访过程中的增加或减少是否与ASD的发生有关,结果显示,两组的 ΔVBQ 中位值均呈正向增加趋势,对于ASD组而言趋势更加突出,但两组间的 ΔVBQ 对比分析未见明显差异,目前尚不足以说明骨质量的进一步恶化致使ASD的发生发展,对此仍需开展样本量更庞大、随访周期更长的研究进一步明确。

拟行腰椎椎间融合手术的患者在手术前通常需要完善MRI检查来更好地规划手术方案,所以使用VBQ来评估椎体骨质量不需要行额外的检查。并且笔者认为,术前的腰椎MRI的完善率相比DEXA更高,且可以保护患者免受辐射,再者VBQ测量的过程并不繁琐,且测量方法可靠,因此存在较好的可行性及实用性,有助于在临床环境中评估骨质量较差且腰椎融合术后发生ASD风险较大的患者,并识别出可能需要进一步评估和干预的个体,通过更加深入的研究,笔者相信VBQ未来有可能成为一种有用的临床测量评估工具,用于协助外科医生进行脊柱手术的术前、术后治疗计划,以降低未来再手术的风险。

TLIF属于经后路腰椎融合术的一种,其手术操作过程不仅对病变椎间盘、关节突关节造成破坏,还会对椎旁肌后群结构完整性造成明显的破坏,椎旁肌退变涵盖了肌肉的质和量两个方面的改变,主要表现为肌肉的萎缩和脂肪浸润,而这可能导致局部的肌肉无力和脊柱稳定性下降,进而引起相邻椎体层面的进一步失稳,导致相邻椎间盘退变进一步发展,二者与腰椎椎间融合术后的ASD发生有密切关系^[13,26]。因此本研究通过MRI对椎旁肌进行TCSA、FCSA的测量,从而间接得出椎旁肌的RFI程度,并通过术前术后测量结果的对比得出TLIF术后椎旁肌的变化及其与ASD发生的相关性。本研究结果显示,在术后随访中,两组的 ΔRFI_{PM} 、 ΔRFI_{ES+MF} 存在明显差异,即ASD组由于术后肌肉缺血、疤痕愈合和去神经支配,椎旁肌的脂肪浸润程度进一步加重,竖脊肌和多裂肌的FCSA减小,相对脂肪浸润程度 ΔRFI_{ES+MF} (OR=1.117, 95%CI: 1.007~1.238, $P=0.037$)的增加促进术后ASD的影响已得到进一步验证。

虽然组间比较中无论是腰大肌还是竖脊肌和多裂肌的TCSA、FCSA的差异,以及术前术后的TCSA、FCSA变化的差异均无统计学意义,但从二者变化趋势看,后群肌肉竖脊肌和多裂肌受到手术破坏而出现萎缩的同时,前群肌肉腰大肌的TCSA和FCSA却出现了代偿性的增加,这与CHO等^[27]的研究结果相似,通过前群肌肉的代偿性肥大可以平衡后路刚性固定带来的压力。既往已有研究评估了经皮螺钉内固定、微创腰椎间盘切除术等技术在减少椎旁肌萎缩和降低脂肪浸润程度上的作用^[28-29],由此可见外科医生通过更加注重在手术过程中对椎旁肌的保护及邻近椎体组织结构的保留,不失为保障患者术后长期疗效的一种措施,术后加强腰背肌后群锻炼的同时也不可忽视前方肌群重要性。

综上,较高的BMI、术前VBQ和术后竖脊肌与多裂肌的相对脂肪浸润程度增加是TLIF术后ASD发生的危险因

素,建议术前合理评估患者综合情况,术中注意保护椎旁肌群,术后需关注腰椎应力的保护,加强腰背部肌肉训练,优化骨质量和体质量管理,将有助于降低术后ASD的发生风险。本研究尚存局限:本研究作为单中心的回顾性研究,随访时间不足、病例样本数量有限,为了进一步准确探究ASD发生的风险因素仍需更大样本及多中心的前瞻性临床研究。限于目前主流术式,本研究仅对TLIF术后的患者进行研究,未对使用其他术式治疗的术后患者进行对比分析,对于腰椎融合术后ASD发生的全面预测仍需通过对不同手术方式的患者进行研究。

* * *

作者贡献声明 郑俊勇负责论文构思、数据审编、正式分析、初稿写作和审读与编辑写作;王松、张鑫和肖萧负责数据审编、正式分析和审读与编辑写作,彭松林负责经费获取、提供资源、监督指导和审读与编辑写作。所有作者已经同意将文章提交给本刊,且对将要发表版本进行最终定稿,并同意对工作的所有方面负责。

Author Contribution ZHENG Junyong is responsible for conceptualization, data curation, formal analysis, writing--original draft, and writing--review and editing. WANG Song, ZHANG Xin, and XIAO Xiao are responsible for data curation, formal analysis, and writing--review and editing. PENG Songlin is responsible for funding acquisition, resources, supervision, and writing--review and editing. All authors consented to the submission of the article to the Journal. All authors approved the final version to be published and agreed to take responsibility for all aspects of the work.

利益冲突 所有作者均声明不存在利益冲突

Declaration of Conflicting Interests All authors declare no competing interests.

参 考 文 献

- [1] YUAN C, ZHOU J, WANG L, *et al.* Adjacent segment disease after minimally invasive transforaminal lumbar interbody fusion for degenerative lumbar diseases: incidence and risk factors. *BMC Musculoskelet Disord*, 2022, 23(1): 982. doi: [10.1186/s12891-022-05905-6](https://doi.org/10.1186/s12891-022-05905-6).
- [2] SCHNAKE K J, RAPPERT D, STORZER B, *et al.* Lumbar fusion-Indications and techniques. *Orthopade*, 2019, 48(1): 50–58. doi: [10.1007/s00132-018-03670-w](https://doi.org/10.1007/s00132-018-03670-w).
- [3] 郭团茂, 陈忠宁, 行艳丽. 腰椎后路椎间植骨融合内固定术后邻近节段椎间盘退行性改变生物力学特点的有限元分析. *中国骨与关节损伤杂志*, 2020, 35(3): 232–235. doi: [10.7531/j.issn.1672-9935.2020.03.003](https://doi.org/10.7531/j.issn.1672-9935.2020.03.003).
GUO T M, CHEN Z N, XING Y L. Finite element analysis of biomechanical characteristics of disc degenerative changes in adjacent segments after posterior lumbar intervertebral bone fusion and internal fixation. *Chin J Bone Joint Inj*, 2020, 35(3): 232–235. doi: [10.7531/j.issn.1672-9935.2020.03.003](https://doi.org/10.7531/j.issn.1672-9935.2020.03.003).
- [4] MCDONALD C L, ALSOOF D, GLUECK J, *et al.* Adjacent segment disease after spinal fusion. *JBJS Rev*, 2023, 11(6): e23.00028. doi: [10.2106/JBJS.RVW.23.00028](https://doi.org/10.2106/JBJS.RVW.23.00028).
- [5] HAFFER H, MUELLNER M, CHIAPPARELLI E, *et al.* Bone quality in patients with osteoporosis undergoing lumbar fusion surgery: analysis of the MRI-based vertebral bone quality score and the bone microstructure derived from microcomputed tomography. *Spine J*, 2022, 22(10): 1642–1650. doi: [10.1016/j.spinee.2022.05.008](https://doi.org/10.1016/j.spinee.2022.05.008).
- [6] LI W, ZHU H, HUA Z, *et al.* Vertebral bone quality score as a predictor of pedicle screw loosening following surgery for degenerative lumbar disease. *Spine*, 2023, 48(23): 1635–1641. doi: [10.1097/BRS.00000000000004577](https://doi.org/10.1097/BRS.00000000000004577).
- [7] 王延, 杨彦茹, 刘涛. 骨密度测定影像学研究进展. *中国医药科学*, 2023, 13(13): 56–59. doi: [10.20116/j.issn2095-0616.2023.13.13](https://doi.org/10.20116/j.issn2095-0616.2023.13.13).
WANG Y, YANG Y R, LIU T. Advances in the application of imaging technology in BMD measurement. *China Med Pharm*, 2023, 13(13): 56–59. doi: [10.20116/j.issn2095-0616.2023.13.13](https://doi.org/10.20116/j.issn2095-0616.2023.13.13).
- [8] 刘浩, 杨红胜, 曾智谋, 等. 腰椎MRI椎体骨质量评分评价绝经后女性骨质疏松的严重程度. *中国组织工程研究*, 2023, 27(4): 606–611. doi: [10.12307/2022.966](https://doi.org/10.12307/2022.966).
LIU H, YANG H S, ZENG Z M, *et al.* Lumbar MRI vertebral bone quality score to evaluate the severity of osteoporosis in postmenopausal women. *Chin J Tissue Eng Res*, 2023, 27(4): 606–611. doi: [10.12307/2022.966](https://doi.org/10.12307/2022.966).
- [9] EHRESMAN J, PENNINGTON Z, SCHILLING A, *et al.* Novel MRI-based score for assessment of bone density in operative spine patients. *Spine J*, 2020, 20(4): 556–562. doi: [10.1016/j.spinee.2019.10.018](https://doi.org/10.1016/j.spinee.2019.10.018).
- [10] SALZMANN S N, OKANO I, JONES C, *et al.* Preoperative MRI-based vertebral bone quality (VBQ) score assessment in patients undergoing lumbar spinal fusion. *Spine J*, 2022, 22(8): 1301–1308. doi: [10.1016/j.spinee.2022.03.006](https://doi.org/10.1016/j.spinee.2022.03.006).
- [11] SOLIMAN M A R, AGUIRRE A O, KUO C C, *et al.* A novel cervical vertebral bone quality score independently predicts cage subsidence after anterior cervical discectomy and fusion. *Neurosurgery*, 2023, 92(4): 779–786. doi: [10.1227/neu.0000000000002269](https://doi.org/10.1227/neu.0000000000002269).
- [12] KUO C C, SOLIMAN M A R, AGUIRRE A O, *et al.* Vertebral bone quality score independently predicts proximal junctional kyphosis and/or failure after adult spinal deformity surgery. *Neurosurgery*, 2023, 92(5): 945–954. doi: [10.1227/neu.0000000000002291](https://doi.org/10.1227/neu.0000000000002291).
- [13] YUN Y I, JEON I, KIM S W, *et al.* Risk factors for adjacent segment disease requiring reoperation after posterior lumbar interbody fusion with screw fixation: focus on paraspinal muscle, facet joint, and disc degeneration. *Acta Neurochir*, 2022, 164(3): 913–922. doi: [10.1007/s00701-021-05073-x](https://doi.org/10.1007/s00701-021-05073-x).
- [14] ROH Y H, LEE J C, HWANG J, *et al.* Long-term clinical and radiological outcomes of minimally invasive transforaminal lumbar interbody fusion: 10-year follow-up results. *J Korean Med Sci*, 2022, 37(13): e105. doi: [10.3346/jkms.2022.37.e105](https://doi.org/10.3346/jkms.2022.37.e105).
- [15] LI G Q, TONG T, WANG L F. Comparative analysis of the effects of OLIF and TLIF on adjacent segments after treatment of L4 degenerative lumbar spondylolisthesis. *J Orthop Surg Res*, 2022, 17(1): 203. doi: [10.1186/s13018-022-03084-7](https://doi.org/10.1186/s13018-022-03084-7).

- [16] O'CONNOR B, DROLET C E, LEVEQUE J A, *et al.* The impact of interbody approach and lumbar level on segmental, adjacent, and sagittal alignment in degenerative lumbar pathology: a radiographic analysis six months following surgery. *Spine J*, 2022, 22(8): 1318–1324. doi: [10.1016/j.spinee.2022.03.010](https://doi.org/10.1016/j.spinee.2022.03.010).
- [17] LEE G Y, LEE J W, CHOI H S, *et al.* A new grading system of lumbar central canal stenosis on MRI: an easy and reliable method. *Skeletal Radiol*, 2011, 40(8): 1033–1039. doi: [10.1007/s00256-011-1102-x](https://doi.org/10.1007/s00256-011-1102-x).
- [18] BURCH M B, WIEGERS N W, PATIL S, *et al.* Incidence and risk factors of reoperation in patients with adjacent segment disease: a meta-analysis. *J Craniovertebr Junction Spine*, 2020, 11(1): 9–16. doi: [10.4103/jcvjs.JCVJS_10_20](https://doi.org/10.4103/jcvjs.JCVJS_10_20).
- [19] JEONG T S, SON S, LEE S G, *et al.* Comparison of adjacent segment disease after minimally invasive versus open lumbar fusion: a minimum 10-year follow-up. *J Neurosurg Spine*, 2021, 36(4): 525–533. doi: [10.3171/2021.7.SPINE21408](https://doi.org/10.3171/2021.7.SPINE21408).
- [20] HEO Y, PARK J H, SEONG H Y, *et al.* Symptomatic adjacent segment degeneration at the L3-4 level after fusion surgery at the L4-5 level: evaluation of the risk factors and 10-year incidence. *Eur Spine J*, 2015, 24(11): 2474–2480. doi: [10.1007/s00586-015-4188-3](https://doi.org/10.1007/s00586-015-4188-3).
- [21] HU Y H, YEH Y C, NIU C C, *et al.* Novel MRI-based vertebral bone quality score as a predictor of cage subsidence following transforaminal lumbar interbody fusion. *J Neurosurg Spine*, 2022, 37(5): 654–662. doi: [10.3171/2022.3.SPINE211489](https://doi.org/10.3171/2022.3.SPINE211489).
- [22] CHEN Z, LEI F, YE F, *et al.* Prediction of pedicle screw loosening using an mri-based vertebral bone quality score in patients with lumbar degenerative disease. *World Neurosurg*, 2023, 171: e760–e767. doi: [10.1016/j.wneu.2022.12.098](https://doi.org/10.1016/j.wneu.2022.12.098).
- [23] MIERKE A, RAMOS O, MACNEILLE R, *et al.* Intra- and inter-observer reliability of the novel vertebral bone quality score. *Eur Spine J*, 2022, 31(4): 843–850. doi: [10.1007/s00586-021-07096-5](https://doi.org/10.1007/s00586-021-07096-5).
- [24] 王松, 张鑫, 肖箫, 等. 联合椎体骨质量构建一个新型绝经后女性骨质疏松性椎体压缩性骨折的预测模型. *骨科*, 2023, 14(5): 393–400. doi: [10.3969/j.issn.1674-8573.2023.05.001](https://doi.org/10.3969/j.issn.1674-8573.2023.05.001).
- [25] WANG S, ZHANG X, XIAO X, *et al.* Construction of a novel predictive model of vertebral compression fracture in combination with VBQ in postmenopausal women. *Orthopaedics*, 2023, 14(5): 393–400. doi: [10.3969/j.issn.1674-8573.2023.05.001](https://doi.org/10.3969/j.issn.1674-8573.2023.05.001).
- [26] CHOE H S, LEE J H, MIN D K, *et al.* Comparison of vertebral and femoral bone mineral density in adult females. *J Phys Ther Sci*, 2016, 28(6): 1928–1931. doi: [10.1589/jpts.28.1928](https://doi.org/10.1589/jpts.28.1928).
- [27] DUAN P G, MUMMANENI P V, GUINN J M V, *et al.* Is the Goutallier grade of multifidus fat infiltration associated with adjacent-segment degeneration after lumbar spinal fusion? *J Neurosurg Spine*, 2020, 34(2): 190–195. doi: [10.3171/2020.6.SPINE20238](https://doi.org/10.3171/2020.6.SPINE20238).
- [28] CHO S M, KIM S H, HA S K, *et al.* Paraspinal muscle changes after single-level posterior lumbar fusion: volumetric analyses and literature review. *BMC Musculoskelet Disord*, 2020, 21(1): 73. doi: [10.1186/s12891-020-3104-0](https://doi.org/10.1186/s12891-020-3104-0).
- [29] SAKAURA H, IKEGAMI D, FUJIMORI T, *et al.* Early cephalad adjacent segment degeneration after posterior lumbar interbody fusion: a comparative study between cortical bone trajectory screw fixation and traditional trajectory screw fixation. *J Neurosurg Spine*, 2019, 32(2): 155–159. doi: [10.3171/2019.8.SPINE19631](https://doi.org/10.3171/2019.8.SPINE19631).
- [30] LIN G X, MA Y M, XIAO Y C, *et al.* The effect of posterior lumbar dynamic fixation and intervertebral fusion on paraspinal muscles. *BMC Musculoskelet Disord*, 2021, 22(1): 1049. doi: [10.1186/s12891-021-04943-w](https://doi.org/10.1186/s12891-021-04943-w).

(2023 – 11 – 30收稿, 2024 – 08 – 15修回)

编辑 余琳



开放获取 本文使用遵循知识共享署名—非商业性使用 4.0国际许可协议(CC BY-NC 4.0), 详细信息请访问

<https://creativecommons.org/licenses/by-nc/4.0/>。

OPEN ACCESS This article is licensed for use under Creative Commons Attribution-NonCommercial 4.0 International license (CC BY-NC 4.0). For more information, visit <https://creativecommons.org/licenses/by-nc/4.0/>.

© 2024 《四川大学学报(医学版)》编辑部

Editorial Office of *Journal of Sichuan University (Medical Sciences)*