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· 论 著 ·

腰椎退变性疾病的神经功能分型及临床意义初探

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[摘要] **目的** 提出一种腰椎退变性疾病(LDD)的神经功能分型, 并初步探索其临床意义。**方法** 选取2019年3月至2020年12月海军军医大学(第二军医大学)第二附属医院骨科收治的LDD患者163例, 根据相应诊断标准分别将其分为神经根型(50例)、脊髓马尾型(42例)、混合型(38例)、马尾综合征型(7例)和局灶型(26例)。所有患者均采用改良经椎间孔入路腰椎椎体间融合术治疗, 统计分析手术临床效果和术后并发症。**结果** 术后随访时间为(19.92±4.95)个月。根据Nakai评定标准, 优68例(41.72%)、良82例(50.31%)、可8例(4.91%)、差5例(3.07%), 优良率为92.02%(150/163)。马尾综合征类型的LDD患者中手术效果差的患者比例高于其他各类型LDD, 差异有统计学意义($P < 0.05$), 其余各类型间比较差异均无统计学意义($P > 0.05$)。**结论** 根据病史及影像学资料, 术前判断LDD的神经功能分型, 有助于选择合适的手术方法并取得理想的疗效。

[关键词] 腰椎退变性疾病; 神经功能分型; 椎体间融合术; 治疗结果; 手术后并发症

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Neurological function classification for lumbar degenerative disease and preliminary exploration of its clinical significance

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[Abstract] **Objective** To propose a neurological function classification (NFC) for lumbar degenerative disease (LDD) and to preliminarily explore its clinical significance. **Methods** Totally 163 patients with LDD admitted to Department of Orthopaedics, The Second Affiliated Hospital of Naval Medical University (Second Military Medical University) from Mar. 2019 to Dec. 2020 were enrolled and divided into the following 5 types according to the corresponding diagnostic criteria: radicular type ($n=50$), spinal cord and cauda equina type ($n=42$), mixed type ($n=38$), cauda equina syndrome type (CEST, $n=7$), and focal type ($n=26$). All patients were treated with modified transforaminal lumbar interbody fusion, and the clinical effects and postoperative complications were statistically analyzed. **Results** The follow-up period was (19.92±4.95) months. According to the Nakai criteria, 68 cases (41.72%) were excellent, 82 cases (50.31%) were good, 8 cases (4.91%) were fair, and 5 cases (3.07%) were poor. The excellent and good rate was 92.02% (150/163). The proportion of patients with poor surgical effects in patients with CEST was significantly higher than those in patients with other types of LDD (all $P < 0.05$), while there was no significant difference among other types (all $P > 0.05$). **Conclusion** According to the medical history and imaging data, it is helpful to determine the NFC of LDD before operation, so as to select appropriate surgical methods and achieve ideal results.

[Key words] lumbar degenerative disease; neurological function classification; interbody fusion; outcomes; postoperative complications

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腰椎退变性疾病(lumbar degenerative disease, LDD)多发生于中老年人群, 是引起下腰痛和下肢神经功能障碍的常见原因^[1-2]。常见的LDD主要包括腰椎间盘突出、腰椎管狭窄、腰椎滑脱等

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疾病,严重影响着中老年人群的生活质量^[3-4]。非手术治疗是LDD治疗的重要手段,其可通过减轻病变部位的炎症、充血和水肿反应缓解神经组织的压迫症状,并逐步恢复腰椎的正常生物力学特性^[5-7]。对于经保守治疗后无明显改善的LDD患者,可以考虑手术治疗^[8-9]。

手术治疗可以通过减压、植骨融合和重建脊柱平衡恢复LDD患者的神经功能,改善生活质量^[10-13]。许多研究证实,与保守治疗相比,手术治疗LDD能够更好地缓解疼痛和降低患者的致残率,促进患者神经功能的康复,因此也被认为是治疗LDD的标准方案^[9,14]。LDD的诊断主要依靠影像学检查和临床症状,不同类型的LDD可能会对手术方法的选择和效果产生影响。然而,目前LDD的临床分类主要基于患者的影像学表现,如腰椎间盘突出症、腰椎管狭窄症、腰椎滑脱症等,而这些分类并不能反映神经组织本身所处的功能状态。因此,目前的LDD的分类标准对于患者手术策略的选择存在局限性,制约了手术疗效的提高。我们基于既往的临床实践和研究,根据LDD患者神经组织受累的特点和程度,提出了一种新的分类方法,即LDD的神经功能分型(neurological function classification, NFC)。本研究回顾了

应用NFC分型的LDD患者的临床数据,验证该分型方法的有效性,以期为LDD的外科治疗提供临床参考。

1 资料和方法

1.1 临床资料 回顾性分析2019年3月至2020年12月海军军医大学(第二军医大学)第二附属医院骨科收治的LDD患者的临床资料。纳入标准:

- (1) 有不同程度的下腰痛或下肢神经症状,术前MRI检查提示存在有多节段的腰椎退变性改变;
 - (2) 经6个月保守治疗后症状均无明显改善;
 - (3) 采用同一术式,且根据NFC分型采取相应的手术应对策略。
- 排除标准:(1) 有腰椎手术史或退行性腰椎侧弯、其他脊柱疾病(如感染性疾病、强直性脊柱炎、脊柱肿瘤、骨折或神经系统疾病);(2) 有心理障碍者;(3) 有外科医师认为不适合参与当前研究的其他疾病。本研究获得海军军医大学(第二军医大学)第二附属医院伦理委员会审批。

1.2 LDD的NFC及其诊断标准 根据LDD患者的神经功能状态,将NFC分为以下5种类型(图1):神经根型、脊髓马尾型、混合型、马尾综合征型和局灶型。NFC各型的诊断标准如表1所示。

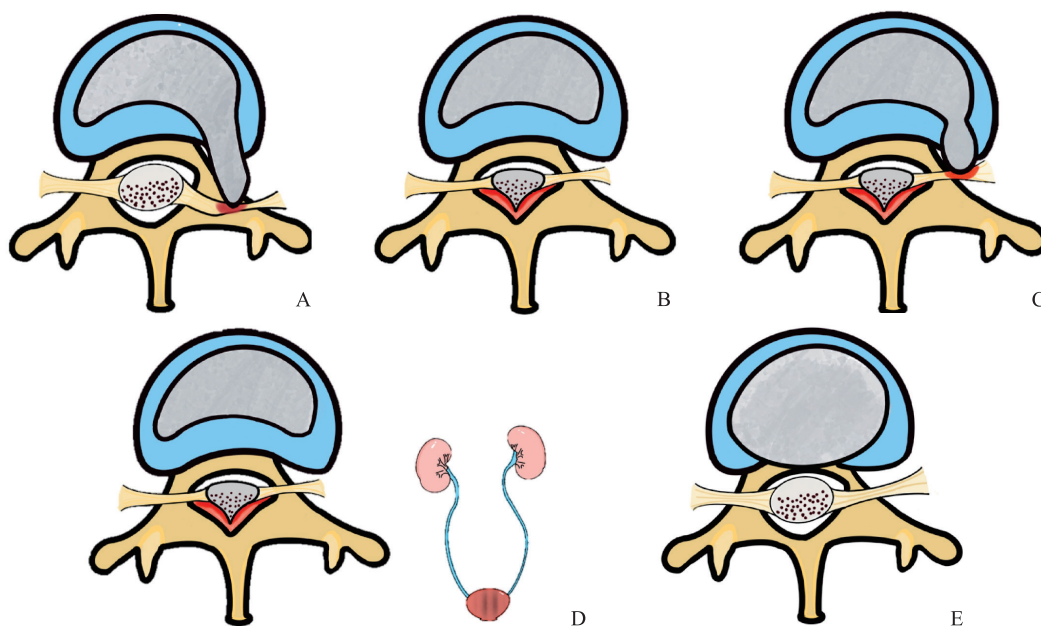


图1 LDD的NFC示意图

Fig 1 Schematic diagrams of NFC for LDD

A: Radicular type; B: Spinal cord and cauda equina type; C: Mixed type; D: Cauda equina syndrome type; E: Focal type. LDD: Lumbar degenerative disease; NFC: Neurological function classification.

表1 LDD的NFC诊断标准

Tab 1 Diagnostic criteria of NFC for LDD

Type	Diagnostic criteria
RT	(1) The patient exhibited typical radicular symptoms (numbness and pain in the lower extremities) consistent with the dermatomal distribution of the lumbar spinal nerves. Physical examination revealed a positive straight leg raising test. (2) Lumbar spine CT or MRI examination showed lateral disc herniation, lateral recess stenosis, or foraminal stenosis, among others. (3) Apart from degenerative diseases of the lumbar spine, other potential causative factors leading to similar symptoms should be ruled out.
SCCET	(1) The patient exhibited intermittent claudication, with gradually worsening numbness, pain, and fatigue in the lower limbs after physical activity, which tended to improve or disappear with rest. (2) CT and MRI showed spinal canal stenosis, characterized by a decreased anteroposterior diameter of the spinal canal, potentially caused by central-type disc herniation, spondylolisthesis, facet joint hypertrophy, ligamentum flavum thickening, among other factors. (3) In addition to degenerative diseases of the lumbar spine, other potential causative factors that could produce similar symptoms should be ruled out. (4) If there was worsening of nerve damage and the appearance of dysfunction in the sphincter muscles, it was diagnosed as cauda equina syndrome.
MT	(1) The patient presented with symptoms, physical examination findings, and imaging features consistent with both radicular and cauda equina syndrome. (2) In addition to degenerative diseases of the lumbar spine, other potential causative factors that could produce similar symptoms should be ruled out. (3) If there was worsening of nerve damage and the appearance of dysfunction in the sphincter muscles, it was diagnosed as cauda equina syndrome.
CEST	(1) Cauda equina syndrome was a relatively rare condition typically caused by large space-occupying lesions within the lumbosacral spinal canal. It was characterized by lower back pain, sciatica, sensory and motor deficits in the lower limbs, as well as dysfunction of the rectum and bladder. (2) Imaging studies may reveal features consistent with either cauda equina or conus medullaris syndrome, or a combination of both. (3) In addition to degenerative diseases of the lumbar spine, other potential causative factors that could produce similar symptoms should be ruled out.
FT	(1) The patient exhibited symptoms of lower back pain, stiffness, and muscle spasms, often accompanied by corresponding tender points. (2) CT and MRI examinations revealed degenerative changes in the lumbar spine. Additionally, findings such as lumbar instability, pars defects, fasciitis, degeneration of the intervertebral discs, or annular fissures may be observed. (3) In addition to degenerative diseases of the lumbar spine, other potential causative factors that could produce similar symptoms should be ruled out.

LDD: Lumbar degenerative disease; NFC: Neurological function classification; RT: Radicular type; SCCET: Spinal cord and cauda equina type; MT: Mixed type; CEST: Cauda equina syndrome type; FT: Focal type; CT: Computed tomography; MRI: Magnetic resonance imaging.

1.3 手术方法 本研究病例均采用改良经椎间孔入路腰椎椎体间融合术 (transforaminal lumbar interbody fusion, TLIF), 所有手术均由同一位医师完成。步骤如下: (1) 患者麻醉成功后取俯卧位。(2) 显露手术节段双侧关节突关节和椎板, 完成双侧椎弓根螺钉 (山东康盛医疗器械有限公司或大博医疗科技股份有限公司生产) 的植入。(3) 将融合侧关节突关节切除后植入合适大小的融合器。如该节段不存在椎间盘退变或不稳则不进行融合处理, 如对侧无症状则不处理, 如存在神经压迫症状则进行开窗减压。(4) 术中 X 线透视

确认螺钉和融合器位置无误后放置引流管, 冲洗后关闭切口。所有患者均于术后 5~7 d 下地活动, 配戴腰围 8~12 周。

1.4 不同 NFC 类型 LDD 手术应对策略 对于神经根型 LDD, 仅对症状侧进行单侧减压, 而对侧无症状不需要处理。对于脊髓马尾型、混合型和马尾综合征型 LDD, 由于双侧均存在神经压迫症状, 因此需要双侧减压, 我们的策略是在症状重的一侧进行融合, 症状轻的一侧仅进行开窗减压处理。对于局灶型 LDD, 根据术者的习惯可选择任意一侧进行融合处理。手术的原则是在确保解除神经压迫的

同时,最大限度地保留棘突、棘间韧带和椎板等脊柱后柱结构。

1.5 NFC判断一致性分析 选择3名住院医师进行LDD的NFC培训,向每位住院医师详细解释每种类型LDD的特定诊断标准。培训后,先测试每位医师对于NFC的掌握情况并进行修正。通过测试后,3名医师独立对符合条件的病例进行分型。3个月后,所有患者数据被随机排列并打乱顺序,然后再次进行分型。由1位独立的医师记录所有结果,用于一致性分析。

1.6 统计学处理 应用SPSS 26.0软件进行统计学分析。计量资料以 $\bar{x}\pm s$ 表示,组间比较采用方差分析;计数资料以例数和百分数表示,组间比较采用Fisher确切概率法。一致性比较采用Kappa检验,Kappa值 ≤ 0.2 为一致性较差,0.21~0.4为一致性一般,0.41~0.6为一致性中等,0.61~0.8为高度一致,0.81~1.0为几乎完全一致^[15-16]。通常认为Kappa值 > 0.6 的一致性良好的,而Kappa值 ≤ 0.4 则意味着一致性很差^[17]。检验水准(α)为0.05。

2 结果

2.1 患者的临床资料 本组病例共163例,男92例、女71例,年龄24~84岁,平均年龄(63.4 \pm 12.2)岁。其中神经根型、脊髓马尾型、混合型、马尾综合征型和局灶型分别占比30.67%(50例)、25.77%(42例)、23.31%(38例)、4.29%(7例)

和15.95%(26例)。手术单节段70例,双节段59例,3个节段及以上34例。163例患者术后均获得随访,随访时间为(19.92 \pm 4.95)个月。

2.2 手术情况 所有病例手术均获成功,神经根型平均手术时间为(136.14 \pm 23.37)min,平均出血量为(189.22 \pm 35.67)mL,平均住院时间为(11.64 \pm 3.02)d;脊髓马尾型平均手术时间为(186.90 \pm 24.45)min,平均出血量为(358.81 \pm 47.28)mL,平均住院时间为(12.26 \pm 2.82)d;混合型平均手术时间为(173.84 \pm 24.07)min,平均出血量为(407.45 \pm 50.57)mL,平均住院时间为(11.97 \pm 2.84)d;马尾综合征型平均手术时间为(195.71 \pm 10.36)min,平均出血量为(369.71 \pm 60.90)mL,平均住院时间为(13.71 \pm 2.14)d;局灶型平均手术时间为(148.46 \pm 19.64)min,平均出血量为(191.73 \pm 51.58)mL,平均住院时间为(11.12 \pm 2.29)d。以上各指标组间比较差异均无统计学意义(P 均 > 0.05)。

根据Nakai评定标准,优68例(41.72%)、良82例(50.31%)、可8例(4.91%)、差5例(3.07%),优良率为92.02%(表2)。Fisher确切概率法表明各类型组手术效果的差异有统计学意义($P=0.001$),其中马尾综合征类型的患者中手术效果差的患者比例高于其他各类型组,差异有统计学意义(P 均 < 0.05),其余各类型组间比较差异均无统计学意义(P 均 > 0.05)。

表2 根据Nakai标准评价LDD不同NFC分型患者的手术效果

Tab 2 Evaluation of surgical effects for LDD patients with various types of NFC according to Nakai criteria

Type	N	Excellent	Good	Fair	Poor	n (%)
Radicular type	50	29 (58.00)	20 (40.00)	1 (2.00)	0	
SCCET	42	16 (38.10)	23 (54.76)	2 (4.76)	1 (2.38)	
Mixed type	38	15 (39.47)	22 (57.89)	1 (2.63)	0	
CEST	7	1 (14.29)	2 (28.57)	1 (14.29)	3 (42.86)*	
Focal type	26	7 (26.92)	15 (57.69)	3 (11.54)	1 (3.85)	
Total	163	68 (41.72)	82 (50.31)	8 (4.91)	5 (3.07)	

* $P < 0.05$ vs other LDD types. LDD: Lumbar degenerative disease; NFC: Neurological function classification; SCCET: Spinal cord and cauda equina type; CEST: Cauda equina syndrome type.

2.3 术后并发症 术后并发脑脊液漏3例,深部感染2例,融合器移位1例,尿路感染2例,术后谵妄1例,肺部感染2例,下肢血栓1例,其中2例经二次手术后痊愈,余均经对症治疗后好转,患者

均顺利出院,随访期间未再复发。不同NFC类型LDD患者术后并发症情况见表3,Fisher确切概率法结果显示各类型间并发症的发生率差异无统计学意义($P > 0.05$)。

表3 不同 NFC 类型 LDD 患者的术后并发症

Tab 3 Postoperative complications of LDD patients with various types of NFC

Complication	n (%)					
	RT N=50	SCCET N=42	MT N=38	CEST N=7	FT N=26	Total N=163
Cerebrospinal fluid leak	0	2 (4.76)	1 (2.63)	0	0	3 (1.84)
Deep-seated infection	0	1 (2.38)	1 (2.63)	0	0	2 (1.23)
Cage displacement	0	1 (2.38)	0	0	0	1 (0.61)
Urinary tract infection	0	0	1 (2.63)	0	1 (3.85)	2 (1.23)
Delirium	0	1 (2.38)	0	0	0	1 (0.61)
Pulmonary infection	1 (2.00)	0	1 (2.63)	0	0	2 (1.23)
Lower limb thrombosis	1 (2.00)	0	0	0	0	1 (0.61)
Total	2 (4.00)	5 (11.90)	4 (10.53)	0	1 (3.85)	12 (7.36)

LDD: Lumbar degenerative disease; NFC: Neurological function classification; RT: Radicular type; SCCET: Spinal cord and cauda equina type; MT: Mixed type; CEST: Cauda equina syndrome type; FT: Focal type.

2.4 NFC 判断一致性 住院医师 A、B 和 C 的观察者内 *Kappa* 值分别为 0.984、0.951 和 0.968。在第 1 次分型测试中,住院医师 A 与 B 之间的观察者间 *Kappa* 值为 0.871,住院医师 A 与 C 之间的相应值为 0.879,住院医师 B 与 C 之间的相应值为 0.838。在第 2 次分型测试中,住院医师 A 与 B 之间的观察者间 *Kappa* 值为 0.894,住院医师 A 与 C 之间的相应值为 0.886,住院医师 B 与 C 之间的相应值为 0.837。上述结果表明该分型的判断一致性良好,容易掌握。

3 讨论

LDD 进展过程中主要出现退行性改变的结构包括腰椎关节突关节、黄韧带、后纵韧带、椎间盘、软骨终板、椎体后缘等^[18-20]。这些退变的组织可能会引起严重的神经压迫症状,包括下肢感觉异常、疼痛、行走困难,甚至出现鞍区感觉障碍和大小便异常等^[21-24]。对于此类患者,保守治疗后可能会获得短期的症状缓解,而从长期来看,症状还会反复发作,可能逐渐进展。因此,通过手术治疗解除神经组织的压迫往往是 LDD 患者首选的治疗方法^[25-27]。

在 LDD 的外科治疗中,通常按照疾病的病因进行分类从而选择相应手术方案,如腰椎椎间盘病、腰椎椎管狭窄及腰椎退变性滑脱等。依据病因分类固然有助于使手术医师理解 LDD 的发病机制和临床特点,但我们认为其对于手术方式的选择以及手术操作的指导意义存在局限性,并不能反映手术要解决的核心要素即受压神经组织本身的功能状态。这可能造成手术创伤的增加,相应并发症的增多,进而影响手术的疗效和患者的预后。

考虑到既往 LDD 病因学分类的不足,我们在长期临床实践的基础上提出了一种基于腰椎神经组织功能状态的新的临床分类标准,即 NFC。对于神经根型 LDD 患者,由于神经组织受压的部位主要位于腰椎椎管侧方,致压原因多为向一侧突出的椎间盘组织、侧隐窝狭窄、关节突关节增生等,而这些病理因素主要影响了神经根走行的路径,因此患者主要表现为下肢神经根性症状。临床上多见于侧方型和极外侧型腰椎间盘突出患者。手术方式的选择可以根据具体致压物的性质选择 TLIF、微创经椎间孔入路腰椎椎体间融合术 (minimally invasive transforaminal lumbar interbody fusion, misTLIF)、椎间孔镜手术等方式,主要减压范围应围绕神经根走行的部位,而对于无症状的对侧和椎管中央后部结构包括棘突、椎板等应予以保留,在确保手术疗效的同时可以有效减少手术并发症。

脊髓马尾型 LDD 受压部位主要位于椎管中央,圆锥以上主要受压的是脊髓组织,圆锥以下受压的则是马尾神经。临床上常见的是腰椎椎管狭窄、中央型腰椎间盘突出症患者。主要临床表现为椎管中央神经组织受压所致的间歇性跛行症状。手术方式的选择我们采用 TLIF 或后路腰椎椎体间融合术 (posterior lumbar interbody fusion, PLIF),术中通常进行双侧开窗减压,而椎管中央后部结构通常予以保留以减少手术创伤。混合型 LDD 则兼有前述 2 种类型 LDD 的临床特点,致压物的来源呈多样化,临床上多见于老年长节段 LDD 患者,此类患者通常存在腰椎多个节段受累,合并退变导致的腰椎管狭窄和椎间盘突出,即有椎管中央部位的神经组织压迫,同时亦存在侧方神经根通路受累

引起的下肢根性症狀。此類患者由於年齡大,手術節段長,往往存在基礎疾病,因此手術併發症發生率相對較高。我們對此類患者的手術策略是對每個手術節段進行細分,如為神經根型,則進行症狀側減壓,如為脊髓馬尾型,則進行雙側開窗減壓,如兩者兼而有之,則在神經根受壓的一側擴大減壓範圍,需確保神經根袖部位獲得徹底的松解。

馬尾綜合症型是LDD的一種特殊類型,通常見於嚴重的腰椎間盤脫出或腰椎椎管狹窄患者。由於神經組織損害嚴重,患者表現為大小便功能障礙,即臨床上俗稱的馬尾綜合症。此類患者通常需要採用TLIF或PLIF進行徹底的神經組織減壓,术中應仔細探查有無神經組織的粘連,避免醫源性損傷。本研究納入的馬尾綜合症型手術病例中,按照Nakai評定標準,有42.86%(3/7)的患者手術效果欠佳,其比例顯著高於其他各型患者($P<0.05$)。這可能與馬尾綜合症型患者病程時間較長且神經壓迫程度較重有關。臨床上值得關注的是此類患者通常需要急診盡早手術,如果神經組織出現不可逆損傷,通常預後較差。

局灶型LDD患者表現為腰痛,通常無下肢神經壓迫症狀。此類患者影像學檢查神經組織無明顯累及,可有腰椎局部節段不穩,椎間盤磁共振成像T2信號減低、纖維環撕裂等表現。臨床上常見於盤源性腰痛、腰椎峽部裂、滑脫、腰椎不穩的患者。我們認為對於反復性腰痛發作,保守治療半年以上無明顯改善,嚴重影響生活質量的局灶型LDD患者應進行手術治療,手術方式應根據致病因素的特點選擇,包括腰椎固定融合或微創手術等。

在本研究中,我們基於長期的臨床實踐提出了一種新的腰椎神經功能分型,即NFC。NFC有助於手術醫師根據患者神經組織所處的功能狀態,更加科學地選擇合適的手術方法,從既往關注LDD的病因轉變為更多關注受壓神經組織本身所處的狀態,從而更好地提高手術方式選擇的針對性,提高手術療效。

本研究仍存在一定的局限性,研究對象隨訪期較短、病例數較少,這可能會對研究結果造成一定的偏倚。為了更準確地評估NFC的應用效果,今後需要進行更大規模的研究並延長隨訪時間。本研究為單中心研究,這可能存在樣本選擇偏倚和地域差異等問題,今後將開展多中心研究,進一步驗證LDD的NFC分型的有效性。

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