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

Dachling Pang, MD, FRCS(C), FACS

University of California, Davis, Sacramento, California, and Regional Centre of Pediatric Neurosurgery, Kaiser Foundation Hospitals of Northern California, Oakland, California

John Zovickian, MD

Regional Centre of Pediatric Neurosurgery, Kaiser Foundation Hospitals of Northern California, Oakland, California

Angelica Oviedo, MD

University of Southern California, Keck School of Medicine, Los Angeles, California, and Children's Hospital Los Angeles, Los Angeles, California

Reprint requests:
Dachling Pang, MD, FRCS(C), FACS, Kaiser Permanente Medical Center, Department of Paediatric Neurosurgery, 280 W MacArthur Blvd, Oakland, CA 94611.
E-mail: PangTV@aol.com

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OBJECTIVE: To show the long-term benefits of total and near-total resection of complex spinal cord lipomas and reconstruction of the neural placode.

METHODS: We analyzed 238 patients with dorsal, transitional, and chaotic lipomas who had total resection as described in part I for overall progression-free survival probability (PFS, Kaplan-Meier analysis) over 16 years. We also analyzed subgroup proportional recurrence hazard (Cox analysis) of 6 outcome predictors of sex, lipoma type, age, preoperative symptoms, previous surgery, and postoperative cord-sac ratio. These results were compared with an age-matched, lesion-matched series of 116 patients followed for 11 years after partial lipoma resection and with the Parisian series of nonsurgical treatment.

RESULTS: The immediate effects of surgery were similar between total and partial resection: both achieved greater than 95% symptom stabilization or improvement rate. The neuro-urologic complication rates for the groups were also similar, 4.2% and 5.2% for total and partial resection, respectively. The combined cerebrospinal fluid leakage and wound complication rate of total resection was much lower at 2.5% than the 6.9% for partial resection, but both were better than published rates. The overall PFS for total resection was 82.8% at 16 years, comparing much more favorably with 34.6% for partial resection at 10.5 years ($P < .0001$). Culling only the asymptomatic patients with virgin (previously unoperated) lipomas to match the patient profile of the Parisian series, the PFS for prophylactic total resection for this subgroup increased to 98.4% at 16 years, versus 67% at 9 years for no surgery and 43.3% at 10.5 years for our own partial resection series, with a remarkable statistical difference between total and partial resection ($P = .00001$). Subgroup analyses showed that sex and lipoma type did not affect outcome. For the other predictor variables, while univariate analyses showed that young age, absence of symptom, and virgin lipomas correlated with better statistical PFS than older age, symptoms, and redo lipomas, these effects vanished with multivariate analyses. Cord-sac ratio stood alone as the only influential outcome predictor in multivariate analysis, with a 96.6% PFS for a low ratio of <30% and an 80.6% progression-free probability for a high ratio of >50%, and a 3-fold increase in recurrence hazard for high ratios ($P = .0009$). This suggested that all the individual effects of the other predictor variables could be reduced to whether a low cord-sac ratio could be achieved with total lipoma resection and placode reconstruction. Cord-sac ratio was the obvious factor that differentiated the outcomes between total and partial resection, the latter associated with a >90% chance of having a high cord-sac ratio.

CONCLUSION: Total and near-total resection of lipomas and complete reconstruction of the neural placode produced a much better long-term progression-free probability than partial resection and nonsurgical treatment. The perioperative complications for total resection were low and compared favorably with published results. A low postoperative cord-sac ratio and well-executed placode neurulation were strongly correlated with good outcome. The ideal preoperative patient profile with early disease stabilization and the best recurrence-free probability is an asymptomatic child less than 2 years without previous lipoma surgery. There are strong indications that partial resection in many cases produces worse scarring on the neural placode and worse prognosis than no surgery.

KEY WORDS: Cord-sac ratio, Lipoma, Neural placode, Outcome prediction, Paired univariate/multivariate analyses, Patient profile, Progression-free survival probability, Proportional hazard ratio, Spinal cord lipoma, Surgical complications

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The technique of total/near-total resection of complex spinal cord lipomas and meticulous reconstruction of the neural placode is described in detail in part I of this study.[1] In part II, we examine the early surgical results, complications, and long-term progression-free survival (PFS) probability of this technique in a prospective series of 238 patients who had dorsal, transitional, and chaotic lipomas treated over a 16-year period. These results are compared with those of a retrospective series of 116 patients who had partial lipoma resection performed by the same surgeon (D.P.) from 1979 to 1991 before the adoption of the total resection technique. The relative merits of total versus partial resection are judged by comparing the long-term outcomes of these 2 series and comparing against that of the only known prospective study of nonsurgical management of asymptomatic lipomas, from L'hôpital Necker-Enfants Malades, Paris, in 2004.

In addition, subsidiary analyses of comparative outcomes were performed between various subgroups within the total and partial resection groups, such as age groups, sexes, lipoma types, presence or absence of symptoms, redo versus "virgin" (unoperated) lesions, and high or low postoperative cord-sac ratio.[1] We aimed first to identify factor(s) that would most accurately and independently predict favorable outcome in total resection, and second to isolate the clinical, anatomical, and technical aspects of total resection that could best explain the outcome differences between total and partial resection. Finally, a method of preoperative patient profiling was devised using multivariate statistical computations of outcome data to identify good- versus poor-risk patients slated for total resection, for purposes of prognostication and preoperative counseling.

PATIENTS AND METHODS

Patients

The study included patients of all ages diagnosed with dorsal and transitional lipomas as defined by Chapman[2] in 1982, and chaotic lipomas, a new category coined in part I.[1] In all cases, at least part of the fat involved the substance of the caudal spinal cord. Terminal (caudal in Chapman[2]) lipomas, in which the fat replaces part of the filum or is inserted directly on the terminal tip of the conus, were excluded because they are simple to resect, their prognosis is much better than that of other varieties, and their management poses no controversy.[3-8] The patients were categorized into 2 main groups: those who had partial resection and those who had total/near-total resection of their lipoma (Figure 1).

Partial Resection Group

From 1979 to 1991, one author (D.P.) performed partial resection on 116 patients with dorsal, transitional, and chaotic lipomas aged 3 months to 76 years (mean age, 7.2 y). There were 84 children aged 3 months to 17.8 years (mean age, 5.4 y) and 32 adults aged 18.1 to 76 years (mean age, 38.5 y). Retrospective chart review determined the pre- and postoperative neurologic and urologic status, operative complications, and timing (from surgery) of the first neurologic or urologic deterioration. All patients before 1985 had computed tomographic myelography (CTM). After 1985, pre- and postoperative magnetic resonance imaging (MRI) was performed. Postoperative MRI for the earlier patients was performed 5 to 7 years after the operation.

Subgroups. Within the partial resection group, there were 82 transitional lipomas, 26 dorsal lipomas, and 8 chaotic lipomas. Patients with partial resection were subclassified into a previously unoperated (virgin) subgroup (84 patients) and a reoperated (redo) subgroup (32 patients). Among the patients in the virgin group, 58 were asymptomatic at surgery (mean age, 3.3 years; age range, 3 mo-13 y), ie, they had no motor, sensory or sympathetic deficits, bladder dysfunction, spinal or foot deformities, or pain, and the diagnosis was made either incidentally or by cutaneous manifestations such as subcutaneous lipoma, hemangioma, hairy patch, taillike appendages, and gluteal crease abnormalities. Twenty-six patients were symptomatic (mean age, 6.2 y; age range, 3 mo-76 y) and presented with a permutation of the neurologic, urologic, skeletal, or pain syndromes. All 32 patients in the redo subgroup were symptomatic before surgery (Table 1).

Definition of Partial Resection. Partial resection consisted of detachment of the lipoma stalk and surrounding adhesions from the dura, debulking of the intradural lipoma, and either primary or graft closure of the dura depending on the availability of healthy dura and the tightness of the closure. Pia-to-pia neurulation of the neural placode was attempted only if the placode was supple. Postoperative MRI always showed a thick slab of fat remaining on the spinal cord (Figure 2).

Total/Near-Total Resection Group

From 1991 to 2006, the study was prospective and consisted of 238 patients with dorsal, transitional, and chaotic lipomas[1] who had total or near-total resection. Their ages were between 2 months and 78 years, with a mean age of 4.8 years. Two hundred two (84%) were children aged 2 months to 18 years (mean, 3.9 y), and 36 (16%) were adults aged 18 to 78 years (mean, 32 y). There were 115 males and 123 females.

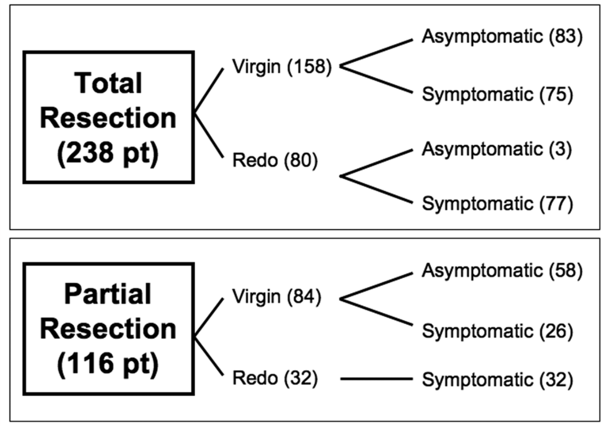

FIGURE 1. *Constituents of the total resection and partial resection groups. Each treatment group is subclassified according to whether the patient had a previous operation (redo) or not (virgin). Each subgroup is further segregated according to whether the patient was symptomatic or not at the time of surgery.*

ABBREVIATIONS: CIC, clean intermittent catheterization; **CSF**, cerebrospinal fluid; **CTM**, computed tomographic myelography; **KM**, Kaplan-Meier; **MCA**, multiple correspondence analysis; **MRI**, magnetic resonance imaging; **PFS**, progression-free survival; **SD**, standard deviation

TABLE 1. Preoperative and early postoperative status in 58 symptomatic patients who had partial resection

Clinical Parameter	Preop-erative	Early Postoperative (3 mo)			
		Normal	Improved	Stable	Worsened
Pain, paresthesia, dysesthesia	28 (48%)	8	14	4	2
Weakness, gait changes	34 (58.6%)	0	13	20	1
Myelopathy	10 (17%)	2	3	5	0
Neurogenic bladder/bowel	20 (34%)	1	6	11	2
Sympathetic dystrophy	9 (15.5%)	0	7	2	0
Scoliosis, foot deformities	21 (36%)	0	0	21	0

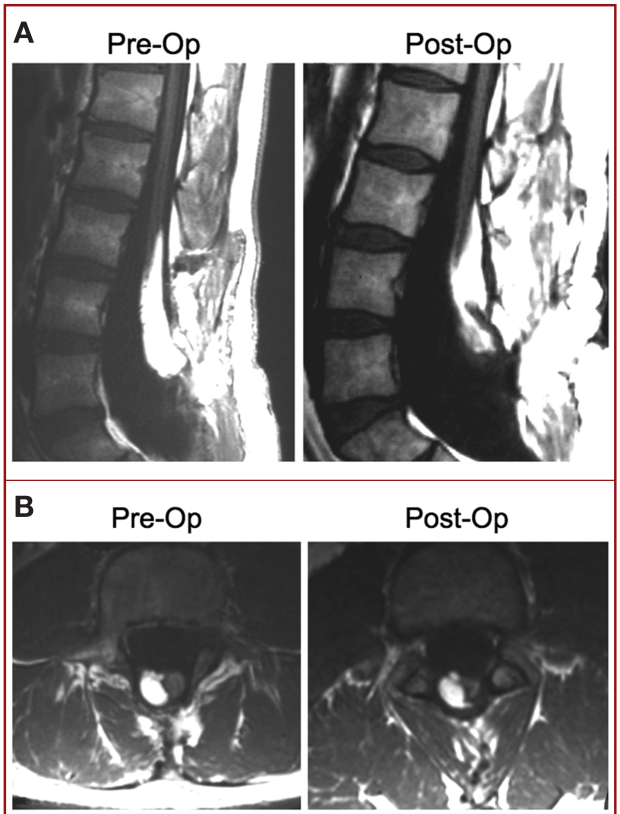

FIGURE 2. *Example of a patient who had partial resection of his transitional lipoma.* **A**, *sagittal pre- and postoperative magnetic resonance images.* **B**, *axial magnetic resonance images. Note the large amount of residual fat after resection, but moderately expanded dural sac around the cord compared with the preoperative image.*

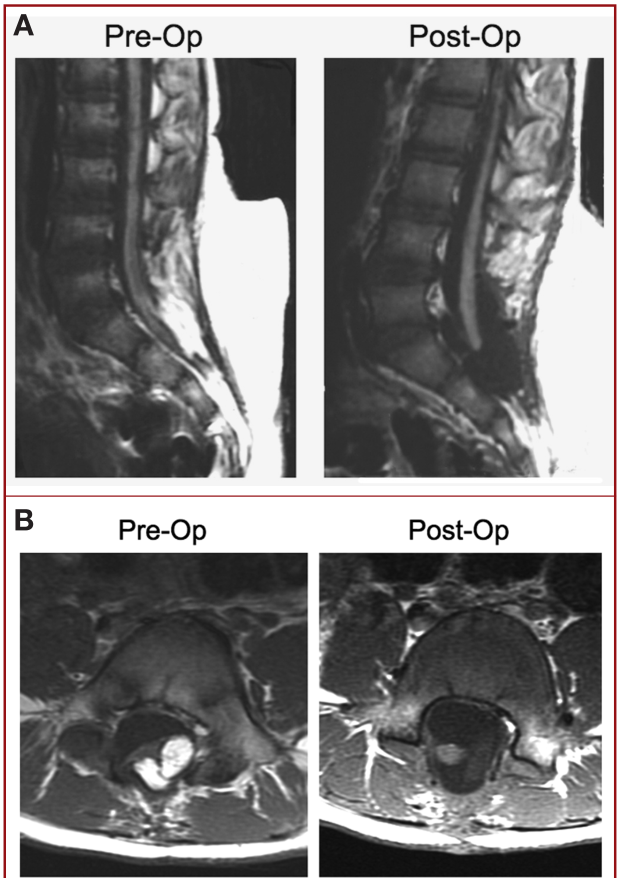

FIGURE 3. *Example of a patient who had a total resection of his transitional lipoma.* **A**, *sagittal pre- and postoperative magnetic resonance images. Note complete absence of residual fat in the conus within a capacious dural sac.* **B**, *sagittal pre- and postoperative magnetic resonance images. Note irregular, flat lipoma-cord interface in the preoperative scan, in contrast to the fat-free, round neurulated neural tube in the postoperative scan.*

The designation "total/near-total resection" consisted of complete detachment of the lipoma and neural placode from the dura and surrounding soft tissues, total or near-total removal of the intradural lipoma using sharp dissection, meticulous pia-to-pia neurulation of the neural placode with microsutures, and expansile graft duraplasty with bovine pericardium (Endura by Integra Inc, Plainsboro, New Jersey) to ensure a capacious dural sac[1] (Figure 3).

Subgroups. Within the total/near-total resection group, there were 185 transitional lipomas, 34 dorsal lipomas, and 18 chaotic lipomas. One hundred fifty-eight (66%) were virgin lipomas, and 80 redo lipomas (34%) had at least 1 previous partial resection. Among the patients with redo lipomas, 21 were previously treated by one of the authors (D.P.), and 59 were by other surgeons.

In the virgin subgroup, 83 patients (53%) were asymptomatic and 75 patients (47%) were symptomatic at the time of surgery. In the redo subgroup, the majority (77 patients) were symptomatic, and only 3 patients were asymptomatic.

Patients with total resection were further subclassified according to whether the cord-sac ratio[1] on postoperative MRI was less than 30%, 30% to 50%, or greater than 50%. The cord-sac ratio was obtained by dividing the sagittal diameter of the cord by the sagittal diameter of the thecal sac at the main region of the lipoma resection.[1]

Preoperative Protocol for Total Resection. Each patient underwent a detailed neurologic examination and urologic evaluation consisting of renal ultrasonography, cystometrogram, and voiding cystourethrogram. All patients also had MRI of the entire spine and craniovertebral junction. Fewer than 5% also had CTM.

Postoperative Follow-up Protocol for Total Resection. All patients were put on bed rest for 48 hours after surgery with an indwelling bladder catheter. Patients were then gradually mobilized, and the bladder catheter was removed. Clean intermittent catheterization (CIC) was instituted if there was incomplete voiding. Postvoid residual urine volume was measured several times daily and reported at follow-up visits.

Clinical follow-ups were set up for 2 and 6 weeks, and then 3- to 6-months intervals thereafter. Documentation was made of emergence of pain syndromes, sensorimotor deterioration, worsening neuropathic bladder or bowel, and progression of spinal and foot deformities.

The first postoperative MRI was performed 3 to 6 months after surgery. At least 1 more MRI was obtained 1 or more years after surgery to look for reappearance or enlargement of the resected lipoma.

Urodynamic tests were repeated 6 to 9 months after surgery and at yearly intervals, or more frequently when indicated by symptoms. Intermittent catheterization was discontinued when the postvoid residual volume was less than 50 mL in adolescents and adults or less than 25 mL in infants and young children.

Outcome Comparisons

Outcome was measured by the percentile probability of PFS after surgery as a function of time. All patients were followed until the onset of symptomatic progression, which constituted the adverse event in the PFS computation. Symptomatic progression included pain or dysesthesia, and worsening sensorimotor deficits, gait, bladder and bowel functions, urodynamics, scoliosis, and sympathetic dystrophy.

Outcome comparisons were made as follows:

1) Between total/near-total resection and partial resection of lipoma
2) Between virgin and redo lipomas in the total/near-total resection and partial resection groups
3) Between asymptomatic and symptomatic lipomas in the total/near-total resection and partial resection groups
4) Among 3 age groups in the total/near-total resection group: less than 2 years, between 3 and 18 years, and over 18 years
5) Among patients with postoperative cord-sac ratios[1] of less than 30%, 30% to 50%, and greater than 50% in the total/near-total resection group
6) Among the 3 anatomical types of lipomas—dorsal, transitional, and chaotic—in the total/near-total resection group
7) Between males and females in the total/near-total resection group
8) Among total/near-total resection from this study, partial resection from this study, and nonsurgical management from the Parisian series of Kulkarni et al[9]

Statistical Methods

PFS curves were constructed with the Kaplan-Meier (KM) method, with the reported progression (adverse event) as endpoint. Survival analysis of the time to neurologic deterioration was performed with the log-rank and Wilcoxon tests at a significance level of .05. The risks for deterioration for groups and subgroups were also compared using the Cox proportional hazard survival regression method. Independent variables tested for survival are listed in the Outcome Comparisons section.

Because some of the variables tested for outcome, such as age, presence or absence of symptoms, virgin versus redo cases, and cord-sac ratio, are somewhat mutually dependent and therefore may exert mutual interference on outcome significance, a multivariate Cox proportional hazard survival regression model was applied to identify those factors that exert the most independent influence, with P values calculated at 95% confidence level. The relationships between age, symptoms, prior surgery, and cord-sac ratio were tested using analysis of covariance. Because one predictor variable (cord-sac ratio) was a postoperative trait and not accountable preoperatively, a second multivariate method, multiple correspondence analysis (MCA), was performed to extract predictive factors for both good and poor outcomes, to devise preoperative patient profiling.

The Cox model was computed with the program Epi-Info (version 3.4.1; Centers for Disease Control and Prevention, Atlanta, Georgia). All other statistical computations were performed with the XLSTAT Data Analysis and Statistical Software (version 2007; Addinsoft, Paris, France).

RESULTS

Clinical Parameters Analyzed

The following clinical parameters were analyzed in each group preoperatively and at 3 months after surgery (early postoperative period):

1) Sensory symptoms, including pain, numbness, dysesthesia, paresthesia, electric shock sensation, and hyperpathia
2) Motor deficits, including asymmetric leg movements in infants, gait changes, loss of walking endurance, and frank muscle weakness
3) Myelopathic signs, including spasticity, clonus, hyperreflexia, and pathologic plantar responses
4) Signs of sympathetic dystrophy, including thin shiny skin, hairlessness, koilonychia, anhidrosis, dependent rubor, and ulceration
5) Symptoms of neuropathic bladder, including urgency, frequency, nocturia, incomplete voiding, postvoid dribbling, stress and urge incontinence, recurrent urinary tract infections, calculus formation, and renal failure
6) Urodynamic abnormalities, including decreased bladder capacity and compliance, detrusor hyperactivity, detrusor-sphincter dyssynergia, large postvoid residual volume, and ureteral reflux
7) Bowel dysfunction, such as chronic constipation, incontinence, and neurogenic megacolon
8) Neurogenic sexual dysfunction, such as erectile dysfunction, climactic inability, and absent or retrograde ejaculation in males and diminished sexual sensation and dyspareunia in females
9) Signs of pelvic muscle insufficiency in females, including prolonged or inefficient labor, and vaginocele, cystocele, or rectocele
10) Foot/leg deformities, including hammer toes, increased pedal arches, ankle and forefoot deformity, and muscle wasting
11) Progressive scoliosis

The occurrence of specific event precipitating symptom onset or aggravation, such as direct trauma or catastrophic bending of the spine, was particularly noted.

Preoperative and Early Postoperative Clinical Status

Partial Resection Group (116 Patients)

Asymptomatic Patients. The 58 asymptomatic patients in the partial resection group were younger than 18 years old and had no previous lipoma surgery. Ninety-five percent of these patients were diagnosed by cutaneous manifestations, and 5% were diagnosed by incidental MRI. After surgery, 1 patient was worse, with new weakness, and 2 patients had stress incontinence.

Symptomatic Patients. Among the 58 patients who were symptomatic preoperatively, 26 had virgin lipomas and 32 had redo lipomas. Twenty-eight patients (48%) had pain or dysesthesia, 34 (58.6%) had weakness, 10 (17%) had myelopathy, 20 (34%) had a neurogenic bladder, 9 (15.5%) had sympathetic dystrophy, and 21 (36%) had either scoliosis or foot deformities (Table 1).

At 3 months follow-up, 13 of 34 patients with weakness improved, but none became normal. Among the 28 patients with pain or dysesthesia, 8 became pain free and 14 became partially so. Bladder function improved in 7 of 20 patients, and all had improved urodynamics. None of the patients with fecal incontinence or neurogenic megacolon improved. There were no changes in the spinal and foot alignments.

In all, 3 patients were made worse by the operation: 1 had severe dysesthesia and increased sensory loss, 1 had weakness and urinary incontinence, and 1 developed urinary retention requiring long-term catheterization.

The early postoperative status of the symptomatic patients can thus be summarized as follows: of 58 patients, only 4 (6.9%) became normal in all aspects, 9 (15.5%) improved in all symptom categories, 7 (12%) improved in some categories, and 35 (60%) were stabilized by the operation, considering all had been deteriorating before surgery (Figure 4). Three patients (5.1%) had worsened neurologic status from surgery. Thus, the majority (95%) of the symptomatic group benefitted from partial lipoma resection, at least in the short term (Table 2).

Of the 116 patients who had partial resection, 6 (5.2%) were made worse by surgery (Table 2).

Total/Near-Total Resection Group (238 Patients)

Asymptomatic Patients. There were 86 asymptomatic patients, and all except 3 had no previous surgery. All 86 were diagnosed because of cutaneous manifestation or by MRI, and were children with a median age of 4.2 years, ranging from 3 months to 17.2 years.

Three patients had transient dysesthesia and numbness in one or both legs immediately after the operation, but in only 1 child did the dysesthesia persist beyond 3 months. This child also had persistent weakness. Three other patients required temporary CIC but recovered before 3 months. In this group, 79 patients (92%) remained neurologically intact after surgery, 6 (7%) had transient deficits, and only 1 (1.2%) was made worse by the operation.

Symptomatic Patients. Of the 152 symptomatic patients in the total/near-total resection group, 121 were children (median age, 6.4 y; age range, 3 mo-18 y), and 31 were adults (median age, 28 y). One hundred nine patients (72%) had pain or irritative sensory symptoms, 140 (92%) had weakness or gait disturbance, 30 (20%) had myelopathy, 84 (55%) had neurogenic bladder, 32 (21%) had sympathetic dystrophy, and 53 (35%) had either worsening scoliosis or foot deformities (Table 3).

Of all symptoms, dysesthetic pain responded the best to surgery, having abated completely in 85 patients, and partially but significantly in 8 patients. Motor deficits improved in 82 patients, but only 9 became normal. Twenty-eight patients improved in

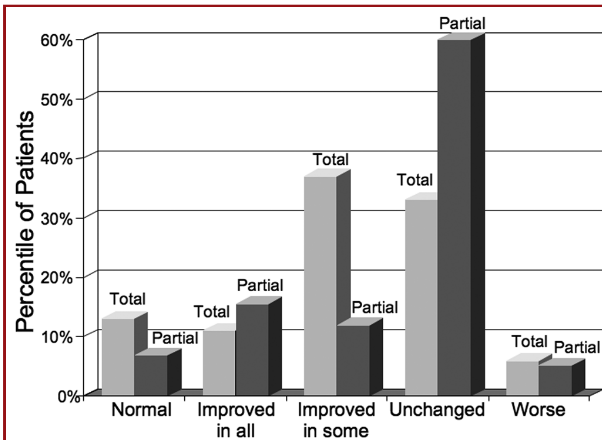

FIGURE 4. *Early postoperative results at 3 months for symptomatic patients in the total/near-total resection group (n = 152) and partial resection group (n = 58). Patients are grouped as "normal" with no signs or symptoms, "improved in all" preoperative symptoms, "improved in some" preoperative symptoms, "unchanged" from preoperative state, or made "worse" by surgery. The early overall improvement and stabilization rates are similar in total and partial resection, suggesting that the immediate benefits of surgery for symptomatic patients are due to untethering and not to the extent of fat removal or placode reconstruction.*

TABLE 2. Overall early postoperative results of partial resection of lipoma at 3 months

	Normal	Improved in All Categories	Improved in Some Categories	Stable	Worsened
Symptomatic patients (n = 58)	4 (6.9%)	9 (15.5%)	7 (12%)	35 (60%)	3 (5.1%)
Asymptomatic patients (n = 58)				55 (95%)	3 (5.1%)
Total (n = 116)					6 (5.2%)

urinary symptoms, but only 5 resumed normal voiding. Twenty-three patients with sympathetic dystrophy improved in the healing of chronic ulceration. Fourteen of 22 patients with advancing scoliosis stabilized, only 3 patients improved in their curvature, and 5 patients continued to progress (Table 3).

In the symptomatic total/near-total resection group, 15 patients (10%) had new dysesthetic pain in the first few weeks after surgery, but by 3 months, only 9 (5.9%) required gabapentin. Three patients (1.7%) had new leg weakness, though none became nonambulatory. Five patients (3.3%) had worsened neurogenic bladder; all had preoperative voiding dysfunction. None of the patients with normal bladder function before surgery was worsened by surgery.

The early postoperative status of the symptomatic patients who had total resection can thus be summarized as follows: of 152 patients, 20 (13%) became normal in all aspects, 17 (11%) improved in all symptom categories, 56 (37%) improved in at least 1 category, and 50 (33%) were stabilized by the operation. Nine patients (5.9%) were made worse by the operation, mostly because of dysesthetic pain (Figure 4). Overall, 94% of symptomatic patients were either improved or stabilized by surgery (Table 4).

Of the 238 patients who had total/near-total lipoma resection, 10 (4.2%) were made worse by the operation (Table 4).

Outcome Analysis

Total/Near-Total Resection Versus Partial Resection

Of 238 patients who underwent total/near-total lipoma resection, 24 (10%) deteriorated during a mean follow-up period of 7.9 years (range, 1.3-15.8 y). KM analysis (Figure 5, upper curve) showed a mean PFS of 13.5 (standard deviation [SD], 0.304) years. The progression-free probability at 16 years was 82.8%. There was no expectation of recurrence after 8.4 years. The deterioration rate between the third and eighth years of follow-up appeared to be steady and constant.

TABLE 3. Preoperative and early postoperative status in 152 symptomatic patients who had total/near-total resection

Clinical Parameter	Preoperative	Early Postoperative (3 mo) Normal	Improved	Stable	Worsened
Pain, paresthesia, dysesthesia	109 (72%)	85	8	7	9
Weakness, gait changes	140 (92%)	9	82	46	3
Myelopathy	30 (20%)	2	5	23	0
Neurogenic bladder/bowel	84 (55%)	5	28	46	5
Sympathetic dystrophy	32 (21%)	0	23	9	0
Scoliosis	22 (14.5%)	0	3	14	5
Foot deformities	31 (20%)	0	2	29	0

Of the 116 patients who had partial lipoma resection, 62 (53.4%) deteriorated over a mean follow-up period of 6.2 years (range, 1.2-11 y). KM analysis (Figure 5, lower curve) of this group showed a mean PFS of 7.05 (SD, 0.315) years. The progression-free probability at 10 years was only 34.6%. There was a relatively constant rate of deterioration over the test period without an apparent arrest of disease progression. Comparison of PFS of the 2 groups showed a strong prevalence of favorable results with the total/near-total resection technique (*P* < .0001).

Virgin Versus Redo Lipomas

The effect of previous surgery on outcome was tested for both the total/near-total resection and the partial resection groups. In the total resection group, 158 patients never had a prior operation; 7 (4.4%) deteriorated during follow-up with a mean PFS of 14.4 (SD, 0.29) years. Eighty patients had at least 1 prior proce-

TABLE 4. Overall early postoperative results of total/near-total resection of lipoma at 3 months

	Normal	Improved in All Categories	Improved in Some Categories	Stable	Worsened
Symptomatic patients (n = 152)	20 (13%)	17 (11%)	56 (37%)	50 (33%)	9 (5.9%)
Asymptomatic patients (n = 86)				85 (98.8%)	1 (1.2%)
Total (n = 238)					10 (4.2%)

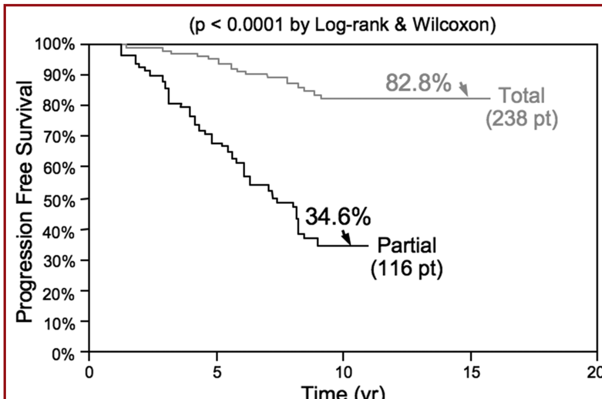

FIGURE 5. *Outcomes of total versus partial resection. Kaplan-Meier analysis for progression-free survival probability in total and partial resection of lipoma. The progression-free probability is 82.8% for total resection at 16 years and 34.6% for partial resection at 10.5 years. The difference is significant (P < .0001 by log-rank and Wilcoxon). Note stabilization of disease after 8 years with total resection, but inexorable deterioration without disease arrest with partial resection. Partial, partial resection; pt, patients; Total, total resection.*

dure, and of these, 17 (21%) deteriorated, with a mean PFS of 11.6 (SD, 0.626) years. Using KM, the progression-free probability at 15.5 years was 91.5% for the virgin lipomas and 66% for the redo lipomas (Figure 6). The difference between the 2 subgroups was significant ($P < .0001$).

In the partial resection group, the same adverse effect of previous surgery was detected. Among the 84 patients with virgin lipomas, 41 (49%) deteriorated during follow-up, with a mean PFS of 7.5 (SD, 0.36) years. This was in contrast to 21 relapses (66%) in the 32 patients with redo lipomas, with a mean PFS of only 5.3 (SD, 0.43) years. The progression-free probability of the virgin subgroup was 40.4% at 11 years, versus 21.9% at 8.4 years for the redo subgroup (Figure 7). The outcome difference was significant.

Asymptomatic Versus Symptomatic Lipomas

In the total/near-total resection group, 86 patients were asymptomatic and 152 patients had symptoms at the time of surgery. The asymptomatic patients fared much better than the symptomatic patients. Only 2 patients (2.3%) had relapse in the asymptomatic subgroup, versus 22 (14.5%) in the symptomatic subgroup. The mean PFS for the asymptomatic patients was 14.8 (SD, 0.32) years, versus 12.3 (SD, 0.45) years in the symptomatic subgroup. The progression-free probability using KM for the asymptomatic subgroup was 95.7% at 15.8 years, compared with 73.3% for the symptomatic subgroup (Figure 8). The difference was significant. Disease stabilization occurred around 9 years in both groups.

Because almost all patients with redo lipomas had symptoms at the time of surgery and redo lesions tend to do worse, we eliminated the patients with redo lipomas and analyzed the effect of preoperative symptoms on outcome in only the 158 patients with virgin lipomas. Of the 83 asymptomatic patients with virgin lipomas, only 1 (1.2%) deteriorated, versus 6 (8%) of 75 patients with symptomatic virgin lipomas. KM analysis showed a progression-free probability of 98.4% at 16 years, stable from the fifth year onward, in the asymptomatic virgin subgroup, versus 79.2% in the symptomatic virgin subgroup (Figure 9). The difference was significant.

In the partial resection group, outcome differences between asymptomatic and symptomatic patients were less significant but showed similar trends as in the total/near-total resection group. In the asymptomatic subgroup of 58 patients, 27 (46.5%) relapsed, with a median PFS of 8.2 years, whereas in the symptomatic subgroup of 48 patients, 35 (60%) relapsed, with a median PFS of only

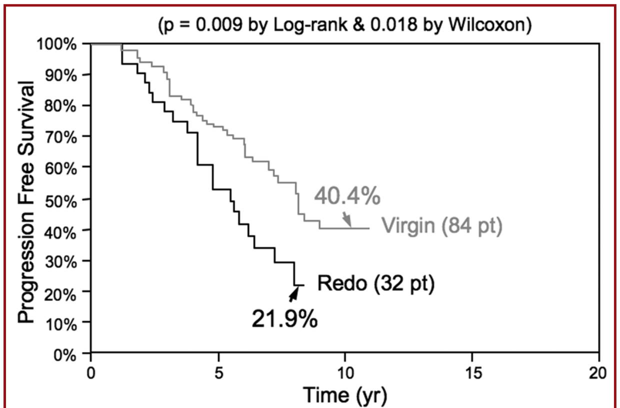

FIGURE 7. *Influence of prior surgery on outcome after partial resection. Kaplan-Meier analysis for virgin and redo lipomas after partial resection. Progression-free probability at 11 years for virgin lipomas is 40.4%, versus 21.9% for redo lipomas. The difference is significant (P = .009 by log-rank and .018 by Wilcoxon). Pt, patients; Redo, redo lipomas; Virgin, virgin lipomas.*

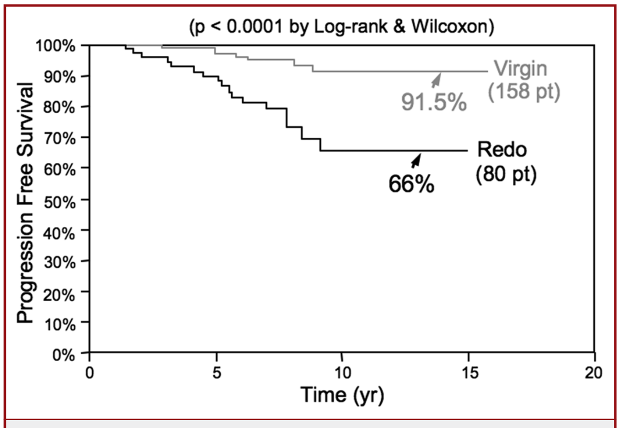

FIGURE 6. *Influence of prior surgery on outcome after total resection. Kaplan-Meier analysis for virgin and redo lipomas after total resection. Progression-free probability for virgin lipomas is 91.5% at 16 years, versus 66% for redo lipomas. The difference is significant (P < .0001). Pt, patients; Redo, redo lipomas; Virgin, virgin lipomas.*

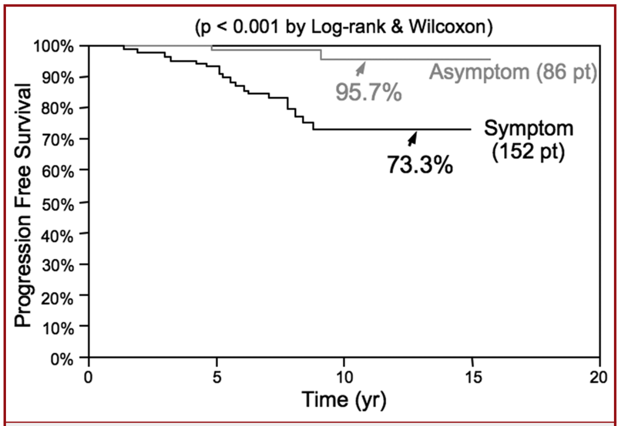

FIGURE 8. *Influence of preoperative symptoms on outcome after total resection. Kaplan-Meier analysis for asymptomatic and symptomatic lipomas after total resection. Progression-free probability at 16 years for asymptomatic lipomas is 95.7%, versus 73.3% for symptomatic lesions. The difference is significant (P < .001). Asymptom, asymptomatic lipomas; pt, patients; Symptom, symptomatic lipomas.*

6.1 year. The progression-free probability at 10 years for the asymptomatic subgroup was 43.3%, versus 26% for the symptomatic subgroup (Figure 10).

Influence of Age on Outcome

The effect of age at surgery on outcome was analyzed for the total/near-total resection group. Patients were categorized into 3 age groups: birth to 2 years (80 patients), 2 to 18 years (122 patients), and older than 18 years (36 patients).

During follow-up, 3 of 80 patients (3.8%) younger than 2 years deteriorated, versus 14 of 122 patients (12.3%) between 2 and 18 years and 6 of 36 patients (16.7%) older than 18 years. KM analysis gave a PFS of 93% at 15 years for the subgroup younger than 2 years, versus 79% for the subgroup aged 2 to 18 years and 65.6% for the subgroup older than 18 years (Figure 11). The differences between groups were significant.

Thus, performing total resection on lipomas when a child is very young seems to predict a better long-term outcome than if operation happens in later childhood or adulthood, but because history of a prior operation exerts such a powerful negative influence on outcome and the incidence of redo lipomas increases with age, we tested the independent effect of age in patients with virgin lipomas separate from those with redo lipomas. KM analysis showed no statistical difference in PFS among the 3 age subgroups in patients with just virgin lipomas (Figure 12). Likewise, there was no difference in outcome between the age subgroups among the patients with redo lipomas.

The influence of age on the partial resection group showed a similar trend as in the total/near-total resection group: the very young patients seemed to do better than the older children and adults. The PFS for partial resection was 49.5%, 32.2%, and 0% for the successively older age subgroups (Figure 13). However, the statistical significance disappeared when the redo lesions were eliminated and comparisons were made on only the virgin subgroup.

Cord-Sac Ratio in Total/Near-Total Resection

The cord-sac ratio[1] had a significant influence on outcome in the total/near-total resection group. The smaller the cord was com-

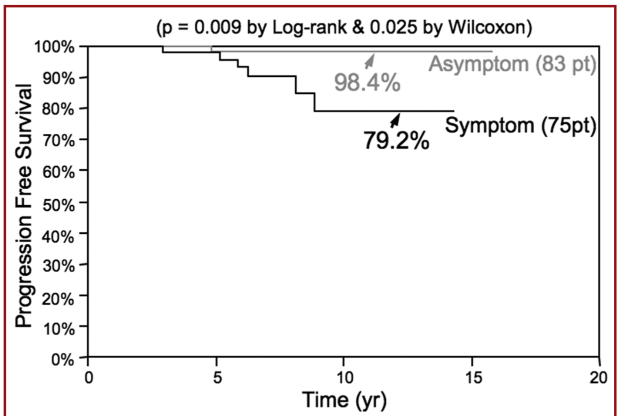

FIGURE 9. *Influence of preoperative symptoms on outcome for virgin lipomas after total resection. Kaplan-Meier analysis for asymptomatic virgin and symptomatic virgin lipomas after total resection. Progression-free probability at 16 years for asymptomatic virgin lipomas is 98.4%, versus 79.2% for symptomatic virgin lipomas. The difference is significant (*P *= .009 by log-rank and .025 by Wilcoxon). Asymptom, asymptomatic virgin lipomas; pt, patients; Symptom, symptomatic virgin lipomas.*

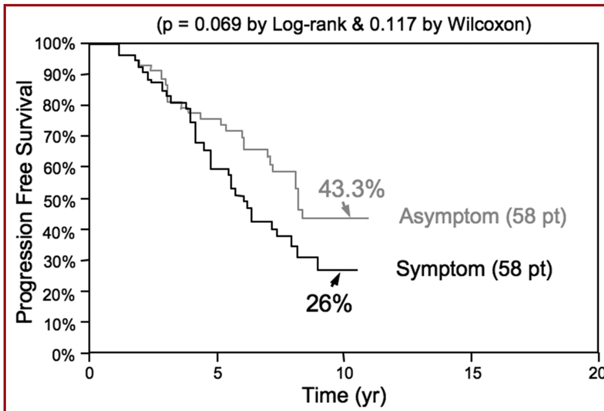

FIGURE 10. *The influence of preoperative symptoms on outcome after partial resection. Kaplan-Meier analysis for asymptomatic and symptomatic lipomas after partial resection. Progression-free probability at 11 years for asymptomatic lipomas is 43.3%, versus 26% for symptomatic lipomas. The difference is not significant (*P *= .069 by log-rank and .117 by Wilcoxon) but shows a similar trend as for total resection, that asymptomatic lesions did better than symptomatic lesions. Asymptom, asymptomatic lipomas; pt, patients; Symptom, symptomatic lipomas.*

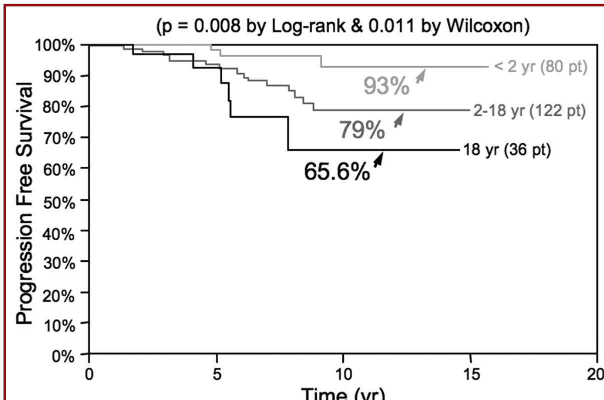

FIGURE 11. *Influence of age on outcome after total resection. Kaplan-Meier analysis for the 3 age groups of patients with lipomas (< 2 years old, 2-18 years old, and > 18 years old) after total resection. Progression-free probability for young children is 93%, better than for older children (79%) and much better than for adults (65.6%). The differences between age groups are significant (*P *= .008 by log-rank and .011 by Wilcoxon). Pt, patients; yr, age in years.*

pared with the thecal sac, the lower was the risk of disease recurrence. Of 162 patients in whom a cord-sac ratio less than 30% was achieved, only 6 (3.7%) deteriorated, versus 11 of 61 patients (18%) with ratios of 30% to 50% and 7 of 15 patients (46.6%) with ratios greater than 50%. KM analysis showed a progression-free probability of 91% at 15 years for the lowest ratio, versus 71.6% for intermediate ratios and 34.6% for the highest ratio subgroup (Figure 14). Thus, the tighter the content-container fit was, the greater was the chance of recurrence.

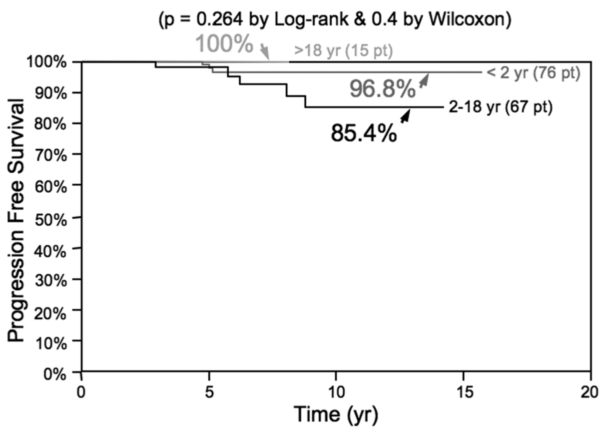

FIGURE 12. *Influence of age on outcome for virgin lipomas after total resection. Kaplan-Meier analysis for the 3 age groups as in Figure 11 of just patients with virgin lipomas after total resection. Progression-free probability for young children is 96.8%, versus 85.4% for older children and 100% for adults (only 15 adult patients). The difference between age groups is not significant (P = .264 by log-rank and .4 by Wilcoxon). Pt, patients; yr, age in years.*

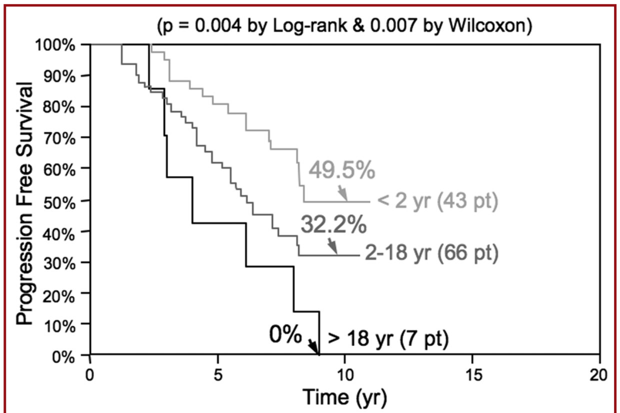

FIGURE 13. *Influence of age on outcome after partial resection. Kaplan-Meier analysis for the 3 age groups as in Figure 12 after partial resection of lipoma. Progression-free probability at 10 years for young children is 49.5%, versus 32.2% for older children and 0% for adults. The differences between age groups are significant (P = .004 by log-rank and .007 by Wilcoxon). Pt, patients; yr, age in years.*

Interesting information emerged when the cord-sac ratio was considered separately for the virgin and the redo subgroups. First, it was easier to achieve a low cord-sac ratio if the lipoma was virgin and not a redo: 74% of patients with virgin lipomas had ratios less than 30% and only 3% had ratios higher than 50%, versus 56% of patients with redo lipomas with ratios less than 30% and 12.3% with ratios higher than 50%.[1] Second, the advantage of a low cord-sac ratio was more dramatic in the virgin subgroup than even for the entire total resection group. There was no recurrence over 16 years among the 117 patients with virgin lipomas who had a low ratio, versus 4 recurrences (11%) among the 36 patients with intermediate ratios and 3 recurrences (60%) among the 5 patients with high ratios. KM analysis showed a progression-free probability of 100% at 15.6 years for low cord-sac ratios and 81.3% for intermediate ratios with stabilization of disease from 8.8 years onward, versus 0% at 8 years for the high-ratio subgroup (Figure 15). The difference was significant.

By comparison, the influence of cord-sac ratio on outcome was less clear for redo lipomas. KM analysis showed a barely significant difference in progression-free probability between the low-ratio and intermediate-ratio subgroups. There was no difference between the intermediate-ratio and high-ratio subgroups. The statistics were also less conclusive because of the small numbers in the > 50% ratio subgroup (n = 10) and the 30% to 50% ratio subgroup (n = 25).

Influence of Lipoma Type on Outcome: Dorsal Versus Transitional Versus Chaotic Lipoma

When the 3 lipoma types were compared regarding outcome, no significant difference in the 15-year PFS was apparent between subgroups (Figure 16). However, there was a huge discrepancy in numbers between the subgroups: only 18 chaotic lipomas and 35

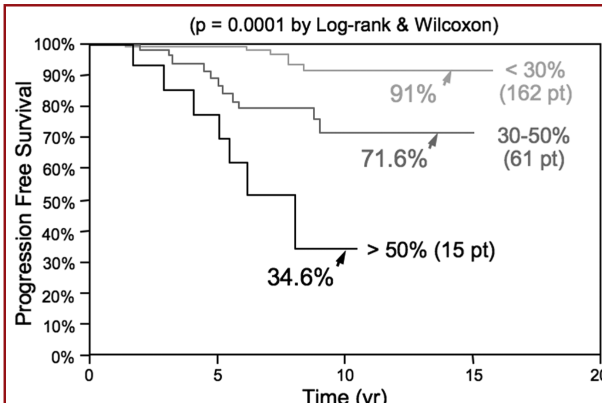

FIGURE 14. *Influence of cord-sac ratio on outcome after total resection. Kaplan-Meier analysis for patients segregated by postoperative cord-sac ratios of < 30%, 30%-50%, and > 50% after total resection of lipoma. Progress-free probability for the < 30% subgroup is 91%, versus 71.6% for the 30%-50% subgroup, and 34.6% for the > 50% subgroup. The differences between subgroups are significant (P = .0001 by log-rank and Wilcoxon). < 30%, 30%-50%, and > 50% indicate the 3 cord-sac ratios. Pt, patients.*

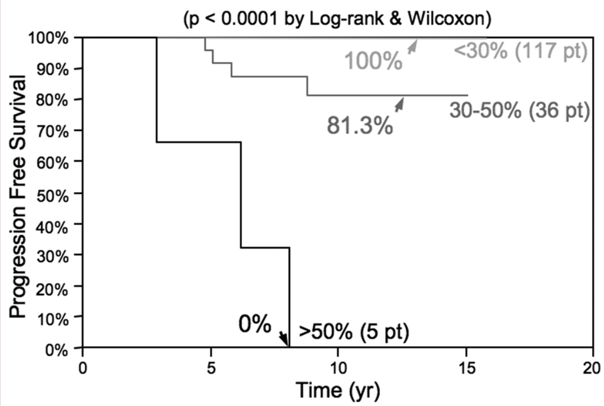

FIGURE 15. *Influence of cord-sac ratio on outcome for virgin lipomas after total resection. Progression-free probability (by Kaplan-Meier analysis) for the < 30% ratio group is 100%, versus 81.3% for the 30%-50% ratio group. The difference is significant (P < .0001). The 0% progression-free survival probability at 8 years for the virgin total resection subgroup with cord-sac ratio > 50% is due to the fact that there were only 5 patients in the virgin group with > 50% ratio and, out of these, 3 recurred, all within 5 years of surgery. These small numbers are not statistically supportable, and the progression-free survival is thus not valid. > 30%, 30%-50%, and > 50% indicate the 3 cord-sac ratios. Pt, patients.*

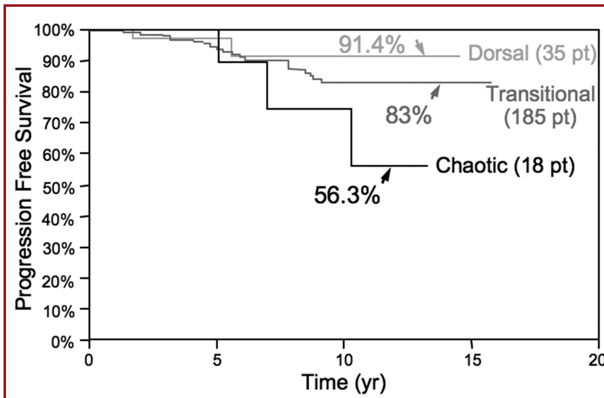

FIGURE 16. *Influence of lipoma type on outcome after total resection by Kaplan-Meier analysis. The progression-free probabilities for the 3 lipoma types are indicated by arrows. There is no significant difference in outcome between dorsal and transitional lipomas (P = .449 by log-rank and .886 by Wilcoxon) even after adjusting for sample size. There are tentative differences between chaotic and the other lipoma types when compared individually (P = .0492 with dorsal lipomas and .0433 with transitional lipomas). Pt, patients.*

dorsal lipomas versus 185 transitional lipomas, a fact that weakened especially the statistical weight of chaotic lipomas and to a lesser extent that of dorsal lipomas. After adjusting for subgroup size differences, the similarity in outcome held up between dorsal and transitional lipomas, but chaotic lipomas seemed to portend a worse outcome (Figure 16). Comparison of chaotic lipomas individually with the dorsal and transitional lipomas, by reducing the degree of freedom from 2 to 1 in the statistical computations, demonstrated tentative differences in outcome between chaotic and the other lipoma types.

Sex and Outcome in Total/Near-Total Resection

There was no difference in outcome between males and females within the total/near-total resection group.

Total/Near-Total Resection, Partial Resection, and Nonsurgical Treatment

Only 1 series of nonsurgical treatment of lipomas is available for comparison with our surgical series. In the study by Kulkarni et al[9] from L'hôpital Necker-Enfants Malades in Paris, published in 2004, 53 children with conus lipomas were prospectively followed up for a mean period of 4.4 years (range, 1-9 y). Thirteen patients (25%) had neurologic deterioration. KM analysis gave a progression-free probability of 67% at 9 years. This number is much lower than in our total/near-total resection group, which had a progression-free probability of 82.4%. However, our partial resection group fared worse than no surgery, having a 9-year progression-free probability of only 34.6%.

Because the Parisian series consists only of patients with asymptomatic lipomas who had no previous surgery, we matched their KM statistics against our equivalent surgical subgroups of asymptomatic virgin lipomas (Figure 17). Of our 83 patients with asymptomatic virgin lesions who had undergone total resection, only 2 (2.4%) deteriorated, giving a progression-free probability of 98.4% at 16 years. This outcome was far superior to nonsurgical treatment. Of our 58 patients with asymptomatic virgin lipomas who had undergone partial resection, 27 (47.3%) deteriorated, giving a progression-free probability of 43.3% at 9 years. This remained considerably worse than nonsurgical treatment (Figure 17). The difference between total and partial resection in patients with just asymptomatic virgin lipomas was significant.

Multivariate Analysis of Factors Affecting Outcome

Because it is probable that certain pairs of predictor variables, such as age and symptoms, age and redo lesions, symptoms and redo, and lipoma type and cord-sac ratio, may be situationally correlated and therefore exert "hidden" mutual interference in their effects on outcome when the variables are considered in isolation, multivariate analyses of all predictor variables were performed to identify factors that exert the most independent influence.

For this purpose, we used the multivariate Cox proportional hazard survival regression model. In this model, the time data to disease recurrence in the total/near-total resection group, ie, the baseline PFS function, was subjected to simultaneous effects of 6 predictor variables, namely, previous surgery (virgin or redo), the presence or absence of symptoms, cord-sac ratio (< 30%, 30%-50%, or > 50%), age (< 2 years, 2-18 years, or > 18 years), lipoma type (chaotic, dorsal, or transitional), and sex. The respective hazard ratio of each variable, ie, the likelihood of a poorer recurrence-

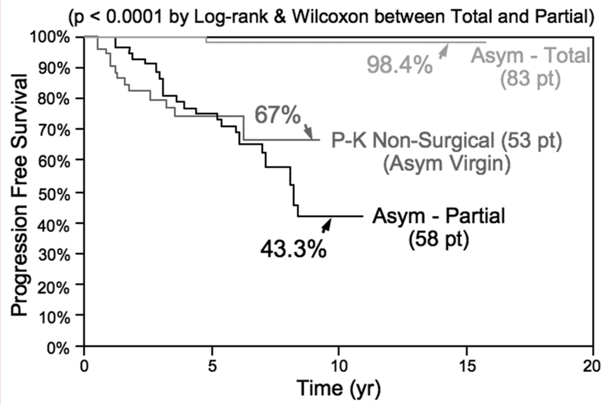

FIGURE 17. *Outcome differences between total resection, partial resection, and nonsurgical management of asymptomatic virgin lipomas by Kaplan-Meier analysis. The nonsurgical survival function graph (P-K Non-Surgical) from the Parisian study[9] is inserted for visual comparison only and is not meant to imply a true head-to-head comparison. Progression-free probability at 16 years for the 83 asymptomatic virgin lipomas that had undergone total resection is 98.4%, much better than 67% in the Parisian series and far superior to the 43.3% in our own partial resection series. The difference between total and partial resection for asymptomatic virgin lipomas is significant (*P *< .0001). Asym-Partial, asymptomatic virgin lipomas treated by partial resection; Asym-Total, asymptomatic virgin lipomas treated by total resection; P-K Non-Surgical (Asym-Virgin), asymptomatic virgin lipomas managed nonsurgically[9]; pt, patients.*

free survival associated with the "adverse" category of that variable (eg, redo lesion in the variable "virgin or redo"), and its corresponding *P* value at 95% confidence interval are listed in Table 5.

The Cox multivariate model showed that when controlling for the other 5 predictor variables, cord-sac ratio exerted the only powerful independent influence on PFS, exhibiting a 3.5 times worse outcome with the higher cord-sac ratios ($P = .0009$) (Figure 18). The presence of symptoms exerted only a moderate effect despite a hazard ratio of 3.97, with an unpersuasive *P* value of .1107. Surprisingly, the adverse effect of redo surgery, resounding by KM (univariate) analysis, was dramatically reduced by controlling for the other factors. It was also obvious that when the effects of cord-sac ratio, symptoms, and previous surgery were normalized, the influences of age, lipoma type, and sex became negligible.

To understand further the relationship between the "nonindependent" predictors (age, symptoms, and redo) and the 1 independent predictor of cord-sac ratio, we performed paired Cox univariate and multivariate analyses for the 3 predictor variables of age, symptoms, and redo lesions (Figures 19-21). For each of these 3 predictors, the univariate model gave high statistical significance, which disappeared in each case with the multivariate model. This suggests that for each nonindependent predictor, its respective influence on outcome must work through some other factor that may be thought of as the "final common pathway."

TABLE 5. Hazard ratios, regression coefficients, and P values of 6 predictor variables on the progression-free survival function in lipoma patients who had total/near-total resection[a]

Variable	Hazard Ratio	Regression Coefficient	*P* Value
Sex	0.8098	−0.211	.6208
Lipoma type	1.4499	0.3715	.5317
Age	1.0073	0.0073	.9862
Symptomatic/ asymptomatic	3.9752	1.3801	.1107
Redo lipoma/ virgin lipoma	2.1002	0.742	.1641
Cord-sac ratio	3.4741	0.9059	.0009

[a] Data were computed using the multivariate cox proportional hazard survival regression model.

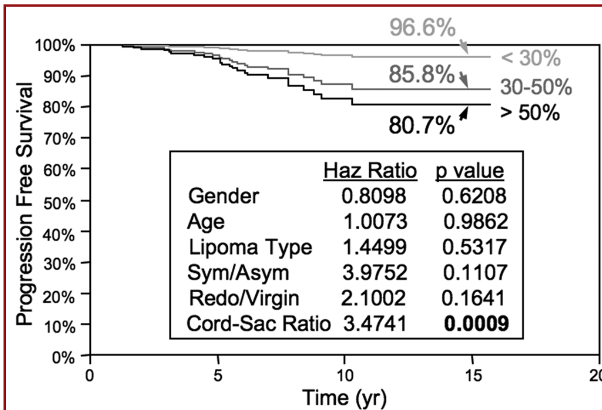

FIGURE 18. *Cox multivariate proportional hazard regression model analyzing the combined influence of 6 predictor variables (sex, age, lipoma type, symptoms, redo versus virgin, and cord-sac ratio) on progression-free survival after total resection, featuring the resultant effect of the 3 cord-sac ratios of < 30%, 30%-50%, and > 50%. The hazard ratios and *P *values for all 6 predictor variables are listed in the miniaturized table, showing that cord-sac ratio exerts the only significant independent influence on outcome. The respective progression-free probabilities, as indicated by the arrows, are 96.6% for low ratio, 85.8% for intermediate ratio, and 80.7% for high ratio. The differences in hazard prediction for the 3 ratios are significant (*P *= .0009, in bold). < 30%, 30%-50%, and > 50% indicate the 3 cord-sac ratios. Sym/Asym, symptomatic versus asymptomatic lipomas.*

Cord-sac ratio, being the only significant independent predictor, best fit the role of this final common pathway. To test this hypothesis, we first examined whether redo lesions exerted their harmful effect chiefly through their association with high cord-sac ratios. An obvious indicator was that redo lipomas are associated with a much higher proportion of high cord-sac ratio than virgin lesions.[1] Analysis of covariance illustrated this strong correlation

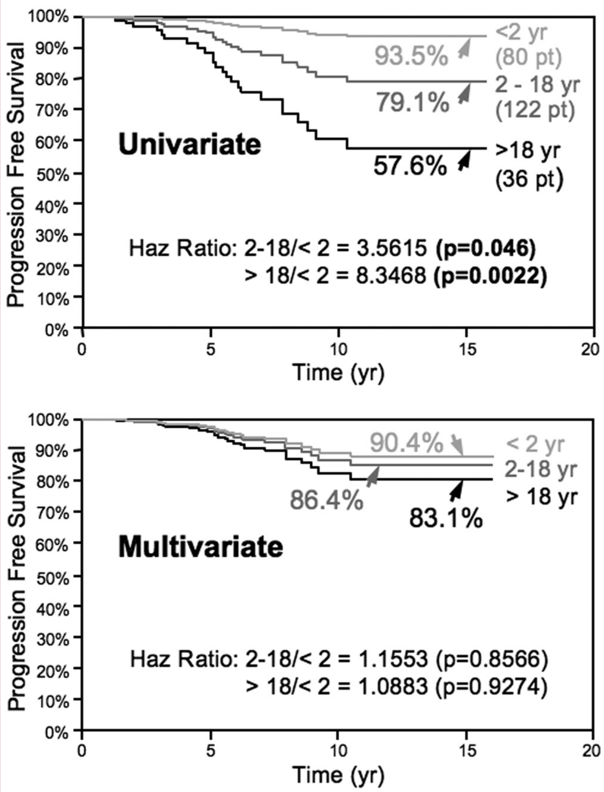

FIGURE 19. *Paired Cox univariate (upper) and multivariate (lower) analyses of the influence of age on progression-free survival. The respective progression-free probabilities for the 3 age groups are indicated by arrows, and their hazard ratios and relevant* P *values are listed for each Cox analysis. This shows that the individual influence (expressed in univariate analysis) of age on outcome disappears when the influences of the other predictor variables are jointly considered (by multivariate analysis). Significant* P *values are in bold. Haz, hazard; Pt, patients; yr, age in years.*

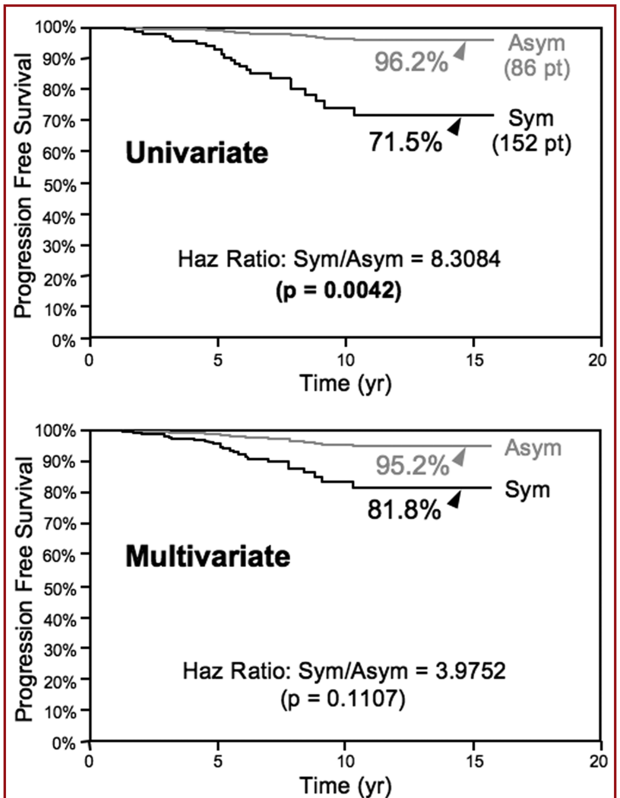

FIGURE 20. *Paired Cox univariate (upper) and multivariate (lower) analyses of the influence of preoperative symptoms on PFS. The respective progression-free probabilities for asymptomatic and symptomatic lipomas are indicated by arrows, and their hazard ratios and relevant* P *values are listed for each Cox analysis. This shows the individual influence (expressed in univariate analysis) of preoperative symptoms on outcome disappears when the influences of the other predictor variables are jointly considered (by multivariate analysis). Significant* P *values are in bold. Asym, asymptomatic lipomas; Haz, hazard; pt, patients; Sym, symptomatic lipomas.*

between prior surgery and high cord-sac ratios (R^2 correlative coefficient = 0.76, $P < .001$). To prove further that good outcome could still be achieved in redo lesions if a low cord-sac ratio could be created, thus verifying the subordinate role of other unidentified attributes of previous surgery, Cox multivariate modeling was performed on cord-sac ratio for just the redo lipomas (Figure 22). A PFS of 86.6% can still be anticipated in redo lipomas if a less than 30% cord-sac ratio can be rendered.

This sequence of analyses, including the respective covariance analysis, can be repeated for the other 2 predictors, age and symptoms, with analogous results.

Preoperative Patient Profiling

With all its colossal impact on outcome, cord-sac ratio is not available before surgery. To create pretreatment composite patient profiles to sort out potentially favorable from unfavorable surgical candidates, we ranked on a relative scale all the preoperative traits that potentially influence outcome using the MCA multivariate method. In an MCA 3-dimensional plot, the mutual influence between the preoperative predictor variables (age, sex, lipoma type, symptoms, and prior surgery) were taken into account while their respective effects on outcome were displayed. Predictor variables were seen either clustering around an outcome category along a principal component signifying dominant influence, with strengths inversely proportional to the distance from the relevant outcome category, or scattered afar from the outcome category, indicating indifferent influence. Outcome was considered bad for patients who showed deterioration, and good if no deterioration was noted during the follow-up period. Age and lipoma types were coded as in the Cox proportional hazard model described previously.

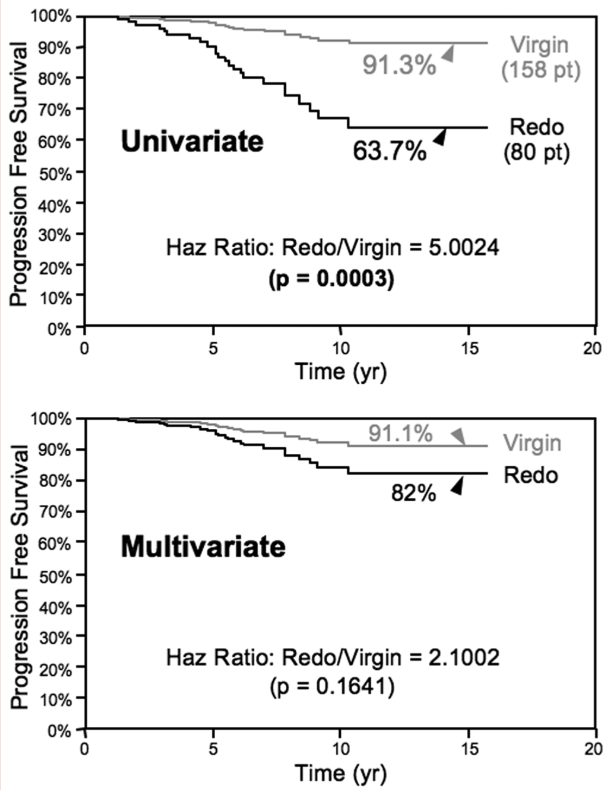

FIGURE 21. *Paired Cox univariate (upper) and multivariate (lower) analyses of the influence of previous surgery on progression-free survival. The respective progression-free probabilities for virgin versus redo lipomas are indicated by arrows, and their hazard ratios and relevant* P *values are listed for each Cox analysis. This shows the individual influence (expressed in univariate analysis) of previous surgery on outcome disappears when the influences of the other predictor variables are jointly considered (by multivariate analysis). Significant* P *value is in bold. Haz, hazard; pt, patients; Redo, redo lipomas; Virgin, virgin lipomas.*

This analysis showed that bad outcome was significantly associated with reoperated lesions and symptomatic cases ($P < .001$). Age, lipoma type, and sex had no significant effect on bad outcome. Good outcome, on the other hand, was strongly correlated with patients younger than 2 years who were asymptomatic and had virgin lipomas. Neither lipoma type nor sex predicted a good outcome. Three-dimensional multivariate plots of these relationships (Figure 23) illustrated clustering of closely associated variables around the respective outcome categories along the F_1 (x) or principal component axis.

Complications of Total/Near-Total Resection and Partial Resection

Postoperative complications were recorded under 3 categories: neurologic, urologic-bowel, and miscellaneous; the last includes

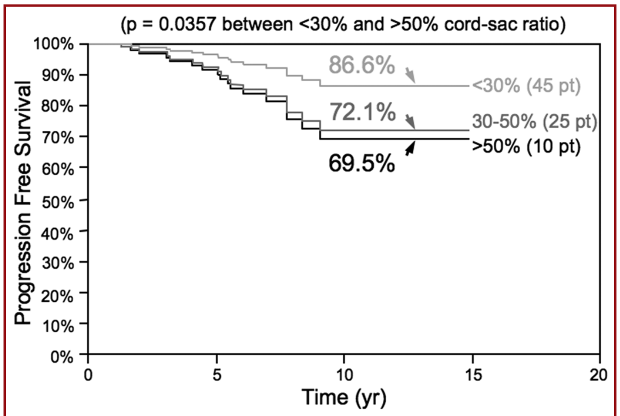

FIGURE 22. *Cox multivariate analysis for the influence of cord-sac ratios on outcome in 80 redo lipomas that underwent total resection. Progression-free probabilities are indicated by arrows. A high progression-free survival of 86.6% can still be managed even in redo lipomas if a cord-sac ratio < 30% can be achieved, indicating the dominant role of cord-sac ratio and, conversely, the subordinate role of other unidentified attributes of previous surgery, on long-term outcome (*P *= .0357 between < 30% and > 50% cord-sac ratios). Pt, patients.*

cerebrospinal fluid (CSF) leakage, infection, and wound problems. Complication rates were compared between the total/near-total resection group and the partial resection group, and within each group, patients with virgin lipomas and redo lipomas were considered separately (Table 6).

Total/Near-Total Resection Group

The most prevalent new postoperative symptom in this group was dysesthetic leg pain with spontaneous electric-shock sensation. If not the most disabling, it was certainly the most annoying symptom, and is the usual reason for patient complaints. The pain is ill-defined, nonfocal, and tends to be worse during sleep and with inactivity. Patients with redo lipomas are 4 times more likely than patients with virgin lipomas to have this pain. The dysesthetic pain usually responds well to gabapentin and mostly abates within 18 months. Of 10 patients to whom gabapentin was initially prescribed, only 2 still required it 3 years later.

Five patients lost some perineal or leg sensation from surgery, but the numbness was mostly unnoticed, except in 1 female, whose sexual gratification was considerably blunted. One patient had partial loss of proprioception in one ankle and some difficulty with navigating in the dark. Four patients, all in the redo group, had some new leg weakness. The patients with new sensorimotor deficits also experienced neuropathic pain.

The most common new urologic symptoms are worsened voiding function and incontinence, correlating with diminished detrusor contractility, and a flatter urethral pressure profile on urodynamics. However, 4 of the 5 patients with worsened bladder symptoms were already on CIC preoperatively, and only 1 patient needed CIC after surgery. Again, urologic and bowel dysfunctions are

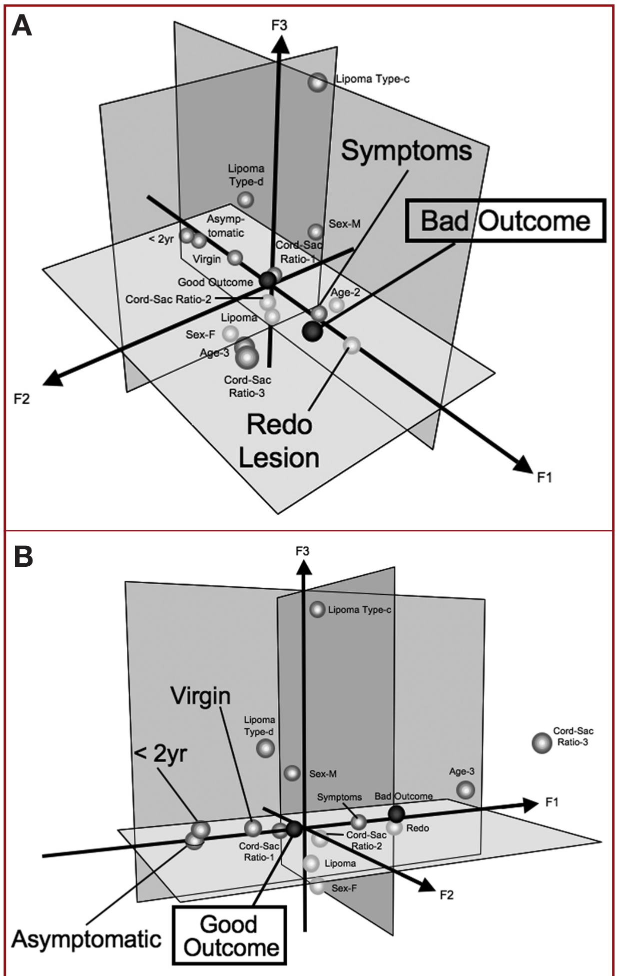

FIGURE 23. *Preoperative profiling of good- versus poor-risk patients for total resection using 3-dimensional multiple correspondence analysis plots that display the respective strength of influence of the 6 predictor variables (sex, age, lipoma type, symptoms, redo versus virgin lipomas, and cord-sac ratio) on outcome after total resection. Light-colored balls represent predictor variables, and dark-colored balls represent outcomes. Only the statistically significant predictors are flagged. Bad outcome implies recurrence, and good outcome implies the absence of recurrence during the follow-up period. Close clustering of variables (with flags) around an outcome signifies strong influence; remote scattering of variables (without flags) from an outcome signifies weak influence.* **A**, *bad outcome is associated with preoperative symptoms and redo lesions.* **B**, *good outcome is associated with children younger than 2 years, asymptomatic lesions, and virgin lipomas.*

much more common in patients with redo lipomas. Overall, 4.2% of patients in the total/near-total resection group had neurologic or urologic setbacks after surgery.

Three patients in this group had wound infection or dehiscence; all 3 were obese adults unwilling to mobilize out of bed and subsequently had wound edge necrosis. All 3 required reclosure and antibiotics. Two patients had overt CSF leak necessitating wound reclosure, and 2 others developed subcutaneous pseudomeningocele that subsequently resolved spontaneously.

We encountered only a single case of graft rejection of the bovine pericardial material. This child developed a huge pseudomeningocele 10 weeks after an initial uneventful recovery. Two attempts at repair with a new bovine graft were unsuccessful, accompanied by blood eosinophil counts of 28% and 34%. At the time of reoperation, the graft-dura suture line showed no healing, and the underlying nerve roots exhibited typical arachnoiditis. (This child was one of the neurologic failures.) The problem was resolved at the third reoperation using an autologous fascia lata graft.

Overall, 13 patients (5.4%) in the total/near-total resection group had complications. Both neurologic-urologic and wound-related problems were 4 or 5 times more prevalent in patients with redo lipomas than in patients with virgin lipomas.

Partial Resection Group

The combined neurologic-urologic complication rate in this group was 5.2%, slightly higher than with total resection (Table 6). However, the urologic complications with partial resection were in fact much higher, offsetting a lower incidence of neuropathic pain compared with total/near-total resection.

Wound complications were almost 3 times more common than with total/near-total resection. CSF leak was particularly problematic, being 5.2%, versus only 0.8% with total resection.

The overall complication rate in the partial resection group was 9.5%, almost twice as high as with total/near-total resection. The incidence among redo lesions was similarly 4 to 5 times higher than with virgin lesions.

DISCUSSION

Early Postoperative Results

The early postoperative results were similar between our total and partial resection groups. For asymptomatic patients in both groups, the rates for neurologic preservation were 98% and 94%, respectively. In symptomatic patients who had total or near-total resection, 61% had normal or improved neurologic status and 33% remained unchanged, thus giving a rate of 94% for improvement or stabilization of disease. For symptomatic patients who had partial resection, 33% were improved and 62% had disease stabilization, at least for the short term.

Our early postoperative results are thus comparable to or better than those in the literature. Pierre-Kahn et al[7] reported 93.6% preservation of function for asymptomatic patients and 91% better or unchanged for patients with symptomatic lipomas. La Marca et al[10] found 98% improvement or stabilization for symptomatic lipomas and 100% preservation of function for asymptomatic patients. The improved or stabilization rates of mixed symptomatic-asymptomatic groups are 94% for Arai et al,[3] 90% for McLone and Naidich,[11] 84% for Hoffman et al,[12] 83% for Sathi et al,[13] 80% for Xenos et al,[8] and 70% for Cochrane et al.[6]

TABLE 6. Neurologic, urologic, and wound complications of total/near-total resection and partial resection of lipoma[a]

Complications (Beyond 3 mo)	Total/Near-Total Resection			Partial Resection		
	Virgin (n = 158)	Redo (n = 80)	Total (n = 238)	Virgin (n = 84)	Redo (n = 32)	Total (n = 116)
Neurologic						
Neuropathic pain	2	8	10 (4.2%)	0	2	2 (1.7%)
Loss of sensation	1	4	5 (2.1%)	1	2	3 (2.6%)
New weakness	0	4	4 (1.7%)	0	2	2 (1.7%)
Total neurologic		8	10 (4.2%)	1	2	3 (2.6%)
Urologic/bowel						
Worsened voiding function/incontinence	0	3	3 (1.3%)	1	4	5 (4.3%)
Worsened urodynamics	1	4	5 (2.1%)	1	3	4 (3.4%)
Required permanent CIC	0	1	1 (0.4%)	0	2	2 (1.7%)
Total urologic	1	4	5 (2.1%)	1	5	6 (5.2%)
Bowel incontinence	0	2	2 (0.8%)	0	0	0
Combined neurologic/urologic/bowel	2	8	10 (4.2%)	1	5	6 (5.2%)
Miscellaneous/wound						
CSF leak	1	1	2 (0.8%)	2	4	6 (5.2%)
Pseudomeningocele	0	2	2 (0.8%)	0	1	1 (0.9%)
Infection—graft	0	1	1 (0.4%)	1	0	1 (0.9%)
Infection—wound	1	2	3 (1.3%)	0	2	2 (1.7%)
Wound dehiscence	0	1	1 (0.4%)	1	2	3 (2.6%)
Bovine graft rejection	0	1	1 (0.4%)	0	0	0
Total miscellaneous/wound	1	5	6 (2.5%)	2	6	8 (6.9%)
Overall complications		13 (5.4%)			11 (9.5%)	

[a] Redo, redo lipoma; virgin, virgin lipoma; CIC, clean intermittent catheterization; CSF, cerebrospinal fluid. Results for virgin and redo lipomas are separately tabulated.

Several conclusions can be made from these numbers. First, prophylactic surgery for asymptomatic lipomas using either complete or partial resection carries a small neurologic risk when performed by experts. Second, the benefits of surgery are obvious for patients with progressive deterioration. Third, the fact that the early improvement and stabilization rates are almost identical between total and partial resection (Figure 4) strongly suggests that the immediate benefits of surgery are due to the abrupt relief of traction on the conus and not to the extent of lipoma resection or placode reconstruction. In our partial resection group, the majority of neural placodes were in fact completely detached from all adhesions, thus accounting for the good early results. We assume the same for those published series that reported equally good early results.[3,7,10,14] Authors who specifically described their inability to completely disconnect the conus from caudal attachment owing to the presence of obscuring residual fat and undelineated cord-lipoma margin also pointed out the corresponding poor outcome of these patients.[5,7,8]

To accept this last point is to refute the notion that neurologic deterioration in spinal lipoma might be due to myelodysplasia, arachnoiditis, or another abstruse mechanism[6,7,9] unrelated to mechanical traction on the cord, which summarily dismisses the causal effect of thorough untethering for good results and conveniently exculpates unsuccessful untethering for poor results. Such a belief is gratuitous and ultimately counterproductive to future research.

Complications and Other Disadvantages of Total Resection

Total or near-total lipoma resection would not be worthy of endorsement if the complications were egregious. Our 4.2% combined neurologic-urologic deterioration rate after total or near-total resection compares more than fairly with the average rate of 3% to 7% in the literature,[3,6-8,10,15,16] and much more favorably with other series with rates as high as 10%.[7,17] Almost all of the published series described partial resection using techniques presumably more conservative than ours.

Our extremely low rates of CSF leak, pseudomeningocele, and wound complications are also much lower than those in most published series, which record CSF leak rates from 2% to 47%[6-8,10-12,15,16,18] and wound dehiscence and infection rates of 2% to 26%.[7,8,10-12,15-17] The probable reasons for our low wound complication are discussed in part I of this study.[1]

Perhaps the most equitable comparison of complications between total and partial resection is between our own respective series. The urologic deterioration rate was lower with total resection than with partial resection, and the incidence of new motor weakness was identical for both groups, but the frequency of postoperative pain was higher with total resection. This may have to do with perturbation at or near the major sensory input areas of the cord during total resection, particularly by the electrocautery. This is why in part I we recommend using the ultrafine irrigating bipolar forceps with low current setting and as sparingly as possible.[1] Fortunately, the dysesthetic pain in question resolves over time (average resolution time, 6-10 months) and responds well to gabapentin. The lower CSF and wound complication with total versus partial resection probably owes to more polished techniques during the later (total resection) series. Finally, the operative time is longer by 30% to 40% with total resection, but the postoperative hospital stay is similar for total and partial resection.

Long-Term Outcome

Total/Near-Total Resection Versus Nonsurgical Management

There should by now be scant dispute that spinal cord lipoma is a progressive disease with a high likelihood of deterioration. Indirect evidence has been mounting since 1985, when Hoffman et al,[12] who correlated neurologic grades with the ages of children with lipomas, found that although many infants were normal or near normal, the percentile of symptomatic children increased stepwise with age. Likewise, La Marca et al[10] found only 3% of conus lipomas asymptomatic at 1 year and none beyond 2 years of age. Koyanagi et al,[18] Arai et al,[3] and others[14,19,20] had similar findings. In 1995, Kanev et al[21] plotted the log-percentile of neurologically intact patients against age and showed a straight down-slope curve without a trend to plateau.

The definitive proof came in 2004 from the Parisian prospective study of nonsurgical management.[9] Chapman, in his comment on this study,[9] discerningly stated that if the outcome results of their nonsurgical and surgical patients were the same, their numbers could legitimately be combined, and the combined actuarial risk of deterioration for asymptomatic lipomas was thus estimated to be approximately 60% over 12 years, with a PFS probability of less than 40%.[4] Because the Parisian study[9] featured only asymptomatic lipomas, one might assume symptomatic lipomas will fare even worse.

Given that children with lipomas have an actuarial life of 65 to 70 years, a long span in the context of a progressive disease, and given further that established neuropathic bladder and sensorimotor deficits seldom fully recover after post factum or salvage surgery,[8,10,11,16,22,23] the argument for prophylactic surgery seems compelling, provided surgery can offer a clear-cut outcome advantage over conservative treatment.

Using the Parisian series as control,[9] our results with total/near-total resection have shown just that. The superiority of total resection is obvious, with its 16-year progression-free probability of 98.4% for asymptomatic lipomas compared with 67% for con-

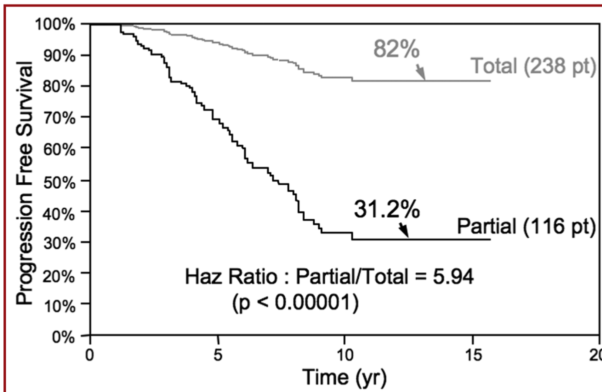

FIGURE 24. *Cox proportional hazard regression analysis for long-term outcome of total versus partial resection of lipomas. Progression-free probabilities for the 2 treatment groups are indicated by arrows. Hazard ratio for symptomatic recurrence of partial/total is 5.94, with a* P *value < .00001. The advantage of total over partial resection is obvious. Partial and Total indicate extent of resection. Haz, hazard; pt, patients.*

servative management. Furthermore, there is strong suggestion of stabilization of disease 8 years after total resection, whereas the probability of deterioration remains cumulative beyond 9 years with nonsurgical treatment.[9] If this trend for prophylactic total resection holds up beyond the first 2 decades, and there is every reason to believe it will, the benefit margin of this technique over the natural history of lipoma should continue to widen with time.

There are no longitudinal data on untreated asymptomatic lipomas in adults, and the actuarial life span for adults is obviously shorter, so a forceful argument cannot be made for prophylactic surgery on adult lipomas. When a lipoma causes symptoms, however, it is widely assumed that deterioration would be inexorable, and aggressive surgery can then be justified.

Total/Near-Total Resection Versus Partial Resection

Our results show that total/near-total resection has a much better long-term outcome than partial resection. This is true for all lipomas as a group as well as for all subgroups when the lesions in each treatment group are segregated by the presence or absence of symptoms, age, and whether previous surgery was performed. The risk of symptomatic recurrence is 5.94 times higher with partial resection compared with total/near-total resection over 12 years by the Cox proportional hazard regression model, with a P value < .00001 (Figure 24). Even though we compared prospective and retrospective data, the impressive difference in long-term PFS between the 2 techniques makes a compelling argument for endorsing total/near-total resection.

Our Partial Resection Series Compared With Published Partial Resection Series

To justify a wider acceptance of total resection as the preferred technique, our series of partial resection must be shown to be in common with other published series. Almost all published series of lipoma surgery advocate partial resection using techniques similar to ours.[2,3,7,8,13,16,19,24-26] Pierre-Kahn et al[7] attempted total resection but desisted after a few cases because of neurologic injury and resorted to partial resection in 34% and "subtotal" resection in 66% of their cases. They were able to neurulate only 17% of their cases, presumably because of the bulk of residual fat. Byrne et al[23] and McLone and Naidich[11] used a carbon dioxide laser to debulk the lipoma but left behind a layer of fat to protect the cord. Stolke et al[26] deliberately refrained from aggressive excision because the separation between fat and cord was deemed poorly demarcated. Most neurosurgeons cut the lipoma stalk, but neurulation either was not mentioned or was performed only occasionally, and the use of dural grafting was noticeably haphazard.[3,8,13,15,16,18,21,27,28]

At first glance, our results with partial resection seem worse than in the literature, but closer analysis matching patient profiles and lipoma types puts our results very much in line with published results. Pierre-Kahn et al[7] reported a 10-year progression-free probability of 40% compared with our results of 35% over 12 years, but their case mix included terminal lipomas and only virgin lesions, and all of their patients were asymptomatic, all factors associated with better outcome. Our lesions were, in contrast, a mixture of redo and virgin lesions, all complex types, and our patients were of all ages and the majority had symptoms, all factors associated with worse outcome. If in our partial resection series only the virgin and asymptomatic cases are preselected, the 12-year PFS increases to 43.3% (Figure 17). This number matches the results of Colak et al,[19] who reported a 10-year PFS of 52%, but again, their series had 37% terminal lipomas and no redo lesions; and the series of Dorward et al,[28] which reported a deterioration rate of 48% with a mean follow-up of only 2.2 years. In their large series (158 cases), La Marca et al[10] reported an 80% progression-free probability at 15 years for asymptomatic patients, but only 36% for symptomatic patients. Cochrane et al,[6] who treated only transitional lipomas, recorded a 10-year PFS of only 20%, the lowest on record. As Colak et al[19] and Pierre-Kahn et al[7] have found in their studies, our PFS curve for partial resection continues to decline beyond 10 years, signifying no stabilization of disease with partial resection.

Advantages of Total/Near-Total Resection

To determine what makes total/near-total resection so much more effective than partial resection in preventing retethering, we look for differences in the distributions of predictor variables in the total and partial resection groups.

Because neither sex nor lipoma type affects outcome, their relevance is negligible. Among the other 4 predictor variables that do have significant influence on outcome, age cannot account for the difference between total and partial resection because the 2 treatment groups are closely age matched. Also, the ratio of redo to virgin lipomas and the ratio of symptomatic to asymptomatic patients are similar between the total and partial resection groups. Moreover, the Cox hazard ratios between categories within each of these predictor subgroups, eg, between redo and virgin lipomas and between symptomatic and asymptomatic patients, are nearly identical in the total and partial resection groups, suggesting that these predictors also exert qualitatively similar effects in each of the treatment groups. Thus, age, symptoms, and prior surgery cannot explain the enormous difference in outcome between total and partial resection.

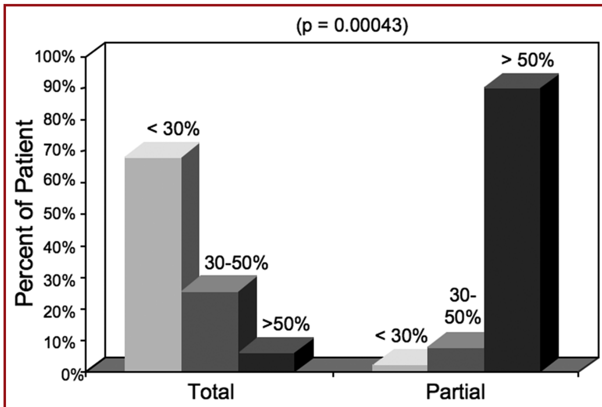

FIGURE 25. *Distribution of cord-sac ratios between the total resection and partial resection groups. Almost 70% of patients who had total resection had a cord-sac ratio < 30%, versus less than 5% of patients who had partial resection. Conversely, only 6% of patients who had total resection had a high ratio of > 50%, versus more than 90% of patients who had partial resection. The difference is significant (*P *= .00043). < 30%, 30%-50%, and > 50% indicate the cord-sac ratios.*

In sharp contrast, the distributions of cord-sac ratios are strikingly dissimilar between the total and partial resection groups (Figure 25), showing a steep bias for low cord-sac ratios with total resection. Cord-sac ratio is thus the most likely factor differentiating total from partial resection.

Cord-Sac Ratio and Its Interplay With Other Outcome Predictors

That a low cord-sac ratio is an extremely important determinant of good outcome is amply supported by the Cox multivariate model, which shows that cord-sac ratio exerts a significant, independent influence on outcome. This means that no matter how the associative influences of the other predictive factors reinforce or cancel each other, the influence of cord-sac ratio stands solitary and undiminished. Regardless of all other influences, a cord-sac ratio higher than 50% predicts a 5.6 times higher risk for disease progression than a low cord-sac ratio of less than 30%, with high statistical significance (Figure 18).

In an operational sense, cord-sac ratio may be thought of as the summated product of the other predictors, ie, as their final common pathway. For example, the adverse effect of older ages can be explained by the fact that the older patients are more likely to have developed symptoms at the time of surgery and to harbor redo lesions, both symptoms and redo lesions are associated with worse outcome, and both are directly or indirectly linked to high cord-sac ratios. Previous surgery on the lipoma undoubtedly makes it much harder to achieve a small cord-sac ratio: the texture and hue of scar tissue within the fat can be confused with the white plane leading to retention of excessive fat and cicatrix and a bulky placode.[1] Because many of the symptomatic lipomas in our total resection group were redo lesions, their poor prognosis may in large part be due to the preeminence of the "redo factor," thus indirectly linking symptoms with high cord-sac ratio. This redo factor has also been shown to be the underlying cause for the effect of age on outcome, for when PFSs for the 3 age groups were calculated separately for virgin and redo lesions, no difference in outcome was observed between age groups within either the virgin or the redo subgroup (Figure 12).

Some authors have commented that adult lipomas are harder to resect than lipomas in children because of more tenacious adhesions between the cord and dura, more stubborn anchorage of the fat to neural tissue,[4] and "arachnoiditis-like" changes in the cord and nerve roots with aging, all potential obstacles to optimal neurulation.[9] We think these are relatively minor impediments that could be deftly handled with practice.

Adhesion Surface on Neural Placode: Importance of Neurulation

Though a loose-fitting placode is undoubtedly important in preventing retethering, to presume a low cord-sac ratio the only requisite for good outcome would be oversimplifying the complex perioperative intradural milieu. A sobering example is the child with allergy to bovine pericardium who had a flawlessly reconstructed placode with a low cord-sac ratio of 20%, which nevertheless was plastered to the ventral dura by reactive arachnoiditis, and the child promptly deteriorated. Thus, even though a loose-fitting sac permits a greater freedom of cord motion within CSF, adhesion to the dura can still happen if what remains exposed is a sticky, unneurulated raw lipoma bed. Meticulous neurulation conceals this raw surface within an imbricated seam. Our experience of reexploring unneurulated placodes leaves no doubt that this raw surface is a conspicuous focus of adhesion to the dura much more than a well-executed seam. Though not an easily quantifiable act, concealment of this adhesive surface through minutely careful neurulation must rank equally with a low cord-sac ratio as staunch insurance against retethering.

Preoperative Profiling for Good- and Poor-Risk Patients

Although cord-sac ratio and the state of neurulation are good outcome indicators, they are postsurgical parameters. It would be useful for prognostication and patient selection to have a presurgery profile to distinguish good-risk from poor-risk patients. MCA shows that poor outcome is highly associated with reoperated and symptomatic lipomas. Good outcome is strongly correlated with children younger than 2 years, absence of symptoms, and previously unoperated lipomas. The PFS probability of the 62 patients in our total resection group who fit this ideal profile increases to a stunning 98.8% at 15 years (Figure 26). Statistical data therefore convincingly argue for performing total resection on spinal cord lipomas when the child is young, before neurologic dysfunction arises, and definitely before an incomplete resection is attempted, regardless of the type of lipoma. Such ideal patients will most likely have a low cord-sac ratio, and in the group of 117 patients with virgin lesions who had a cord-sac ratio of < 30%, no disease recurrence was noted in 16 years (Figure 14).

For the less fortunate patients who are older, already experiencing symptoms, and worst of all, also having had previous surgery, the prospect for long-term disease control is less optimistic. This less sanguine prospect is probably due to a lower likelihood of attaining a low cord-sac ratio.

Untidy Issues

For all the lofty statistics and extravagant analyses, 2 parameters remain untidy issues: symptoms and lipoma types.

Asymptomatic Versus Symptomatic Lesions. Even though multivariate analysis found no statistical difference in outcome between symptomatic and asymptomatic lesions, the *P* value of .1107 was only marginally below significance level. Univariate analysis showed a strong correlation between asymptomatic lesions and good outcome, and even when the analysis was run on just the virgin lesions to eliminate the redo factor, asymptomatic patients still came out better (Figure 9).

Several large series in the literature[7,10,28] also report considerably better prognosis for asymptomatic cases. It was once argued that symptomatic patients tend to be older children and their follow-up coincides with the age of rapid growth and strenuous athletic lifestyle, both known triggers of new symptoms, whereas asymptomatic patients are more often infants. The follow-up conditions of the 2 groups are thus not comparable because the symptomatic older child is being assessed at a more susceptible age.[10] Although this may explain some of the differences, the series of Byrne et al[23] of 100 infants still shows a markedly better outcome for asymptomatic lesions. Thus far, the weight of evidence suggests

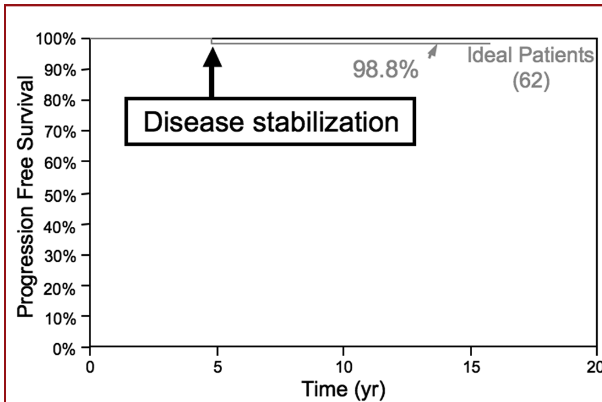

FIGURE 26. *Kaplan-Meier analysis for progression-free survival showing the predicted outcome of the 62 "ideal" patients for total resection, ie, asymptomatic children younger than 2 years with virgin lipomas. The progression-free probability at 16 years is 98.8%, with disease stabilization after 5 years from surgery.*

that the difference in prognosis between symptomatic and asymptomatic lipomas is real.

We have not identified any consistent dissimilarity in neuroimaging, anatomy, or histology between symptomatic and asymptomatic lesions. However, we suspect that there may be inherent differences within their respective spinal cords. Perhaps the already malfunctioning cord once "injured" by the tethering becomes more "fragile" and develops a much lower threshold for new symptoms with even "slight" retethering. Perhaps those spinal cords that show early symptoms are also selectively predisposed to deteriorate further with only minor environmental changes and are thus destined to have a poorer outcome.

Lipoma Types and Outcome. According to statistics, lipoma type should not matter, but in reality it probably does. One of the limitations of biostatistics is the inadequacy of assigning rigid categories (of variables) to represent the almost endless vicissitudes of biologic forms. For example, within the unwieldy category of transitional lipomas, there are lesions with very orderly arrangements of fat-cord margins and dorsal root entry zone arrays as well as manageable quantities of fat, and also those with nothing recognizable but giant, bewildering plumes of fat. The surgical risks and success rates for these 2 extremes cannot be the same, and a homogeneous blending of their diverse statistical weights can accordingly be misleading. Thus, the blank statistical conclusion of no outcome difference between lipoma types should not be overinterpreted, nor should it replace an experienced surgeon's impression that certain complex, sprawling transitional lipomas connote a graver prognosis and require more elaborate preparations than a discrete, compact dorsal lipoma.

More difficult than the worst transitional lipomas are some chaotic lipomas. Because of small sample size, the chaotic lipomas in our series cannot be shown by statistics to have a worse outcome than dorsal or transitional lipomas, but chaotic lipomas are among some of the most difficult resections we have performed and are certainly the most hazardous. Because the anatomical demarcation between fat and neural tissue is unpredictable in these lesions, it is prudent to be less aggressive and resect just enough dorsal fat to enable a comfortable neurulation, and to not violate the pial coating of the ventral fat if complete resection and ventral neurulation are not deemed feasible. Consequently, chaotic lipomas are associated with higher cord-sac ratios and larger amounts of remainder fat than the other 2 lipoma types, and their postoperative MRI scans sometimes look appalling (Figure 27). Given sufficient numbers, chaotic lipomas may turn out to be the worst form of lipoma for long-term disease control.

Is Partial Resection Worse Than No Resection?

This is a prickly question because an affirmative answer seems self-serving in the present context, but it would be disingenuous to ignore the fact that our results for partial resection are clearly worse than those in the Parisian series[9] of conservative treatment. Even if we select only our asymptomatic patients, which in essence eliminates all the surgically more treacherous redo lesions, the PFS for partial resection is still only 43% at 11 years, compared with the 67% of the nonsurgical series.[9] Other series of partial resection do not fare much better. If shorn of the terminal lipomas, the series of Colak et al[19] would have a PFS of less than 50%, and the partial resection series of Pierre-Kahn et al[7] would have a PFS lower than 40%. The transitional lesions of Cochrane et al[6] had only 20% PFS over 10 years, and Cornette et al[24] reported rapid progression of symptoms after partial resection.

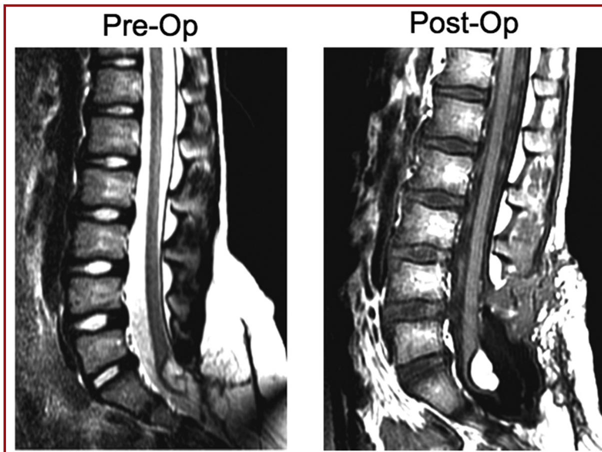

FIGURE 27. *Preoperative and postoperative sagittal magnetic resonance images of a chaotic lipoma showing a large amount of residual fat after total resection. Note enlarged postoperative dual sac.*

We were impressed after tackling more than 100 redo lipomas that the once abraded but unneurulated placode can be much more firmly fused to the dura by unyielding scar than an unchastened lipoma stalk. If the likelihood of deterioration had to do with the rigidity of transfixation of the cord, one would anticipate partial resection to incur earlier and perhaps worse recurrence than if no surgery had been performed. It would also explain why partial resection typically gives instantaneous relief of symptoms due to the initial untethering but is unable to sustain this effect in the long run because of delayed scar formation, in an increasingly failing course that compares poorly with the natural history of the disease.

However, it would be unfair to condemn all historic series of partial resection, because at least 1 series reports better results than nonsurgical treatment. The large Chicago series[10] records a 15-year PFS of 80% for asymptomatic lipomas, which comes close to our 96% for total resection of asymptomatic lipomas, though their 34% PFS for symptomatic lipomas is much worse than the 73% for our symptomatic lesions. It is, however, unclear how aggressive the resections were from the Chicago series. In 2 subsidiary series from the same institution,[11,23] the surgeons succeeded in neurulating most of the neural placodes after partial lipoma resection, which suggests a close enough shaving of fat from the bare placodes to render them pliable for neurulation. It is conceivable that the bulk and surface condition of the reconstructed cords in the Chicago series were at least within range of our best examples of total resection and radical reconstruction.

Thus, it seems the crowded archive of lipoma surgery comprises a continuum of techniques ranging from perfunctory whittling of fat without placode reconstruction to aggressive resection of the whole lipoma and meticulous pia-to-pia neurulation of the placode and expansile duraplasty. It is tempting to hypothesize the extent of "clean" neural reconstruction is commensurate with the clinical outcome, and that the projected outcome of nonsurgical treatment situates somewhere between these 2 extremes on this continuum. This would imply that in some cases, less than thorough surgery may prove more costly to the patient in the long run than no surgery.

CONCLUSION

Total/near-total resection of complex spinal cord lipomas and complete reconstruction of the neural placode produce a much better long-term PFS than partial resection. In comparing our own statistics with published data, we find that total/near-total resection confers significantly greater benefits than nonsurgical management in the subset of patients with asymptomatic virgin lipomas. The postoperative neurologic, urologic, and wound complications for total/near-total resection are either comparable to or much lower than those in other series reporting on partial resection.

Multivariate analyses show that low postoperative cord-sac ratio and well-executed neurulation of the neural placode are strongly correlated with good long-term outcome. The ideal patient profile with early disease stabilization and the best recurrence-free survival has been identified as a child younger than 2 years who is without symptoms or history of previous surgery.

Based more on experience than hard statistics is the impression that chaotic lipomas are the most difficult lesions to resect and may ultimately prove to be the most problematic lipoma type. Also, there are strong indications that partial resection in some cases produces worse scarring at the lipoma-cord interface and thus may actually worsen prognosis than if no surgery were performed.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices in this article.

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COMMENTS

In part I of this extensive report, Pang et al eloquently describe their operative technique for successfully untethering complex spinal lipomas. The centerpiece of their method is the ability to safely remove a maximal amount of lipomatous tissue while untethering the conus. This maximizes the volume of the reconstructed thecal sac in relation to the contained conus-lipoma remnant and allows the raw surfaces of the conus to be largely eliminated by reapposing pial surfaces (neurulation). These measures reduce the likelihood of retethering and also provide for a better watertight dural reconstruction. The detailed protocol for pre- and postoperative evaluation that has been rigorously applied to all patients allows for reliable quantitative analysis of results. This demonstrates a striking improvement in long-term benefit compared with previous reports, whereas the incidence of immediate neurologic/urologic complications is comparable and the likelihood of wound complications, especially cerebrospinal fluid leak, is significantly lower.

The fact that early stabilization and improvement rates are similar for partial and near-total lipoma removals indicates that the benefit is related to untethering rather than reduction in lipoma mass with decompression of the conus. It also suggests that later deterioration of function reflects retethering rather than compression of the conus by an enlarging bulk of lipoma. It is also an encouraging confirmation that late deterioration is typically related to something we can address surgically rather than being due to some other obscure mechanism that does not lend itself to operation. The authors demonstrate that neurologic deterioration before surgery is associated with a worse outcome. This argues compellingly for prophylactic surgery. Similarly, previous surgery is a risk factor, suggesting as the authors do that one should "get it right the first time."

Paul H. Chapman
Boston, Massachusetts

This is a remarkable article. The authors' results far exceed anything in the literature. A significant number of our lipomas of the conus originated from the dorsal root entry zone unilaterally. This resulted in the placode being tipped toward the side of the lipoma and the extremely short nerve roots, both dorsal and ventral roots, exiting the dura together with lipoma. The nerve roots were so short that freeing them and neurulation of the placode were impossible. Many of these patients, amazingly, remained asymptomatic, but a few deteriorated. Except for these, almost all patients in our asymptomatic group had near total resection even of the intramedullary portion. For years, we have been closing the placode in almost all our myelomeningoceles and where possible in our lipomas of the conus. Unfortunately for our patients, it may have reduced the number of symptomatic retethering but certainly did not prevent it in all. I agree with early operation for asymptomatic children.

David G. McLone
Chicago, Illinois

Directional Selection is a shift in the average value of a trait over time, for example, organisms slowly getting taller. The evolution of the long necks of giraffes has been explained by two primary theories: that the longer necks allowed the giraffes to browse vegetation that was out of the reach of other herbivores in the vicinity, giving them a competitive advantage, or that the long necks evolved as a secondary sexual characteristic, giving males an advantage in "necking" contests to establish dominance and obtain access to sexually receptive females. (Credit istockphoto)