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ORIGINAL PAPER

Asymptomatic lumbosacral lipomas—a natural history study

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Abstract
Background Inevitable deterioration due to mechanical tethering is perceived as the natural history for complex congenital spinal lipomas of the conus medullaris region, even if asymptomatic at presentation. The conventional wisdom that prophylactic surgical untethering improves outcome has been challenged recently [1, 2]. This study examines the natural history of asymptomatic un-operated children with lumbosacral lipomas (LSL) and investigates whether predictive factors herald deterioration.
Methodology Over the past decade, children presenting with complex LSL to a single clinician at Great Ormond Street Hospital (GOSH), London, UK have undergone a thorough assessment focusing on neurological and urological evaluation and MRI of the lumbosacral spine. For children deemed to be asymptomatic, conservative management has been adopted with close periodic surveillance of neurological and urological function, thus avoiding untethering surgery unless symptomatic deterioration occurs. A retrospective review identified this cohort of children asymptomatic of their LSL and their progress closely recorded.
Discussion This study suggests that the natural history of this subgroup of dysraphic patients may be more benign than hitherto considered. Conservative management with adoption of a novel surveillance policy and timely intervention only in the presence of symptomatic deterioration resulted in 71 % of this series remaining clinically asymptomatic at mean follow up period of 5.9 years (range, 1.0–19.3 years). At 10 years, the cumulative risk of deterioration determined by the Kaplan–Meier method was 40 %. Children aged <2 years, female, with presence of a transitional type of LSL and associated syrinx were independently associated with a higher risk of deterioration.

Keywords Lumbosacral lipoma · Conus medullaris · Spinal dysraphism · Spinal untethering

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Introduction

Congenital lumbosacral lipomas (LSL) are one of the commonest forms of spinal dysraphism and are associated with a female:male (F:M) ratio of 2:1. The incidence of diagnosed lesions is estimated to be 1:4,000 births of which 54–86 % are located in the conus medullaris region [3]. Chapman proposed an anatomical classification of LSL based upon the relationship of the lipoma to the conus medullaris [4]. Dorsal lipomas are located entirely on the dorsal aspect of the lower spinal cord and always spare the conus. Caudal types are attached to the termination of the spinal cord and involve the tip of the conus. An intermediate form, the transitional type represents a complex malformation that extends inferiorly from the dorsum of the terminal spinal cord to involve both the conus and elements of the cauda equina. This latter type is frequently further complicated by rotation of the neural placode to one side or the other resulting in forward displacement and apparent shortening of the nerve roots. The dura is typically deficient dorsally and occasionally laterally where the lipoma erupts through the spinal defect. More recently, Pang [5] has described an additional subtype, the chaotic lipoma in which the lipoma,

whilst having a discrete attachment to the dorsal portion of the terminal spinal cord or conus in its upper portion, soon blends with the conus and roots of the cauda equina and comes to lie ventral to the spinal cord at its lower attachment. In this article, such lipomas are included within the transitional group. For an overview of current hypotheses regarding LSL embryology, refer to Finn and Walker [3].

That LSL can be responsible for progressive neurological, urological and orthopaedic deficit is beyond doubt [2, 6, 7]. Various pathophysiological mechanisms to account for deterioration have been described including the mass effect due to direct compression from the lipoma as well as primary dysplasia of the spinal cord [8]. However, it is mechanical stretching or "tethering of the spinal cord" that is the most widely quoted mechanism and indeed, the rationale upon which surgical intervention is based [9]. In the latter half of the 20th century, the general neurosurgical consensus was that neurological deterioration was inevitable; the recovery from preoperative deficit rare; and that surgery was both efficacious and safe [4, 10–12].

Most of these publications, however, are uncontrolled, retrospective, single clinician/single institution series. Interpreting data from many previous publications has been further compromised by considering asymptomatic and symptomatic patients together, or including simple filar lipomas as well as complex transitional lipomyelomeningoceles in the same series. Symptomatic and asymptomatic patients may represent quite different underlying biology, and whilst division of a lipomatous filum terminale is usually a simple procedure with few complications and enduring efficacy [2, 11, 13], untethering surgery for a transitional type lipoma is a significant undertaking and even in experienced hands, neurological-, urological- and wound-related morbidity may be significant.

Until recently, the accepted dogma has been that the results of surgical intervention are better than the natural history of the disease; however, there is a virtual absence of natural history data upon which to base this assertion. In the last decade, there has been much debate as to whether prophylactic surgical untethering actually improves outcome of patients with LSL. The true natural history for this condition was not examined until 1994 when the Paris group followed 53 asymptomatic children prospectively and found that, at 9 years, 33 % exhibited evidence of deterioration [1]. This was not significantly different from a historical control group of 100 asymptomatic patients that had prophylactic surgery and at the same time point, 46 % exhibited evidence of deterioration. To date, this has been the only natural history study published, and there is, thus, a clear need for further evidence to support or refute the conclusions.

In this study, we attempt to examine the natural history of asymptomatic un-operated patients with LSL and discuss the results of a more critical and selective policy of management comprising close neurological and urological surveillance reserving surgery for those cases where a demonstrable deterioration has occurred.

Methods

Patient selection

A retrospective search of clinical letters, imaging and urological investigations at GOSH during a time period of July 1998 to December 2009 identified a cohort of children diagnosed with lipomas of the conus region. All patients who at presentation were deemed asymptomatic were recorded. Inclusion criteria were the presence of LSL on MRI, lack of neurological abnormality on clinical examination, and lack of urological dysfunction as assessed by bladder function tests and/or urodynamic assessment (see below for protocol). Older children (referred most commonly because of the cutaneous lesion) were still included if they met the requirements of asymptomatic status and thus assumed to have been asymptomatic from birth. Exclusion criteria were simple lipomas of the filum terminale, presence of any chronic neurological or urological abnormality at time of presentation, patients who had less than 1 year follow up or dysraphism occurring in the context of coexisiting congenital anomalies of the urogenital or lower gastrointestinal tract, e.g., anorectal malformations and extrophy.

Patient monitoring

The initial assessment of all patients included a thorough clinical examination by a neurosurgeon with emphasis on cutaneous stigmata of dysraphism and neurological deficit. MRI of the lumbar spine facilitated the anatomical classification of LSL as proposed by Chapman [4]. The presence of a syrinx in the spinal cord above the lipoma was recorded as this has been previously thought to be of prognostic significance [14, 15].

A new urological assessment protocol, the bladder function assessment, was devised in collaboration with our paediatric urological team that permitted regular, minimally invasive examination of the urinary tract and bladder function. The results are reviewed in a multidisciplinary clinic comprising neurosurgery, urology, clinical nurse specialists and physiotherapists. This assessment is performed every 3 to 6 months until continence is established. Thereafter, children are followed by annual assessments. If children are deemed "at risk" for renal scarring on non-invasive assessment, then they proceed to invasive urodynamic studies.

The non-invasive bladder function assessment comprises a detailed medical history with a focus on micturition/bowel

habits and urinary tract infections. A "wet nappy alarm" (Malem Medical, Ltd., Nottingham, UK) allows measurement of voiding frequency in infants. Urinary frequency, volume, flow rate and post-micturition residual (using ultrasonography) are recorded.

Invasive urodynamic assessment involved placement of both a bladder and a rectal catheter to record intravesical and abdominal pressures, respectively. At least two filling/voiding cycles were observed to calculate age-adjusted bladder capacity, compliance and detrusor pressures, and characterise detrusor overactivity during bladder filling and efficiency of bladder emptying during voiding.

Patients were considered to have deteriorated if they developed evidence of motor, sensory or gait dysfunction, bladder or bowel disturbance as determined by urological assessment or back/leg pain thought to be attributable to spinal cord tethering. The time in months from birth to the neurological deterioration as observed by a health care professional was recorded as the primary outcome.

Data manipulation and statistics

The computer package used was Matlab v7.0. Survival analysis was computed with SPSS v17. Where stated, comparisons of differences between measurements used Wilcoxon signed-rank test. Significance was assumed when $p<0.05$,

Results

Patient characteristics

Fifty-six children with female:male (F:M) ratio=36:20 were identified with asymptomatic LSL and were followed by close surveillance for a mean follow-up period of 5.9 years (range 1.0–19.3 years). The most common mode of presentation was detection at birth of cutaneous stigmata of LSL (Table 1). All children presented within a year of birth as a result of further investigation for lumbosacral cutaneous stigmata, except one female who at 3 months of age developed an acute onset of right lower limb weakness having previously been normal with no other neurological features. Of the asymptomatic patients, 45 % had transitional type, 32 % dorsal type and 23 % caudal type LSL. Within the whole group, 13 % had an associated syrinx, of which the transitional:dorsal:caudal ratio was 4:2:1.

Table 1 Percentage of patients presenting with various cutaneous stigmata of lumbosacral lipomas. Several patients had multiple stigmata

Cutaneous stigmata	Percent
Swelling	75
Haeamangioma	11
Dimple	11
Skin tag	4
Dermal sinus	4
Appendage	2

Deterioration characteristics

Out of the 56 asymptomatic children, 16 (28.6 %) became symptomatic with neurological deterioration at a median age of 1.9 years (range 3.0 months–9.4 years). The survival curve demonstrating the cumulative probability of remaining asymptomatic in patients with LSL who were conservatively managed is presented in Fig. 1. At 2 and 10 years, the cumulative risks of deterioration, as determined with the Kaplan–Meier method are 18 % and 40 %, respectively. The modes of deterioration were bladder or bowel dysfunction ($n=11$), pain ($n=5$), lower limb deformity ($n=5$), lower limb weakness ($n=3$) and sensory deficit ($n=0$); some patients exhibited more than one mode of deterioration.

Of the initially asymptomatic children, 36.1 % of the females deteriorated versus 15.0 % males. Survival analysis confirms significantly different rates of deterioration between females and males (Wilcoxon statistic $p=0.034$; see Fig. 2). However, at 10 years, the cumulative probability of remaining asymptomatic is very similar in each group.

The Kaplan–Meier survival curve stratified to each LSL anatomical type can be seen in Fig. 3. A pairwise analysis demonstrated that the only significant difference in rates of deterioration were between transitional and dorsal types (Wilcoxon statistic $p=0.02$). Of the deteriorators, 69 % had a transitional type, 19 % caudal type and 12 % a dorsal LSL, respectively.

If present the syrinx was located at the centre of the spinal cord and spanned between 1 and 6 vertebral segments (the largest spanned T12–L5). No patients had a syrinx extending up to the cervical or upper thoracic levels, sand none suffered from associated hydrocephalus or Chiari malformation. A subgroup analysis of the children with a syrinx irrespective of MRI anatomical LSL location revealed a significant increase in rate of deterioration in comparison with those without this additional anomaly (Fig. 4. Wilcoxon statistic $p=0.007$).

Post-operative progress and complications

All children who deteriorated underwent surgery at a median age of 2.4 years (range 3.0 months–17.0 years). Surgery comprised a subtotal resection of the LSL with attempted untethering of the spinal cord in all cases guided by electrophysiological nerve root mapping. No children experienced acute neurological deterioration post-operatively (assessed at

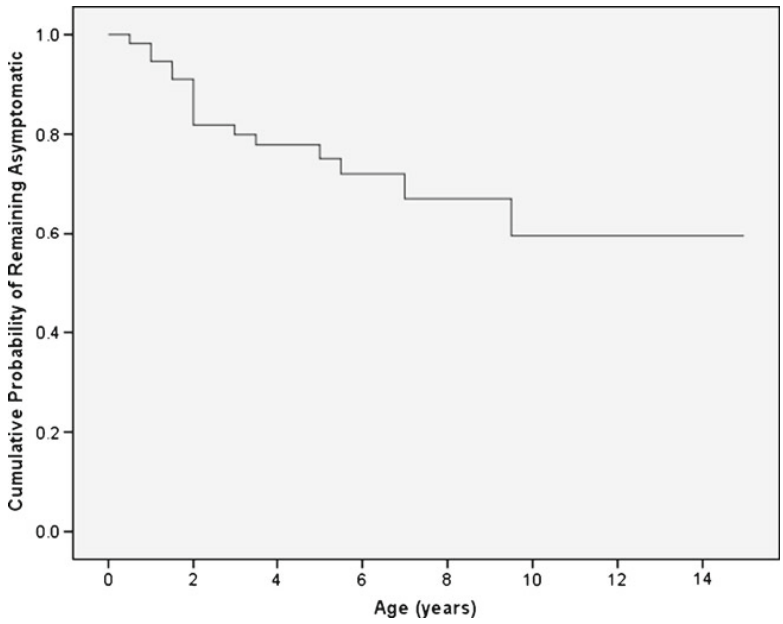

Fig. 1 Survival curve showing the cumulative probability of remaining asymptomatic in patients who are conservatively managed (n=56)

Age of children (years)	0	1	2	4	6	8	10
Cumulative risk of deterioration (%)	-	9	18	22	28	33	40
Number of children remaining	56	53	44	32	20	10	6

discharge and then at 6 weeks post-operative follow-up). Patients went on to receive neurological and urological surveillance at 6 months and then annually thereafter. The median post-operative follow-up period was 2.5 years (range 2.0 months–11.7 years), during which nine children experienced improvement in their pre-operative deficit. Seven children remained symptomatic (F:M=6:1), of whom four remained static and three females experienced further deterioration. Two females deteriorated at 2.0 years post-initial surgery and one female deteriorated at 2.6 and 7.8 years, all developed worsening pain and urological disturbance. Repeat untethering surgery at each episode of deterioration returned the children to their level of function prior to the repeat surgery. None of those undergoing repeat untethering returned to normal urological function. Regular monitoring and timely urological intervention ensured that none of the symptomatically stable children progressed to develop renal scarring. Post-operative complications comprised two wound infections of which one required additional surgical exploration and debridement, and the other was managed with antibiotics alone. One pseudo-meningocoele required formal surgical repair, and one cerebrospinal fluid leak was managed by placement of an additional suture on the ward.

Discussion

The assumption that all children born with LSL will eventually deteriorate has underpinned the rationale for offering prophylactic untethering surgery to all children with this anomaly, even if at the time of presentation no neurological or urological deficit can be identified. It is only recently that the validity of this assumption has been questioned and attempts made to examine the true natural history of this entity, an entity which, even in the most experienced surgical hands may pose a formidable operative challenge. It must be emphasised that this study is not an attempt to challenge the efficacy of spinal cord untethering in general, but specifically, in relation to its role in those children deemed to be asymptomatic at the time of presentation. Rather it is an attempt to add to our understanding of the natural history of this condition and evaluate the role of a more individualised approach to surgical management.

Whilst there have been those that have questioned the role of prophylactic surgery in spinal dysraphism [16], series have been small and have included a heterogeneous collection of dysraphic anomalies. The only existing attempt to specifically evaluate natural history of spinal lipomas has been by the

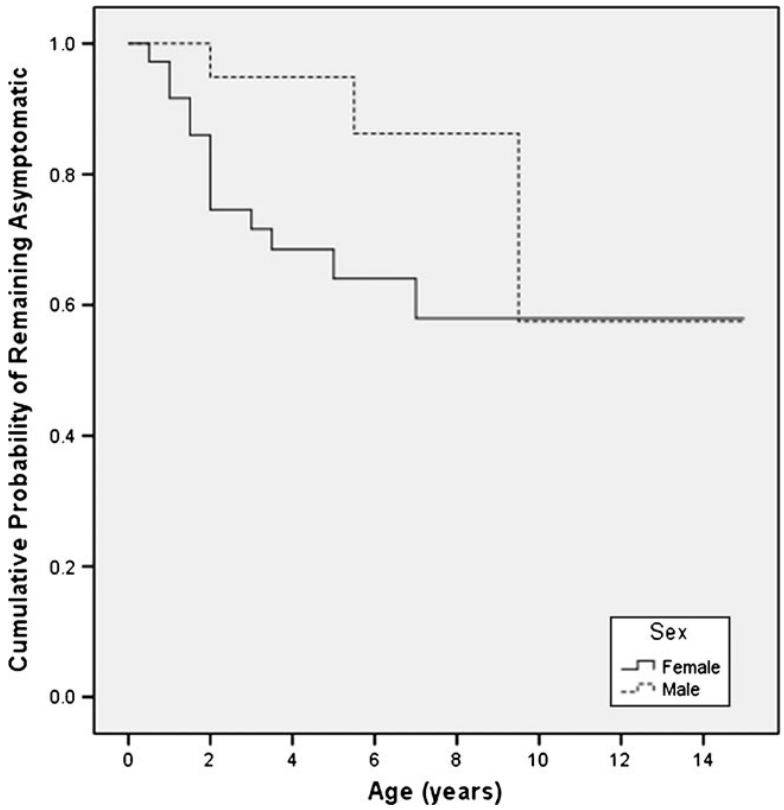

Fig. 2 Survival curve showing the cumulative probability of remaining asymptomatic in patients stratified to gender (female:male=36:20)

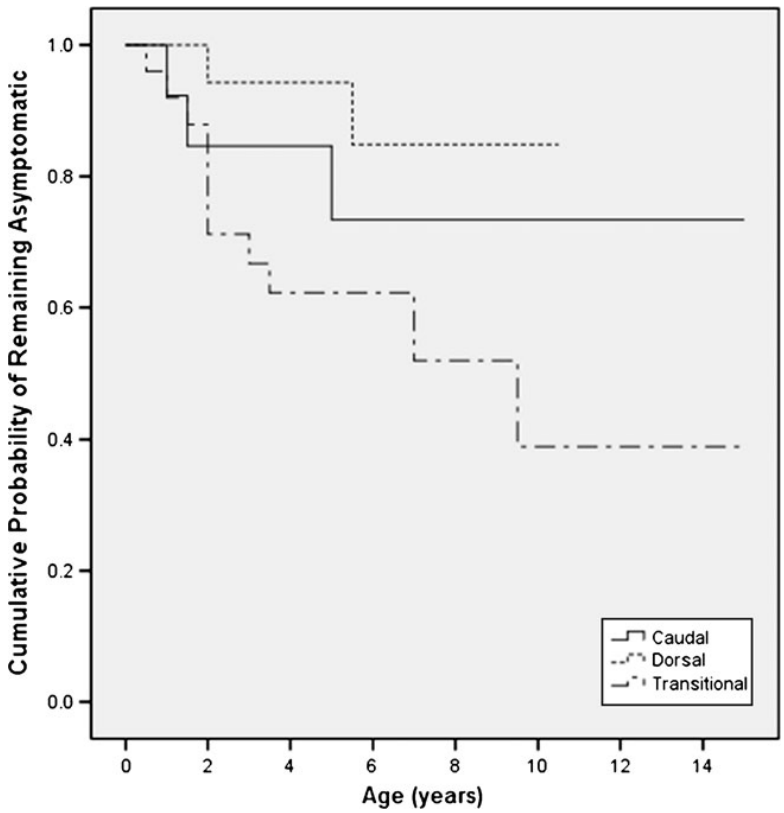

Fig. 3 Survival curve showing the cumulative probability of remaining asymptomatic in patients stratified to anatomical location (transitional n=25, dorsal=18, caudal=13)

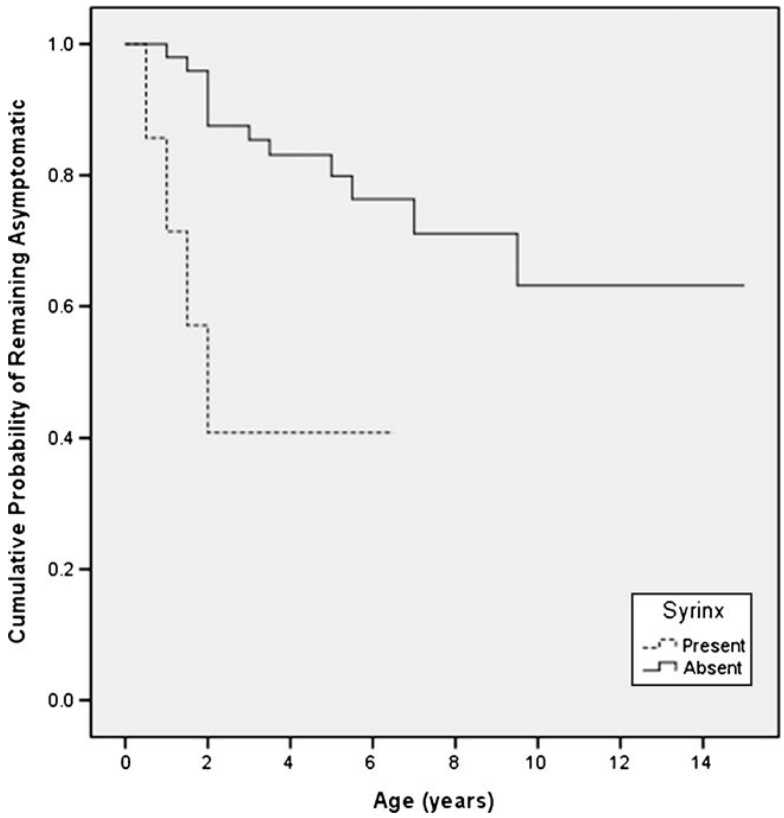

Fig. 4 Survival curve showing the cumulative probability of remaining asymptomatic in patients with the presence (n=7) and absence (n=49) of a syrinx

team from Necker-Enfants Malades, Paris (1) and thus, we believed it important that a comparable cohort be followed at an independent institution to assess whether their observations would be reproduced. The two series compare favourably in terms of the number of patients (56 vs. 53), the female:male ratio (approximately 2:1) and inclusion criteria (there were no filar lipomas in either series). The duration of follow-up and end point criteria were also similar. The Kaplan–Meier cumulative risk of deterioration for the London series at 2 years is 18 % and at 10 years is 40 %, whereas in the Paris series, at 3 years, it is 20 % and at 9 years, it is 33 %. These similarities support the notion that these results are a reasonably accurate reflection of the natural history of untreated asymptomatic lipoma. Kulkarni went on to compare their natural history results with an earlier cohort in whom prophylactic untethering surgery had been preformed and found that there was little difference in the functional outcome between the surgical and conservatively managed groups with a risk of deterioration at 8 years of 40 % and 33 %, respectively. Similar rates of *late* deterioration following conventional surgery for LSL have been recorded elsewhere including Xenos who calculated an actuarial risk 21 % deterioration at 5 years [13], Colak a deterioration rate of 40 % at 8 years [17], and Pang 47.3 % at 9 years for partial resection of the lipoma [5]. Thus, allowing for the inevitable variations between surgical series, it seems reasonable to conclude that following partial resection of the lipoma, a deterioration rate of approximately 40 % at 8 years can be anticipated, a rate certainly no better than the natural history. If we take into account the additional adverse effect of previous surgery on a subsequent attempt at untethering [5], then one might reasonably conclude that an initial partial resection was worse than natural history. It is quite evident that children born with LSL are at risk of neurological and urological deterioration even if they are asymptomatic at initial presentation; however, we can no longer state that deterioration is inevitable and use this argument to justify a surgical intervention that is complex, not without risk and of questionable long-term efficacy.

Given that it now seems that more than half of asymptomatic patients may not deteriorate (at least for 10 years), it is perhaps pertinent to re-evaluate the type and role of surgery in the management of LSL's. To date, the mainstay of surgical treatment for complex lipomas has been disconnection of the lipoma from the dura, subtotal resection of lipoma and reconstruction of the thecal sac. Whilst the short-term results of this approach have been acceptable in most hands, the problem is that these initial results are not maintained but show a significant rate of deterioration over time. The recent surgical results described by Pang et al. are so exceptional that they potentially represent the most significant advance in the history of this subject [5, 18]. Pang et al. describe a radical surgical approach comprising total or near

total resection of the lipoma guided by meticulous neurophysiological nerve root mapping combined with reconstruction of the neural placode and thecal sac. Using this technique, they report progression-free survival of 82.8 % at 16 years for all patients and 98.4 % if only the asymptomatic cases are considered. These results not only supersede previous surgical results but are clearly better than natural history as described in ours and the Paris study.

What then might be the reasons for not adopting this radical surgical approach as the gold standard of lipoma treatment? Firstly, there is the issue of reproducibility. The technique described by Pang is only recently gaining wider acceptance, and there will be an inevitable lag before others will be in a position to endorse or refute the efficacy of the procedure. Secondly, the technique is surgically demanding; it requires meticulous microsurgical technique and is heavily reliant upon precise intra-operative electrophysiological monitoring facilities that might not be available to all neurosurgeons. Given the relative rarity of these cases, there is potentially a lengthy learning curve before proficiency is achieved. Finally, as demonstrated in this and the Paris paper, there are cases that are asymptomatic at presentation and will remain so during follow-up and thus should probably be spared an operation.

In the assumption that at least until sufficient corroborative data is available, a more circumspect policy for patient selection should be pursued, perhaps the next objective should be to discern whether there are factors, identifiable at the time of presentation, that might identify those asymptomatic individuals at particular risk of deterioration to whom our more aggressive surgical efforts might be best directed.

The F:M ratio in this London series was 1.8:1 and is similar to that reported in many larger series [2, 10, 19]. Cutaneous anomalies were present in all of our patients, with subcutaneous swelling the most common abnormality. The majority of asymptomatic children with LSL had a transitional type of lipomas (45 %), and it is this form of lipoma that comprised the largest group of deteriorators (in agreement with the Paris series). Interestingly, children who deteriorated tended to do so early, with deterioration occurring at a median age of 1.9 years. This trend was also seen in the Paris series where deterioration was observed between 6 months and 3.2 years of follow-up [1]. A sex difference was observed in this series that has been noted previously. A survival analysis revealed significantly different rates of deterioration between females and males; not only were females 2.4 times more likely to deteriorate than males but also that deterioration tended to occur earlier in females compared with males. In this study, only three out of 20 males deteriorated at 1.7, 5.5 and 9.4 years of age. In a previous study from our institution, it was noted (though did not achieve statistical significance) that the risk of urological deterioration appears worse for females compared than males [20]. Whether the sphincter innervation is more susceptible to the effects of tethering in females compared with males is not known; however, the influence of sex on long-term outcome for lipoma has received relatively scant attention in the literature to date and should perhaps be pursued further in the future.

Very few studies have attempted to consider the prognostic implication of each anatomical location of the LSL, and indeed, commonly in the larger series, different LSL types have been grouped together precluding such an analysis [2, 11].

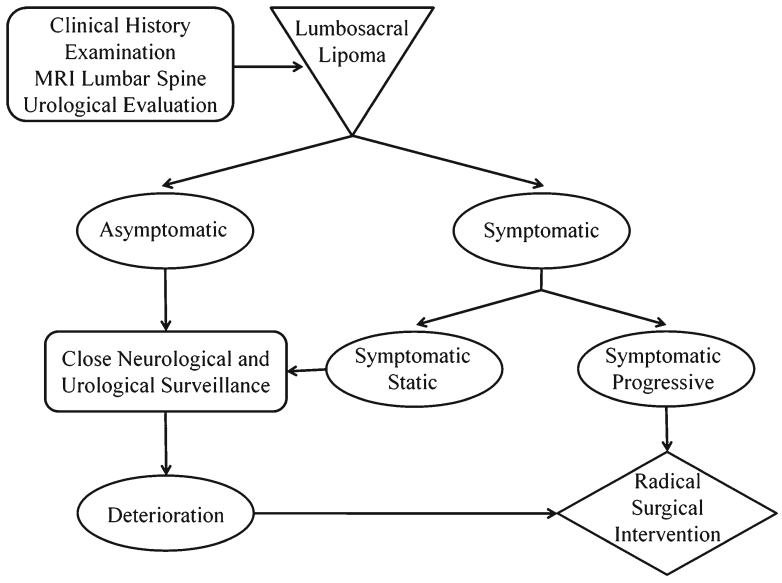

Fig. 5 Evidence-based algorithm for management of a child with spinal lipoma

This current series suggest that the transitional type of LSL has an increased rate of deterioration compared to the dorsal type, a finding that is replicated in other studies [17, 21, 22]. This is perhaps unsurprising given that the transitional LSL are typically larger lesions, the neural placode is commonly rotated resulting in very asymmetric nerve roots and by definition, there is usually an intimate association with those nerve roots serving sphincter innervation.

Syringomyelia is associated with spinal dysraphism, and the incidence of a syrinx in relation to LSL has been reported in 5–25 % of cases [13, 23–25]. In the current study, 13 % of the children had a syrinx, with a range of one to six vertebral segments. Irrespective of anatomical LSL location, children with a syrinx deteriorated more rapidly in comparison to those without. Of the four children with a syrinx who deteriorated and underwent untethering surgery, 50 % had a total collapse of the syrinx cavity. No children have so far developed a syrinx post-operatively. Further work needs to focus on the pathogenesis, clinical characteristics and optimal surgical treatment of syringomyelia in the context of spinal dysraphism.

Thus, within this series of asymptomatic LSL female sex, transitional type lipoma and the presence of syrinx cavity each appeared to correlate with a greater risk of deterioration. The numbers are small though they do raise the possibility that in the future, we may be in a position to better predict those asymptomatic patients at increased risk for deterioration.

Developing an evidence-based algorithm for management

The controversy surrounding spinal cord untethering for lipoma has spawned important developments over the past 10–15 years. We have seen ample evidence to demonstrate the limited long-term efficacy of traditional spinal cord untethering techniques. More recently, we have evidence presented that radical surgery might overcome many of the shortcomings of our previous interventions, and finally, we now also have some insight into the natural history of the condition. From this data, can we now present a more evidence-based algorithm for the management of the child presenting with spinal lipoma? With this objective in mind, we have now adopted the following management guideline (Fig. 5):

All new patients are evaluated with clinical history, motor examination, MRI and urological evaluation to include bladder function assessment. On the basis of this evaluation, patients are considered to be either asymptomatic or symptomatic (i.e., with evidence of a deficit attributable to the dysraphic anomaly). For symptomatic patients, they are further divided into those who are symptomatic with a fixed deficit (e.g., an ankle or foot deformity present since birth) which are termed "symptomatic static" and those who are symptomatic with a new or worsening deficit which are termed "symptomatic progressive". For the latter group with a progressive deficit (e.g., the child with new pain or new onset bladder symptoms), an attempted radical surgical intervention is undertaken. For the asymptomatic patients, a policy of close neurological and urological surveillance is pursued 6 months until continence is established when surveillance is reduced annually. If, at any stage, new changes are identified, then the child is considered as symptomatic progressive and treated accordingly. For the child with a fixed deficit (symptomatic static), at present, our policy is to treat along the same lines as asymptomatic, accepting that this is a particularly controversial group; again, any evidence of progression would lead us to recommend radical surgery. It is clearly essential to monitor closely the outcome of this management algorithm over time. If, in our hands, radical surgery can be shown to be safe in the short-term and achieve results comparable to Pang in the longer term, then the indications for radical surgery could be justifiably extended.

Conclusion

The London and Paris experiences of LSL natural history suggests that it is no longer appropriate to advise prophylactic surgery on the basis that deterioration is inevitable. Over half of asymptomatic lipoma patients are likely to remain so at 10 years from diagnosis. Spinal cord untethering is not without risk and, in most hands, the outcome of traditional surgical techniques may be little better than with conservative treatment.

This study suggests that there may be prognostic features associated with an increased risk of deterioration. These are age <2 years, female sex, transitional type of LSL or associated syrinx. Patients deemed to be high risk might benefit from more regular review. The numbers are, however, small, and this is an area in need of future study.

On the basis of this study and recent published data, we propose a management algorithm for newly diagnosed patients with spinal lipoma. This selective policy attempts to recognise the benign course of the disease in many patients whilst delivering the most effective long-term results for those who otherwise might be destined for a cycle of repeated interventions and increasing disability.

References

1. Kulkarni AV, Pierre-Kahn A, Zerah M (2004) Conservative management of asymptomatic spinal lipomas of the conus. Neurosurgery 54:868–875
2. 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
3. Finn MA, Walker ML (2007) Spinal lipomas: clinical spectrum, embryology, and treatment. Neurosurg Focus 23:E10
4. Chapman PH (1982) Congenital intraspinal lipomas: anatomic considerations and surgical treatment. Childs Brain 9:37–47
5. 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. Neurosurgery 66:253–273
6. Gourineni P, Dias L, Blanco R, Muppavarapu S (2009) Orthopaedic deformities associated with lumbosacral spinal lipomas. J Pediatr Orthop 29:932–936
7. Kang JK, Lee KS, Jeun SS, Lee IW, Kim MC (2003) Role of surgery for maintaining urological function and prevention of retethering in the treatment of lipomeningomyelocele: experience recorded in 75 lipomeningomyelocele patients. Childs Nerv Syst 19:23–29
8. Hirsch JF, Pierre-Kahn A (1988) Lumbosacral lipomas with spina bifida. Childs Nerv Syst 4:354–360
9. Tani S, Yamada S, Knighton RS (1987) Extensibility of the lumbar and sacral cord. Pathophysiology of the tethered spinal cord in cats. J Neurosurg 66:116–123
10. Hoffman HJ, Taecholarn C, Hendrick EB, Humphreys RP (1985) Management of lipomyelomeningoceles. Experience at the Hospital for Sick Children, Toronto J. Neurosurg 62:1–8
11. La Marca F, Grant JA, Tomita T, McLone DG (1997) Spinal lipomas in children: outcome of 270 procedures. Pediatr Neurosurg 26:8–16
12. McLone DG, Naidich TP (1986) Laser resection of fifty spinal lipomas. Neurosurgery 18:611–615
13. Xenos C, Sgouros S, Walsh R, Hockley A (2000) Spinal lipomas in children. Pediatr Neurosurg 32:295–307
14. Beaumont A, Muszynski CA, Kaufman BA (2007) Clinical significance of terminal syringomyelia in association with pediatric tethered cord syndrome. Pediatr Neurosurg 43:216–221
15. Erkan K, Unal F, Kiris T (1999) Terminal syringomyelia in association with the tethered cord syndrome. Neurosurgery 45:1351–1559
16. Jamil M, Bannister CM (1992) A report of children with spinal dysraphism managed conservatively. Eur J Pediatr Surg 2(Suppl 1):26–28
17. Colak A, Pollack IF, Albright AL (1998) Recurrent tethering: a common long-term problem after lipomyelomeningocele repair. Pediatr Neurosurg 29:184–190
18. 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. Neurosurgery 65:511–529
19. Atala A, Bauer SB, Dyro FM, Shefner J, Shillito J, Sathi S, Scott M (1992) Bladder functional changes resulting from lipomyelomeningocele repair. J Urol 148:592–594
20. Dorward NL, Scatliff JH, Hayward RD (2002) Congenital lumbosacral lipomas: pitfalls in analysing the results of prophylactic surgery. Childs Nerv Syst 18:326–332
21. 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 (Wien) 143:857–864
22. Cochrane DD, Finley C, Kestle J, Steinbok P (2000) The patterns of late deterioration in patients with transitional lipomyelomeningocele. Eur J Pediatr Surg 10(Suppl 1):13–17
23. Iskandar BJ, Oakes WJ, McLaughlin C, Osumi AK, Tien RD (1994) Terminal syringohydromyelia and occult spinal dysraphism. J Neurosurg 81:513–519
24. Gupta RK, Sharma A, Jena A, Tyagi G, Prakash B, Khushu S (1990) Magnetic resonance evaluation of spinal dysraphism in children. Childs Nerv Syst 6:161–165
25. Taviere V, Brunelle F, Baraton J, Temam M, Pierre-Kahn A, Lallemand D (1989) MRI study of lumbosacral lipoma in children. Pediatr Radiol 19:316–320