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ORIGINAL ARTICLE

Treatment results for lumbar epidural lipomatosis: Does fat matter?

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Abstract

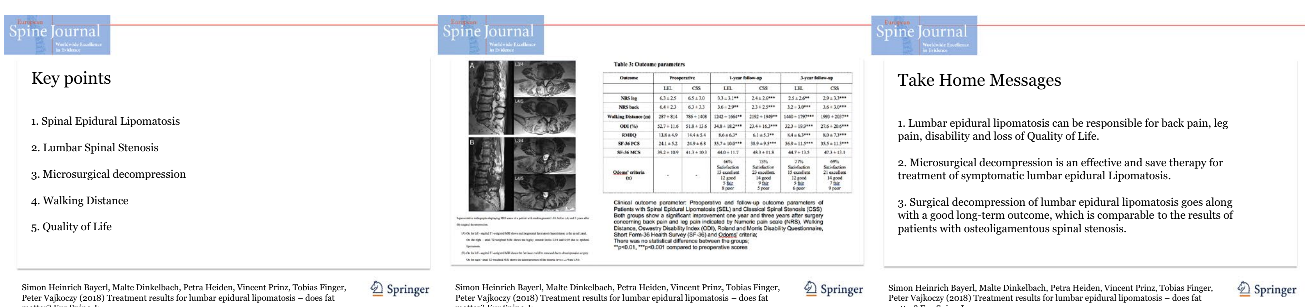
Purpose The lumbar epidural lipomatosis (LEL) is a rare disease that can cause sciatic pain syndrome or neurological deficits comparable to symptoms caused by a classical spinal canal stenosis. In severe cases surgical decompression was conducted. However, the outcome after decompressive surgery has only been investigated in small case series. In this study we compared the outcome of LEL patients after microsurgery with the outcome of patients with classical spinal stenosis (CSS).

Methods Patients with LEL ($n=38$) and patients with CSS ($n=51$), who received microsurgical decompression, were followed in a prospective observational study for 3 years. The clinical results including the Oswestry Disability Index, Numeric Pain Rating Scale (NRS), Roland and Morris Disability Questionnaire, the Short Form-36 Score and the Walking Distance were analysed and compared between both groups.

Results Patients with LEL improved significantly after microsurgical decompression in a 3-year follow-up concerning back pain, leg pain and pain-associated disability equal to patients with CSS ($NRS_{back\_LEL\_preop.}=6.4$; $NRS_{back\_CSS\_preop.}=6.3$; $NRS_{back\_LEL\_3\text{-}years}=3.2$; $NRS_{back\_CSS\_3\text{-}years}=3.6$; $NRS_{leg\_LEL\_preop.}=6.3$; $NRS_{leg\_CSS\_preop.}=6.5$; $NRS_{leg\_LEL\_3\text{-}years}=2.5$; $NRS_{leg\_CSS\_3\text{-}years}=2.9$; $ODI_{LEL\_preop.}=52.7$; $ODI_{CSS\_preop}=51.8$; $ODI_{LEL\_3\text{-}years}=32.3$; $ODI_{CSS\_3\text{-}years}=27.6$). The microsurgical decompression had a positive effect on the health-related quality of life, and patient satisfaction was high in both groups (LEL group—71%, CSS group—69%).

Conclusions LEL can influence the quality of life dramatically and cause a high degree of disability. A surgical decompression is a safe and effective procedure with a good clinical outcome comparable to the results in patients with an osteoligamentous spinal stenosis. Therefore, microsurgical decompression can be recommended in patients with LEL if conservative treatment fails.

Graphical abstract These slides can be retrieved under Electronic Supplementary Material.



Keywords Spinal epidural lipomatosis · Lumbar spinal stenosis · Microsurgical decompression · Walking distance · Quality of life

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-018-5771-1) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

Introduction

Lumbar epidural lipomatosis (LEL) is defined by an epidural space occupying accumulation of fat resulting in a narrowing of the spinal canal. It can occur idiopathically as well as secondarily due to Cushing syndrome, obesity, endocrine disorders and is associated with a high visceral fat accumulation in patients [1]. The LEL is a rare tissue collection. However, it is detectible in about 6% of patients with symptomatic spinal stenosis [2]. If the LEL is located in the lumbar spine, the cauda equina compression can result in symptoms with high pain intensity and severely reduced quality of life comparable to a classical osteoligamentous spinal stenosis. Radicular pain syndromes, back pain, immobility and neurological symptoms up to a cauda equina syndrome can occur. Therefore, an effective therapy concept for these patients is needed. If the symptoms are mild, a conservative treatment can be performed. If conservative treatment fails or neurological symptoms appear, a surgical decompression might be necessary and many case reports and case series describe positive results concerning surgical decompression. However, the general feeling of many surgeons still is that in contrast to the osteoligamentous stenosis the surgical treatment of LEL does not result in good outcomes and overall remains frustrating. So far there is no prospective evidence for LEL patients after microsurgery nor is there prospective evidence for medical therapy. This study was designed to enable a long-term follow-up of patients with epidural lipomatosis and to compare the results with those of patients with classical spinal stenosis in a prospective observational manner.

Materials and methods

Patients with symptomatic lumbar epidural lipomatosis and patients with classical spinal stenosis, who have been operated between 2013 and 2015, were prospectively followed for 3 years and outcome scores were analysed.

All patients suffered from symptoms typical for spinal stenosis, e.g., sciatica and back pain. Symptoms were refractory to conventional pain therapy including physiotherapy, manual therapy and pain medication. All patients received a microsurgical decompression via a one-sided laminotomy with undercutting and bilateral decompression, hemilaminectomy or laminectomy. Before surgery functional X-rays of the lumbar spine were performed in all patients to exclude an anterior sliding of the stenotic segment. A stable spondylolisthesis Meyerding Grade I was detected in ten patients.

Study design and ethical approval

Data were collected in a prospective observational study. An informed consent was enrolled from all included patients. The ethical approval was given by the local ethics committee (reference number: EA1/101/17).

Diagnosis of lumbar epidural lipomatosis

The LEL was diagnosed in preoperative MRI scans. Epidural fat was identified due to its hyperintensity in T1 and T2 images. If a space occupying fat accumulation resulted in a compression of the dural sac, a lipomatosis was diagnosed. Thirty-eight patients met these criteria and were decompressed microsurgically (Fig. 1).

All patients with LEL were graded using the Ishikawa and the Borré classification [3, 4].

Groups

The patients were assigned to the lumbar epidural lipomatosis group (LEL group) or to the Classical Spinal Stenosis Group (CSS group). Age, gender, body mass index (BMI), follow-up time, operated levels, complications, pain medication and besides diseases were collected and compared to compare the demographic parameters of the groups.

Radiographic parameters

Radiographic parameters were analysed on preoperative full spine standing X-rays to visualize factors influencing patients' outcome as preoperative spino-pelvic parameters. Pelvic and spinal parameters were collected including the pelvic incidence, pelvic tilt, the sacral slope, the lumbar lordosis and thoracic kyphosis, the spino-sacral angle, the sagittal vertical axis (SVA, vertical distance between C7 plumb line and the posterior edge of the sacrum) and sacrum–bicoxofemoral distance (SFD, distance between the posterior edge of sacrum and the femoral heads). To assess the global sagittal balance, the ratio of the C7 plumb line to the sacrum–bicoxofemoral distance (C7PL/SFD) was calculated [5, 6].

Clinical outcome measurements

Clinical outcome scores were collected preoperatively, 1 year and 3 years after surgery. Patients completed the 11-point Numerical Rating Scale (NRS) for leg and back pain for the assessment of pain level. The Walking Distance, the Oswestry Disability Index (ODI) and the Roland and Morris Disability Questionnaire (RMDQ) were completed

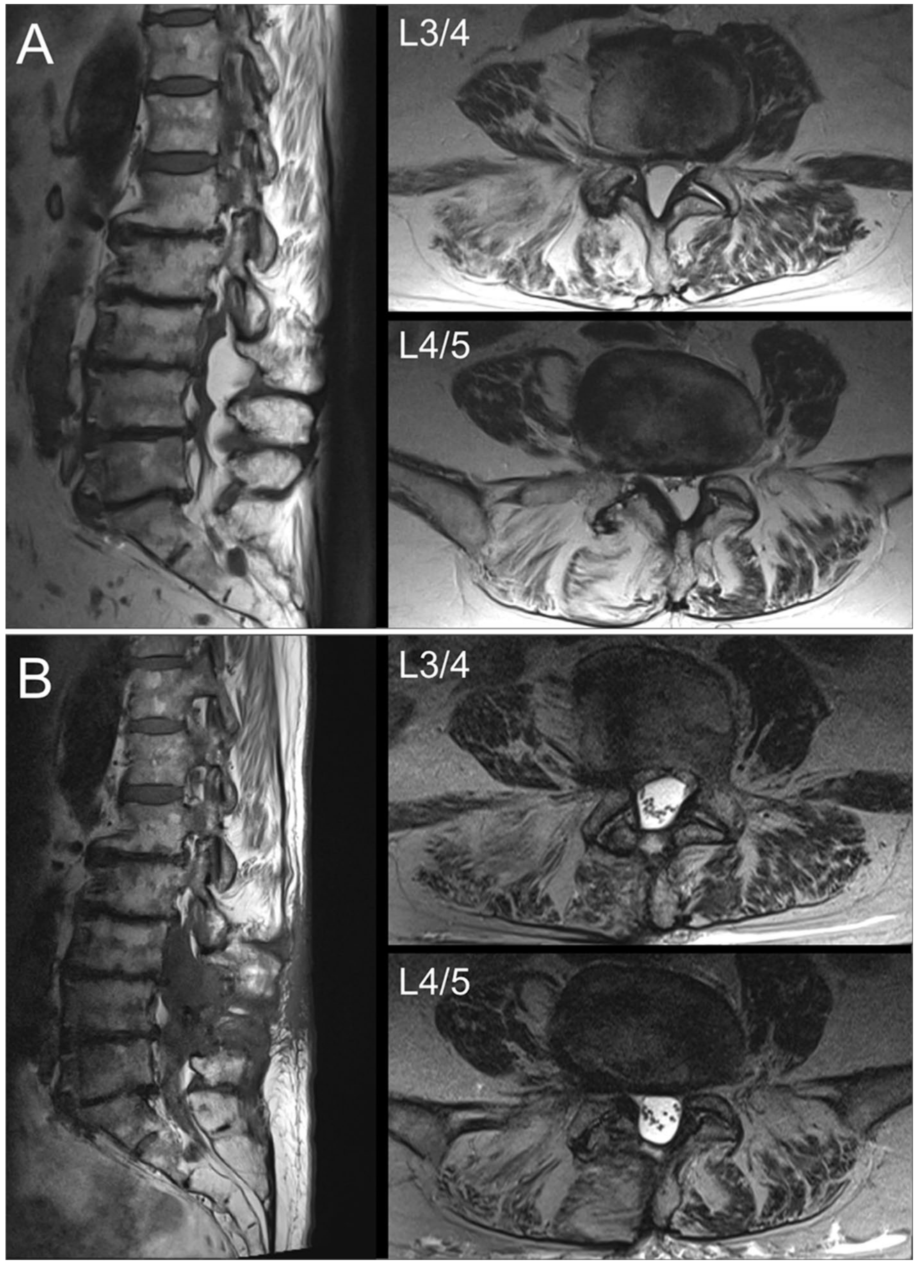


Fig. 1 Representative radiographs displaying MRI scans of a patient with multisegmental LEL before (**a**) and 3 years after (**b**) surgical decompression. **a** On the left—sagittal T1-weighted MRI shows multisegmental lipomatosis hyperintense in the spinal canal. On the right—axial T2-weighted MRI shows the highly stenotic levels L3/4 and L4/5 due to epidural lipomatosis. **b** On the left—sagittal T1-weighted MRI shows the fat tissue could be removed due to decompressive surgery. On the right—axial T2-weighted MRI shows the decompression of the stenotic levels L3/4 and L4/5

to investigate the pain-associated disability of the patients. Health-related quality of life was displayed by the Short Form-36 Health Survey. Furthermore, Odom's criteria were collected to illustrate patients' satisfaction.

Statistical analysis

For statistical analysis GraphPad Prism 5.0c (San Diego, CA, USA) was used. After analysing the normal distribution, either the Kruskal–Wallis test or the analysis of variance (ANOVA) was performed to compare both groups. To compare measurements in the single groups at each point in time, ANOVA or Friedmann test was used. We defined *p* values below 0.05 as statistically significant.

Results

Groups

Thirty-eight patients who have been operated between 2013 and 2015 were assigned to the LEL group. Fifty-one patients who were observed on the same follow-up interval were included in the CSS group. Demographic parameters such as age, gender and BMI were very similar in both groups.

Beyond that, there was no difference concerning the amount of operated segments and perioperative complications. However, in the LFL group the most frequent stenotic segment was L5/S1, whereas the most frequent stenotic segment in the CSS group was L4/5 ($p = 0.002$). With 50% the amount of patients with preoperative daily opioid use was higher in the LEL group than in the CSS group (27%) (Table 1).

Three patients suffered from rebleeding, and 2 of them needed a surgical evacuation of the haematoma. Two patients suffered from postsurgical pneumonia, one from postoperative cerebrospinal fluid fistula, and one patient from postoperative superficial wound healing disturbance, which did not need further surgical procedures (Table 1).

Lumbar epidural lipomatosis

Thirty-eight patients with lumbar epidural lipomatosis presented with different types of fat distribution in the epidural space. Some patients presented with a monosegmental lumbar stenosis due to an isolated epidural Lipomatosis ($n = 6$; Fig. 2a), several patients suffered from a LEL localized at the lumbosacral junction ($n = 14$; Fig. 2b), and several patients appeared with a multisegmental LEL ($n = 18$; Fig. 2c).

All patients with LEL were graded with Grade 2 or 3 in Ishikawa classification and Grade 2 or 3 according to the Borré Classification (Fig. 2) [3, 4].

Twenty-two patients (58%) suffered from a BMI higher then 30, 16 patients (42%) suffered from type 2 diabetes, 28 patients (74%) suffered from arterial hypertension, 12 patients (34%) received permanent glucocorticoid medication, and 4 patients (11%) suffered from hypothyroidism.

In 30 of 38 patients with LEL, perioperative blood lipid levels were available. LEL patients presented with an increased blood cholesterol level (202 ± 38 mg/dl) as well as increased LDL level (152 ± 46 mg/dl) and increased triglyceride level (211 ± 90 mg/dl). Altogether 24 of 30 patients with LEL presented with generally increased blood lipid and lipoprotein levels.

Surgical technique

All patients received a microsurgical decompression. The approach was either a unilateral laminotomy with decompression of the ipsilateral side and undercutting for decompression of the contralateral side [7] or a hemilaminectomy with undercutting to the contralateral side. In the LEL group 32% of patients received a hemilaminectomy, whereas in the CSS group only 14% were operated via a hemilaminectomy approach (Table 1). The fat which was accessible via the chosen approach was removed along the dural sac bilaterally.

Sagittal parameters

The measurements of preoperative sagittal parameters were very similar in both groups. In the LEL group 3 and in the CSS group 7 as you can see in Table 2 patients appeared with a spondylolisthesis Meyerding Grade 1 without major instability in functional X-rays. Sacro-pelvic parameter, lumbar lordosis and thoracic kyphosis were comparable in both groups. Furthermore, in both groups patients suffered from a loss of sagittal balance illustrated by the sagittal vertical

Table 1 Patients' data

	Lumbar epidural lipomatosis $n = 38$	Classical spinal stenosis $n = 51$	p (btw. groups)
Follow-up (months)	37.2 ± 8.1	37.8 ± 7.9	0.666
Age (years)	70.0 ± 8.3	72.9 ± 9.4	0.105
Gender	$m = 22, f = 16$	$m = 28, f = 23$	0.781
BMI (kg/m^2)	29.8 ± 5.5	28.1 ± 5.0	0.131
Operated levels/patient	1.6 ± 0.9	1.6 ± 0.7	0.685
Complications (n)	3 (7.9%)	4 (7.7%)	0.862
Hemilaminectomy (n)	12 (32%)	8 (14%)	0.077
Segments (L1/2/L2/3/L3/4/L4/5/L5/S1)	0/8/8/17/21	0/11/30/36/5	**0.002**
Preop. daily opioid use (n)	19 (50%)	14 (27%)	**0.029**

Follow-up time, age, gender (f = female, m = male), body mass index (BMI), operated levels per patient, perioperative complications (complications), the number of hemilaminectomy approaches do not differ significantly between the groups. In the classical spinal stenosis group 4/5 was very frequently the affected level, whereas in the lumbar epidural lipomatosis group the fat accumulation was more frequently on L5/S1. A higher percentage of patients with epidural lipomatosis received daily opioid medication preoperatively than in the classical spinal stenosis group

Values are given as mean values ± standard deviation

p values below 0.05 were defined as statistically significant

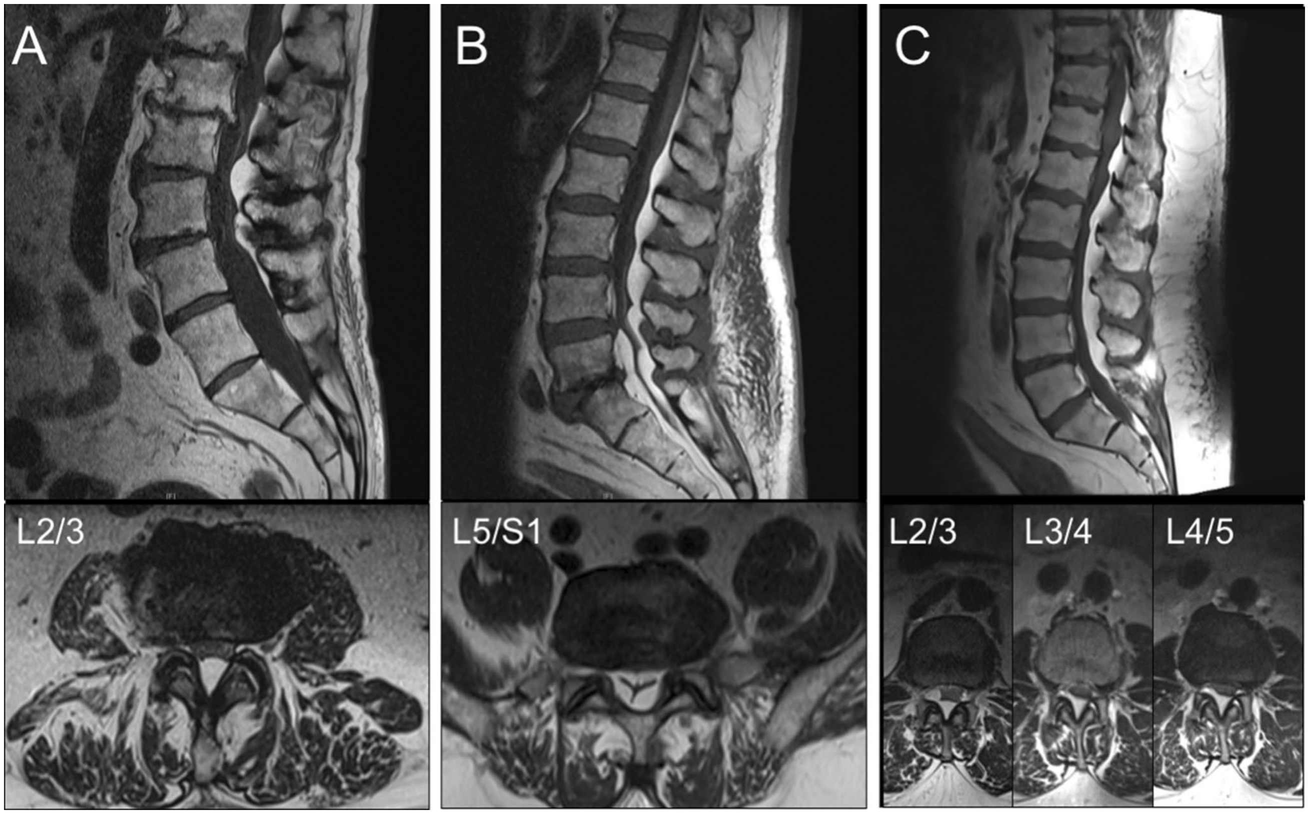


Fig. 2 Representative radiographs displaying MRI scans of different types of LEL with a sagittal T1-weighted MRI in the upper images and axial T2-weighted MRI scans in the lower images. **a** Monosegmental lumbar LEL with only a single stenotic level in L2/3 (decompression via a laminotomy easily possible). **b** Multisegmental LEL with only a single stenotic level at L5/S1. The fat accumulation is compressing the dural sac not only on the height of the vertebral disc, but also dorsal to the vertebral body L5 (decompression via a hemilaminectomy L5 should be preferred to address the whole stenotic area). **c** Multisegmental LEL with several stenotic segments at L2/3 L3/4 and L4/5 (a hemilaminectomy of L3 and L4 and partly of L2 lamina should be preferred)

Table 2 Radiological parameters

	Lumbar epidural lipomatosis $n = 38$	Classical spinal stenosis $n = 51$	p (btw. groups)
LL (°)	42.2 ± 12.5	42.9 ± 12.6	0.698
TK (°)	34.3 ± 13.7	39.5 ± 12.2	0.271
PI (°)	54.8 ± 9.8	55.4 ± 13.1	0.751
SS (°)	35.2 ± 6.8	35.6 ± 11.6	0.958
PT (°)	19.8 ± 8.4	19.7 ± 7.3	0.851
SSA (°)	117.4 ± 5.21	121.3 ± 13.4	0.335
SVA (mm)	56.0 ± 38.1	43.9 ± 40.7	0.340
C7/SFD	1.0 ± 0.7	0.9 ± 0.9	0.633
Spondylolisthesis (I°)	3	7	0.395

Sagittal spinal curvature: lumbar lordosis (LL) and thoracic kyphosis (TK)

Pelvic parameters: pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS)

Balance parameters: spino-sacral angle (SSA), sagittal vertical axis (SVA), the ratio between SVA and the vertical bicoxofemoral axis (C7/SFD) and the presence of a spondylolisthesis Meyerding Grade 1 were analysed from preoperative radiographs

Values are given as mean values ± standard deviation axis (SVA), the spino-sacral angle and the ratio of the SVA to the sacro-femoral distance (Table 2).

Clinical baseline parameters

The clinical baseline parameters were very similar in both groups. There was no significant difference concerning NRS, ODI, RMDQ or health-related quality of life when patients were elected for surgery (Table 3).

Clinical outcome parameters

In both groups, surgical decompression had a very similar effect on the clinical course of the patients. The patients benefitted strongly concerning their level of leg pain and back pain. This results in the distinct improvement resulted in a multiplication of the walking distance in both groups. Equal results were measurable regarding the ODI and RMDQ. Patients presented with a clearly reduced pain-associated disability. The physical component summary of the Sf-36 score showed a significant improvement concerning the health-related quality of life. The mental component summary of the SF-36 improved after surgical decompression as well, however not statistically significant (Table 3).

Due to the clinical benefit, the patient satisfaction in both groups was high. In the 3-year follow-up 70% of patients in the LEL group scored Odom's criteria with "good" or "excellent as 69% of patients in the CSS group did (Table 3).

Six patients suffered from an isolated lumbar lipomatosis, 20 from a lumbosacral lipomatosis, and 12 from a multisegmental lumbar lipomatosis. All three subgroups benefitted from surgical decompression. Although the clinical outcome was slightly better in the group with lumbosacral LEL (lsLEL) compared to patients with isolated lumbal LEL (ilLEL) and multisegmental lumbar LEL (mLEL) ((Δ difference between preoperative scores and 3-year scores) $\Delta NRS_{leg\_ilLEL} = 2.8 \pm 1.9$; $\Delta NRS_{leg\_lsLEL} = 4.8 \pm 3.1$; $\Delta NRS_{leg\_mLEL} = 2.8 \pm 2.8$; $\Delta NRS_{back\_ilLEL.} = 1.5 \pm 2.9$; $\Delta NRS_{back\_lsLEL} = 4.2 \pm 2.8$; $\Delta NRS_{back\_mLEL} = 2.4 \pm 5.0$), this difference was not statistically significant.

Discussion

This prospective observational investigation is the most extensive study to illustrate the long-term course of patients with a symptomatic spinal stenosis caused by lumbar epidural lipomatosis, who received a microsurgical decompression of the stenotic levels. Patients were followed for 3 years after surgery and showed a very favourable outcome scoring with a distinct improvement of pain, pain-associated disability and health-related quality of life. The results of 38 LEL patients were compared to 51 patients with classical spinal stenosis, and no obvious difference could be seen concerning all outcome scores in both groups. A simultaneous clinical improvement of both groups could be recorded, and the overall benefit lasted for 3 years. The satisfaction rate

Table 3 Outcome parameters

Outcome	Preoperative		1-Year follow-up		3-Year follow-up	
	LEL	CSS	LEL	CSS	LEL	CSS
NRS leg	6.3 ± 2.5	6.5 ± 3.0	3.3 ± 3.1**	2.4 ± 2.6***	2.5 ± 2.6**	2.9 ± 3.3***
NRS back	6.4 ± 2.3	6.3 ± 3.3	3.6 ± 2.9**	2.3 ± 2.5***	3.2 ± 3.0***	3.6 ± 3.0***
Walking distance (m)	287 ± 814	786 ± 1408	1242 ± 1664**	2192 ± 1949**	1440 ± 1797***	1993 ± 2037**
ODI (%)	52.7 ± 11.6	51.8 ± 13.6	34.8 ± 18.2***	23.4 ± 16.3***	32.3 ± 19.9***	27.6 ± 20.6***
RMDQ	13.8 ± 4.9	14.4 ± 5.4	8.6 ± 6.3*	6.1 ± 5.3**	8.4 ± 6.3***	8.0 ± 7.3***
SF-36 PCS	24.1 ± 5.2	24.9 ± 6.8	35.7 ± 10.0***	38.9 ± 9.5***	36.9 ± 11.5***	35.5 ± 11.3***
SF-36 MCS	39.2 ± 10.9	41.3 ± 10.3	44.0 ± 11.7	48.3 ± 11.8	44.7 ± 13.5	47.3 ± 13.1
Odom's criteria (*n*)	–	–	66% Satisfaction 13 Excellent 12 Good 5 Fair 8 Poor	73% Satisfaction 23 Excellent 14 Good 9 Fair 5 Poor	71% Satisfaction 15 Excellent 12 Good 5 Fair 6 Poor	69% Satisfaction 21 Excellent 14 Good 7 Fair 9 Poor

Clinical outcome parameter: preoperative and follow-up outcome parameters of patients with spinal epidural lipomatosis (SEL) and classical spinal stenosis (CSS)

Both groups show a significant improvement 1 year and 3 years after surgery concerning back pain and leg pain indicated by Numeric Pain Scale (NRS), Walking Distance, Oswestry Disability Index (ODI), Roland and Morris Disability Questionnaire, Short Form-36 Health Survey (SF-36) and Odom's criteria

There was no statistical difference between the groups

$^{**}p < 0.01$, $^{***}p < 0.001$ compared to preoperative scores of the patients in the LEL group was 71% and in the SCS group 69%. These results are comparable to larger studies investigating the outcome of patients with classical spinal stenosis [8].

While the pathogenesis of spinal epidural lipomatosis is largely unknown, there are currently several hypotheses, which try to explain the pathological epidural fat accumulation. A highly rated factor is a dysfunctional metabolism as in endogenous increased glucocorticoid production or iatrogenic administration. Corresponding to that, several case reports and case series described an association of patients with LEL with Cushing syndrome [9] due to steroid therapy or in patients with endocrinological disease like Cushing's disease. Other studies reported obesity to be responsible for LEL [10]. One study described spinal lipomatosis to be associated with a higher visceral fat accumulation, higher insulin and elevated uric acid levels (metabolic syndrome) [1, 11]. Another subgroup of patients with spinal lipomatosis might be idiopathically affected without secondary disease being responsible for the epidural space occupying fat collection [12].

These multiple causes for LEL suggest that many different treatment concepts might be necessary to offer a causal therapy for every individual patient. Case reports described the possibility of diets to reduce the epidural fat component [13, 14]. There are several supplementary conservative approaches, one of them being the optimization of medical treatment for endocrine disorders (hypothyroidism, hypercortisolism) or the reduction of iatrogenic glucocorticoid medication, and these are likely to result in a reduction of disabling symptoms. In cases of mild manifestation of LEL a conservative causal treatment is a possible approach, which has been favourized in literature reviews [15]. In patients with severe neurological deficits [16] or significantly reduced mobility, a decompressive surgery has been performed as a reasonable treatment and the conceptual approach was mainly adopted from classical spinal stenosis patients [17]. The operative approach in these stronger affected patients has been analysed by case reports and small case series; they report distinct clinical improvement of mobilization due to surgical decompression [18]. However, the scientific evidence for conservative treatment is low as well as scientific evidence for surgical treatment is low. Up to date there is no study comparing conservative treatment to surgical therapy. Furthermore, there is not a single prospective study investigating the long-term course of LEL patients. In our present study we could underline that microsurgical decompression of patients with LEL is safe and successful, and in addition to that distinct clinical improvement continues for at least 3 years in decompressed LEL patients. As far as we know, our study currently represents the largest prospective investigation of the short- and long-term clinical course of LEL patients.

The characteristics of the LEL patient cohort in our study were similar to those of other studies. 32% of patients had a glucocorticoid-associated LEL. More than 50% of patients had a metabolic syndrome, and the majority of LEL patients were male. Overall, these data are congruent to previous study results [3, 19]. The reason for that is not conclusively clarified. However, it is well known that men with the same degree of overweight have a significantly higher amount of visceral fat compared to women [20]. This visceral type of fat distribution might be associated with the epidural fat accumulation in the spinal canal.

The distribution of the stenotic segments in the lumbar spine of LEL patients and CSS patients is very similar as it was found in earlier case series [3, 19]. LEL is known to appear mostly at the lumbosacral segment, whereas CSS is more often localized at L3/4 and L4/5 [17]. Patients with LEL appeared with a higher preoperative opioid use than patients with CSS, which indicates that in patients with LEL the diagnosis is made late and the conservative treatment has been exhausted.

In this study a microsurgical approach via a laminotomy with undercutting or a hemilaminectomy approach was used depending on the individual decision of each surgeon. Because the LEL pathology is not only localized at the level of the vertebral disc but on the entire height of the vertebral body as well, a hemilaminectomy might be necessary in some multisegmental cases. The hemilaminectomy approach enables a decompression of the dural sac along the entire rout (Fig. 2) and facilitates the achievement of haemostasis, which might have had an influence on decision making of the responsible surgeon. Corresponding to that, the hemilaminectomy was the approach of choice in 32% of cases in the LEL group and only in 14% of cases in the CSS group.

One limitation of this study is the number of recruited patients, which is owed to the low incidence of symptomatic LEL. Further, we did not investigate the outcome of patients, who received the best medical treatment for LEL. Therefore, a comparison of operative and conservative treatment for symptomatic LEL is missing. This comparison should be performed in a future study.

The prevalence of spinal epidural lipomatosis in patients who received an MRI of the spine with and without spine-related symptoms is 2.5% [21]. The prevalence in patients with a symptomatic spinal stenosis is about 6% [2]. In accordance with that, the frequency of patients with LEL and the awareness of this disease being responsible for spine-related symptoms like back pain and sciatica are highly probably underestimated [22]. Considering these facts the relevance to evaluate safe and standardized therapy plans is indispensable. This study demonstrates that an operative decompression of patients with LEL is a safe procedure with a low rate of complications and long-term clinical benefit.

Conclusions

This study illustrates that patients with symptomatic LEL who received a microsurgical decompression have a favourable outcome concerning pain and pain-associated disability as well as quality of life. Furthermore, a long-term benefit after surgery is very likely, satisfaction rates are high, and complication rates are low despite the obese, old and multimorbid patient population. A surgical decompression can be offered with a similar prognosis to patients with classical spinal stenosis.

The answer is “no, fat does not matter”. Concerning the outcome of decompressive microsurgery, there is no difference between patients with spinal stenosis—no matter whether it is caused by osteoligamentous compression or lumbar epidural lipomatosis.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with ethical standards of the institutional research comittee (reference number: EA1/101/17) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent All authors confirmed consent for publication.

References

1. Morishita S, Arai Y, Yoshii T et al (2018) Lumbar epidural lipomatosis is associated with visceral fat and metabolic disorders. Eur Spine J. https://doi.org/10.1007/s00586-018-5584-2
2. Malone JB, Bevan PJ, Lewis TJ et al (2018) Incidence of spinal epidural lipomatosis in patients with spinal stenosis. J Orthop 15:36–39. https://doi.org/10.1016/j.jor.2017.11.001
3. Borré DG, Borré GE, Aude F, Palmieri GN (2003) Lumbosacral epidural lipomatosis: MRI grading. Eur Radiol 13:1709–1721. https://doi.org/10.1007/s00330-002-1716-4
4. Ishikawa Y, Shimada Y, Miyakoshi N et al (2006) Decompression of idiopathic lumbar epidural lipomatosis: diagnostic magnetic resonance imaging evaluation and review of the literature. J Neurosurg Spine 4:24–30. https://doi.org/10.3171/spi.2006.4.1.24
5. Barrey C, Roussouly P, Le Huec J-C et al (2013) Compensatory mechanisms contributing to keep the sagittal balance of the spine. Eur Spine J 22(Suppl 6):S834–S841. https://doi.org/10.1007/s00586-013-3030-z
6. Barrey C, Roussouly P, Perrin G, Le Huec J-C (2011) Sagittal balance disorders in severe degenerative spine. Can we identify the compensatory mechanisms? Eur Spine J 20 Suppl 5:626–633. https://doi.org/10.1007/s00586-011-1930-3
7. Thomé C, Zevgaridis D, Leheta O et al (2005) Outcome after less-invasive decompression of lumbar spinal stenosis: a randomized comparison of unilateral laminotomy, bilateral laminotomy, and laminectomy. J Neurosurg Spine 3:129–141. https://doi.org/10.3171/spi.2005.3.2.0129
8. Weinstein JN, Tosteson TD, Lurie JD et al (2010) Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the spine patient outcomes research trial. Spine (Phila Pa 1976) 35:1329–1338. https://doi.org/10.1097/BRS.0b013e3181e0f04d
9. Lee M, Lekias J, Gubbay SS, Hurst PE (1975) Spinal cord compression by extradural fat after renal transplantation. Med J Aust 1:201–203
10. Badami JP, Hinck VC (1982) Symptomatic deposition of epidural fat in a morbidly obese woman. Am J Neuroradiol 3:664–665
11. Yildirim B, Puvanesarajah V, An HS et al (2016) Lumbosacral epidural lipomatosis: a retrospective matched case-control database study. World Neurosurg 96:209–214. https://doi.org/10.1016/j.wneu.2016.08.125
12. Al-Yafeai R, Maghrabi Y, Malibary H, Baeesa S (2017) Spinal cord compression secondary to idiopathic thoracic epidural lipomatosis in an adolescent: a case report and review of literature. Int J Surg Case Rep 37:225–229. https://doi.org/10.1016/j.ijscr.2017.06.041
13. Borstlap ACW, van Rooij WJJ, Sluzewski M et al (1995) Reversibility of lumbar epidural lipomatosis in obese patients after weight-reduction diet. Neuroradiology 37:670–673. https://doi.org/10.1007/s002340050177
14. Kniprath K, Farooque M (2017) Drastic weight reduction decrease in epidural fat and concomitant improvement of neurogenic claudicatory symptoms of spinal epidural lipomatosis. Pain Med. https://doi.org/10.1093/pm/pnw313
15. Fassett DR, Schmidt MH (2004) Spinal epidural lipomatosis: a review of its causes and recommendations for treatment. Neurosurg Focus 16:E11. https://doi.org/10.3171/foc.2004.16.4.12
16. Cushnie D, Urquhart JC, Gurr KR et al (2018) Obesity and spinal epidural lipomatosis in cauda equina syndrome. Spine J 18(3):407–413. https://doi.org/10.1016/j.spinee.2017.07.177
17. Weinstein JN, Lurie JD, Tosteson TD et al (2007) Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. N Engl J Med 356:2257–2270. https://doi.org/10.1056/NEJMoa070302
18. Fogel GR, Cunningham PY, Esses SI (2005) Spinal epidural lipomatosis: case reports, literature review and meta-analysis. Spine J 5:202–211
19. Ferlic PW, Mannion AF, Jeszenszky D et al (2016) Patient-reported outcome of surgical treatment for lumbar spinal epidural lipomatosis. Spine J 16:1333–1341. https://doi.org/10.1016/j.spinee.2016.06.022
20. Ross R, Shaw KD, Rissanen J et al (1994) Sex differences in lean and adipose tissue distribution by magnetic resonance imaging: anthropometric relationships. Am J Clin Nutr 59:1277–1285. https://doi.org/10.1093/ajcn/59.6.1277
21. Theyskens NC, Paulino Pereira NR, Janssen SJ et al (2017) The prevalence of spinal epidural lipomatosis on magnetic resonance imaging. Spine J 17:969–976. https://doi.org/10.1016/j.spinee.2017.02.010
22. Al-Omari AA, Phukan RD, Leonard DA et al (2016) Idiopathic spinal epidural lipomatosis in the lumbar spine. Orthopedics 39:163–168. https://doi.org/10.3928/01477447-20160315-04

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