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Congenital lumbosacral lipomas: pitfalls in analysing the results of prophylactic surgery

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Abstract *Objectives:* Our objectives were to examine the assumption that the natural history of congenital lumbosacral lipomas in children presenting early and those presenting late is the same, and to determine whether there are factors that might predict the post-operative outcome of surgery among the presenting features of children with lumbosacral lipomas. *Methods:* The authors present a clinical series of 50 consecutive cases of congenital lumbosacral lipoma that had been treated surgically. All patients underwent both pre- and post-operative urological assessment and pre-operative imaging with MRI. The case notes, urology assessments and MRI films were studied to provide data on the clinical presentation, follow-up history and urological outcome of the children, as well as on the anatomical features of their lipomas. *Results:* Analysis of the data revealed a predominance in girls and a bimodal distribution of age at presentation with peaks at 0–2 and 7–8 years. Skin stigmata were more frequent in children below 6 years of age than in older children (P=0.035). The MRI scans demonstrated that the conus lay within the sacral canal more often in girls than boys (P=0.025). Severe bladder dysfunction was significantly more frequent in those presenting at =3 years of age (P=0.017) and there were more normal outcomes in patients operated upon before the age of 3 than in those operated upon at or after this age (P<0.0001). Eight patients who had been operated upon had severe urological problems at the time of their last assessment (median age of 8 years and 2 months). They were predominantly girls with major pre-operative urological dysfunction. *Conclusions:* Formal pre-operative urological assessment proved to be the strongest determinant of final urological outcome. Other predictors of poor urological outcome were large lipoma size and sacral position for the lipoma. This series demonstrates how early and late presenting children may represent different patient groups, follow different natural histories and may therefore not be reliable for comparison purposes. Future studies of prophylactic untethering need to follow cohorts beyond the age of deterioration found in untreated cases (8 years) and must report the salient MRI features that we suggest are predictive of poor outcome.

Keywords Lipoma · Lipomyelomeningocele · Tethered cord · Spinal dysraphism

Introduction

Since Garceau's original description [8] the clinical features of spinal cord tethering have become well known and the association with "occult" dysraphic syndromes has been established. Congenital lumbosacral lipomas are the commonest of these spinal malformations and comprise a heterogeneous clinico-pathological group. The lipoma forms a bridge between local neural tissue and the spinal level of origin to produce cord tethering. The natural history of tethering is presumed by most paediatric neurosurgeons to be one of inevitable neurological deterioration, [2] although neither the timing nor the type of such deterioration can be predicted in each individual patient [5]. The precise mechanism by which cord tethering leads to progressive neurological deterioration remains obscure but impairment of neuronal mitochondrial metabolism is probably involved [17]. Surgical untethering operations have been advocated by a variety of authors [7, 9, 10, 11, 13] on the premise that these procedures can improve long-term neurological outcome and are most beneficial when performed prophylactically. However, this assertion has been challenged by Pierre-Khan et al. [15] who, in a retrospective review of 291 cases, found insufficient evidence of long-term benefit from prophylactic untethering to recommend the continuation of this policy, particularly in the more complex cases (dorsal and terminal lipomas) rather than those involving the filum only.

Although the anatomical detail provided by MRI studies is valuable for diagnosis and operative planning, the appearances of the lipoma and cord alone do not differentiate patients at risk of deterioration from those who are not. This is exemplified by cases of clinical re-tethering following an earlier surgical release where the MRI appearances are no different from clinically successful untethered cases [6, 14]. Children with spinal lipomas are also particularly prone to developing problems with bladder function, from a mild detrusor instability leading to occasional episodes of urge incontinence to a neuropathic bladder [18]. However, the relationship between the pre-operative urological status of a child with a spinal lipoma and subsequent deterioration has not previously been described, nor has there been a satisfactory attempt to correlate such deterioration with the MRI scan findings at presentation.

There are no case-controlled studies on prophylactic untethering for congenital spinal lipomas in the literature. The majority of papers instead present the outcome in those patients operated upon early (usually under 1 or 2 years of age) and compare their post-operative progress with the clinical status of those patients who present at an older age [9, 10, 13]. Such studies have been cited to support the hypothesis that prophylactic surgery is beneficial because the late presenters (with no early surgery) show evidence of more clinical deficits than the early presenters (who underwent prophylactic surgery). The significant drawback with this approach is that the natural history of the disease for the two groups is assumed to be identical, which may not be correct. Thus, late presenters may be more likely to come to medical attention because of urological and neurological deterioration and may comprise a particularly high-risk group whereas early presenters may more often be brought to medical attention because of cosmetic defects and may comprise a low-risk group.

The aim of the present study was not to answer the question 'Is prophylactic untethering of the lipomatous spinal cord of benefit?' but to examine whether there were clinical and radiological differences between those patients presenting early and those presenting late, and whether there were clinical or radiological indicators at presentation that could be correlated with the patients' subsequent progress. Furthermore, we noted the age of deterioration of those children who lost a previously acquired neurological or urological function in order to assess whether there was a particular age at which those children not previously operated upon were likely to deteriorate. We have previously suggested that prophylactic untethering of the cord for any of the congenital conditions with which it may be associated can only be claimed as successful when the children have been followed up until they are well past such an age without evidence of deterioration [1].

Materials and methods

All children with a diagnosis of congenital lumbosacral lipoma operated upon between January 1991 and September 1996 (a period during which it was the department's policy to offer surgery for all such patients) were studied for the purpose of this report. All patients underwent pre-operative assessment with MRI scans and both pre- and post-operative urological assessments.

The presenting clinical features were divided into categories of skin stigmata (including subcutaneous lipomas, naevi, dimples, hair patches, sinuses), neuro-orthopaedic abnormalities (including muscle wasting and disparity of foot size, and for older children, gait disturbance and scoliosis) and urological dysfunction. The post-operative status of each patient was classified as normal, stable (a pre-operative deficit which did not alter during follow-up), or deterioration. Deterioration was defined as either an abnormality of lower limb or bladder function that became apparent by its failure to develop at the appropriate time or as loss of a previously established function.

The lipomas were classified according to their MRI appearances into dorsal, terminal and filum lipomas (modified from Chapman [4] by removal of the "transitional" category). The site and size of each lipoma was also recorded. The site was described as lumbar or sacral and the size was measured as the longest vertical intradural dimension visible on the sagittal images. This allowed separation into seven site/size groups of 1–2-cm lumbar lipomas, 2.1–4-cm lumbar lipomas, over 4-cm lumbar lipomas, 1–2-cm sacral lipomas, 2.1–4-cm sacral lipomas, over 4-cm sacral lipomas and filo-lipomas. The level of the conus medullaris was recorded as that of the adjacent vertebral body. The presence of other dysraphic abnormalities (including subcutaneous tracks, hydromyelic

cavities and sacral hypoplasia) was also noted when these were apparent on the MRI scan.

All patients underwent both pre- and post-operative urological assessment. Patients without urological symptoms were screened by undergoing ultrasound scanning and micturating cysto-urethrograms. All patients with established urological symptoms (or abnormalities on their screening investigations) went on to formal urodynamic testing via either a supra-pubic or urethral catheter. The pre-operative urological status was classified as either normal, having moderate abnormalities (a residual urine of less than 25 cc, mild detrusor instability, ureteric dilatation in the absence of renal damage) or severe dysfunction (neuropathic bladder, marked detrusor instability, scarred kidneys or other evidence of established renal damage). The age at which patients gained continence and, in the case of urological deterioration when this was lost, were also recorded.

Each of the variables determined for these patients was analysed for trends and compared with all other variables to discern correlations and statistically significant differences. The data were analysed with contingency tables and chi -squared tests for statistical analysis. Significance was accepted at a level of $P<0.05$.

Results

During the study period there were 50 new cases of congenital lumbosacral lipoma operated upon by one surgeon (RDH). There were 32 girls and 18 boys (gender ratio 1.8:1) with a median age at the time of surgery of 3 years and 7 months (range 4 months–16 years). The age at surgery showed a bimodal distribution which was similar in both sexes, with 22 operations (44%) being performed below 3 years of age and the remainder showing a peak at 7–8 years of age (Fig. 1).

The review of presenting symptomatology revealed that several of the children presented with clinical conditions could be allocated to more than one category (skin stigmata, neuro-orthopaedic abnormalities and urological dysfunction). Thus, 40 (80%) had some superficial stigmata indicative of the underlying dysraphic state, 17 (34%) had neurological or orthopaedic symptoms and 15 (30%) had urological symptoms. Whilst this pattern of presenting features was similar for both sexes, there were differences according to the age at presentation. Thus, skin stigmata were significantly more frequent (and often the only abnormality) in the younger children, a finding that became statistically significant for those presenting before 6 years of age ($P=0.035$, Fig. 2).

Analysis of the MRI scans revealed that the site of the intradural lipoma was lumbar in 13 (26%), sacral in 31 (62%) and located in the filum terminale in 6 (12%). Of the lumbar lipomas 2 (4%) measured 1–2 cm in length, 8 (16%) were 2.1–4 cm and 3 (6%) were over 4 cm in their maximum longitudinal intradural dimension. Of the sacral lipomas 7 (14%) were 1–2 cm in length, 13 (26%) were 2.1–4 cm and 11 (22%) were over 4 cm. The conus medullaris was found to lie in the lumbar region in 31 cases (62%) and in the sacral region in 19 cases (38%). However, when analysed according to gender, the conus was found to lie within the sacral canal significantly more often in girls than in boys ($P=0.025$, Fig. 3). Not surprisingly, there was a highly significant association found between the level of the conus and the level of the lipoma ($P<0.001$). The classification of the lipoma type was dorsal conus in 22 (44%), terminal conus in 22 (44%) and filum terminale in 6 (12%). When the lipoma position was compared with the vertebral position within the canal it was found that sacral lipomas were significantly more often terminal in position than dorsal

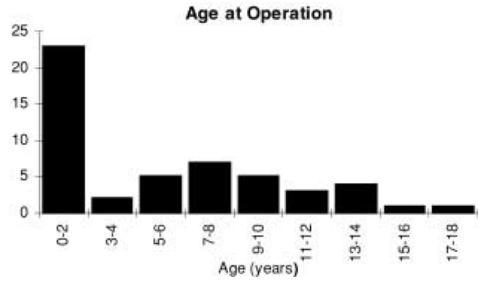


Fig. 1 Graph showing the bimodal distribution of age at surgery for the 50 cases of congenital lumbosacral lipoma

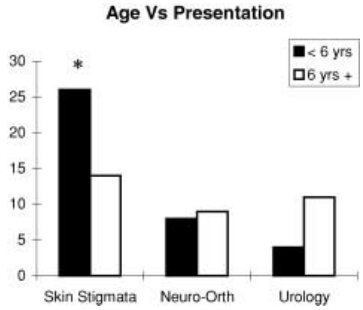


Fig. 2 Bar graph showing the presenting features according to age. Skin stigmata were more frequent in the children presenting before 6 years ($P=0.035$)

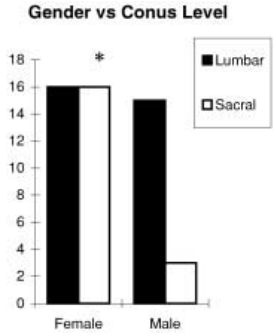


Fig. 3 Bar graph showing the position of the conus medullaris according to gender. The conus lay within the sacral canal more often in girls than in boys ($P=0.025$)

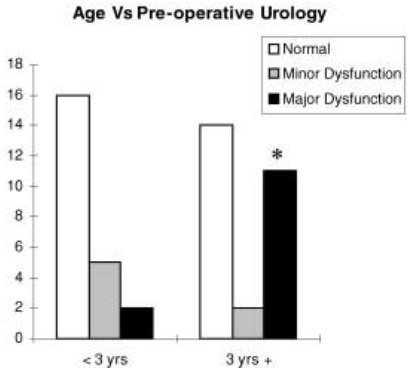


Fig. 4 Bar graph showing the pre-operative urology according to age. Major urological dysfunction was significantly more frequent in those of 3 years or more (P=0.017)

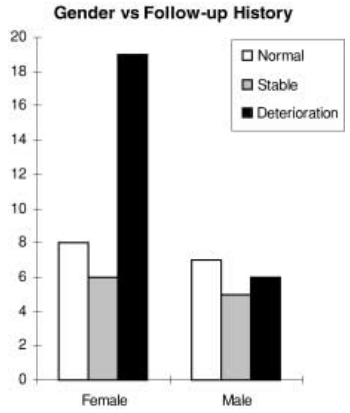


Fig. 5 Bar graph showing the follow-up history according to gender. Although not statistically significant, deterioration appeared more frequent for girls than boys

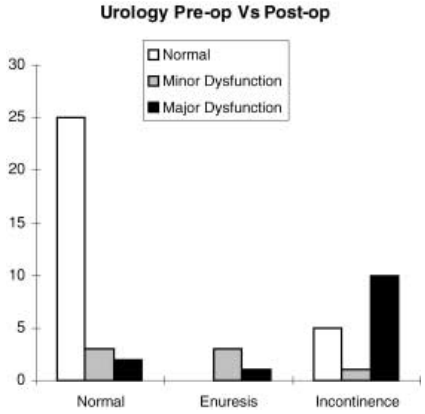


Fig. 6 Bar graph showing the urological outcome according to the pre-operative urological status

(*P*=0.00088). Pre-operative imaging also revealed a small (extending over two or less vertebral levels) hydromyelic cavity in 13 cases (26%), a moderate degree of hydromyelia (three to six levels) in 3 (6%) and a large (over six levels) cavity in 3 (6%) cases. The sacrum was normal in 23 cases (46%) while sacral dysgenesis, of various degrees, was evident in the remaining 27 cases (54%).

The pre-operative urological examinations revealed no abnormality of either bladder function or of the upper urinary tract in 30 (60%) children, moderate abnormalities were found in 7 cases (14%) and a neuropathic bladder or other severe abnormality in 13 (26%). When the pre-operative urological findings were analysed according to age at operation it was found that severe urological problems were significantly more frequent in those over 3 years of age (*P*=0.017, Fig. 4). In addition, most of the moderate urological abnormalities were seen in the younger children, with the older children being more clearly divided into the normal and severe categories. There was no correlation between conus level and urological status at presentation.

During their post-operative follow-up (mean of 2 years and 3 months, range 1 month–6 years and 5 months – median 2 years) 12 children (24%) deteriorated in that they lost at some stage a function that had been normal both pre- and post-operatively. Five children developed a neuro-orthopaedic syndrome, having previously had normal neurological and limb development, and 8 children lost previously established urinary continence (1 patient developed both lower limb problems and urinary incontinence). Out of the remaining 38 cases 11 (22%) had stable deficits, 12 (24%) displayed progression of a pre-existing neuro-orthopaedic syndrome, and 15 (30%) remained entirely normal. Although not statistically significant, there were apparent differences in the follow-up patterns for boys and girls (Fig. 5).

Examination of the results from the last urological assessment during follow-up revealed that 30 (60%) patients were normal, 16 (32%) incontinent and 4 (8%) dry by day but having persistent enuresis. Loss of previously achieved continence occurred in 8 patients, 7 of whom were girls. These problems occurred between the ages of 3 and 10 years, median age 8 years and 2 months. Comparison of the patients' urological assessment at presentation with that at their last follow-up revealed that 5 out of the 30 children who had had normal pre-operative urodynamics became incontinent during follow-up, while 2 of the children with severe urodynamic abnormalities pre-operatively achieved normal urinary control during follow-up (Fig. 6). These 2 children both had terminal sacral lipomas with the conus tethered at L5. Further analysis revealed that children with severe dysfunction at their pre-operative urological assessment were

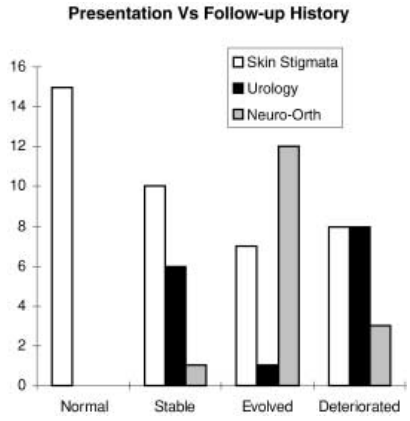


Fig. 7 Bar graph showing the different patterns of follow-up history for each category of presenting clinical features

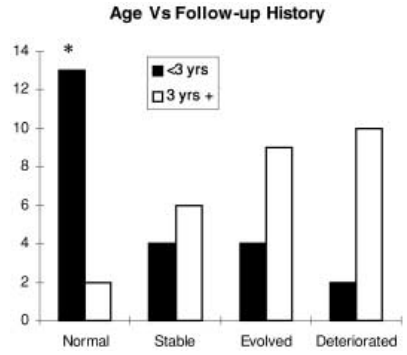


Fig. 8 Bar graph showing follow-up history according to age. There were more normal outcomes in those operated upon before the age of 3 than those operated upon after this age ($P<0.0001$)

significantly more likely to be incontinent at follow-up ($P<0.0001$) and to deteriorate further during follow-up ($P<0.0001$) than those with either normal bladder function or only moderate abnormalities.

When the presenting conditions were compared with the follow-up histories some interesting patterns were revealed (Fig. 7). For example, deterioration due to loss of a previously established function was seen more in patients presenting with skin stigmata and urological symptoms than in those presenting with the neuro-orthopaedic syndromes. Furthermore, a normal follow-up history was only seen in patients presenting with skin stigmata alone (i.e. none of the patients recovered from a deficit sufficiently to achieve complete normality during follow-up). Analysis according to age at operation revealed that there were significantly more normal outcomes in those operated upon before the age of 3 than those operated upon after this age ($P<0.0001$, Fig. 8). The type of lipoma (dorsal, terminal, filum) was not a factor predictive of outcome.

Discussion

The purpose of any prophylactic intervention is to prevent (or postpone) some anticipated, undesirable event. Therefore, a precise understanding of the nature, extent and age at onset of such undesirable events is essential for any meaningful analysis of the results of such prophylactic interventions. In the case of prophylactic surgery designed to prevent future neurological and in particular urological problems by releasing a spinal cord tethered by a lipomatous malformation, these conditions have yet to be fulfilled. Whilst the association between lipomas and neurological, urological and orthopaedic conditions is well established, linking the actual timing of onset of any disability and its subsequent progression to the mechanical effects of tethering is not straightforward. Even the definition of deterioration itself during the passage from infancy to childhood is complex. For instance, when a child with a spinal lipoma (who in infancy was thought to be normal) demonstrates symptoms of bladder dysfunction only when he or she should be achieving control of micturition, does this represent the emergence of a pre-existing problem previously "masked" by the immaturity of the nervous system (just as a hemiplegia associated with a porencephalic cyst may not become obvious until a child is well over 6 months old) or does it represent a "true" deterioration that could have been prevented by prophylactic surgery?

The best method of demonstrating the benefit of prophylactic surgical untethering of the lipomatous spinal cord would be to conduct a randomised controlled trial of surgery versus an expectant policy. This would require the patients to be matched not only for their sex and for the size, type and location of their lipoma but also for associated conditions evident at presentation and for their age at presentation. To date no such trial has been conducted, nor is one likely to be, given the comparative rarity of the condition, the clinical and radiological variations to be matched, and differences in the quality and extent of what can be very complex surgery. Paediatric neurosurgeons must therefore rely upon indirect evidence in order to demonstrate the effectiveness (or lack of effectiveness) of prophylactic untethering surgery. Most studies rely upon a comparison between the condition at follow-up of children operated upon prophylactically (who typically presented early and were operated upon when no disability was apparent) with the condition of older children who presented with recent neurological and urological deterioration and had not previously been operated upon [3, 7, 9, 10, 11, 12, 13].

Such studies are flawed by the assumption that "early" and "late" presenters are identical with regard to their natural history. Should these two groups represent two different patient populations then no valid comparison can be made. The fact that children operated upon when they are asymptomatic are more likely to remain asymp-

tomatic when children who had previously not been operated upon are presenting with new symptoms (either "emerging" or "true" deterioration) then becomes meaningless. This is not to say that prophylactic untethering might not be effective, merely that our methods to date of demonstrating its efficacy are flawed.

The first aim of our study was to determine whether the presenting features of those children presenting late were sufficiently similar to those presenting early to allow comparisons to be made between them. On the basis of our data we suggest that the answer to this question is "no". Children presenting with lipomas at a young age are not necessarily merely younger representatives of the same patient population as those presenting at an older age. The incidence of neurological, urological and orthopaedic problems at presentation is lower and many present solely because of their skin stigmata. By contrast a majority of the older children present with neurological and, in particular, urological symptoms (which in turn could be correlated with the level of the lipoma). There are also more children with sacral lipomas amongst those patients who initially presented late and amongst those operated upon early who despite their surgery then went on to deteriorate. Although a favourable outcome was more likely to be seen in those children operated below the age of 3 years, this applied to children who were normal at that time, while those with existing urological problems when first seen were significantly more likely to deteriorate during follow-up and to be incontinent at the time of their last assessment. Although this could be interpreted as supporting the benefit of prophylactic surgery it is just as possible that it is the pre-operative status of the child that determines the likelihood or otherwise of that child deteriorating rather than the effects of their untethering surgery. Thus, it would be unwise to assume that children presenting early (before the age of 2 years, for example) with no urological problems but with skin stigmata alone belong to the same group (from a clinicopathological point of view) as children whose skin signs were overlooked (or ignored) until they were 7, 8 or 9 years of age when they were developing problems with urinary control.

An alternative approach to assessing the long-term benefit of prophylactic untethering surgery is to determine the median age at which those patients not previously operated upon deteriorate and then to follow up those patients who have been operated upon prophylactically to an age sufficiently older than this to allow a statistically valid analysis of the protective effects of their early surgery. Unfortunately, there is in the literature no reliable indication of the median age of deterioration amongst "unprotected" patients by which to judge the length of follow-up required. We have attempted to answer the question by separating those patients who have deteriorated into those who developed normal functions (e.g. micturition and lower limb function) and later lost these functions from those whose abnormal function only became apparent when normal function failed to develop (while recognising that the latter group may contain patients from both groups).

In our series the median age of loss of established urological function in children who had not previously been operated upon was 8 years (range 3–10 years). Twelve of our patients who were urologically normal at their original presentation had passed this age at their last follow-up (2 filo-lipomas, 5 lumbar lipomas and 5 sacral lipomas). Ten of these achieved continence and remained continent, and 2 did not. These 2 patients (1 filolipoma and 1 lumbar lipoma) had normal bladder function pre- and post-operatively, went on to achieve continence at 5 years of age but then deteriorated – 1 at 7 years and the other at 9 years and 6 months – a timing (in terms of age) similar to those children who had not previously been operated upon, and in whom deterioration had led to their presentation. A previous study from our unit which analysed the outcome of children with split cord malformations [1] suggested an average age at deterioration of 7 years (range 3–11 years) for those who had not undergone early prophylactic surgery, a figure that correlates closely with the median age of urological deterioration in this series both for children who had not previously been operated upon and for the 2 who deteriorated in the years following their surgery. It is therefore important that future studies (of any form of dysraphism likely to lead to cord tethering) describe the children's follow-up not just in terms of how many years have elapsed since their surgery but by recording the ages that these children have reached – with or without deterioration – so that a more accurate assessment can be made of the effects of their surgery. Such studies should also contain details of the ages at which deterioration has occurred in those children not previously operated upon, and those whose deterioration has involved the loss of a previously acquired function should be recorded separately from those in whom that particular function has never properly developed.

The second question posed by our study was whether it was possible to make any predictions about the future urological status of children operated upon prophylactically for the untethering of their spinal cord lipomas. The peculiar susceptibility of children with lipomas of the spinal cord to urological problems is well known [16] and Vernet et al. [18] have emphasised the value of complete urological assessment both pre-operatively and during follow-up in order to assess the effects of surgery and to detect deterioration before clinical impairment appears. For the children in this study the final urological outcome was strongly correlated with their urological status, with the site and size of their lipoma and with their age at presentation. Thus, poor urological outcome was predicted by an age of greater than 3 years, female gender, a lipoma of more than 2 cm in vertical height, a

sacral lipoma and severe urological disturbance at presentation. Wu et al. [19] also found that the principal predictor of long-term normal bladder function was a child's pre-operative urodynamic status.

Conclusions

Our experience with congenital lumbosacral lipomas leads us to conclude that the natural histories of patients with congenital lumbosacral lipomas may vary in ways not previously recognised, covering a spectrum, at one end of which there is a group of children (predominantly boys) presenting early with skin stigmata who are neurologically and urologically normal. Their lipomas tend to lie in the lumbar region and they are at risk of relatively late urological deterioration (around the age of 8 years). At the other end of the spectrum is a group (predominantly girls) with large sacral lipomas who present with neurological and/or urological symptoms and who are more likely to have persistent neurological and urological deficits despite surgical treatment.

Finally, it should be emphasised that it was not the intention of this study, with its small numbers and relatively short follow-up, to stand as evidence either for or against the benefit of prophylactic operations designed to protect unaffected children with spinal cord lipomas from the potentially devastating effects of spinal cord tethering. Rather we would emphasise the difficulties inherent in the present methods of assessing these operations and suggest another parameter (the age beyond which children must be followed if their surgery is to be deemed effective) that all future studies should include in their results. In addition, we propose that knowledge of the symptoms at presentation allows some predictions to be offered when counselling parents about the likely effects of surgery. It is also essential for full details of the radiological appearances of the lipomas as well as the pre- and post-operative urological status of each child to be included in future studies if meaningful conclusions about the efficacy of prophylactic surgery are to be made.

References

1. Andar UB, Harkness WFJ, Hayward (1997) Split cord malformations of the lumbar region: a model for the neurosurgical management of all types of 'occult' spinal dysraphism? Pediatr Neurosurg 26:17–24
2. Bruce DA, Schut L (1979) Spinal lipomas in infancy and childhood. Childs Brain 5:192
3. Byrne RW, Hayes EA, George TM, McLone DG (1995) Operative resection of 100 spinal lipomas in infants less than 1 year of age. Pediatr Neurosurg 23:182–186
4. Chapman PH (1982) Congenital intraspinal lipomas. Childs Brain 9:37–47
5. Chumas PD (2000) The role of surgery in asymptomatic lumbosacral spinal lipomas (editorial). Br J Neurosurg 14:301–304
6. Colak A, Pollack IF, Albright AL (1998) Recurrent tethering: a common long-term problem after lipomyelomeningocele repair. Pediatr Neurosurg 29:184–190
7. De Gennaro M, Lais A, Fariello G, et al (1991) Early diagnosis and treatment of spinal dysraphism to prevent urinary incontinence. Eur Urol 20:140–145
8. Garceau GJ (1953) The filum terminale syndrome. (The cord traction syndrome.) J Bone Joint Surg [Am] 35:711–716
9. Hirsch JF, Pierre-Kahn A (1988) Lumbosacral lipomas with spina bifida. Childs Nerv Syst 4:354–360
10. Hoffman HJ, Taecholarn C, Hendrick EB, et al (1985) Management of lipomyelomeningoceles. Experience at the Hospital for Sick Children, Toronto. J Neurosurg 62:1–8
11. Keating MA, Rink RC, Bauer SB, et al (1988) Neurological implications of the changing approach in management of occult spinal lesions. J Urol 140:1299–1301
12. Koyanagi I, Iwasaki Y, Hida K, et al (1997) Surgical treatment supposed natural history of the tethered cord with occult spinal dysraphism. Childs Nerv Syst 13:268–274
13. La Marca F, Grant JA, Tomita T, et al (1997) Spinal lipomas in children: outcome of 270 procedures. Pediatr Neurosurg 26:8–16
14. Levy LM, Di Chiro G, McCullough, et al (1988) Fixed spinal cord: diagnosis with MR imaging. Radiology 169:773–778
15. Pierre-Kahn A, Zerah M, Renier D, et al (1997) Congenital lumbosacral lipomas. Childs Nerv Syst 13:298–334
16. Scatliff JH, Kendall BE, Kingsley DPE, et al (1989) Closed spinal dysraphism: analysis of clinical, radiological, and surgical findings in 104 consecutive patients. Am J Neuroradiol 10:269–277
17. 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
18. Vernet O, Farmer J-P, Houle A-M, Montes JL (1996) Impact of urodynamic studies on the surgical management of spinal cord tethering. J Neurosurg 85:555–559
19. Wu HY, Kogan BA, Baskin LS, et al (1998) Long-term benefits of early neurosurgery for lipomyelomeningocele. J Urol 160:511–514