表2　処方の実際

1．腰痛や殿部から下肢の痛み（坐骨神経痛）を呈する症例に対して	2．殿部から下肢のしびれや間欠跛行を呈する症例に対して
処方例 ①セレコックス（100 mg）2T分2 ミオナール（50 mg）3T分3 ②ロルカム（4 mg）3T分3 ムコスタ（100 mg）3T分3 ③ロキソニン（60 mg）3T分3 セルベックス（50 mg）3C分3 ④ボルタレンサポ（25, 50 mg）頓用あるいは朝・夕定時使用 処方①, ②, ③のいずれかを用いて, 処方④は適宜追加する. ミオナールの代わりにテルネリン（1 mg）3T分3, アロフト（20 mg）3T分3などでもよい. ②, ③に筋弛緩薬を併用してもよい.	処方例 ①アンプラーグ（100 mg）3T分3 メチコバール（500 μg）3T分3 ユベラN（200 mg）3T分3 ②オパルモン（5 μg）3〜6T分3 ノイロトロピン（4単位）4T分2 ③リリカ（75 mg）2T分2
3．下肢のこむら返りやけいれんに対して	4．1, 2, 3の症状に対する処方が無効な腰痛や下肢の痛みやしびれに対して
処方例 ①プレタール（100 mg）2T分2 ②芍薬甘草湯（2.5 g）1P分1就寝前あるいは2P分2（朝, 夕） ③ノイロトロピン（4単位）4T分2	処方例 ①リボトリール（0.5 mg）1T分1就寝前 トリプタノール（10 mg）1T分1就寝前 ②オピオイド鎮痛剤やトラムセット配合錠 ①②のどちらかを追加処方する.

て有効であると報告されている.

8．神経障害性疼痛治療薬

プレガバリン（リリカ®）

本剤は2007年に欧米で認可を得て, 本邦では2010年に認可を得て市場に急速に普及している神経障害性疼痛をターゲットとした今日もっとも注目を集めている薬剤である. 従来の薬剤とは異なる作用機序を持ち, 神経シナプスにおいてCa^{2+}チャンネルの$\alpha_2\delta$サブユニットへの高い結合親和性により, Ca^{2+}のシナプス末端への流入を低下させ, 興奮性神経伝達物質の過剰放出を抑制することで, 過剰興奮したニューロンを鎮静化し鎮痛作用を発揮する. 帯状疱疹後神経痛や糖尿病性末梢神経障害による疼痛だけでなく, 腰部脊柱管狭窄症による神経障害にも有効である.

9．オピオイド鎮痛薬

本邦では今日までNSAIDsが広く用いられてきたが, 近年では非オピオイド鎮痛剤で治療困難な慢性疼痛に対してオピオイド鎮痛剤も用いられる傾向にある. 今後は患者の病態に合わせて使用される頻度が増加すると思われる. ただし, 血中濃度の慎重なコントロールと副作用対策が必要である.

①フェンタニル（デュロテップ®パッチ）

3日に1回貼付する経皮吸収型持続性疼痛治療剤である. モルヒネから切り替えられる場合が多い（オピオイドローテーション）.

②ブプレノルフィン（ノルスパンテープ®）

週に1回貼付する非常に簡易型の経皮吸収型持続性疼痛治療剤である.

10．湿布剤・塗布剤

ともに疼痛部位に直接貼布（塗布）できることから, 迅速に局所の消炎・鎮痛効果が得られやすい. 副作用も少ないため, 使用しやすい製剤である.

11．その他

①ノイロトロピン（ノイロトロピン®）

本剤はワクシニアウイルスを接種した兎の炎症皮膚組織から抽出分離された生体活性物質を成分とする鎮痛薬である. NSAIDsやオピオイドと異なり, プロスタグランジン産生系やオピオイド系に作用せずに, 鎮痛作用を示す. したがって,

これらの薬剤との併用により相加的な鎮痛作用が得られる．特に慢性絞扼性神経障害に対して優れた効果を示し，腰部脊柱管狭窄症による下肢の痛みやしびれに対する有効性も報告されている．

② トラマドール塩酸塩とアセトアミノフェンの配合（トラムセット®配合錠）

トラマドール塩酸塩は非麻薬性オピオイドで，μオピオイド受容体に対する作用およびモノアミン再取り込み阻害作用により，鎮痛効果を示す．アセトアミノフェンは1940年代から汎用されているアニリン系解熱鎮痛剤で，末梢でのシクロオキシゲナーゼ阻害作用は弱く，主に中枢神経系で鎮痛作用を示す．作用機序の異なる2剤の併用により，侵害受容性疼痛と神経障害性疼痛の両方に有効性が期待できる．

まとめ

腰部脊柱管狭窄症の薬物治療について述べた．腰部脊柱管狭窄症における症状は多彩であるが，薬物治療によりそれらの症状の改善が得られることも少なくない．処方においては個々の患者の病態に合わせた適切な薬物選択をすることが重要である．一方で薬物療法を含む保存療法に固執するあまり手術のタイミングを逃し，不可逆的な神経障害を発症させることは避けなければならない．

文 献

1）Matsumoto M, Watanabe K, Tsuji T, et al.：Nocturnal leg cramps：a common complaint in patients with lumbar spinal canal stenosis. Spine（Phila Pa 1976）34：E189-194, 2009
2）石井　賢，戸山芳昭：疾患と治療．石黒直樹，他編：ファーマナビゲーター COX-2 阻害薬編．メディカルレビュー社，東京，2006
3）石井　賢，千葉一裕：腰部脊柱管狭窄の診断．菊地臣一編：プライマリケアのための腰部脊柱管狭窄―外来マネージメント．医薬ジャーナル社，大阪，2004
4）石井　賢，千葉一裕：内科医が知っておきたい他科疾患―整形外科疾患―．クリニカル プラクティス 24：1039-1042, 2005

■原著論文

腰椎変性すべり症に対する棘突起縦割式椎弓切除術の治療成績

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抄録：腰部脊柱管狭窄症90例（LCS群）と術前に%slip 10%以上の前方すべりを認めた55例（DS群）を対象に，縦割術の治療成績を検討した．DS群で平均1.5%の%slipの進行を認めたが，術後2年時の平均JOAスコア改善率はDS群74.7±25.0%，LCS群68.7±25.4%で，両群間に有意差は認めなかった．高齢者のDSに対する縦割術は，有効な治療法と考えられた．

＊ Lumbar spinous process-splitting laminectomy for degenerative spondylolisthesis

Key words：lumbar spinous process-splitting laminectomy 腰椎棘突起縦割式椎弓切除術，degenerative spondylolisthesis 変性すべり症，lumbar spinal canal stenosis 腰部脊柱管狭窄症

背　景

腰部脊柱管狭窄症（以下LCS）に対する後方除圧術は，多くの脊椎外科医に用いられてきた最も一般的な手術手技の一つで，その術後成績はおおむね良好である．しかし，腰椎変性すべり症（degenerative spondylolisthesis; DS）によるLCS例に対する手術治療では，後方除圧術のみか固定術を併用するか（除圧固定術），いまだ議論がつきない．高齢者では全身合併症を伴う場合が多いことから，DSを合併したLCSに対しても，われわれは可能な限り侵襲のより少ない後方除圧術を選択してきた．本研究の目的は，65歳以上で，%Slip 10%以上のDS例に対する腰椎棘突起縦割式椎弓切除術（縦割術）による後方除圧術の治療成績を検討することである．

方　法

2005年1月～2006年12月に，65歳以上でLCSに対して縦割術による後方除圧術を行った194例のうち，術後2年以上経過観察が可能であった145例（男性94人，女性51人，平均年齢73±6歳）を対象とした（follow-up率74.7%）．当科でのLCSに対する後方除圧術の適応は1）当該椎間の%slipが20%以下，2）側方すべりを認めない，3）後方開大10度以下，としてきた．さらに上記に当てはまらない不安性を伴う症例でも，糖尿病，心臓疾患（高血圧は除く）などの合併症がある症例，または破壊性脊椎関節症例では，縦割術を適応した症例もあった．合併症の定

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義は，疾患の周術期管理を他科に依頼する必要があるものとした．これらの症例のうち，%slip 10%以上の前方すべりを認めた症例は55例（DS群）で，それ以外は90例（LCS群）であった．これらの症例を対象に1）術前のすべりの有無，2）術前の%slip，3）術後の%slip進行，4）術前の後方開大および椎間可動域を調査しJOAスコアで評価した臨床成績との関連を検討した．さらに5）術前椎間可動域と術後2年時の%slipの進行との関係についても検討した．%slipおよび後方開大角は臥位前屈単純X線側面像で計測した．椎間可動域は臥位前後屈位単純X線側面像における当該椎間の角度の差より算出した．なお，57例（39.3%）に重篤な術前合併症を認め，その内訳は，心疾患（狭心症，不整脈）22例，糖尿病22例，悪性腫瘍10例，脳梗塞後4例，腎不全3例であった．

手術方法：L4/5に対する除圧術の場合，L4棘突起先端を露出し，棘突起を縦割する．メスでL3/4，L4/5の棘上・棘間靱帯も縦割し，コブまたはノミを用いて棘突起基部から分離させ，付着する傍脊柱筋と棘上・棘間靱帯とともに左右に圧排し，L4椎弓およびL4/5の除圧部を展開する（図1）．エアトームで黄色靱帯の周囲を掘削して，黄色靱帯の露出と切除を行う．外側陥凹部を対側よりノミでトランペット型に切除して，同部を除圧する．除圧終了後は，縦割した棘突起を締結・再建する．

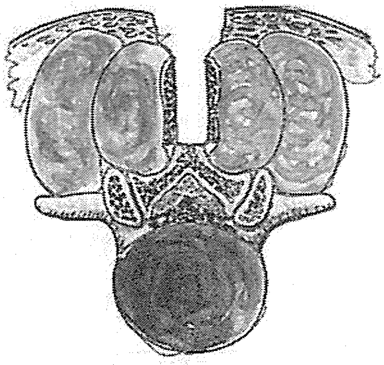

図1 腰椎棘突起縦割式椎弓切除
縦割した棘突起を，付着する傍脊柱筋と棘上・棘間靱帯とともに左右に圧排し，椎弓を展開する．除圧終了後は，縦割した棘突起を締結・再建する．

術前後のJOAスコアの比較，術前後の%slipの比較ではpaired t-testを，DS群とLCS群のJOAスコアおよび改善率の比較ではstudent t-testを使用した．そして$p<0.05$を有意差ありとした．術前%slipとJOAスコア改善率，術前後方開大角および椎間可動域と術後2年のJOAスコア改善率，術前椎間可動域と術後2年時の%slipの関連性の検討では，回帰分析を用いた．なお，上記の検討の際はSPSS ver. 16.0を使用した．

結　果

全症例の平均JOAスコアは術前14.5±4.6点が術後2年時には24.8±4.2点に有意に改善し（$p<0.001$），平均改善率は71±25%であった．術後合併症は25例（17.2%）に発生し，その内訳は，術後血腫9例（6.2%），硬膜損傷5例（3.4%），創癒合不全3例（2.0%），一過性神経麻痺1例，創感染1例であった．同一椎間に対する再手術例は4例（2.8%）で，DS群では除圧椎間が原因で腰下肢痛が再発した1例に対し固定術を施行した．LCS群では除圧椎間の腰椎椎間板ヘルニア摘出術を2例に，椎間関節嚢腫切除を1例に施行した．

1．術前すべりの有無

DS群の平均JOAスコアは，術前14.8±4.4点から術後2年時には25.2±4.7点に，有意に改善した（$p<0.001$）．LCS群の平均JOAスコアは，術前14.4±4.7点から術後2年時には24.5±3.9点に，有意に改善した（$p<0.001$）．術前JOAスコア，術後2年時のJOAスコアに関し，両群間で有意差はなかった．2年時の平均改善率はDS群74.7±25.0%，LCS群68.7±25.4%で，両群間に有意差はなかった．

2．術前%slip（図2）

術前%slipが増加するに従って，術後2年時のJOAスコア改善率が低下する負の相関を認めた（$R=0.41$）．

3．術後%slip進行

DS群の術前平均%slipは17.3±5.3%（10-32%）で，術後2年時には18.8±5.9%（12-35%）へ有意に進行した（$p=0.04$）．DS群で%slipが5%

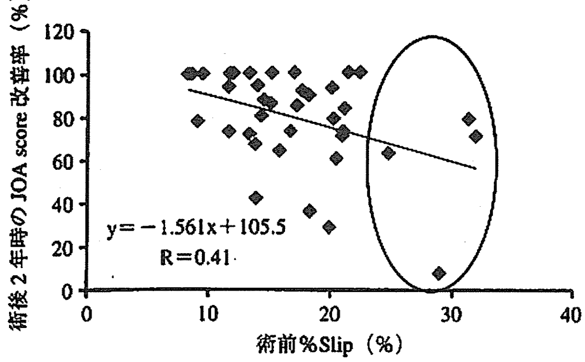

図2　術前の%slipと術後2年時のJOAスコア改善率
術前%slipと術後2年時のJOAスコア改善率との間に負の相関を認めた（R=0.41）．術前%slipが25%を超えると，改善率が大きく低下する傾向を認めた．

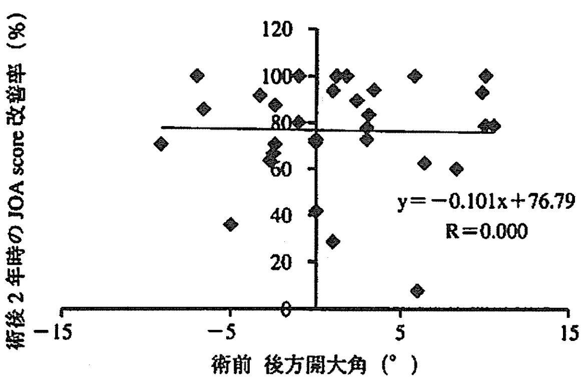

図3　術前の後方開大角と術後2年時のJOAスコア改善率．術前の後方開大角と術後2年時のJOAスコア改善率の間に，有意な相関は認めなかった．

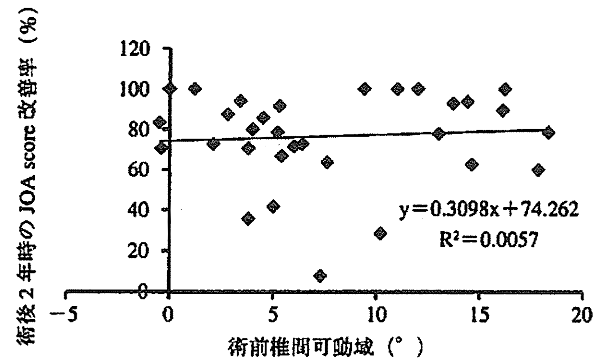

図4　術前の椎間可動域と術後2年時のJOAスコア改善率．術前の椎間可動域と術後2年時のJOAスコア改善率の間に，有意な相関は認めなかった．

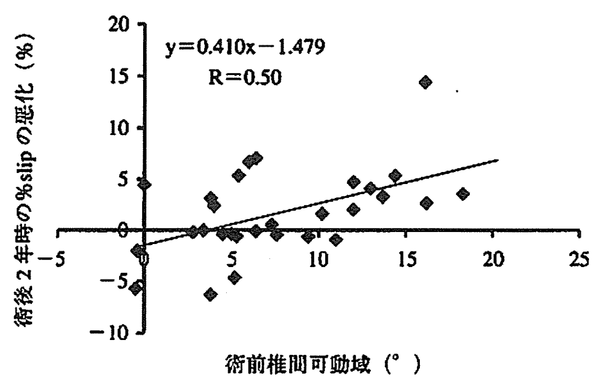

図5　術前椎間可動域と術後2年時の%slip悪化
術前椎間可動域と術後2年時の%slip悪化との間に，R=0.50の正の相関を認めた．

以上進行した5例の術後2年時の平均改善率は68.2±26.3%で，5%未満の50例（平均改善率71.1±24.0%）と同等であった．

4．術前後方開大角（図3）および椎間可動域（図4）

術前の当該椎間の後方開大角および椎間可動域と，術後2年時のJOAスコア改善率との間に，有意な相関はなかった．

5．術前椎間可動域と術後2年時の%slipの悪化（図5）

術前椎間可動域と術後2年時の%slipの進行との間に，R=0.5の正の相関を認めた．

考　察

DSを伴ったLCSに対する除圧術と除圧固定術の適応に関しては，いまだ結論は出ていない．しかし，明らかな不安定性を有する場合は，除圧固定術が除圧術より良好な成績であると考えられている[2,4,5,10,24]．しかし，そのなかで前向き無作為化対象試験を実施したのはHerkowitzとKurzらによる除圧術と除圧固定術を比較した報告だけであり[5]，高いエビデンスが示されている報告は少ない．一方，DSに対する除圧術の有効性を報告した論文も散見される[3,8,11,23]．われわれは全身合併症を有する割合が大きい高齢者には，DSでも後方除圧術で十分に対応できると考えてきた．

本研究結果では，DS群の%slipは術前17.3±5.3%から術後2年時には18.8±5.9%へ，平均1.5%の有意なすべりの進行を認めたが，DS群とLCS群の術後2年時のJOAスコアまたはJOAスコア改善率は同等であった．さらに，5%以上のすべりの進行を5例に認めたが，それらの症例の術後2年時のJOAスコア改善率は，それ以外の

症例と同等であった．またDS群において，当該部位が原因の下肢痛の再発に対する固定術施行例が1例あったが，DS群での再手術例はこの1例のみで，術後成績はおおむね良好であった．以上の結果より，DSを伴ったLCSに対する縦割法を用いた後方除圧術は，DSを合併しないLCSと同等の術後成績が期待できると考えられた．

本研究の結果，術後の%slip悪化は術後成績不良因子とはならなかったが，術前%slipが大きい症例ほど，術後成績は低下する傾向を認めた．特に25%を超える症例では，術後2年時のJOAスコアが大きく低下しており，固定術適応の一つの指標になると考えられた．しかし，本研究に含まれている%slipが20%を超える症例は，ほとんどが何らかの全身合併症を有する症例である．そのため，これらの症例に対する固定術の適応は，術前%slipの程度だけでなく，手術侵襲や術後合併症の可能性も含め，慎重に検討する必要があると考えられた．

術前の椎間可動域や後方開大角が，術後成績不良因子および固定術の適応の指標と報告されている[14,16,18,19]．しかし，本研究においては，術前後方開大角，術前椎間可動域と術後JOA改善率との間には有意な関係は認めなかった．一方，術前椎間可動域と術後のすべりの悪化には$R=0.5$の相関を認めたが，術後のすべりの悪化は術後JOA改善率と相関は認めなかった．高齢者の場合，当該椎間の術前椎間可動域および後方開大角を固定術適応の指標とすべきかどうかは，さらなる検討を要すると考えられた．

われわれはLCSに対し，脊柱および傍脊柱の後方支持組織の温存を目的として「腰椎棘突起縦割式椎弓切除術」（縦割術）を施行し，良好な成績を報告してきた[6,20-22]．縦割術の利点として，術後創部痛の軽減[1,9,15,21]，傍脊柱筋の温存[20,21]が挙げられる．教室の飯塚らは，DSに対する縦割術後は%slipや椎間可動域は増大するが，棘上/棘間靱帯を犠牲にする従来の手技と比較すると，これらの不安定性の悪化は予防できていたと報告した[6]．そもそもDSでは，すべりは自然経過でも進行し[12,13]，内視鏡や顕微鏡などを駆使した低侵襲手術後でも，ある程度の術後不安定性の増大は避けられない[7,17]．そのため，DSに対する後方除圧術の成績向上のためには，後方支持組織を温存して術後の脊柱不安定性増大を最大限予防することはもちろんであるが，ある程度，術後の不安定性増大を想定して，神経除圧を行う必要があると考える．縦割術では反対側から外側陥凹部への良好な視野が得られ，working spaceも豊富であるから，同部の十分な除圧が容易であり，有効な方法であると考えられた．

まとめ

65歳以上のDSに対する縦割術後2年時，%slipの有意な悪化を認めたが，JOAスコアおよびその改善率はLCSと同等であった．高齢者のDSを伴うLCSでは縦割術による後方除圧術は有効な治療法と考えられた．

文献

1）網代泰充，徳橋泰明，古賀昭義，ほか：棘突起縦割進入法による腰椎椎弓切除術．東日本整災会誌，19：141－145，2007．

2）Bridwell, K.H., Sedgewick, T.A., O'Brien, M.F., et al.: The role of fusion and instrumentation in the treatment of degenerative spondylolisthesis with spinal stenosis. J. Spinal Disord., 6: 461－472, 1993.

3）Cornefjord, M., Byrod, G., Brisby, H., et al.: A long-term (4- to 12-year) follow-up study of surgical treatment of lumbar spinal stenosis. Eur. Spine J., 9: 563－570, 2000.

4）Ghogawala, Z., Benzel, E.C., Amin-Hanjani, S., et al.: Prospective outcomes evaluation after decompression with or without instrumented fusion for lumbar stenosis and degenerative Grade I spondylolisthesis. J. Neurosurg. Spine, 1: 267－272, 2004.

5）Herkowitz, H.N. and Kurz, L.T.: Degenerative lumbar spondylolisthesis with spinal stenosis. A prospective study comparing decompression with decompression and intertransverse process arthrodesis. J. Bone Joint Surg. Am., 73: 802－808, 1991.

6）飯塚慎吾，渡辺航太，松本守雄，ほか：腰

椎変性すべり症に対する棘突起縦割式椎弓切除術の検討. 日脊椎脊髄病会誌, 19：421, 2008.

7) Ikuta, K., Tono, O. and Oga, M.: Clinical outcome of microendoscopic posterior decompression for spinal stenosis associated with degenerative spondylolisthesis —minimum 2-year outcome of 37 patients. Minim. Invasive Neurosurg., 51: 267-271, 2008.

8) Katz, J.N., Lipson, S.J., Lew, R.A., et al.: Lumbar laminectomy alone or with instrumented or noninstrumented arthrodesis in degenerative lumbar spinal stenosis. Patient selection, costs, and surgical outcomes. Spine (Phila Pa 1976), 22: 1123-1131, 1997.

9) 喜多寛俊, 中村潤一郎, 佐々木 淳, ほか：マイクロボーンソーを用いた棘突起正中縦割進入法による腰椎椎弓切除術の経験. 東日本整災会誌, 18：405-408, 2006.

10) Mardjetko, S.M., Connolly, P.J. and Shott, S.: Degenerative lumbar spondylolisthesis. A meta-analysis of literature 1970-1993. Spine (Phila Pa 1976), 19: 2256S-2265S, 1994.

11) Matsudaira, K., Yamazaki, T., Seichi, A., et al.: Spinal stenosis in grade I degenerative lumbar spondylolisthesis: a comparative study of outcomes following laminoplasty and laminectomy with instrumented spinal fusion. J. Orthop. Sci., 10: 270-276, 2005.

12) Matsunaga, S., Ijiri, K. and Hayashi, K.: Nonsurgically managed patients with degenerative spondylolisthesis: a 10- to 18-year follow-up study. J. Neurosurg., 93: 194-198, 2000.

13) Matsunaga, S., Sakou, T., Morizono, Y., et al.: Natural history of degenerative spondylolisthesis. Pathogenesis and natural course of the slippage. Spine (Phila Pa 1976), 15: 1204-1210, 1990.

14) 中山潤一, 井口哲弘, 栗原 章, ほか：【脊椎外科最近の進歩】腰部脊柱管狭窄症に対する非固定広範椎弓切除術の術後10年以上の超長期成績. 臨整外, 35：497-501, 2000.

15) 小倉 卓, 長谷 斉, 池田 巧, ほか：棘突起正中縦割進入法による腰椎椎弓切除術. 脊椎・脊髄神経手術手技, 6：124-127, 2004.

16) 佐久間吉雄, 玄 奉学, 河野 裕, ほか：腰椎内視鏡下除圧術における術後成績不良となる危険因子の検討. J. Spine Res., 1：1354-1359, 2010.

17) Sasai, K., Umeda, M., Maruyama, T., et al.: Microsurgical bilateral decompression via a unilateral approach for lumbar spinal canal stenosis including degenerative spondylolisthesis. J. Neurosurg. Spine, 9: 554-559, 2008.

18) 高森義博, 有水 淳, 伊崎輝昌, ほか：腰椎変性すべり症に対する後方除圧術の術後成績. 整形外科, 59：1077-1080, 2008.

19) 徳橋泰明, 松崎浩巳, 若林 健, ほか：【脊椎外科最近の進歩】腰椎すべり症に対するpedicle screw fixationの10年以上経過例. 臨整外, 35：473-480, 2000.

20) Watanabe, K., Hosoya, T., Shiraishi, T., et al.: Lumbar spinous process-splitting laminectomy for lumbar canal stenosis. Technical note. J. Neurosurg. Spine, 3: 405-408, 2005.

21) Watanabe, K., Matsumoto, M., Ikegami, T., et al.: Reduced postoperative wound pain after lumbar spinous process splitting laminectomy for lumbar spinal canal stenosis —A randomized controlled study. J. Neurosurg. Spine, in press.

22) 渡辺航太, 細谷俊彦, 白石 建：手術手技 私のくふう 腰部脊柱管狭窄症に対し後方軟部支持組織を温存する術式 棘突起縦割式椎弓切除術. 臨整外, 38：1401-1406, 2003.

23) 山崎 健, 村上秀樹, 吉田知史, ほか：【脊椎疾患における鑑別診断と治療法選択の根拠】治療法選択とその根拠 腰椎 変性すべり 腰椎変性すべり症の術後成績と満足度 固定群・非固定群の比較. 別冊整形外, 50：200-206, 2006.

24) Yone, K. and Sakou, T.: Usefulness of Posner's definition of spinal instability for selection of surgical treatment for lumbar spinal stenosis. J. Spinal Disord., 12: 40-44, 1999.

Lumbar spinous process-splitting laminectomy for degenerative spondylolisthesis

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Abstract: Lumbar spinous process splitting laminectomy (split laminectomy) was developed to reduce intraoperative damages to posterior supporting structures of the lumbar spine during decompression surgery for lumbar spinal canal stenosis (LCS). The purpose of this study was to evaluate postoperative 2 years radiological and clinical outcomes of split laminectomy for degenerative spondylolisthesis (DS) in comparison with LCS. Fifty-five DS patients and ninety LCS patients were included in this study. A mean age at the time of surgery was 73±6 years. In split laminectomy, spinous process was spilt with paraspinal muscles kept attached. The mean preoperative JOA score of 14.4±4.7/29 points in LCS group significantly recovered to 24.5±3.9/29 points with the mean recovery rate of 68.7±25.4% ($p<0.001$). Though the mean preoperative %slip of 17.3±5.3% in DS group was significantly increased to 18.8±5.9% postoperatively, the mean preoperative JOA score of 14.8±4.4/29 points in DS group significantly recovered to 25.2±4.7/29 points with the mean recovery rate of 74.7±25.0% ($p<0.001$). No significant differences were recognized between the two groups. One patient in DS group underwent reoperation for recurrence of lower extremity pain. Postoperative 2 years clinical and radiological results of split laminectomy for DS were favorable. Split laminectomy may be effective and less invasive surgery for patients with DS.

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Nocturnal Leg Cramps

A Common Complaint in Patients With Lumbar Spinal Canal Stenosis

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Study Design. Questionnaire survey on leg cramps for patients with lumbar spinal canal stenosis (LCS).

Objective. To evaluate the prevalence of leg cramps in patients with LCS treated surgically and the relationship between leg cramps and the surgical outcomes.

Summary of Background Data. Although it has been anecdotally reported that LCS patients have suffered from leg cramps, the true prevalence remains unknown.

Methods. One hundred twenty LCS patients who underwent decompression surgery (men 85, women 35, mean age 73.5) and 370 elderly subjects from the general population (men 162, women 208, mean age 75.6) were enrolled in the study. The participants filled in a questionnaire regarding: (all participants) (1) experience of leg cramps, (2) frequency and time of the day of the cramp attacks; (for LCS patients only), (3) changes in cramps before and after surgery, (4) activities of daily living disturbance because of leg cramps, (5) satisfaction with surgery and walking ability, (6) the Roland-Morris Disability Questionnaire, and (7) the Oswestry Disability Index.

Results. Eighty-five (70.8%) patients with LCS and 137 (37.2%) of the control population experienced leg cramps (age and sex adjusted odds ratio; 4.6, $P < 0.01$). Leg cramps occurred once or twice a week in 34.9% of the LCS group and once in several months in 44.5% of the control group, and occurred nocturnally in 73.3% of the LCS patients and in 91.6% of the control group. In LCS patients, leg cramps improved after surgery in 18.2%, remained unchanged in 45.5%, and worsened in 26.1%, and activities of daily living were disturbed in 47.6%. There was no significant difference in satisfaction with surgery, the Oswestry Disability Index, the Roland-Morris Disability Questionnaire scores, or walking ability between the LCS patients with or without leg cramps.

Conclusion. LCS patients had significantly more frequent attacks of nocturnal leg cramps than the control population, and leg cramps disturbed the quality of the patients' life, and they rarely improved after decompression surgery. Leg cramps should be recognized as one of the symptoms of LCS, which disturb the patients' quality of life.

Key words: leg cramp, lumbar spinal canal stenosis, decompression surgery, nocturnal. **Spine 2009;34: E189–E194**

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Neurogenic claudication, back and leg pain are the most common symptoms in patients with lumbar spinal canal stenosis (LCS), and they can be managed successfully by aggressive conservative treatments and/or surgery in the majority of patients. In addition to these frequently observed symptoms, patients with LCS sometimes complain of paresthesia, chillness, and restless leg sensation in their lower extremities, which have not, to date, attracted wide attention of spine care professionals. One of such complaints is leg cramps, which are acute involuntary painful contractions of the muscles in the lower extremities, and are likely to affect the elderly population as well as athletes and pregnant women.[1–6] Several general population surveys have reported that leg cramps occur in 38% to 50% of the elderly population.[1–4] Although their etiology remains to be clarified, leg cramps have been reported to be associated with neuromuscular diseases, diabetes, hyperthyroidism, hypertension, hypocalcaemia, hypokalaemia, vascular diseases, and some medications including diuretics, statins, steroids, and nifedipine, β-blockers, and so on.[2,6,7] To date, there have been few reports regarding the relationship between leg cramps and LCS, and it remains unknown whether surgical interventions have any impact on leg cramps in patients with LCS.

The purpose of this study was to elucidate the prevalence of leg cramps in patients with LCS and the relationships between leg cramps and the outcome of surgery in such patients. Our hypotheses are that the prevalence of leg cramps is higher in patients with LCS than the general population, and that surgery improves leg cramps.

Materials and Methods

During the period from 2000 to 2006, 271 patients with LCS underwent 1- or 2-level posterior decompression surgery without fusion. Of these patients, those who satisfied the following criteria were included in this study: (1) Patients with typical signs and symptoms of LCS (leg pain, neurogenic claudication) that was confirmed on magnetic resonance imaging and myelography; (2) those without any history of previous lumbar spine surgeries; (3) those without severe scoliosis (Cobb angle >20°) or spondylolisthesis (% slip >20%) which required instrumented fusion; and (4) those without any history of neuromuscular diseases such as cerebral palsy, congenital, and acquired myopathy, *et cetera*. These criteria were satisfied by 201 patients, to whom the questionnaire was mailed, inviting them to participate in this study.

Three hundred seventy elderly subjects from the general population without any history of back surgery, who had undergone a general health checkup and completed the questionnaire served as the controls. All participants in both groups filled in the questionnaire regarding: (1) Experience of leg cramps; (2) frequency and time of the day of cramp attack; (3) area of cramps; and (4) walking ability. Only the LCS patients filled in the questionnaire regarding: (5) changes in cramps before and after surgery; (6) residual sciatica (evaluated by visual analogue scale, VAS 0–100 points) and numbness in the legs and feet; (7) activities of daily living (ADL) disturbance by leg cramps; (8) satisfaction with surgery; (9) the Roland-Morris Disability Questionnaire (RDQ)[8]; (10) the Oswestry Disability Index (ODI)[9];and (11) treatment for leg cramps (Table 1). A part of the questionnaire was originally developed for this survey by a group of orthopedic surgeons and public health scientists. Association of diabetes mellitus and hypertension, which are the most common comorbidities of elderly people and which have been reported to be associated with leg cramps[6,7,10] were also investigated. For the LCS patients, charts were also reviewed regarding surgical methods, medications, and perioperative complications.

Statistical Analyses

Stata9 software (Stata Corp., College Station, TX) was used for statistical analyses. The χ^2 test and a logistic regression analysis were used as the statistical tests to compare the difference in the prevalence of leg cramps between the LCS patients and the control population. A P value less than 0.05 was considered statistically significant.

Results

Comparison Between the LCS and Control Group

One hundred twenty LCS patients who responded to the mail were finally included to the present study. There were 85 men and 35 women with a mean age of 73.5 ± 8.0 years. The mean follow-up period after surgery was 3.6 ± 1.9 years (Table 2). In the control group, there were 162 men and 208 women with a mean age of 75.6 ± 6.5 years. There was a statistically significant difference in the male to female ratio, between the LCS patient group and the control group ($P < 0.001$). Eighty-five (70.8%) patients with LCS and 137 (37.2%) of the controls experienced leg cramps (age and sex adjusted odds ratio; 4.6, 95% confidence interval; 2.87–7.35, $P <$ 0.001) (Table 3). Regarding comorbidities, hypertension was observed in 35.8% of the LCS patients and 41% of the control subjects (P = 0.39), and diabetes in 14.2% and 6.2%, respectively (P = 0.014). When the odds ratio for leg cramps was determined after the adjustment by these comorbidities, its prevalence was still significantly higher in LCS patients than in the control subjects (4.87, 95% confidence interval, 3.01–7.88, $P < 0.001$).

Leg cramps occurred once or twice a week in 34.9% of the LCS group and once in several months in 44.5% of the control group, so that the frequency of leg cramps was significantly higher in the LCS group ($P < 0.001$). Leg cramps occurred at night during sleep in 73.3% of the LCS patients and 91.6% of the control group, and at night before sleep in 14.0% and 2.5%, respectively. Although leg cramps mostly occurred nocturnally in both groups, LCS patients had leg cramps while awake more frequently than control subjects. Leg cramps occurred mostly in the calves both in the LCS patients (74.4%) and in the control subjects (64.2%). The laterality of leg cramps was elicited only for the LCS patients. Thirty-five patients (40.7%) had leg cramps bilaterally, 28 (32.6%) in the left, and 18 (20.9%) in the right. With regard to walking ability, 58.3% of the LCS patients and 81.9% of control subjects could walk more than 1 km ($P < 0.001$).

Table 1. Questionnaire for LCS Patients and Control Subjects

Q1 Have you recently experienced cramps in the legs?
- Yes
- No

Q2 How often do you have leg cramps?
- More than once a d
- Once a d
- Once a several d
- Once a several wk
- Once a several mo
- Once a yr

Q3 What time of the day do you have leg cramps?
- During sleep (midnight to dawn)
- In the morning
- In the afternoon
- In the evening

Q4 Where do you have leg cramps most?
- Calf
- Shin
- Anterior thigh
- Posterior thigh
- Foot

Q5 How long can you walk?
- No limitation
- Longer than 1 km
- 500 m-1 km
- 100–500 m
- Less than 100 m

For LCS patients only

Q6 Do you have residual sciatic leg pain now?
- Yes (If yes, mark on visual analogue scale)
- No

Q7 Do you have numbness in the legs and feet?
- Yes
- No

Q8 Did you have changes in leg cramps after surgery?
- Better than before surgery
- Unchanged
- Worse than before surgery
- No cramps before or after surgery

Q9 Are you satisfied with surgery?
- Very satisfied
- Satisfied
- Intermediate
- Dissatisfied
- Very dissatisfied

For LCS patients with leg cramps only

Q10 On which side do you have leg cramps?
- Right
- Left
- Both

Q11 Do leg cramps disturb your activity of daily livings?
- Extremely disturbed
- Moderately disturbed
- Slightly disturbed
- Not so disturbed
- Never disturbed

Q12 What kind of treatment have you had for leg cramps
- Medications()
- Massage
- Acupuncture
- Physical therapy
- None

Table 2. Profiles of LCS Patients and Control Subjects

	LCS Patients	Control	
No. Patients	120	370	*P*
Mean age	73.5 ± 8.0	75.6 ± 6.5	0.23
Gender			
Male	85	162	<0.001
Female	35	208	
Mean follow-up (yr)	3.6 ± 1.9		

Relationships Between Leg Cramps and Surgery in LCS Patients

In LCS patients, leg cramps improved after surgery in 18.2%, remained unchanged in 45.5%, and worsened in 26.1% (unknown, 10.2%) (Figure 1). Sixty-eight patients (56.7%) still had residual leg pain (mean VAS, 50.6 ± 3.3) and 81 patients (67.5%) had residual numbness in the legs. Forty-nine of the 68 patients with residual leg pain (72.1%) and 36 of the patients without it (69.2%) had leg cramps ($P = 0.84$), whereas 65 of 81 patients with residual leg numbness (80.2%) and 20 of 39 patients without it (51.3%) had leg cramps ($P = 0.002$). Leg cramps disturbed the subjects' ADL to various degrees in 47.6% of the patients (Figure 2). The patients with leg cramps (70.2%) and those without (57.1%) were satisfied with surgery ($P = 0.2$). There was no significant difference in RDQ scores, ODI scores, or

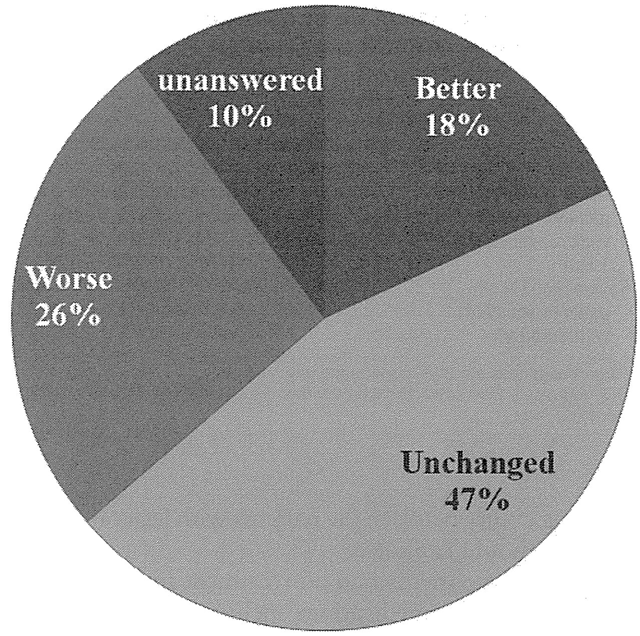

Figure 1. Changes in leg cramps after surgery.

Table 3. Comparison Between LCS Patients and Control Subjects on Leg Cramps

	LCS Patients	Controls	
No. Patients	120	370	*P*
Leg cramps			
Yes	85 (71.4)	137 (37.0)	<0.001
No	35 (28.6)	233 (63.0)	(Adjusted odds ratio 4.59, 95% confidence interval 2.87–7.35)
How often			
More than once a d	13 (15.1)	0 (0)	
Once a d	6 (7.0)	4 (2.9)	
Once a several d	30 (34.9)	17 (12.4)	<0.001
Once a several wk	20 (23.3)	49 (35.8)	
Once a several mo	16 (18.6)	61 (44.5)	
Once a yr	1 (1.2)	6 (4.4)	
When			
During sleep (midnight to dawn)	63 (73.3)	109 (91.6)	
In the morning	4 (4.7)	2 (1.9)	
In the afternoon	7 (8.1)	5 (4.2)	0.002
In the evening	12 (14.0)	3 (2.5)	
Where			
Calf	64 (74.4)	86 (64.2)	
Shin	6 (7)	7 (5.2)	
Anterior thigh	6 (7)	21 (15.7)	0.032
Posterior thigh	10 (10.6)	12 (9.0)	
Foot		8 (6.0)	
Which side			
Right	18 (20.9)		
Left	28 (32.6)		
Both	35 (40.7)	Not asked	
Unanswered	5 (5.8)		
Walking ability			
No limitation	36 (30.0)	184 (49.9)	
Longer than 1km	34 (28.3)	118 (32.0)	
500 m-1 km	14 (11.7)	31 (8.4)	<0.001
100–500 m	25 (20.8)	29 (7.9)	
Less than 100 m	11 (9.2)	7 (1.9)	
Comorbidities			
Hypertension	43 (35.8)	150 (41.1)	0.39
Diabetes	17 (14.2)	23 (6.2)	0.014

Parentheses indicate percentage.

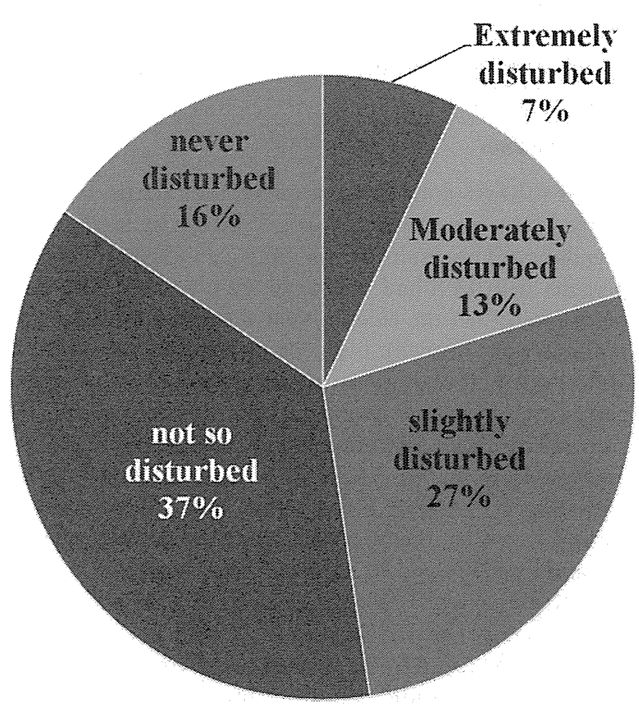

Figure 2. ADL disturbance by leg cramps.

Table 4. Comparison of Surgical Outcomes Between Patients With or Without Leg Cramps

	Cramp (+)	Cramp (−)	P
ODI	20.8 (17.8–23.8)	18.2 (13.0–23.5)	0.37
RDQ	7.7 (6.2–9.2)	5.2 (3.0–7.3)	0.53
Walking ability (% of patients able to walk longer than 1 km)	58.8	57.2	0.89
Satisfaction (% of patients satisfied with surgery)	70.2	57.2	0.83

Parentheses indicate 95% confidence interval.
ODI indicates Oswestry Disability Index; RDQ, Roland Morris Disability Questionnaire.

walking ability between the patients with leg cramps and those without (Table 4).

Fifty-eight patients had no treatment for leg cramps, and only 9 took medications including vitamin B and antispasmodic drugs (Esperisone, and others). Twenty-three patients had massage, acupuncture, and/or heat therapy at the time of the investigation.

Thirty-six patients (42.4%) with leg cramps and 15 patients (42.9%) without leg cramps took medications that have been reported to be related to the occurrence of leg cramps including diuretics, statins, steroid, and nifedipine, antidepressants, and/or β-blockers ($P = 1.00$). Thus, there was no statistically significant association between medication and incidence of leg cramps in the LCS patients.

Perioperative complications were observed in 5 patients including 1 hematoma, which required evacuation, 3 dural tears, which were treated with dural sutures with no serious sequelae, and 1 transient nerve root palsy. Of these 5 patients, 3 (60%) complained of leg cramps, suggesting that perioperative complications did not aggravate leg cramps.

Discussion

This is the first study that compared the prevalence of leg cramps between patients with LCS and a general elderly population. The results of this study demonstrated that the patients with LCS had nocturnal leg cramps significantly more often than the elderly control subjects (the first hypothesis was affirmed). Leg cramps disturbed the ADL in almost one-half of the patients, seldom improved after surgery, or even became worse in 26% of the patients (the second hypothesis was denied). However, regardless of leg cramps, more than one-half of the patients were satisfied with surgery, possibly because they had improvement in clinical symptoms that was suggested by good walking ability, and low ODI and RDQ scores after surgery.

Despite several basic studies, the mechanisms of leg cramps are yet to be clarified,[10–12] and it is unknown why cramps occur frequently at night while people are sleeping. EMG studies during a muscle cramp demonstrated involuntary repetitive firing of motor unit action potentials at a high frequency, and thus, abnormalities in the motor units including motor neurons, neuromuscular junctions, and muscles can cause cramps.[10–12] It is reported that elderly people lose motor neurons as a result of aging, making this population prone to muscle cramps.[13] It has been speculated that the nocturnal frequency of leg cramps is due to changes in hydrostatic pressure and ionic shift across the cell membrane in the calf muscles in a recumbent position, leading to hyperexcitability of the motor neurons.[10] The disturbing pain, which occurs during cramps, is the result of accumulation of metabolites and focal ischemia.

There are many diseases or disorders reported to be associated with cramps; lower motor neuron disorders including amyotrophic lateral sclerosis, poliomyelitis, peripheral neuropathy, and lumbar spinal radiculopathy; metabolic disorders including diabetes, pregnancy, uremia, liver cirrhosis, and hypothyroidism; acute extracellular volume depletion including excessive perspiration, hemodialysis, diarrhea, and diuretic therapy; hereditary disorders; and medications including diuretics, antidepressants, calcium blockers, β-blockers, statins, and steroid, and so on. In this study, we compared LCS patients with a general population as the control. Because the questionnaire for the control subjects did not include detailed comorbidities except for common diseases such as hypertension and diabetes, we included these 2 common diseases related to leg cramps as independent variables with age and gender for the logistic regression analysis. Because the adjusted odds ratio was as high as 4.87, exclusion of other rare pathologic conditions mentioned above from logistic regression analysis might not change the result of the analysis. In LCS patients, we filed all medications administered to the patients, and evaluated the prevalence of leg cramps with stratification by medications to investigate their possible association with leg cramps, but we found no difference in the prevalence between patients with such medications and those without. From these results, although there may be other confounding factors for leg cramps, we can conclude that LCS is definitely a causative factor of leg cramps.

The incidence of leg cramps was significantly higher in LCS patients than in the control population in this study. However, studies on the association between leg cramps and lumbar spinal diseases have been scarce. Rish empirically stated that leg cramps were frequently seen in patients with lumbar radiculopathy.[14] Haskell and Fiebach conducted a retrospective chart review of 50 elderly patients who took quinine sulfate for nocturnal leg cramps in comparison with age-matched controls.[15] They found that peripheral vascular disorders and peripheral neurologic deficits were more common in the patients than in the controls. Demircan *et al* reported the "cramp finding" in patients with lumbar disc herniation.[16] They held the leg of the patients against forceful knee flexion, and if they felt a disturbing cramp in the leg or thigh, the cramp finding was considered to be positive. They identified the positive cramp finding in 72% of the patients with surgically treated lumbar disc herniation. Such a high incidence of leg cramps in patients with lumbar radiculopathy could be attributed to disturbance in the functions of the lumbar spinal nerves controlling the tonus of the muscles innervated by them.[12] In our study, however, decompression surgery did not improve leg cramps in more than a half of the patients although the lumbar spinal nerve roots were decompressed and, therefore, should have improved the leg cramps. Possible reasons are as follows: (1) The lumbar nerve roots were irreversibly damaged by long-lasting compression, which was suggested by the results of the study that leg cramps were more often observed in patients with residual numbness after surgery.[17] Kobayashi *et al* conducted an experimental study using a dog nerve root compression model, and found that dysfunction of the motor neurons is not confined to degeneration at the site of compression but also extends to the motor neurons within the lumbar spinal cord as a result of the axonal reaction, and they stressed that motor deficits would not resolve immediately after surgery; (2) after decompression, reinnervation of the affected muscles can enhance the hyperexcitability of the motor units[10,11,18]; and (3) most of the patients became able to walk farther than before surgery, which might have lead to muscle fatigue and accumulation of metabolites in the lower extremities, causing leg cramps.

Proposed remedies for leg cramps are stretching, massage, intake of vitamins B and E, magnesium, quinine, and anticonvulsants such as carbamazenpine.[19–24] Quinine is an antimalarial drug, and has been reported to be effective for leg cramps by decreasing the excitability of the motor endplate, thereby reducing the muscle contractility. However, the results of these treatment options for leg cramps varies among different studies, and efficacies of these treatment options for LCS patients remains unknown and needs to be clarified in further studies, taking into consideration the high prevalence rate of leg cramps and the associated disturbance of ADL.

This study has several limitations. First, this study was conducted retrospectively using the custom-made questionnaire, and the response rate was only 60%. Some of the questions were answered depending on patients' recall. These issues originated from the retrospective fashion of the present study might cause substantial bias in the results. Further prospective study is necessary using validated questionnaire on leg cramps to eliminate the bias. Second, the subjects of this study only included LCS patients who underwent decompression surgery alone, and we did not include LCS patients who were treated conservatively or treated by fusion surgery. Therefore, we could not evaluate the relationship between conservative treatments (or natural history) and leg cramps or the relationship among different surgical methods and improvement of leg cramps after surgery. In the present study, we only included patients who underwent decompression surgery alone to minimize the possible confounding factor and simplify the analyses. However, further study is necessary to elucidate the impact of conservative treatments or different surgical methods on improvement of leg cramps after surgery. Third, we chose an elderly general population who had participated in a general health checkup and asked them to fill in the questionnaire regarding leg cramps without any matching for age or gender. Therefore, age and gender distributions were different between the patients and the control. To adjust for these differences, we used logistic regression analyses using age, gender, and comorbidities as independent variables.

In conclusion, nocturnal leg cramps are more prevalent in LCS patients than in the general elderly population and should be recognized as one of the symptoms of LCS, which disturbs LCS patients' quality of life.

Key Points

- Questionnaire on leg cramps for patients with LCS and general elderly population.
- One hundred twenty patients who underwent decompression surgery without fusion (men 85, women 35, mean age 73.5, mean follow-up 3.6 years) and 370 senile town populations without history of back surgery (men 162, women 208, mean age 75.6) were enrolled in this study.
- Eighty-five (70.8%) patients with LCS and 137 (37.2%) control populations experienced leg cramps (age and sex adjusted odds ratio; 4.6, $P <$ 0.01).
- Leg cramps improved after surgery in 18.2%, unchanged in 45.5%, and worsened in 26.1% of the patients, and disturbed activity of daily living in 47.6% of the patients with leg cramps.
- Leg cramps should be recognized as 1 of the symptoms of LCS which disturbs patients' quality of life.

References

1. Young JB, Javid M, George J. Rest cramps in the elderly. *J R Coll Physicians Lond* 1989;20:103–6.
2. Abdulla AJ, Jones PW, Pearce VR. Leg cramps in the elderly: prevalence, drug and disease associations. *Int J ClinPract* 1999;53:494–6.
3. Naylor JR, Young JB. A general population survey of rest cramps. *Age Ageing* 1994;23:418–20.
4. Butler JV, Mulkerrin EC, O'Keeffe ST. Nocturnal leg cramps in older people. *Postgrad Med J* 2002;78:596–8.
5. Dahle LO, Berg G, Hammar M, et al. The effect of oral magnesium substitution on pregnancy-induced leg cramps. *Am J Obstet Gynecol* 1995;173: 175–80.
6. Vinciguerra G, Belcaro G, Cesarone MR, et al. Cramps and muscular pain: prevention with pycnogenol in normal subjects, venous patients, athletes, claudicants, and in diabetic microangiopathy. *Angiology* 2006; 57:331–9.
7. Kanaan N, Sawaya R. Nocturnal leg cramps. Clinically mysterious and painful–but manageable. *Geriatrics* 2001;56:34–42.
8. Roland M, Morris R. A study of the natural history of back pain, part I: development of a reliable and sensitive measure of disability in low-back pain. *Spine* 1983;8:141–4.
9. Fairbank JC, Pynsent PB. The Oswestry Disability Index. *Spine* 2000;25: 2940–52.
10. Miller TM, Layzer RB. Muscle cramps. *Muscle Nerve* 2005;32:431–42.
11. Jansen PH, Lecluse RG, Verbeek AL. J Past and current understanding of the

pathophysiology of muscle cramps: why treatment of varicose veins does not relieve leg cramps. *Eur Acad Dermatol Venereol* 1999;12:222–9.
12. Jansen PH, Joosten EM, Vingerhoets HM. Muscle cramp: main theories as to aetiology. *Eur Arch Psychiatry Neurol Sci* 1990;239:337–42.
13. Vandervoort AA. Aging of the human neuromuscular system. *Muscle Nerve* 2002;25:17–25.
14. Rish BL. Nerve root compression and night cramps. *JAMA* 1985;254:361.
15. Haskell SG, Fiebach NH. Clinical epidemiology of nocturnal leg cramps in male veterans. *Am J Med Sci* 1997;313:210–4.
16. Demircan MN, Colak A, Kutlay M, et al. Cramp finding: can it be used as a new diagnostic and prognostic factor in lumbar disc surgery? *Eur Spine J* 2002;11:47–51.
17. Kobayashi S, Uchida K, Yayama T, et al. Motor neuron involvement in experimental lumbar nerve root compression: a light and electron microscopic study. *Spine* 2007;32:627–34.
18. Kiernan MC, Hart IK, Bostock H. Excitability properties of motor axons in patients with spontaneous motor unit activity. *J Neurol Neurosurg Psychiatry* 2001;70:56–64.
19. Coppin RJ, Wicke DM, Little PS. Managing nocturnal leg cramps–calf-stretching exercises and cessation of quinine treatment: a factorial randomised controlled trial. *Br J Gen Pract* 2005;55:186–91.
20. Roffe C, Sills S, Crome P, et al. Randomised, cross-over, placebo controlled trial of magnesium citrate in the treatment of chronic persistent leg cramps. *Med Sci Monit* 2002;8:CR326–30.
21. Mandal AK, Abernathy T, Nelluri SN, et al. Is quinine effective and safe in leg cramps? *Clin Pharmacol* 1995;35:588–93.
22. Man-Son-Hing M, Wells G. Meta-analysis of efficacy of quinine for treatment of nocturnal leg cramps in elderly people. *BMJ* 1995;310:13–7.
23. Jansen PH, Veenhuizen KC, Wesseling AI, et al. Randomized controlled trial of hydroquinine in muscle cramps. *Lancet* 1997;349:528–32.
24. Man-Son-Hing M, Wells G, Lau A. Quinine for nocturnal leg cramps: a meta-analysis including unpublished data. *J Gen Intern Med* 1998;13:600–6.

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Reduced postoperative wound pain after lumbar spinous process–splitting laminectomy for lumbar canal stenosis: a randomized controlled study

Clinical article

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Object. To reduce intraoperative damage to the posterior supporting structures of the lumbar spine during decompressive surgery for lumbar canal stenosis (LCS), lumbar spinous process–splitting laminectomy (LSPSL or split laminectomy) was developed. This prospective, randomized, controlled study was conducted to clarify whether the split laminectomy decreases acute postoperative wound pain compared with conventional laminectomy.

Methods. Forty-one patients with LCS were enrolled in this study. The patients were randomly assigned to either the LSPSL group (22 patients) or the conventional laminectomy group (19 patients). Questionnaires regarding wound pain (intensity, depth, and duration) and activities of daily living (ADL) were administered at postoperative days (PODs) 3 and 7. Additionally, the authors evaluated the pre- and postoperative serum levels of C-reactive protein and creatine phosphokinase, the amount of pain analgesics used during a 3-day postoperative period, and the muscle atrophy rate measured on 1-month postsurgical MR images.

Results. Data obtained in patients in the LSPSL group and in 16 patients in the conventional laminectomy group were analyzed. The mean visual analog scale for wound pain on POD 7 was significantly lower in the LSPSL group (16 ± 17 mm vs 34 ± 31 mm, respectively; p = 0.04). The mean depth-of-pain scores on POD 7 were significantly lower in the LSPSL group than in the conventional group (0.9 ± 0.6 vs 1.7 ± 0.8, respectively; p = 0.013). On POD 3, the mean serum creatine phosphokinase level was significantly lower in the LSPSL group (126 ± 93 U/L) than in the other group (207 ± 150 U/L) (p = 0.02); on POD 7, the mean serum C-reactive protein level was significantly lower in the LSPSL group (1.1 ± 0.6 mg/dl) than in the conventional laminectomy group (1.9 ± 1.5 mg/dl) (p = 0.04). The number of pain analgesics taken during the 3-day postoperative period was lower in the LSPSL group than in the conventional laminectomy group (1.7 ± 1.3 tablets vs 2.3 ± 2.4 tablets, respectively; p = 0.22). The mean muscle atrophy rate was also significantly lower in the LSPSL group (24% ± 15% vs 43% ± 22%; p = 0.004).

Conclusions. Lumbar spinous process–splitting laminectomy for the treatment of LCS reduced acute postoperative wound pain and prevented postoperative muscle atrophy compared with conventional laminectomy, possibly because of minimized damage to the paraspinal muscles. *(DOI: 10.3171/2010.9.SPINE09933)*

Key Words • **lumbar spinal canal stenosis** • **randomized controlled study** • **spinous process–splitting laminectomy** • **wound pain**

Lumbar spinal canal stenosis was described in detail in 1954 by Verbiest,[24] who reported on patients with symptoms induced by the narrowing of the lumbar spinal canal. His patients had been treated using extensive laminectomy, which has been regarded as the standard treatment for LCS. In an extensive laminectomy, bilateral paraspinal muscles are dissected and detached extensively from the spinous processes, laminae, and facet joints; the spinous process and laminae are then removed to decompress the nerve tissues. Such intraoperative damage to the posterior supporting structures of the lumbar spine result in significant muscle atro-

Abbreviations used in this paper: ADL = activities of daily living; CPK = creatine phosphokinase; CRP = C-reactive protein; JOA = Japanese Orthopaedic Association; LCS = lumbar canal stenosis; LSPSL = lumbar spinous process–splitting laminectomy; POD = postoperative day; VAS = visual analog scale.

phy,[5–7,9,13,14,20] which can lead to failed–back surgery syndrome.[21] To overcome these problems, various decompressive surgeries for LCS have been developed with the intention of preserving the posterior supporting structures of the lumbar spine.[16,17,19,22,26–29]

In 2002, we developed a new lumbar laminectomy technique for the treatment of LCS.[25] In this technique, which we named LSPSL (or the "split laminectomy"), the lamina is exposed by longitudinally splitting the spinous process into halves, with the muscular and ligamentous attachments to the spinous process left intact (Fig. 1). According to our retrospective study, a group of patients with persistent severe pain and progressive neural dysfunction caused by LCS benefited from LSPSL and their back muscles were significantly well preserved, compared with patients who underwent conventional laminectomy.[10,25] Based on our clinical experience with LSPSL, we assumed that the split laminectomy preserves the back muscles, leading to a reduction in acute wound pain after surgery.

The purpose of this prospective, randomized, controlled study was to evaluate acute postoperative wound pain after either LSPSL or conventional laminectomy.

Methods

This prospective, randomized study was approved by the medical ethics committee of Keio University Hospital.

Inclusion and Exclusion Criteria

To be eligible for the study, the following criteria had to be met: 1) presence of neurogenic claudication; 2) symptoms persistent for more than 6 months despite conservative therapy; 3) clinical symptoms and neurological signs in the lower limbs corresponding to the level of stenosis on MR imaging or myelography; and 4) 1- or 2-level decompression necessary.

Radiographic instability of the lumbar spine and degenerative spondylolisthesis were not regarded as exclusion criteria. However, the following exclusion criteria were adopted: 1) spinal canal stenosis due to congenital, spondylolytic, traumatic, and iatrogenic causes; 2) any previous operation in the lumbar area; 3) presence of other specific spinal disorders (such as ankylosing spondylitis, neoplasm, or metabolic diseases); 4) intermittent claudication resulting from peripheral arterial disease; 5) severe osteoarthrosis or arthritis in the lower limbs; 6) neurological disease causing impaired lower-limb function, including diabetic neuropathy; 7) psychiatric disorders; and 8) multilevel spinal canal stenosis requiring decompression at 3 or more levels.

Patient Population

Patients were recruited between December 2004 and December 2005. Before randomization, eligible patients were informed that they would be the candidates for a study

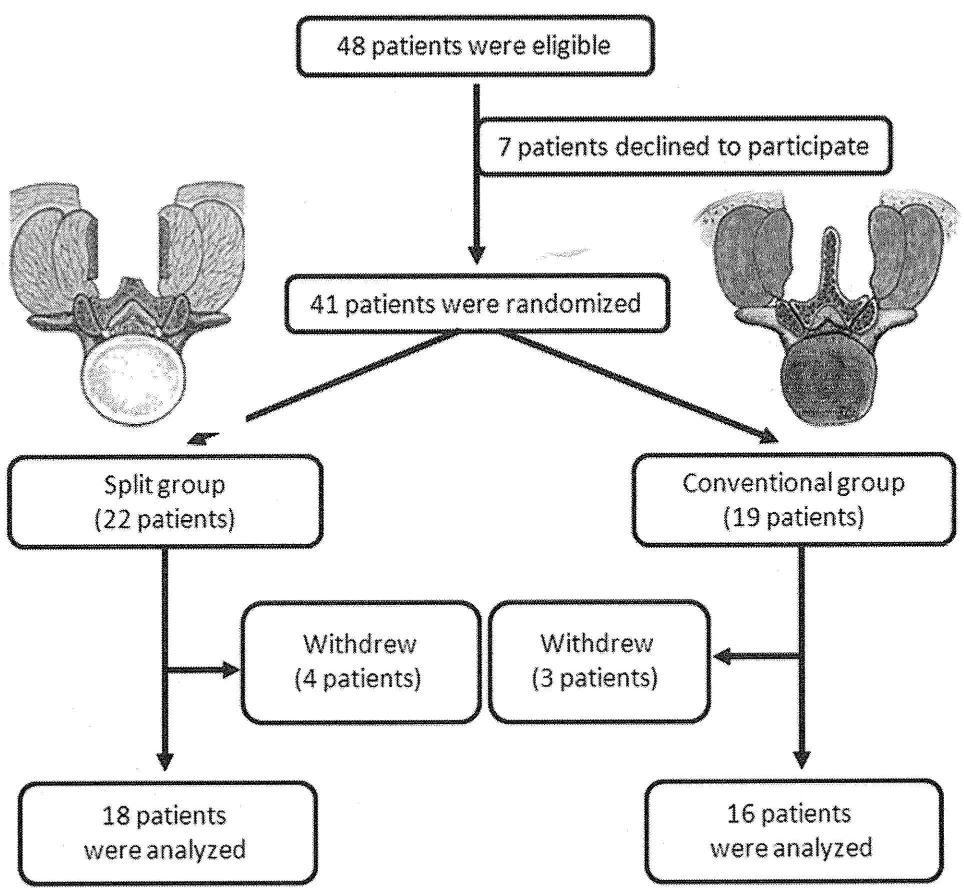

Fig. 1. Flow chart of the study and drawings representing the 2 laminectomies.

comparing 2 different procedures for the surgical treatment of LCS. Then, written consent was obtained from all participants. The baseline examinations consisted of plain radiography of the lumbar spine, myelography, CT, and MR imaging. Standard physical and neurological examinations were performed, and the JOA score for low-back pain[4] was calculated. The JOA Scale consists of 3 main parts: subjective symptoms, clinical signs, and ADL restrictions. The subjective symptoms section has 3 components: low-back pain, leg pain, and gait, with all 3 components having a possible score range of 0–3 points depending on severity. The clinical signs section also has 3 components: straight leg–raising test, sensory disturbance, and muscle disturbance, with all 3 components having a possible score range of 0–3 depending on the severity. The ADL section has 7 components based on the individual's ability to: turn over while lying down, stand, wash one's face, lean forward, sit for approximately 1 hour, lift or hold heavy objects, and ambulate. Each of these components is scored according to the severity of restriction (severe restriction, 0; moderate restriction, 1; no restriction, 2). After completion of the baseline examinations, identification data for the eligible patients who agreed to participate in the study were faxed to a central office, where they were randomized into either the LSPSL group or the conventional laminectomy group. The randomization was stratified according to sex, age (≤ 64 years or > 65 years), and the number of decompression levels (1 or 2). Only the attending surgeon of the patient was informed about which method to use for the specific patient. Overall, 5 spine surgeons participated in this study.

Forty-eight patients met the inclusion criteria for the study (Fig. 1), and 41 agreed to participate. These patients were assigned to either the LSPSL group (22 patients) or the conventional laminectomy group (19 patients). Four patients in the LSPSL group were subsequently withdrawn from the study because a conversion to posterior lumbar interbody fusion was necessary in 1 patient and the number of decompression levels was increased from 2 to 3 after randomization in 3 patients. Three patients in the conventional laminectomy group were also withdrawn from the study. In 1 of these 3 patients, a herniotomy was performed in addition to the laminectomy, and in the other 2 patients the number of decompression levels was increased from 2 to 3 levels after randomization.

Measurements

Questionnaires were administered on PODs 3 and 7. The questionnaire contained 3 questions regarding wound pain (intensity, depth, and duration) and questions regarding ADL. For the question concerning the intensity of the wound pain, a VAS consisting of a numerical rating scale from 0 (no pain) to 10 (worst possible pain) was used. For the question concerning depth of pain, a patient in whom pain felt "superficial" was assigned 1 point, "deep to the muscle" was assigned 2 points, and "deep to the bone" was assigned 3 points. For the question concerning duration of pain (that is, from the start of the pain to the relief of the pain), "a few seconds" was assigned 1 point, "a few minutes" was assigned 2 points, "a few hours" was assigned 3 points, and "all day" was assigned 4 points. For the evaluation of ADL, the ADL domain in the JOA Scale (JOA-ADL score) was used. One year postoperatively, standard physical and neurological examinations were performed, and the JOA score was calculated.

In addition to the questionnaire, we also evaluated the pre- and postoperative serum levels of CRP and CPK, the amount of pain medication taken during the 3-day postoperative period, and the muscle atrophy rate as demonstrated on 1-month postoperative axial MR images. Pain medication usage was determined by counting the number of tablets dispensed by the nurses at each patient's request. A nonsteroidal antiinflammatory drug, Loxoprofen, which is a popular analgesic in Japan, was used in the present study.

To evaluate the magnitude of the surgical damage to the paraspinal muscles, the cross-sectional area of the paraspinal muscles (multifidus) was measured on preoperative and 1-month postoperative T2-weighted axial MR images using the NIH Image software (Imaging Research). The axial images were obtained at the decompressed intervertebral level. In cases of 2-level decompression, the caudal level was chosen for the evaluation of muscle atrophy because the influences of the injury to the medial branch of the posterior ramus of the spinal nerve would be more evident at the caudal level. The rate of muscle atrophy was calculated using the following formula: atrophy rate (%) = (1 − total postoperative area/total preoperative area) × 100.

Statistical Analysis

Data were analyzed using the SPSS 16.0 J statistical software package. A Mann-Whitney U-test was used to compare the mean scores or values between the groups. Statistical significance was defined as $p < 0.05$ for a 2-sided hypothesis. Mean data are presented ± SD.

Surgical Techniques

Split Laminectomy. For a 1-level (L4–5) decompression, a posterior midline skin incision is made between the L-3 and L-5 spinous processes to expose the tip of the L-4 spinous process (Fig. 1). The cortex of the tip of the L-4 spinous process is removed at the midline using a high-speed drill with a fine 2-mm diamond-tipped bur, and then, using an osteotome, the spinous process is divided to the base and detached from the L-4 lamina, leaving the bilateral paraspinal muscles attached to the lateral aspects of the split spinous process. The supra- and interspinous ligaments between L3–4 and L4–5 are also split longitudinally with a scalpel. An ample working space for the laminectomy is obtained by retracting the split halves of the spinous process bilaterally, together with its attached paraspinal muscles. The L-4 lamina is removed using a high-speed drill and Kerrison rongeurs, and the nerve tissue is decompressed in the standard fashion. After the decompression of the affected nerve roots and the thecal sac, the halves of the split L-4 spinous process are reapproximated using a strong nonabsorbable suture. The 1-level posterior L4–5 decompression, thus, can be accomplished by removing the L-4 caudal portion of the lamina, preserving the supra- and interspinous ligaments of L3–4 and L4–5 and the L-4 spinous process, with minimal damage to the paraspinal muscles.

Conventional Laminectomy. A posterior midline skin incision is made between the L-3 and L-5 spinous processes to expose the L4–5 interlaminar space (Fig. 1). Bilateral paraspinal muscles are detached from the L-4 and L-5 spinous processes, and then, using a chisel to expose the L4–5 interlaminar space, the L-4 and L-5 spinous processes are detached from the lamina. Last, the nerve tissue is decompressed in the same manner as for the LSPSL.

Postoperative Care

The patients in both groups were allowed to sit up and walk without lumbar support on the 1st POD.

Results

Data in 18 patients (10 men and 8 women) in the LSPSL (split-laminectomy) group and 16 patients (8 men and 8 women) in the conventional laminectomy group were included in the final analyses. We observed no significant intergroup differences in mean age at the time of surgery, mean number of decompressed levels, mean operative time, mean intraoperative blood loss, or number of surgeries performed by each surgeon (Table 1). The mean preoperative JOA score in the LSPSL group was 16.4 ± 4.7 and that in the conventional laminectomy group was 14.9 ± 4.0 (Table 2). The subjective symptoms portion of the JOA score indicated that lower-leg pain and gait disturbance were severe in both groups. No significant intergroup difference was recognized in 3 parts of subjective symptoms, clinical signs, and ADL restrictions. At 1 year postoperatively, the mean preoperative JOA score of 16.4 ± 4.7 was increased to 25.8 ± 3.4 (mean recovery rate 75% ± 21%) in the split-laminectomy group, whereas in the conventional laminectomy group the mean preoperative JOA score of 14.9 ± 4.0 was increased to 25.4 ± 2.9 (mean recovery rate 74% ± 17%). Significant intergroup differences were not recognized in these clinical parameters. No obvious perioperative complication was recognized. One patient in the split-laminectomy group underwent posterior intervertebral fusion 1 year later to treat symptoms that recurred 6 months after LSPSL. One patient in each group did not attend the 1-year follow-up examination because of general health problems.

TABLE 1: Demographics of the split-laminectomy group (LSPSL) and the conventional laminectomy group*

Parameter	Laminectomy Group (%)	
	Split (LSPSL)	Conventional
no. of patients	18	16
mean age (yrs)†	69 ± 10	71 ± 8
male/female ratio†	10:8	8:8
mean no. of decompressed levels†	1.4 ± 0.5	1.4 ± 0.5
mean intraoperative time (min)†	69 ± 29	82 ± 36
mean intraoperative blood loss (g)†	44 ± 75	55 ± 48
no. of ops performed by each surgeon‡		
K.I.	4 (22)	6 (38)
Y.O.	3 (17)	1 (6)
H.T.	4 (22)	2 (13)
M.N.	1 (6)	1 (6)
M.M.	6 (33)	6 (38)

* Mean values are presented ± the SD.
† No significant intergroup difference according to the Mann-Whitney U-test.
‡ No significant intergroup difference according to the chi-square test.

TABLE 2: Clinical results preoperatively and 1-year postoperatively*

Parameter	Possible Range	Laminectomy Group	
		Split (LSPSL)	Conventional
mean preop JOA score	0–29	16.4 ± 4.7	14.9 ± 4.0
subjective symptoms	0–9	3.5 ± 1.3	3.5 ± 1.3
low-back pain	0–3	1.7 ± 0.9	1.7 ± 0.8
lower-leg pain	0–3	0.9 ± 0.2	0.8 ± 0.4
gait ability	0–3	0.9 ± 0.9	1.0 ± 0.7
clinical symptoms	0–6	5.1 ± 1.0	5.0 ± 0.7
ADL restrictions	0–14	8.9 ± 2.7	7.5 ± 2.9
mean postop 1-yr JOA score	0–29	25.8 ± 3.4	25.4 ± 2.9
subjective symptoms	0–9	7.5 ± 1.4	7.3 ± 1.0
low-back pain	0–3	2.5 ± 0.5	2.3 ± 0.5
lower-leg pain	0–3	2.4 ± 0.8	2.3 ± 0.5
gait ability	0–3	2.7 ± 0.5	2.7 ± 0.5
clinical symptoms	0–6	5.7 ± 0.7	5.7 ± 0.6
ADL restrictions	0–14	12.8 ± 1.6	12.5 ± 1.9
recovery rate (%)†		75 ± 21	74 ± 17

* No significant intergroup difference according to the Mann-Whitney U-test for the JOA score or recovery rate. Mean values are presented ± the SD.
† Recovery rate: (postoperative points − preoperative points)/(29 − preoperative points).

The VAS Score for Wound Pain

On POD 3, the mean VAS score was 43 ± 27 mm in the LSPSL group and 44 ± 26 mm in the conventional laminectomy group. Although on POD 7 the mean score was reduced to 16 ± 17 mm in the LSPSL group and 34 ± 31 mm in the conventional group ($p = 0.002$), a significant decrease was recognized only in the former group. Additionally, on POD 7 a significant intergroup difference was recognized ($p = 0.04$) (Fig. 2).

Depth of Pain

On POD 3, the mean depth-of-pain score was 1.6 ± 0.7 in the LSPSL group and 1.6 ± 0.7 points in the conventional laminectomy group. On POD 7, although the score was significantly reduced to 0.9 ± 0.6 in the split-laminectomy group ($p = 0.021$), no change was recognized in the conventional group (depth-of-pain score 1.7 ± 0.8). On POD 7, a significant intergroup difference was recognized ($p = 0.013$) (Fig. 3).

Duration of Pain

On POD 3, the mean duration-of-pain score was 2.5 ±

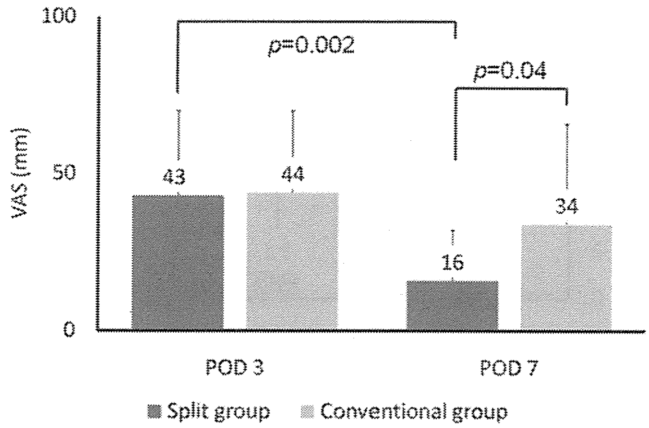

FIG. 2. Bar graph identifying VAS scores of acute postoperative wound pain on PODs 3 and 7. The mean VAS score of 43 ± 27 mm in the split-laminectomy group on POD 3 was significantly reduced to 16 ± 17 mm on POD 7 (p = 0.002). A significant difference was recognized between the 2 groups on POD 7 (p = 0.04).

1.4 in the LSPSL group and 2.9 ± 1.3 in the conventional group. On POD 7, the score was significantly reduced to 1.5 ± 1.5 in the split-laminectomy group (p = 0.045) and 2.5 ± 1.6 in the conventional laminectomy group. Although the mean scores were lower in the LSPSL group, no significant differences were recognized between the 2 groups (Fig. 4).

The JOA-ADL Scores

The preoperative mean JOA-ADL score was 8.8 ± 2.7 in the LSPSL group and 7.5 ± 2.7 in the conventional group. The scores decreased to 6.3 ± 3.0 in the former and 4.9 ± 4.5 in the latter group POD 3. The scores increased to 7.9 ± 2.6 and 7.8 ± 4.2, respectively, on POD 7. No significant intergroup differences were recognized (Fig. 5).

Serum CRP and CPK Levels

The mean preoperative serum CPK level was 99 ± 64 U/L in the split-laminectomy group and 115 ± 86 U/L in the conventional laminectomy group. The value increased to 126 ± 93 U/L on POD 3 and then decreased to 71 ±

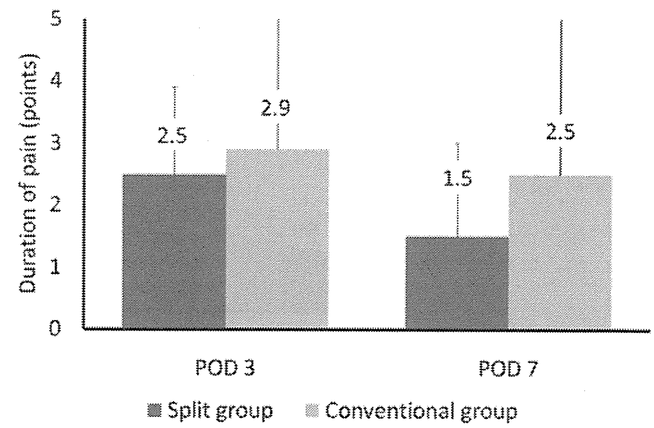

FIG. 4. Duration-of-pain scores on PODs 3 and 7. The mean score of 2.5 ± 1.4 in the split-laminectomy group on POD 3 was significantly reduced to 1.5 ± 1.5 (p = 0.045). No significant differences were recognized between the groups.

50 U/L on POD 7 in the split-laminectomy group. In the conventional laminectomy group, the value increased to 207 ± 150 U/L on POD 3 and then decreased to 106 ± 86 U/L on POD 7. A significant difference was recognized between the 2 groups only on POD 3 (p = 0.02) (Fig. 6).

The mean preoperative serum CRP level was 0.3 ± 0.3 mg/dl in the LSPSL group and 0.2 ± 0.3 mg/dl in the conventional laminectomy group. In the LSPSL group, the value increased to 5.3 ± 3.7 mg/dl on POD 3 and then decreased to 1.1 ± 0.6 mg/dl on POD 7. In the conventional laminectomy group, the value increased to 5.5 ± 3.2 mg/dl on POD 3 and then decreased to 1.9 ± 1.5 mg/dl on POD 7. A significant intergroup difference was recognized between the 2 groups on POD 7 (p = 0.04) (Fig. 6).

Analgesics Taken During the 3-Day Postoperative Period

Although the mean number of analgesic medications taken during the 3-day postoperative period was smaller in the LSPSL group than the conventional group (1.7 ± 1.3 tablets vs 2.3 ± 2.4 tablets, p = 0.22), no significant difference was recognized.

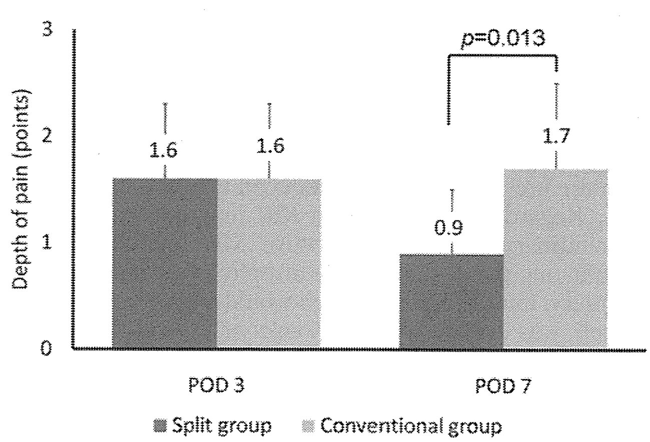

FIG. 3. Depth-of-pain scores reflecting acute postoperative wound pain on PODs 3 and 7. The mean score of 1.6 ± 0.7 in the split-laminectomy group on POD 3 was significantly reduced to 0.9 ± 0.6 (p = 0.021). A significant difference was recognized between the 2 groups on POD 7 (p = 0.013).

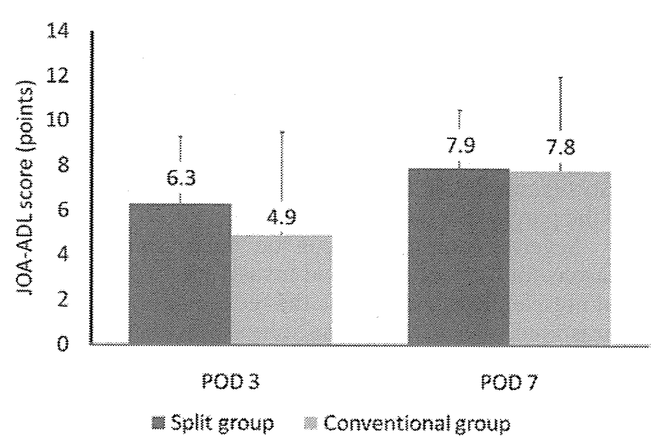

FIG. 5. Bar graph identifying JOA-ADL scores on PODs 3 and 7. The mean JOA-ADL score of 6.3 ± 3.0 in the split-laminectomy group and 4.9 ± 4.5 in the conventional laminectomy group on POD 3 increased to 7.9 ± 2.6 and 7.8 ± 4.2, respectively, on POD 7. No significant intergroup differences were recognized.

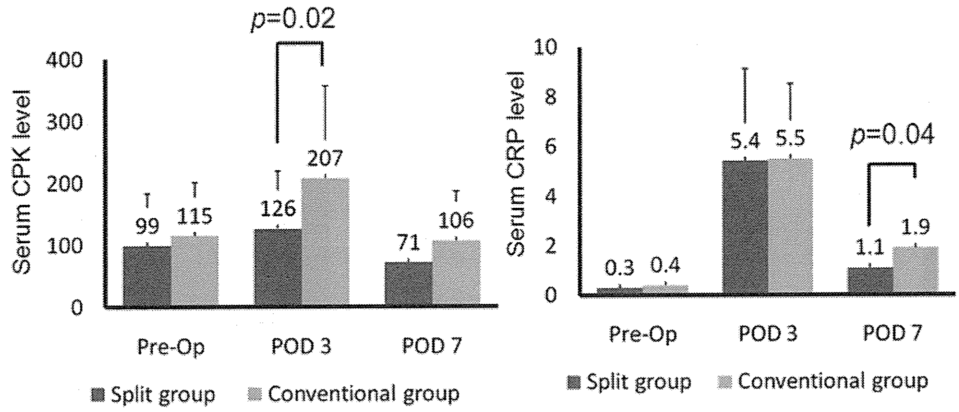

FIG. 6. Serum CPK and CRP levels before surgery (Pre-Op) and on PODs 3 and 7. The mean preoperative serum CPK level of 99 ± 64 U/L in the split-laminectomy group increased to 126 ± 93 U/L on POD 3, and then decreased to 71 ± 50 U/L on POD 7. A significant difference was recognized between the groups only on POD 3 (p = 0.02). The mean preoperative serum CRP level of 0.3 ± 0.3 mg/dl in the split-laminectomy group increased to 5.4 ± 3.7 mg/dl on POD 3, and then decreased to 1.1 ± 0.6 mg/dl on POD 7. A significant difference was recognized between the groups only on POD 7 (p = 0.04).

Atrophy Rate of Paraspinal Muscles at the 1-Month Postoperative Examination

The mean atrophy rate in the split-laminectomy group was significantly lower than that in the conventional group (24% ± 15% and 43% ± 22%, respectively; p = 0.004).

Discussion

The results of the present study indicated that, after posterior decompression surgery for LCS, acute postoperative wound pain was milder in the LSPSL (split-laminectomy) group than in the conventional laminectomy group. All mean scores regarding wound pain were lower in the split-laminectomy group. In particular, significant differences were observed between the groups in the VAS scores on POD 7 and the depth of pain on POD 7. The reduced postoperative wound pain in the LSPSL group may be due to the reduction of damage to the paraspinal muscles. Because serum CPK and CRP levels are the indicators of muscle damage,[8,11,12,23] the results (mean serum CPK levels on POD 3 and CRP level at POD 7 being significantly lower in the split-laminectomy group) indicated that the extent of the surgical invasiveness to the paraspinal muscles was lesser in the split-laminectomy group. Additionally, the muscle atrophy rate at 1 month being significantly lower in the split-laminectomy group also suggested that the procedure is less invasive in terms of the paraspinal muscles.

Several assumptions can be made concerning the reasons for the more minimal invasiveness to the paraspinal muscles in LSPSL. First, the reduced dissection of the paraspinal muscles from the spinous process—the result of splitting the spinous process—might also reduce the invasiveness of the procedure to the paraspinal muscles. Second, in conventional laminectomy, because the midline structures disturb one's access to the lateral recesses, paraspinal muscle dissection would extend to the medial side or sometimes to the lateral side of the facet joints. This would be associated with an increased chance of damaging the medial branch of posterior ramus. The posterior ramus emerges from the intervertebral foramen and passes dorsolateral to the superior articular process, and it splits into their terminal medial and lateral branches. The medial branch then enters the multifidus.[1–3,18] Because the medial branch is tethered to the periosteum, lateral to the facet joints, by fibers of the intertransverse ligaments,[1] the dissection of the muscles lateral to the facet joints may increase the risk of injuring the medial branch of the posterior ramus, which will finally result in denervation of the multifidus.[1] Furthermore, the medial branch of the posterior ramus is at risk of being injured, even by lateral retraction of the paraspinal muscles,[1,15] whereas in the split laminectomy a wide visualization of the central canal and the lateral recess is achieved by retracting the split spinous processes bilaterally, enabling minimal dissection of the paraspinal muscles and minimal detachment of the muscles from the facet joints. Kawaguchi et al.[5–7] reported that muscle injury is closely related to retraction pressure in their experimental and clinical trials. In a split laminectomy, the broad visualization of the central canal and the lateral recess may diminish the retraction pressure on paraspinal muscles. Additionally, interposition of the split spinous processes between the paraspinal muscles and the retractors may acts as a mechanical buffer to reduce the retraction pressure against the paraspinal muscles. All of these factors may explain why the paraspinal muscles in the split-laminectomy procedure are associated with reduced invasiveness.

Regarding the timing of MR imaging, based on our preliminary data of consecutive MR images taken for evaluating paraspinal muscle atrophy after decompressive surgery, muscle edema, which would cause the muscles to swell, was evident within 2 weeks of surgery. Sometimes, the muscle area after conventional laminectomy was larger than that of preoperative areas and that of the split laminectomy because of muscle edema. Thus, we decided that the measurement of muscle area as a parameter of invasiveness within 2 weeks would be inappropriate. Because the muscle edema would decrease to an almost normal level by 1 month postoperatively, we chose to obtain MR images 1 month after surgery to evaluate muscle atrophy.