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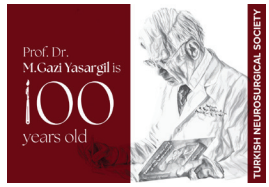

Neurosurgical Management and Follow-up of Pediatric Lumbosacral Lipomas: A Single-Center Experience with 28 Patients

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ABSTRACT

AIM: To evaluate the efficacy of surgical interventions for pediatric lumbosacral lipomas (LSL) by focusing on preoperative symptoms, postoperative outcomes, and long-term prognosis.

MATERIAL and METHODS: The medical records and magnetic resonance images (MRI) of 28 pediatric patients (15 boys and 13 girls aged 1–17 years) who underwent LSL resection between 2018 and 2023 were retrospectively reviewed. The study assessed surgical indications, techniques (including using neuromonitoring and the extent of lipoma resection), and postoperative management. The LSLs were classified based on their location and relationship with the spinal cord, which informed the surgical approaches and prognostic predictions. Outcome measures included neurological function, as assessed by the Hoffmann grading system, and complications such as wound dehiscence and cerebrospinal fluid leakage.

RESULTS: The dorsal LSLs demonstrated a 62.5% total resection rate with 37.5% symptomatic improvement after surgery. The caudal LSLs demonstrated a lower total resection rate (46.15%), with 30.77% of the patients experiencing symptom worsening. Transitional LSLs demonstrated a 100% positive outcome after total resection. Chaotic LSLs, the most complex LSL, had a postoperative deterioration rate of 40% after subtotal resection. Overall, surgical complications were noted in 17.8% of the patients.

CONCLUSION: Surgical management of symptomatic pediatric patients with LSL yields significant benefits, with a careful balance between radical resection and preservation of neurological function. The type of lipoma significantly influences surgical planning and outcomes. Despite challenges in achieving complete resection in chaotic LSLs, tailored surgical approaches based on preoperative imaging and lipoma classification can optimize patient outcomes.

KEYWORDS: Lipomyelomeningocele, Spinal dysraphism, Neurogenic bladder, Lumbosacral lipoma

ABBREVIATIONS: LSL: Lumbosacral lipomas, **CUSA:** Cavitron ultrasonic surgical aspirator, **MRI:** Magnetic resonance imaging, **CIC:** Clean intermittent catheterization, **PFS:** Progression-free survival, **IVS:** Interactive virtual simulation, **SNS:** Split notochord syndrome, **TFTS:** Tight filum terminale syndrome, **CISS:** Constructive interference in steady state, **CSF:** Cerebrospinal fluid

INTRODUCTION

Lumbosacral lipomas (LSL) are congenital lesions of the conus medullaris and filum terminale. One of the most prevalent types of occult spinal dysraphism (spina bifida occulta) is LSL (11). The LSL (except filar lipomas) is believed to develop from the early disjunction of the neural tube from the surrounding ectoderm, resulting in a patent posterior opening of the neural plate and infiltration of mesodermal tissues, including fatty tissue and less frequently osteochondral tissues (17,24,35).

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Although adipose tissue is a common cause of tethered cord syndrome, it is unclear whether the underlying pathology of spinal cord dysfunction is due to developmental dysplasia, growth-induced mechanical traction, or both. Tethered cord syndrome caused by LSL may cause progressive neurological deficits such as sensorimotor complications, urinary symptoms, foot deformities (14), neuropathic ulcers, neurogenic bladder (secondary renal failure), and pain (17). LSLs are believed to be associated with tethered roots, filum, and cord, and untethering these structures may prevent deterioration.

LSL can be classified into dorsal, transitional, caudal, filar, and chaotic types (2) according to the lipoma location and involvement of the cord and caudal roots. The classification is closely related to the surgical procedure chosen, residual volume, postoperative outcome, and prognosis (2,29,30,31). The criteria for surgical intervention and the most effective surgical approach for intradural spinal lipomas remain debatable (5,22).

This study aimed to present the preoperative symptoms, postoperative outcomes, and prognosis of patients with LSL, as well as the surgical technical nuances and clinical decision-making regarding lipoma type. This comprehensive analysis was performed to enhance our understanding of LSL and contribute to developing effective surgical strategies for patients with this condition.

MATERIAL and METHODS

The Institutional Review Board approved our retrospective study (No: 09.2023.900; date: 14.07.2023). Following established guidelines, all patients gave informed consent for the surgical procedures.

Patient Population and Outcome Analysis

The authors retrospectively analyzed the medical records and MRI images of pediatric patients with LSLs. From 2018 to 2023, we surgically treated 28 pediatric patients (15 boys and 13 girls). The patients' ages ranged from 1 to 17 (average, 7.1 years). The average follow-up period was one year.

The preoperative evaluations performed were neurological examination, electrophysiological studies (sensorimotor evoked potential), and urologic evaluation, including ultrasonography of the kidney and bladder, voiding cystourethrography, and urodynamic study. A lumbosacral MRI was obtained to diagnose and classify the lipoma and determine a surgical plan (Figure 1). Intraoperative neuromonitoring was performed in all the patients. A postoperative MRI was obtained to confirm that a radical excision was performed.

Dorsal and transitional LSLs were classified according to Chapman's classification, and chaotic and caudal LSLs were classified according to Arai and Pang's classification (2,6,29,30).

The indications for surgery were as follows: (i) new or progressive neurological symptoms, including sensorimotor deficits, difficulty in voiding, and/or defecation problems; (ii) aggravation of foot deformities and walking problems; (iii) development of syringes or its aggravation during follow-up; and (iv) pain.

Patients with a LSL may have intact neurology or various neurological symptoms and deficits. These symptoms include pain, changes in reflexes, sensorimotor loss, foot deformities, and urinary and sphincter issues. Hoffmann described a functional grading scheme in this study to assess treatment results (16).

If the patient complained of new symptoms or symptom progression and exhibited worsening of electrophysiological and urodynamic study results, the patient was considered to have deteriorated.

The following parameters were analyzed to determine their effect on surgical outcomes: sex, age, abnormalities on preoperative evaluation, lipoma type, presence of preoperative syrinx, amount of lipoma resected, pial reconstruction, and duraplasty.

We excluded individuals with incomplete medical records or insufficient follow-up data, essential for a comprehensive assessment of the condition's natural history and surgical outcomes.

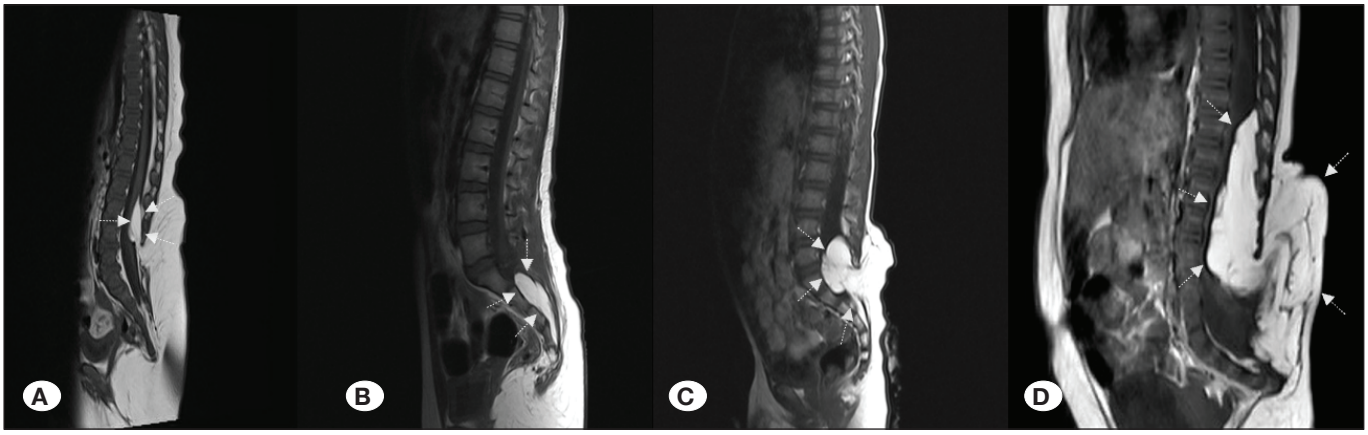

Figure 1: Lumbosacral lipoma classification using a T1-sequence magnetic resonance image. **A)** Dorsal, **B)** caudal, **C)** transitional, and **D)** chaotic.

Surgical Treatment

The authors performed untethering and total/near-total resectioning of all lipomas except chaotic ones. An ultrasonic aspirator and neuromonitoring were performed in all the patients. The skin and soft tissue were incised as one up to the subcutaneous lipoma. Frequently, lipoma removal reveals a fatty stalk connecting the subcutaneous tissue with the intraspinal lipoma via a defect in the lumbodorsal fascia or a spina bifida.

If possible, one level above the cranial end and one below the caudal end of the lipoma were exposed to ensure proper orientation. When required, a laminotomy or laminectomy was performed to access the lateral edges of the dural sac. Visualization of the normal dura rostrally and caudally allowed us to understand the anatomy of the malformation. After that, the bulk of the extradural fat was safely removed. Under microscopic magnification and illumination, the dura was opened in the midline, approximately 1 cm rostral to the lipoma. The midline incision was deepened up to the cord and lipoma adhesion level. The dura was separated just lateral to the cord, and the lipoma's adhered portions were circumferentially released with careful inspection of the roots. The free dural edge on each side was retracted with sutures to expose the cord and roots at the deepest lipoma's deepest edge. The point of fusion of the pia, spinal cord, and lipoma was identified. The roots were exposed at their exit point from the spinal cord, and microscissors were used to separate the fat cord from the root. After the lipoma was excised, the cord was shaped into a tubular form with intermittent 6/0 sutures under neuromonitoring. Subsequently, a wide duraplasty was performed to prevent retethering. In some patients, a cavitron ultrasonic surgical aspirator (CUSA) was used to shrink the lipoma tissue.

Electrophysiological determinations in chaotic lipomas are crucial to differentiate normal tissue from lipoma. Roots embedded in fat tissue may not be identified in any other way. The white plane on the dorsal side of a chaotic lipoma was handled the same way as other lipomas. However, the billows of fat on the ventral side of the placode were left alone because the dorsal part of the lipoma, unless iatrogenically invaded, is tethered to the spinal cord(28). After resection of the chaotic lipoma, the dura was closed, and a wide duraplasty was performed.

RESULTS

The medical records and MRI images of 28 pediatric patients (15 boys and 13 girls, age range 1–17 years) who underwent surgery for LSL between 2018 and 2023 were retrospectively analyzed. Among the 28 LSLs, 8 (28.5%) were dorsal, 13 (46.4%) were caudal, 2 (7.1%) were transitional, and 5 (17.8%) were chaotic (Table I).

We found distinct outcome patterns across the LSL subtypes (Table II). Among the eight treated patients with dorsal LSL, five achieved total resection (62.5%). Near-total resection was achieved in one patient, and subtotal resection was achieved in two patients. Three of the eight patients (37.5%) postoperatively exhibited symptomatic improvement. The remaining five

Table I: Comparison of LSL Types According to Resection

LSL Type	Subtotal Resection	Near- Total Resection	Total Resection	Total Patient
Dorsal Type	2	1	5	8
Caudal Type	7	0	6	13
Transitional Type	0	0	2	2
Chaotic Type	5	0	0	5

LSL: *Lumbosacral lipoma.*

Table II: Comparison of LSL Types According to Changing Neurological Symptoms Before and After Surgery

LSL Type	Worsened compared to the preoperative	Same compared to the preoperative	Better compared to the preoperative	Total resection (%)
Dorsal Type	0	5 (2 of them have no symptoms preoperatively.)	3	75.0
Caudal Type	4	4 (2 of them have no symptoms preoperatively.)	5	46.0
Transitional Type	0	1(have no symptoms preoperatively.)	1	100.0
Chaotic Type	2	3	0	0.0

LSL: *Lumbosacral lipoma.*

patients (62.5%), including two asymptomatic patients before surgery, experienced no change in neurological status.

The caudal LSL group consisted of 13 patients. Among these, total resection was achieved in six patients, and subtotal resection was achieved in seven patients. Postoperatively, four patients (30.77%) experienced worsening of symptoms, and five patients demonstrated improvement (30.77%). The condition of four patients, including two patients who were asymptomatic preoperatively, remained unchanged.

Total resection was achieved in patients with transitional LSL. Both patients demonstrated positive outcomes, with one patient improving symptoms and the other maintaining their preoperative asymptomatic status.

The chaotic LSL was the most challenging to treat, with subtotal resection being achieved on all five patients due to the condition's inherent complexity. Postoperatively, two patients (40%) experienced a decline in their condition, while three patients did not experience a significant change in their symptoms.

Among all the patients who worsened, four with voiding problems required clean intermittent catheterization (CIC). Five other patients had surgical complications, including wound dehiscence (n=3) and cerebrospinal fluid (CSF) leakage (n=2), which required revision surgery.

Hoffmann's grading score was 1.61 on average in all the patients. The average score was 2 for dorsal LSL, 1.41 for caudal LSLS, 3 for transitional LSL, and 1.4 for chaotic LSL. Syringomyelia was observed in 10 patients (35.7%) preoperatively, four patients (14.2%) exhibited diastematomyelia, and eleven study participants (39.2%) had skin problems.

DISCUSSION

In pediatric neurosurgery, managing LSL is a difficult chore. A surgeon's involvement calls for carefully assessing the pros and cons involved. Our analysis utilizing data from many studies offers a thorough overview of current approaches and their outcomes. Customizing treatment plans for every patient comes first, weighing factors such as the type of lipoma, patient age, and symptoms experienced. Our work aims to add to the present LSL management information database. We present a classification-based approach to improve understanding of surgical operations. The present work meticulously explores the possible effects of the degree of lipoma excision on long-term neurological outcomes. While our study builds on other studies, it aims to provide more thorough knowledge by focusing on the outcomes linked with several types of lipomas and surgical approaches. These points of view help neurosurgeons make better decisions and encourage more discussion in pediatric neurosurgery.

Our study demonstrates various perspectives on LSL management and highlights the importance of personalized treatment strategies. We advocate for surgery in symptomatic patients and a conservative approach with surgical intervention as needed in asymptomatic patients. Our ultimate goal is to preserve neurological function while minimizing risks. A thorough understanding of preoperative neuroimaging, lesion types, intraoperative guidance, and surgical techniques are essential for successful outcomes. Thus, objective evaluation and continuous improvement in surgical approaches, treatment strategies tailored to individual patients, and a surgeon's expertise are essential. When it comes to managing complex lipomas, we agree with the findings of Pierre-Kahn et al. that asymptomatic patients should be followed up neurologically, urologically, and orthopedically. However, symptomatic patients should be advised surgery, and the lipoma should be excised as much as possible while untethering the cord and roots. To plan a precise surgical strategy that untethers the neural tissues with minimal risk of injury, it is paramount to interpret the preoperative neuroimaging to determine the LSL type and detect any other anomalies (e.g., diastematomyelia). In patients with lipomyelomeningoceles, the lesion should be carefully excised to avoid injury of neural tissues protruding from the spinal canal (13,34). In patients with a concomitant split cord malformation, the diastematomyelia should be resected first, and the lipoma should be excised last. Although the primary surgical procedure is the same for all the lipoma types, the surgical nuances differ from one type to the other. Because the chaotic LSL engulfs the roots, total lipoma resection without worsening neurological deficits is considered nearly impossible. However, over the last decades, Pang et al. have claimed that total excision is more successful than subtotal resection (29,30). However, total lipoma resection requires much surgical experience.

In our surgical experience, we do not attempt total resection in chaotic LSLs. Instead, we perform maximal resection without attempting a hazardous approach and always perform a large duraplasty. In case of a slight decrease in intraoperative motor evoked potentials or electromyography response (a 50% decrease in amplitude or 10 % prolongation in latency) at the lipoma near the root exit zone, we discontinue the lipoma resection after untethering all the attachments to the dura and the roots. To avoid retethering, we perform a wide duraplasty to ensure the cord never touches the dura. If the patient complains of new or progressive symptoms and demonstrates worsening of electrophysiological and urodynamic study results, the patient is considered to have deteriorated, and re-surgery is considered. We believe that removing an additional small amount of fat tissue at the risk of injuring the cord is unacceptable.

The utilization of CUSA in lipoma resection presents a balanced profile of advantages and drawbacks. CUSA offers precise tissue dissection with minimal trauma and mobilization of the surrounding neural structures, essential in delicate pediatric neurosurgeries. CUSA's ability to selectively emulsify fatty tissue while preserving neural tissue helps, especially in getting more complete resections. Still, its utilization comes with challenges. By way of a steep learning curve, knowledge of this method can allow us to reduce the risk of inadvertent damage to neurovascular structures. Moreover, producing heat and the likelihood of tissue cavitation necessitate careful use to minimize thermal harm. Future studies and discussions should define CUSA's optimum use parameters and approaches for LSL resection to maximize its benefits and

reduce risks. Recently, we have been performing sharp dissections for lipoma resections instead of utilizing CUSA.

Effective long-term care and monitoring necessitate a scheduled follow-up once LSLs are removed. Three, six, and twelve months after surgery should be the times for follow-up appointments. After that, the patients should be under observation annually. During these visits, a thorough clinical neurological examination should be performed in search of any signs of tethered cord syndrome recurrence, changes in neurological function, or development of new symptoms. MRI is indicated to look for spinal cord retethering and lipoma growth both at the one-year follow-up and then every two years. Bladder performance is suggested to be checked via annual urodynamic tests. Parents and other caregivers should also be informed on the indicators of retethering or neurologic deterioration to enable fast reporting. Should postoperative problems arise to protect the quality of life, this proactive method provides rapid care. Carefully recorded long-term outcome data can direct future patient therapy and aid in understanding the success of surgical operations.

Whether patients getting LSL resections retain their quality of life depends heavily on postoperative therapy of neurogenic bladder and bowel dysfunction (18). Often using a multidisciplinary approach, this postoperative care demands gastroenterological, pediatric urological, and rehabilitative therapy. Continuity regimens are customized to the patient, usually incorporating dietary changes, a bowel schedule with planned toileting, CIC for bladder control, and regular use of stool softeners or laxatives. Cases of refractory bladder or bowel dysfunction may call for sacral neuromodulation, botulinum toxin injections, or anticholinergic drugs. Regular follow-up with urodynamic exams and bowel function evaluations lets one track development and change therapeutic plans. This whole approach systematically addresses these individuals' long-term and acute functioning issues.

In our analysis, the percentage of patients with poor outcomes and neurological impairment (17.8%) exceeded that recorded in earlier investigations (7). This suggests that even being objective about our findings, we should aim to achieve the best results. Should our findings contradict those of the literature, the signs for surgical intervention should be customized individually. Unsuccessful surgical attempts must be carefully reviewed, improved on, or corrected by someone with better results, or conservative management should be followed. Each surgeon should determine the indications for surgery according to the underlying pathology and their success rate with the lesion. By incorporating these perspectives, we aim to provide a comprehensive understanding of LSL management and contribute to developing evidence-based guidelines for clinicians.

Several authors have classified LSLs, including Chapman and Arai et al., with implications for surgical procedure selection, residual volume, postoperative outcomes, and prognosis. Asymptomatic filum lipomas and dorsal LSLs demonstrate favorable prognoses, while transitional and chaotic LSLs yield poorer outcomes (2,6,30). Our findings align with these studies, particularly regarding the outcomes of different lipoma types, where transitional and chaotic LSLs demonstrated poorer prognoses than dorsal LSLs.

Several methods besides conventional techniques have been proposed for preoperative assessment and intraoperative guidance. Kim et al. proposed the use of extended lumbosacral spine MRI instead of whole spine MRI for better image quality around the primary lesion and minimal additional time and cost (19). Some studies have demonstrated the dynamic morphological changes and clinical value of constructive interference in steady state (CISS) MR imaging in LSLs. They emphasized the need for close monitoring and timely intervention in infants to address these changes effectively (15,23). Nonaka et al. emphasized the importance of stable intraoperative neurophysiological monitoring, particularly in infants. They found the bulbocavernosus reflex more reliable than motor-evoked potentials (MEPs) in very young patients, underscoring the necessity of meticulous intraoperative monitoring to mitigate surgical risks. This is consistent with our conclusion, revealing notable postoperative improvements using modern intraoperative monitoring systems (25). Shin et al. assessed the average thickness of the filum terminale on sonography for LSL screening in young infants and proposed an acceptable cutoff value of 1.1 mm, much below the standard 2 mm threshold. For the detection of filum terminale lipomas, this new cutoff value showed great sensitivity (94%) and specificity (86%), therefore offering a more reliable diagnosis tool for early management (36). By using three-dimensional multi-fusion images applied with a haptic device for planning LSL operations, Ogura et al. presented a preoperative interactive virtual simulation (IVS). This IVS improves resection accuracy and lowers complications by enabling exact preoperative planning and intraoperative guidance. Including IVS in our surgical planning procedures would enhance our capacity to customize surgical techniques to particular patient requirements (27).

Surgical indications for symptomatic LSL patients are well established. Nevertheless, the indications in patients without symptoms are subject to debate. When analyzing the arguments favoring and against preventative surgery, Chumas observed the lack of comprehensive prospective studies that may offer a definitive answer to this matter (8). Although several studies advocate for early intervention to avoid future neurological damage, others propose a cautious strategy because of the risks associated with surgery and the potential for tethering (40). Our recommendation for asymptomatic patients who are being closely followed and monitored is to adopt a conservative approach. Surgical intervention should only be considered if there are clear signs of neurological deterioration or the appearance of new symptoms. This ensures that the benefits of intervention outweigh the risks associated with surgery.

The management of LSLs is intricate because of the diverse characteristics of these lesions and their different clinical presentations. The problems are highlighted in a recent systematic analysis conducted by Perera et al., which uncovers substantial variation in patient outcomes and therapeutic approaches among 913 cases. The study suggests that although

nearly two-thirds of patients who were treated with surgery or conservative measures maintained clinical stability, 17.6% worsened, primarily due to neuropathic bladder dysfunction. Compared to subtotal resection (10-67%), near-total excision of lipomas yielded better deterioration-free survival rates (77.2-98.4%). However, 4.5% necessitated re-do untethering operations. The study underscored the significance of using standardized terminology, evaluation instruments, and surgical procedures to enhance uniformity in results and efficiently direct management approaches (32). This aligns with our findings, emphasizing the importance of individualized treatment plans based on lipoma type and patient-specific factors, supported by comprehensive preoperative imaging and intraoperative neuromonitoring to optimize surgical outcomes.

Pierre-Kahn et al. found that unoperated asymptomatic patients with lipomyelomeningocele demonstrated better outcomes after ten years than those who underwent surgery (33). Conversely, Pang and other authors advocate for total lipoma resection, regardless of the clinical status, to prevent potential complications (12,28). La Marca et al. suggested that all spinal lipomas should be surgically excised prophylactically as early as possible. Furthermore, interdisciplinary follow-up is required postoperatively to perform a reintervention if necessary (21). Usami et al. clarified the preoperative characteristics of filum terminale lipomas and elucidated the surgical effects. They suggested that early intervention, particularly in symptomatic patients, can lead to significant improvements and prevent further deterioration (39).

De Vloo et al. and Tu et al. provided insights into the long-term outcomes of radical resection techniques and the natural history of congenital neurological deficits associated with LSL. Both studies emphasize the importance of individualized treatment strategies and suggest that observation followed by intervention upon symptom development can be an acceptable approach for managing these patients (9,38).

Kulkarni et al. and Pierre-Kahn et al. demonstrated that 33% of patients with asymptomatic conus lipomas experience worsening within nine years, and 32% of them require surgical intervention (20,33). Conservative management, followed by surgery if necessary, resulted in 88% of patients remaining neurologically intact after ten years. In contrast, only 53% of patients who underwent surgery remained neurologically intact. Insufficient evidence supports recommending prophylactic surgery for asymptomatic patients with conus lipomas, and predicting worsening in patients remains a challenge. Thus, conservative monitoring and follow-up, with surgery as needed, appears to be the most appropriate approach for asymptomatic patients with conus lipomas.

Wykes et al. analyzed 56 patients over an average of six years and found a progression-free survival (PFS) rate of 71% and an estimated 10-year PFS rate of 60%. This indicated that surgery was contemplated for the remaining 29% of patients who exhibited signs of clinical worsening. They determined that age <2 years, female sex, transitional-type lipoma, and presence of syrinx were adverse prognostic factors. Thus, these factors should be considered when determining treatment options and individualized patient management (41). Talamonti et al. analyzed 56 patients diagnosed with LSL, of whom 32 had surgical intervention and 24 received conservative treatment. Notwithstanding the absence of a statistically significant distinction among the groups, the authors advised surgical intervention for all patients diagnosed with non-transitional lipomas (37).

When combined with other rare spinal dysraphisms, such as split notochord syndrome (SNS) and tight filum terminale syndrome (TFTS), the surgical treatment of LSLs is even more difficult. Alelyani et al. successfully handled a rare instance of SNS linked with spinal cord lipoma and spinal column duplication employing microsurgical untethering. This example emphasizes the vital need for early diagnosis, knowledge of the pathophysiology of spinal cord tethering, and careful microsurgical procedures for best results (1). Likewise, Bao et al. underlined that TFTS in children can show with a typically positioned conus, challenging the diagnosis. Their research implies that clinical presentation, physical and radiological tests, MRI, and pathological abnormalities in the filum terminale should form the basis of diagnosis. Notwithstanding conus location, they support early sectioning of the filum when neurological symptoms exist (4). First, address the split cord deformity before moving on with the lipoma excision when handling LSLs related to split cord malformations and diastematomyelia. This sequential surgical method helps reduce risks and enhance surgical outcomes by precisely untethering roots before addressing the LSLs.

The results of our study on postoperative complications and the necessity for revision procedures align with the research conducted by El-Ali et al., which emphasized the requirement of a multidisciplinary approach, including neurosurgeons and plastic surgeons, to successfully address functional and aesthetic issues. Implementing this comprehensive strategy is essential for achieving the best possible patient care and tackling the complex issues raised by LSL (10).

Pang et al. conducted a thorough investigation, including patients who underwent either total or near-total lipoma resections under a 20-year follow-up (31). They discovered that patients with total and near-total resections showed a 20-year PFS rate of 88.1%. By contrast, over 10.5 years, the PFS rate among patients who solely underwent subtotal resections was much lower at 34.6%. Of the asymptomatic individuals, those with entire resections showed a PFS rate of 98.8% over 20 years; those with subtotal resections showed a PFS rate of 40% over 10.5 years. Conservative patients treated in Paris and London showed PFS rates of 67% over nine years and 60% over ten years, respectively. With rates of 96.9% for a ratio of 30 to 50, 86.2% for a ratio of 30 to 50, and 78.3% for a ratio >50, Pang et al. also noted the cord/dural sac ratio as the single independent variable influencing PFS. According to their study, the perfect patient profile is an asymptomatic younger age, less than two years, without a past surgical history, with a PFS rate of 99.2%. These results highlight the need to consider elements including the degree of lipoma resection, patient's age, symptomatology, and cord/dural sac ratio when designing surgical procedures and provide insightful analysis on managing LSLs. Pang et al. also stress the pos-

sible advantages of complete resections in particular patient groups, which might result in better long-term results (31).

Total lipoma resection achieves better long-term protection against symptomatic recurrence than partial resection (3). However, LSLs' surgical management and underlying pathology must be better understood, especially in chaotic LSLs. Because the chaotic LSL engulfs the roots, total lipoma resection is challenging without worsening neurological deficits. However, recently published studies encourage surgeons to perform total resection for chaotic LSLs (30,31).

Filar lipomas are very different from other LSLs and are, thus, not included in this study. Our policy for a growing child with filar lipomas is to advise surgery. Dorsal lipomas can be more easily treated than transitional and chaotic LSLs because of the more accessible surgical anatomy and lower risk of operational deficits. Thus, these LSLs may be excised even if they are asymptomatic.

Our study is limited by its retrospective design and the small sample size from a single institution, which may affect the generalizability of the findings. The variability in long-term follow-up and reliance on subjective assessment criteria also present challenges in evaluating surgical outcomes. In the future, prospective, multicenter studies with more extensive and diverse populations should be performed to validate our study findings. Standardizing surgical techniques and incorporating advanced intraoperative imaging and neuromonitoring tools with artificial intelligence techniques, such as deep learning algorithms, could refine surgical strategies. Additionally, long-term longitudinal studies that include quality-of-life assessments will be crucial for a more comprehensive understanding of the natural history of LSLs and the long-term impact of surgical intervention. Investigations into the molecular and genetic underpinnings of these conditions may also provide insights into predictive factors of disease progression and potential nonsurgical treatments, which may expand the scope of patient care and management (26).

CONCLUSION

Our study highlights the importance of individualized treatment strategies for LSLs. We advocate for surgery in all symptomatic patients and a conservative approach with surgical intervention as needed in asymptomatic patients with a conus lipoma. A thorough understanding of preoperative neuroimaging, lesion types, and surgical techniques, in addition to consideration of prognostic factors, is essential for achieving successful outcomes. The natural course of LSLs demonstrates a 35%–40% worsening rate, which raises questions about the need for surgery and which patients should undergo surgical intervention. Based on the available evidence, symptomatic patients should undoubtedly undergo surgery, and asymptomatic patients with filum or dorsal lipomas may be considered for surgical treatment. When possible, total resection and extensive dural sac reconstruction should be pursued for dorsal lipomas. In patients with asymptomatic transitional or chaotic LSLs, surgical intervention should be considered if the surgery yields a 10-year PFS of 60%–65% or higher. Individualized treatment planning, close monitoring, and multidisciplinary collaboration are essential in managing these patients.

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Declarations

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AUTHORSHIP CONTRIBUTION

Study conception and design: EC, AD
Data collection: EC, CK
Analysis and interpretation of results: EC, CK, AD
Draft manuscript preparation: EC, AD
Critical revision of the article: EC, CK, AD
Other (study supervision, fundings, materials, etc...): EC, AD
All authors (EC, CK, AD) reviewed the results and approved the final version of the manuscript.

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