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ORIGINAL ARTICLE

Radical excision of lumbosacral lipoma: an early experience of "followers"

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Abstract

Background Indication, timing, and method for surgical treatment of lumbosacral lipoma are controversial. Radical resection of the lumbosacral lipoma and complete reconstruction of the placode are supported in that better long-term outcome can be achieved without increasing complication rate compared with traditional surgical techniques.

Objective We analyzed the early surgical outcomes of lumbosacral lipoma treated with the untethering and radical excision of fat.

Methods Retrospective analysis of surgically treated 81 fresh lumbosacral lipoma cases with dorsal, transitional, and chaotic types and true lipomyelomeningocele (LMMC) was performed. Caudal and filar types were excluded.

Results Complete untethering was accomplished in 98%. Radical excision of the lipoma was attempted in all cases and achieved in 83%. Postoperative neurological complication was observed in 8 cases (10%). Group of lipoma types (dorsal + transitional vs. chaotic + true LMMC) and availability of radical lipoma excision turn out to be factors related to neurological outcomes in univariate analysis ($p < 0.001$ and $p = 0.027$, respectively). Group of lipoma types, availability of radical excision, and postoperative cord/dural sac (C/D) ratio are related factors in multivariate analysis ($p = 0.025$, $p = 0.049$, and $p = 0.031$).

Conclusions As a follower of untethering and radical excision of fat, careful consideration is required to plan the surgery of lumbosacral lipoma on account of the "underestimated" complication rate. Type of the lipoma is the important factor determining the surgical outcome. Availability of complete radical excision and postoperative C/D ratio are the operative factors related to the neurological outcomes.

Keywords Lumbosacral lipoma · Neurological outcome · Radical excision · Complications · Untethering

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Introduction

Lumbosacral lipomatous malformation is commonly called as "lumbosacral lipoma." It is classified into dorsal, transitional, caudal, filar, and chaotic types according to the anatomical features which are associated with different surgical procedures and outcome [1, 3, 12]. The literature on natural course rates 33–47.3% of symptomatic progression [8, 13, 16] and wide range of symptomatic relief after untethering surgery which led to debates on the value of prophylactic surgery in asymptomatic cases. Moreover, timing and the method of operation are varied according to surgeons. In 1997, the Paris group [15] published an article on worse outcome of partial resection compared with natural course in the lumbosacral lipoma of conus type and suggested conservative policy in asymptomatic patients. In 2009, however, Pang et al. [12, 13] reported an excellent outcome after radical resection of lipoma with voluminous dural reconstruction in asymptomatic patients. The surgery on the lumbosacral lipoma is not without risk whether the extent of lipoma resection is partial or radical, and the postoperative neurological (including urological) complication rates were reported 4.2%–7.9% [12, 15].

Currently, the radical resection of lipoma has been gradually spread among the pediatric neurosurgeons although surgical indications in asymptomatic patients are still in debate. Since the operative technique requires experience and systematic intraoperative monitoring is required, there is a limit to be implemented in many centers. In addition, although Pang et al., the pioneer group, have reported excellent progression-free survival with overwhelming stability, it is necessary to confirm whether this method can safely deliver the same results to other pediatric neurosurgeons. Therefore, it is necessary to announce the results on this method by "follower" groups.

Our group has introduced the policy of radical resection of lipoma with intraoperative electrophysiological monitoring (IOM) in 2009. Thereafter, we experienced a learning curve in the aspects of lipoma surgery and IOM. Because the previously reported outcomes after radical resection of lipoma are from the pioneers and world leaders in this field, we present our postoperative early outcome data as one of the "followers" of radical resection surgery with IOM to share the information on the phase of learning curve with those who started this method later than the leaders. We investigated on the rates of complete untethering, radical resection of lipoma, and postoperative complication at postoperative 6 months and analyzed the factors influencing outcome.

This study was approved by the Institutional Review Board (IRB) of the hospital. The waiver of consent was granted under IRB review.

Material and methods

Patient population

We retrospectively reviewed 81 patients who were surgically treated with a fresh lumbosacral lipoma excluding caudal and filar types in our institution from November 2009 to December 2015. There were 40 male patients and 41 female patients. The median age of patients was 3 months, ranging from 1 month to 42 years (Table 1). Only three adult patients are included.

The indication for surgery was one of the following cases: (1) new appearances or aggravation of neurological symptoms including voiding or defecation problems and/or newly detected or aggravated abnormalities on preoperative evaluations ($n = 40$). Patients who do not correspond to (1) are included in surgical candidates if one of the following is applicable: (2) abrupt increases in the size of an extraspinally herniated sacs that may aggravate tethering ($n = 5$), (3) abrupt increases in the size of intraspinal lipomas that compress the spinal cord ($n = 7$), (4) cases in which syringes develop or aggravate during follow-up ($n = 19$), and (5) difficulty in careful inspection to detect changes of symptoms by caregivers ($n = 10$). Of the 32 patients who underwent surgery before 3 months, the number of patients corresponding to each surgical indication was as follows: (1) $n = 15$, (2) $n = 4$, (3) $n = 3$, (4) $n = 6$, and (5) $n = 4$.

Table 1 Demographic and preoperative clinical characteristics of the surgically treated 81 lumbosacral lipoma patients

Median age	3 mo (1 mo–42 yo)
Sex (M:F)	40:41
Abnormality on evaluation	
Free	41 (51%)
Abnormal	40 (49%)
Lipoma type	
Dorsal	20 (25%)
Transitional	43 (53%)
Chaotic	4 (5%)
True LMMC	14 (17%)
Syrinx	
Present	36 (44%)
Absent	45 (56%)

mo months old, *yo* years old, *M* male, *F* female, *LMMC* lipomyelomeningocele

Because of the small spinal canal and postoperative enlargement of residual lipoma in young infants, surgery was performed after 3 months of age unless early surgery is indicated. If neurological symptoms, signs, or abnormalities in electrophysiological and urodynamic studies were detected, especially when they were progressive, or if remarkable enlargement of the syrinx or extraspinally herniated sac was noted, early surgery was indicated [10]. Slit-like structures less than 2 mm in the spinal cord were considered dilated or persistent central canal rather than syrinx [4].

The preoperative evaluation included neurological examination, electromyography (EMG), nerve conduction test, and urologic evaluation including bladder scan, ultrasonography (US) of the kidney and bladder, voiding cystourethrography, and urodynamic study (UDS) if indicated. For the radiological evaluation, US of the spine was used as a screening test and spine magnetic resonance imaging was taken to confirm the diagnosis, to evaluate the lesion, and to make a surgical plan. For reliability of tests, electrophysiological and UDS were performed after 2 months of age if possible. Of the 58 (72%)

patients who showed no symptoms or signs at the time of surgery, 17 (17/58 = 29%) patients had preoperative abnormalities in the electrophysiological or UDS. Therefore, 41 (51%) patients had no apparent abnormalities in the preoperative evaluation and 40 (49%) patients had abnormal findings in the preoperative examination. In the present article, "neurological symptoms/signs/complications" include urologic and bowel problems as well as motor and sensory dysfunctions.

The lipomas were classified as dorsal, transitional, chaotic, or true lipomyelomeningocele (true LMMC). Caudal and filar lipomas were not included in this study. Dorsal and transitional followed classical Chapman's classification, and chaotic followed Pang's classification [3, 12] [2,3]. True LMMC is defined as a lesion in which the distal spinal cord and cerebrospinal fluid (CSF) space are herniated out of the spinal canal through the lamina defect. According to these criteria, there were 20 cases (25%) of dorsal type, 43 cases (53%) of transitional type, 4 cases (5%) of chaotic type, and 14 cases (17%) of true LMMC (Table 1). A syrinx was found in 36 (44%) cases before the surgery (Table 1).

Operative techniques

All the cases underwent untethering and attempted total/ near-total resection of the lipoma until the "white plane" of the border between the spinal cord and the lipoma was identified [12]. For radical resection of lipoma, microscissors or small sharp scissors were commonly used. However, if the interface between the lipoma and spinal cord is of irregular shape or too concave, we used an ultrasonic aspirator [2, 11]. After radical resection of the lipoma, neurulation was done through pial reconstruction. If the residual dura after lipoma excision is not sufficient to cover the remaining cord spaciously, duraplasty with porcine intestinal dural substitute (SurgiSIS, Cook Biotech Inc., West Lafayette, IN) was performed. In cases where the range of exposure included more than two levels of the lumbar spine, a laminotomy rather than laminectomy was performed and the reconstructive laminoplasty was done afterward.

Regarding IOM, until October 2009, gross motor responses on stimulation by a nerve stimulator were visually checked and the monitoring of the anal sphincter was not possible. In November 2009 when the first case of the present series was operated on, monitoring and mapping by electromyographic responses (vastus medialis, tibialis anterior, abductor hallucis) including anal sphincters became possible. Concentric electrodes were used for stimulation. In May 2012, a specialized IOM team started to support surgery with additional monitoring of somatosensory and motor evoked potentials, and bulbocavernosus reflex [5]. IOM was performed using the NIM-Eclipse nerve monitoring system (Medtronic Xomed Inc., Jacksonville, FL).

Outcome analysis

We retrospectively reviewed the medical records and images to determine whether complete untethering and radical excision of lipoma were performed during surgery. "Complete untethering" means the release of the spinal cord from all abnormal tight connections to surrounding structures, and "radical removal" includes removal of lipoma and thick fibrous tissue posterior to the "white plane" except intended tiny remnants around the rootlets.

The neurological outcome of surgical treatment was determined by evaluating motor, sensory, voiding, and defecation at postoperative 6 months. If the patient complained of new symptoms or progression of symptoms compared with the preoperative state and shows an evident worsening in electrophysiological and urodynamic studies, it was regarded as neurological deterioration. The factors affecting the surgical outcome including gender, age, presence of abnormalities on preoperative evaluation, type of lipoma, presence of preoperative syrinx, operator, performance of radical resection of lipoma, pial reconstruction or duraplasty, and postoperative cord/dural sac (C/D) ratio were analyzed [12]. Fisher's exact test was used for univariate analysis of categorical data, and multivariate analysis was performed using logistic regression analysis. Statistical analyses were performed using SPSS 22 (IBM Corp., Armonk, NY).

Results

Rates of complete untethering and radical resection of lipoma

Complete untethering was possible in 79 (98%) cases except two of chaotic type. Radical resection of lipomas was possible in 67 (83%) cases. Of the 14 patients who did not undergo radical resection, two patients were chaotic type. In two others, radical resection was discontinued because of decreased intraoperative motor evoked potentials (MEP, $n = 2$)

Table 2 Neurological outcome of the patients

Remained normal	37/41 (90%)
Improved	20/40 (50%)
Static	16/40 (40%)
Worsen	8/81 (10%)
Preoperatively free	4/41 (10%)
Preoperatively abnormal	4/40 (10%)

or presence of EMG responses on electrical stimulation with low amplitude of 0.5 mA at the lipoma near the root exit zone ($n = 10$). These 12 cases were operated on in the early period of this study.

Neurological outcomes

Postoperative neurological outcome of the patients is summarized in Table 2. Of the 41 patients who had no neurological abnormality in the preoperative evaluation, 37 (90%) patients remained normal but 4 (10%) were worsened. Of the 40 patients who had abnormalities in the preoperative examination, 20 (50%) were improved, 16 (40%) remained static, and 4 (10%) became worse. Among the 81 total patients, 8 (10%), of whom 4 had preoperative neurological abnormalities and 4 had not, showed postoperative deterioration. In detail, there were 3 patients with weakness in their ankle and foot and having voiding problems that require clean intermittent catheterization (CIC). Another 3 had only weakness of ankle and foot, and the remaining 2 had voiding problems which require CIC with or without defecation problems. Postoperative motor weakness occurred unilaterally in all patients except one who also developed a voiding problem. Other surgical complications occurred in 4 cases: 2 cases of wound dehiscence, 1 of CSF leakage which needed revision, and 1 of wound infection.

Both of the dorsal and the transitional types showed a low neurological complication rate of 5% and 2%, respectively. However, the neurological complication rates of the chaotic type and true LMMC were 50% and 29%, respectively (Table 3). When the factors affecting the neurological outcome were examined, it was found that there was a correlation between lipoma types and the outcome among preoperative factors. The difference in neurological complication rates according to the type was statistically significant ($p = 0.002$), more pronounced when the dorsal and transitional types were considered the low-risk group, whereas the chaotic type and true LMMC the high-risk group ($p = 0.001$) (Table 4). Among the operative factors, achievement of the radical excision was associated with good neurological outcome ($p = 0.027$). These factors were also found to be statistically significant in multivariate analysis ($p = 0.025$ and $p = 0.049$, respectively). In addition, the postoperative C/D ratio turned out to be associated with postoperative neurological outcomes.

Table 3 Neurological outcome according to lipoma types

	No worsening	Worsening	Total
Dorsal	19 (95%)	1 (5%)	20
Transitional	42 (98%)	1 (2%)	43
Chaotic	2 (50%)	2 (50%)	4
True LMMC	10 (71%)	4 (29%)	14
Total	73	8	81

Analysis of the correlation between perioperative factors and the group of lipoma types (high risk vs. low risk) showed a correlation between the group of lipoma types and age group at operation, preoperative syrinx and completeness of pial reconstruction (Table 5). In the high-risk lipoma group, 72% of the patients required surgical treatment at early infant younger than 3 months of age, whereas, in the low-risk lipoma group, only 28% ($p = 0.002$) did so. Preoperative syrinx was observed in 52% of patients in the low-risk group, but only in 17% of patients in the high-risk group ($p = 0.008$). Finally, complete pial reconstruction was performed in 89% of patients in the low-risk group, but only in 67% of the high-risk group ($p = 0.034$).

Discussion

Our rate of complete untethering was 98%. Although our indication of surgery is rather conservative, we attempted complete untethering and maximum safe decompression as much as possible. In 2 cases of chaotic type, however, the intralipoma location of ventral roots precluded aggressive complete untethering in spite of various surgical methods. In some cases of complex anatomy, neurological status was deteriorated even untethering was complete. Our experience of IOM (data not shown) suggested that the neurological damage occurred mainly at the time of untethering rather than the resection of lipoma.

The rate of radical resection of lipoma was 83%. Again, chaotic type was the main hurdle for the radical resection of lipoma in 2 cases. In early years when the other 12 cases of incomplete resection of lipoma were operated on, our team was anxious about the cord injury during the procedure of radical resection of lipoma. We stopped radical resection if frequent and sustained abnormal EMG responses occurred or significant changes in MEP (a decrease in amplitude > 50% or prolongation in latency > 10%) were observed even transiently. We thought that the removal of additional small amount of fat tissue with a risk of cord injury is not acceptable. However, as we found that those cases showed no postoperative deficits, the range of fat removal became gradually more radical.

Because majority of patients in this study have undergone surgery in infancy, there are difficulties in evaluating patients, especially in urological aspect. At 6 months postoperatively, most children are still under 1 year of age. Although more difficult to interpret, we regard as “normal voiding” if the voiding pattern and residual urine are compatible with age. When self-voiding is impossible, overflow or continuous dribbling is present, or residual urine increases, we regard it as “abnormal voiding” and perform UDS. Although there might

Table 4 Univariate and multivariate analyses of the preoperative or operative factors on neurological outcome

Variables		Reference	Univariate[a]			Multivariate[b]		
			OR	95% CI	*p* value	OR	95% CI	*p* value
Preoperative factors	Gender	Male	1.713	0.381–7.701	0.712	12.182	0.567–261.821	0.110
	Age group	< 3 mo	0.352	0.078–1.591	0.253	0.010	0.000–1.622	0.467
	Group of lipoma types	Low risk	15.250	2.742–84.810	0.001*	161.716	1.912–13,680.733	0.025*
	Syrinx	Absent	0.155	0.018–1.325	0.070	0.197	0.005–8.210	0.393
	Neurological status	Normal	1.028	0.239–4.425	1.0	0.070	0.003–1.463	0.086
Operative factors	Radical excision	Non-radical	0.159	0.034–0.739	0.027*	0.005	0.000–0.988	0.049*
	Pial reconstruction	Incomplete	0.265	0.055–1.283	0.113	0.075	0.003–1.919	0.117
	Duraplasty	Not done	1.098	0.244–4.954	1.0	0.047	0.001–1.539	0.086
	Postoperative C/D ratio	< 50%	0.422	0.074–2.418	0.297	0.001	0.000–0.517	0.031*

OR odds ratio, *95% CI* 95% confidence interval, *mo* months old, *C/D ratio* cord/dural sac ratio

[a] Fisher's exact test, [b] logistic regression, $*p < 0.05$

be some limitations, we think that this is somewhat inevitable as far as we include young children in pretoilet training period.

The neurological outcome in this series is marked by the fact that the proportion of poor outcome groups with neurological deterioration (10%) is higher than that reported by previous leading groups (4.2–7.9%) [12, 15]. This is probably because of the exclusion of caudal or filar lipoma which requires relatively simple and safe procedures in this study. If caudal lipoma is included, the rate of neurological complications is reduced to 7%. In addition, the operation policy of our institute (aggressive untethering is attempted once the operation is determined although the indication for surgery is rather conservative), the initial learning curve of radical resection of lipoma, and newly introduced and less settled IOM might also influence the result. The rate of exacerbation was similar in all patients, with or without preoperative abnormal findings. In patients whose preoperative work-up results were normal, not a few (10%) patients worsened after the operation. This means that the risk of untethering itself is not low. Surgeons should be careful with this in mind when deciding the surgery.

In cases of chaotic type lipoma or true LMMC, untethering is not easy due to complicated and distorted anatomical structures, and there is a possibility of deterioration during this process [1, 12]. Our results show that patients in this group have much worse neurological outcomes.

In the univariate analysis, the feasibility of radical lipoma excision was found to be related to surgical outcome. However, it is difficult to interpret that more radical removal of fat is more protective from neurological damage in early postoperative outcome evaluation. Instead, we think that the feasibility of radical removal is rather an indirect reflection of how complex the lesions were. Availability of radical excision means that the lesions were clear to identify the anatomical structure so that untethering can be achieved properly as well as the removal of lipoma and fibrous tissue. The statistical significance of the postoperative C/D ratio in multivariate

Table 5 Perioperative factors related to the high-risk group of lipoma types

Factors	Reference	OR	95% CI	*p* value
Gender	Male	1.290	0.450–3.697	0.790
Age group	< 3 mo	0.166	0.052–0.532	0.002*
Preoperative syrinx	Absent	0.182	0.048–0.691	0.008*
Preoperative abnormality	Normal	2.929	0.995–8.623	0.059
Radical excision of lipoma	Non-radical	0.291	0.085–0.994	0.071
Completeness of pial reconstruction	Incomplete	0.250	0.071–0.878	0.034*
Duraplasty	Not done	2.800	0.829–9.458	0.107
Postoperative C/D ratio (< 50%, ≥ 50%)	< 50%	3.208	0.382–26.910	0.441

OR odds ratio, *95% CI* confidence interval, *mo* months old, *C/D ratio* cord-sac ratio

Fisher's exact test, $*p < 0.05$

Table 6 Distribution of patients according to the age group and preoperative syrinx

	No syrinx	Syrinx	Total
< 3 mo	23	9	32
≥ 3 mo	22	27	49
Total	45	36	81

mo months old, Chi-square test, odds ratio = 3.136, 95% confidence interval 1.208–8.145, $p = 0.022$

analysis and the availability of complete pial reconstruction as correlated with the group of lipoma types are also probably due to some influences of complex anatomy to these factors.

The difference in anatomical complexity according to the group of lipoma types also affected the operation timing. Although the age did not affect the neurological outcome on univariate analysis, the group of high-risk lipoma types required surgical treatment at a relatively early infancy. This suggests that thorough and frequent clinical attention is needed in these high-risk group patients from a very young age.

One of the distinct features in our results is that preoperative syrinx was observed more frequently in the low-risk lipoma group. However, there is no correlation between preoperative syrinx and postoperative neurological outcome. This seems to be different from the known evidence and our clinical experiences that syrinx is associated with neurological deterioration [9, 16]. Perhaps, this may be related to age at surgery. In the high-risk lipoma group, proportion of the patients who got the operation at a younger age (< 3 months) group was much larger than in the low-risk group, which might be the result of our surgical indication. This period might be too early to form the syrinx in the patients. The results of the correlation between age group and preoperative syrinx in our data support this indirectly (Table 6).

Initially, we thought that the neurological outcome may be worse in early years of this study because of our lack of experience in radical resection of lipoma and IOM. However, annual incidence of postoperative neurological complication was not significantly changed which means that it was not influenced by the year of operation but depended on the proportion of the group of high-risk lipoma types. The learning curve of the new methods, radical resection of lipoma and IOM, had less impacts compared with the lipoma type during this period.

One of the concerns is how the specific changes of the IOM have affected the postoperative neurological outcome [6, 7, 14]. However, since the systematic IOM was mainly carried out in the latter part of the included period, there was a limit in analyzing these results. In addition, there was another limitation to clearly separate the effect of changed IOM method on the outcome from that of changed surgical method because both methods were changed during the same period. For this reason, comparative analysis with surgical outcome of our past periods was not conducted. These factors can be further investigated through subsequent studies.

Conclusion

Complete untethering and radical excision of lipoma was achieved in the most lumbosacral lipoma cases. Except for simple filar and caudal lipomas, the postoperative neurological complication rate which includes voiding and defecation problems was higher than the previous reports. There was no difference of this rate in the group that had no abnormality in the preoperative examination, which implies careful consideration is needed when deciding the surgery. In particular, among complex lumbosacral lipomas such as chaotic type and true LMMC, there was a significant correlation with postoperative neurological deteriorations.

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Compliance with ethical standards This study was approved by the Institutional Review Board (IRB) of the hospital. The waiver of consent was granted under IRB review.

Conflict of interest There are no conflicts of interests.

References

1. Arai H, Sato K, Okuda O, Miyajima M, Hishii M, Nakanishi H, Ishii H (2001) Surgical experience of 120 patients with lumbosacral lipomas. Acta Neurochir 143:857–864
2. Blount JP, Elton S (2001) Spinal lipomas. Neurosurg Focus 10:e3
3. Chapman PH (1982) Congenital intraspinal lipomas: anatomic considerations and surgical treatment. Childs Brain 9:37–47
4. Holly LT, Batzdorf U (2002) Slitlike syrinx cavities: a persistent central canal. J Neurosurg 97:161–165
5. Hwang H, Wang KC, Bang MS, Shin HI, Kim SK, Phi JH, Lee JY, Choi J, Cha S, Kim K (2017) Optimal stimulation parameters for intraoperative bulbocavernosus reflex in infants. J Neurosurg Pediatr 20:464–470. https://doi.org/10.3171/2017.6.PEDS16664
6. Kothbauer K, Schmid UD, Seiler RW, Eisner W (1994) Intraoperative motor and sensory monitoring of the cauda equina. Neurosurgery 34:702–707 discussion 707
7. Krassioukov AV, Sarjeant R, Arkia H, Fehlings MG (2004) Multimodality intraoperative monitoring during complex lumbosacral procedures: indications, techniques, and long-term follow-up review of 61 consecutive cases. J Neurosurg Spine 1:243–253. https://doi.org/10.3171/spi.2004.1.3.0243
8. Kulkarni AV, Pierre-Kahn A, Zerah M (2004) Conservative management of asymptomatic spinal lipomas of the conus. Neurosurgery 54:868–873; discussion 873–875
9. Lee JY, Phi JH, Cheon JE, Kim SK, Kim IO, Cho BK, Wang KC (2012) Preuntethering and postuntethering courses of syringomyelia associated with tethered spinal cord. Neurosurgery 71:23–29. https://doi.org/10.1227/NEU.0b013e31824cebc6

10. Lee JY, Phi JH, Kim SK, Cho BK, Wang KC (2011) Urgent surgery is needed when cyst enlarges in terminal myelocystoceles. Childs Nerv Syst 27:2149–2153. https://doi.org/10.1007/s00381-011-1532-8
11. Pang D (2015) Total resection of complex spinal cord lipomas: how, why, and when to operate? Neurol Med Chir (Tokyo) 55:695–721. https://doi.org/10.2176/nmc.ra.2014-0442
12. Pang D, Zovickian J, Oviedo A (2009) Long-term outcome of total and near-total resection of spinal cord lipomas and radical reconstruction of the neural placode: part I-surgical technique. Neurosurgery 65:511–528; discussion 528–529. https://doi.org/10.1227/01.NEU.0000350879.02128.80
13. Pang D, Zovickian J, Oviedo A (2010) Long-term outcome of total and near-total resection of spinal cord lipomas and radical reconstruction of the neural placode, part II: outcome analysis and preoperative profiling. Neurosurgery 66:253–272; discussion 272–273. https://doi.org/10.1227/01.NEU.0000363598.81101.7B
14. Paradiso G, Lee GY, Sarjeant R, Hoang L, Massicotte EM, Fehlings MG (2006) Multimodality intraoperative neurophysiologic monitoring findings during surgery for adult tethered cord syndrome: analysis of a series of 44 patients with long-term follow-up. Spine (Phila Pa 1976) 31:2095–2102. https://doi.org/10.1097/01.brs.0000231687.02271.b6
15. Pierre-Kahn A, Zerah M, Renier D, Cinalli G, Sainte-Rose C, Lellouch-Tubiana A, Brunelle F, Le Merrer M, Giudicelli Y, Pichon J, Kleinknecht B, Nataf F (1997) Congenital lumbosacral lipomas. Childs Nerv Syst 13:298–334; discussion 335
16. Wykes V, Desai D, Thompson DN (2012) Asymptomatic lumbosacral lipomas–a natural history study. Childs Nerv Syst 28:1731–1739. https://doi.org/10.1007/s00381-012-1775-z