

Clinical Characteristics and Functional Outcomes After Surgery for Spinal Dysraphism: A Retrospective Cohort Study

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Abstract

Introduction

Spinal dysraphism includes heterogeneous congenital lesions that may affect motor, bladder, and bowel function. This study described the clinical spectrum, perioperative events, and functional outcomes after surgery.

Methods

We retrospectively studied 276 patients who underwent surgery for spinal dysraphism. Neurological function was recorded using the modified McCormick grade. Preoperative and postoperative grades were compared with the Wilcoxon signed-rank test. Simple group comparisons explored factors associated with improvement. Categorical variables were compared with the chi-square or Fisher's exact test, and continuous variables with the Mann-Whitney U test.

Results

The median age was 2.3 years (interquartile range, 0.73-5.0), and 148 patients (53.6%) were male. Motor weakness was present in 212 (76.8%), bladder involvement in 146 (52.9%), and bowel involvement in 62 (22.5%). The median modified McCormick grade was 4 before surgery and 3 after surgery ($P < 0.001$). Functional grade improved in 108 patients (39.1%), remained unchanged in 162 (58.7%), and worsened in six (2.2%). Immediate postoperative complications occurred in 29 patients (10.5%). Improvement was associated with lower preoperative motor power, greater preoperative functional disability, selected caudal dysraphic phenotypes, sac repair, and detethering in unadjusted comparisons. Bladder involvement did not change significantly after surgery ($P = 0.625$).

Conclusion

Most patients had stable or improved postoperative functional grades. Because the cohort was retrospective and anatomically heterogeneous, the observed associations should be considered descriptive rather than predictive across diverse lesions and operative approaches. Standardized long-term neurological and urological follow-up is needed.

Categories: Neurosurgery

Keywords: modified mccormick grade, myelomeningocele, neurological outcome, pediatric neurosurgery, spinal dysraphism, tethered cord

Introduction

Spinal dysraphism comprises open and closed congenital malformations caused by abnormal development of the spinal cord, meninges, vertebral elements, and adjacent tissues. The spectrum includes myelomeningocele, meningocele, lipomyelomeningocele, split cord malformation, dermal sinus tract, thickened filum terminale, and other tethering disorders. Neurological impairment may be present at birth or emerge during growth, and the effects extend beyond motor disability to bladder, bowel, orthopedic, and psychosocial morbidity [1,2].

Surgery is directed at closure of exposed defects, release of tethering, removal of dermal or compressive tracts, preservation of neural tissue, and prevention of further deterioration. Outcomes vary with lesion anatomy, age at presentation, associated abnormalities, baseline disability, and operative requirements. Studies of tethered cord syndrome suggest that pain and selected motor symptoms may improve after untethering, whereas bladder dysfunction is less consistently reversible [3-6]. Lipomatous malformations

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and postoperative retethering add uncertainty to treatment selection and long-term surveillance [7-10].

Myelomeningocele repair, intraoperative neuromonitoring, age-related differences, and reoperation each create additional management considerations [11-15]. Most published series address a single dysraphic subtype or procedure. A combined cohort complements subtype-specific studies by describing the clinical spectrum, overlapping anatomical components, operative management, immediate complications, and early functional status encountered within a single surgical referral setting. This approach does not assume clinical equivalence between subtypes or establish comparative procedural effectiveness. The primary objective of this study was to describe demographic and clinical characteristics, anatomical patterns, surgical interventions, immediate postoperative complications, and neurological functional grade and bladder outcomes assessed on postoperative day 10 among 276 surgically treated patients. The secondary objective was to explore unadjusted associations between baseline clinical characteristics, dysraphic phenotypes, surgical procedures, and improvement in modified McCormick grade. These exploratory analyses were intended for hypothesis generation rather than independent prediction or causal inference.

Materials And Methods

Study design and participants

This retrospective observational cohort study included patients admitted and surgically treated at our center from January 2015 to December 2024. The report follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations [16]. Eligibility required clinically and radiologically confirmed congenital spinal dysraphism and adequate clinical, radiological, operative, and paired preoperative and postoperative functional records (Table 1). Records with insufficient information for inclusion and duplicate entries for the same index procedure were excluded; only the index procedure was included for each patient. Exclusion of incomplete records may introduce selection bias. Unavailable clinical details could not be evaluated. Long-term follow-up and attrition beyond the day-10 assessment were not characterized.

Inclusion criteria	Exclusion criteria
Patients diagnosed clinically and radiologically with congenital spinal dysraphism	Patients without a confirmed diagnosis of congenital spinal dysraphism
Patients who underwent surgical treatment for spinal dysraphism during the study period	Patients managed conservatively without surgery
Patients with open or closed spinal dysraphism	Patients with acquired spinal conditions or other non-dysraphic spinal lesions
Availability of relevant clinical, radiological, operative, and postoperative records	Records with insufficient clinical, radiological, operative, or outcome information
Patients with documented preoperative and postoperative functional assessment	Patients without adequate preoperative or postoperative functional assessment
Only the index surgical procedure was included for each patient	Duplicate records or repeat entries for the same index procedure

TABLE 1: Eligibility criteria

Variables and surgical management

Recorded variables included age, sex, documented maternal folic acid intake, defect location, lower-limb motor power, preoperative bladder and bowel involvement, imaging-defined dysraphic components, operative procedures, immediate postoperative complications, and postoperative day-10 outcomes. Motor power was recorded using the Medical Research Council scale. Anatomical indicators were not mutually exclusive because complex dysraphism may include more than one component. Operations were individualized according to lesion anatomy and clinical indications rather than a uniform comparative treatment protocol and included sac excision with repair, laminectomy with detethering, fibrous spur dissection, shunt placement, and dermal sinus tract excision.

Outcome definitions

Functional disability was recorded on the five-level modified McCormick scale, with higher grades indicating greater disability. Postoperative assessment was performed on postoperative day 10. Improvement was defined as a postoperative grade lower than the preoperative grade; unchanged and worsened grades were reported separately. The scale is not specifically validated across all dysraphic phenotypes and does not

adequately characterize bladder or bowel function. The retrospective records did not establish uniform assessment procedures or interobserver reliability. Overall clinical and bladder outcomes were recorded in the source records as good, satisfactory, or poor according to the treating team's clinical assessment. Because standardized operational definitions were unavailable, these categories were analyzed as recorded and interpreted only descriptively; they were not used to establish domain-specific recovery. Bladder involvement was recorded separately as involved or not involved before surgery and on postoperative day 10. This binary measure does not capture severity of incontinence, residual urine, catheterization requirements, or urodynamic changes. Bowel involvement was recorded preoperatively, but detailed postoperative bowel assessments were unavailable. Long-term neurological, bladder, and bowel recovery could not be evaluated.

Statistical analysis

Continuous variables are presented as mean and standard deviation or median and interquartile range (IQR), as appropriate. Categorical variables are presented as counts and percentages. Preoperative and postoperative modified McCormick grades were compared with the Wilcoxon signed-rank test. Paired binary bladder status was compared with the exact McNemar test. Exploratory comparisons between patients who improved and those who did not used the Mann-Whitney U test for continuous variables and the Pearson chi-square or Fisher's exact test for categorical variables, as appropriate. All tests were two-sided, and $P < 0.05$ was considered statistically significant. Analyses were performed using Python 3 (Python Software Foundation, Beaverton, Oregon) with SciPy (SciPy Community, NumFOCUS, Austin, Texas). No multivariable adjustment was performed. Baseline disability, lesion anatomy, overlapping dysraphic components, and selection of procedures according to clinical indications remained potential confounders. These comparisons were exploratory and did not establish independent predictors or treatment effects.

Ethical approval

The study was approved by the Institutional Ethics Committee of King George's Medical University, Lucknow, Uttar Pradesh, India, at its meeting held on October 25, 2023 (approval no. 2068/Ethics/2023, dated October 28, 2023; reference code: XXI-PGTSC-IIA/P47). The study was conducted using deidentified retrospective clinical records, and no identifiable patient information has been presented.

Results

Cohort characteristics

The cohort included 276 surgically treated patients. The mean age was 4.30 years (standard deviation, 5.71), the median age was 2.3 years (IQR, 0.73–5.0), and 77 patients (27.9%) were younger than one year. There were 148 male patients (53.6%). Documented maternal folic acid intake was present in 102 cases (37.0%). Motor weakness was present in 212 patients (76.8%), bladder involvement in 146 (52.9%), and bowel involvement in 62 (22.5%). Lumbosacral lesions were most common. Tethered cord, myelomeningocele, and lipomyelomeningocele were the leading anatomical components (Table 2).

Characteristic	Value
Age	
Mean (SD), years	4.30 (5.71)
Median (IQR), years	2.3 (0.73-5.0)
Age group	
<1 year	77 (27.9)
1–5 years	137 (49.6)
6–10 years	30 (10.9)
11–18 years	28 (10.1)
>18 years	4 (1.4)
Male sex	148 (53.6)
Documented maternal folic acid intake	102 (37.0)
Any preoperative motor weakness	212 (76.8)
Preoperative bladder involvement	146 (52.9)
Preoperative bowel involvement	62 (22.5)
Defect location	
Lumbosacral	119 (43.1)
Lumbar	60 (21.7)
Sacral	43 (15.6)
Cervical	19 (6.9)
Thoracolumbar	18 (6.5)
Thoracic	12 (4.3)
Cervicothoracic	5 (1.8)
Myelomeningocele	92 (33.3)
Lipomyelomeningocele	77 (27.9)
Meningocele	30 (10.9)
Split cord malformation	43 (15.6)
Tethered cord	101 (36.6)
Dermal sinus tract	46 (16.7)
Hydrocephalus	33 (12.0)

TABLE 2: Baseline clinical and anatomical characteristics

Values are presented as n (%) unless stated otherwise. Anatomical categories are not mutually exclusive.

IQR: interquartile range; SD: standard deviation.

Operations and outcomes

Laminectomy with detethering was performed in 235 patients (85.1%), sac excision with repair in 203 (73.6%), dermal sinus excision in 45 (16.3%), fibrous spur dissection in 41 (14.9%), and primary shunt placement in 31 (11.2%). The median modified McCormick grade was 4 (IQR, 2–4) before surgery and 3 (IQR, 2–3) on postoperative day 10 (Wilcoxon signed-rank test, $P < 0.001$). Functional grade improved in 108 patients (39.1%), was unchanged in 162 (58.7%), and worsened in six (2.2%).

Immediate postoperative complications occurred in 29 patients (10.5%). Cerebrospinal fluid leak occurred in 11, re-exploration for leak in five, shunt malfunction in six, wound dehiscence in six, and meningitis in one (Table 3). Bladder involvement was recorded in 146 patients before surgery and 148 on postoperative day 10. Of 276 patients, 127 remained without involvement, three changed from not involved to involved, one changed from involved to not involved, and 145 remained involved. Only four patients changed binary status (exact McNemar test, $P = 0.625$; Table 4). This result does not exclude changes in bladder function that were not captured by the binary measure. Bowel involvement was present in 62 patients (22.5%) preoperatively; detailed postoperative bowel outcomes were unavailable.

Variable	Value
Laminectomy and detethering	235 (85.1)
Sac excision and repair	203 (73.6)
Dermal sinus excision	45 (16.3)
Fibrous spur dissection	16 (5.8)
Primary shunt placement	24 (8.7)
Preoperative modified McCormick grade, median (IQR)	4 (2-4)
Postoperative modified McCormick grade, median (IQR)	3 (2-3)
Improved functional grade	108 (39.1)
Unchanged functional grade	162 (58.7)
Worsened functional grade	6 (2.2)
Any immediate postoperative complication	29 (10.5)
Overall outcome	
Good	135 (48.9)
Satisfactory	121 (43.8)
Poor	20 (7.2)
Bladder outcome	
Good	136 (49.3)
Satisfactory	78 (28.3)
Poor	62 (22.5)

TABLE 3: Operative details and clinical outcomes

Values are presented as n (%) unless stated otherwise. The paired Wilcoxon signed-rank comparison of preoperative and postoperative modified McCormick grades included all 276 patients and yielded $W = 393.0$ ($P < 0.001$).

IQR: interquartile range.

Paired preoperative and postoperative binary bladder assessments were performed for all 276 patients. Bladder involvement was recorded in 146 patients before surgery and 148 afterward. Among 130 patients without preoperative bladder involvement, 127 remained uninvolved and three were recorded as involved postoperatively. Among 146 patients with preoperative bladder involvement, 145 remained involved and one was recorded as not involved postoperatively. Thus, only four patients changed binary bladder status, and the paired difference was not significant (exact McNemar test, $P = 0.625$) (Table 4).

Preoperative status	Postoperative not involved	Postoperative involved	Total
Not involved	127	3	130
Involved	1	145	146
Total	128	148	276

TABLE 4: Paired preoperative and postoperative binary bladder status

Values are patient counts; N = 276 paired assessments. Exact McNemar test, P = 0.625. Binary involvement does not measure symptom severity or urodynamic change.

Exploratory comparisons

Patients whose functional grade improved by postoperative day 10 had lower preoperative motor power and greater preoperative functional disability than patients who did not improve. Improvement also differed across selected anatomical and operative groups. These comparisons were unadjusted and may reflect baseline disability, lesion anatomy, and surgical selection. Greater baseline disability also provided more opportunity for grade improvement. The associations do not establish independent predictors or causal effects of any lesion or operation (Table 5).

Variable	Improved, n = 108	Not improved, n = 168	Test statistic	P-value
Age, years	2 (0.667-4)	2.4 (0.75-5.625)	U=8519.5	0.393
Preoperative motor grade	3.5 (2.5-3.5)	4 (3.5-5)	U=4631.5	<0.001
Preoperative modified McCormick grade	4 (4-4)	2 (2-4)	U=15398.5	<0.001
Myelomeningocele	45 (41.7)	47 (28.0)	chi-square=5.54, df=1	0.019
Lipomyelomeningocele	39 (36.1)	38 (22.6)	chi-square=5.95, df=1	0.015
Meningocele	2 (1.9)	28 (16.7)	chi-square=14.89, df=1	<0.001
Tethered cord	47 (43.5)	54 (32.1)	chi-square=3.67, df=1	0.056
Sac excision and repair	88 (81.5)	115 (68.5)	chi-square=5.74, df=1	0.017
Laminectomy and detethering	98 (90.7)	137 (81.5)	chi-square=4.39, df=1	0.036
Any immediate complication	15 (13.9)	14 (8.3)	chi-square=2.16, df=1	0.142

TABLE 5: Unadjusted comparisons by functional improvement

Continuous variables are presented as median (interquartile range) and were compared using the Mann–Whitney U test. Categorical variables are presented as number (percentage) and were compared using Pearson’s chi-square test. U denotes the Mann–Whitney test statistic, and df denotes degrees of freedom. P < 0.05 was considered statistically significant. These comparisons are unadjusted and should not be interpreted as independent predictors or causal effects.

Discussion

This cohort shows the breadth of spinal dysraphism encountered in operative practice and the frequent overlap of anatomical abnormalities. On postoperative day 10, modified McCormick grades were stable or improved in most patients, while a small proportion worsened. Immediate complications affected approximately one in ten patients and were mainly related to cerebrospinal fluid leakage, wounds, infection, or shunt function. Binary bladder involvement changed little, although the available measure could not capture degrees of continence or urodynamic improvement. The exploratory group comparisons are intentionally simple. Lower preoperative motor power and higher preoperative disability were associated with recorded improvement. However, improvement was defined by change from the baseline grade, so patients with greater initial disability had more opportunity to improve. This mathematical relationship limits interpretation and does not imply that treatment should be delayed until disability becomes severe. The paired comparison describes an early change in recorded functional status and cannot establish durable neurological recovery.

Detethering of the cord aims to relieve mechanical traction and prevent additional neurological injury. Prior pediatric series describe stabilization or improvement in selected symptoms after surgery, with variation according to anatomy, presentation, and duration of deficits [3-7]. The present findings are compatible with that literature but do not compare surgery with observation and cannot estimate treatment effect. Likewise, differences among myelomeningocele, lipomyelomeningocele, meningocele, and tethered cord groups, as well as among operative groups, may reflect baseline severity, anatomy, and selection for surgery. Without a nonsurgical control group or adjustment for these differences, the study cannot establish surgical effectiveness or comparative procedural benefit.

The minimal change in bladder status should not be interpreted as proof that surgery has no urological benefit. Bladder function is multidimensional, and a simple "involved" or "not involved" field may miss changes in continence, residual urine, infection frequency, renal function, and urodynamic measurements. Published work also shows that urological recovery after untethering is variable and may be less predictable than pain relief or motor stabilization [2,3,8]. Future cohorts should use standardized urodynamic endpoints and patient-reported measures. Detailed postoperative bowel outcomes were unavailable, so no inference about bowel recovery can be made. Prospective assessments should report neurological, bladder, and bowel outcomes separately.

Lipomyelomeningocele and detethering require particular caution because anatomy and clinical course vary widely [8-10]. Myelomeningocele repair also carries risks related to wound closure, infection, and associated hydrocephalus [11,12]. In the current cohort, cerebrospinal fluid and wound-related events were the most frequent immediate problems. These findings support careful closure, infection prevention, shunt surveillance, and structured follow-up, but they do not identify the best operative technique.

Strengths and limitations

The study includes a comparatively large operative cohort and describes a broad range of lesions, neurological findings, procedures, and postoperative day-10 clinical outcomes. Paired preoperative and postoperative grades provided a direct summary of functional change, and the statistical analysis was limited to transparent descriptive and group comparisons.

The retrospective, single-center design is vulnerable to selection bias, missing clinical details, and nonstandardized assessment. Requiring adequate paired records may preferentially select patients with more complete documentation. Although the postoperative assessment occurred on day 10, long-term follow-up was unavailable; sustained recovery, subsequent deterioration, retethering, and reoperation could not be evaluated. Standardized operational definitions for the good, satisfactory, and poor categories were unavailable, limiting reproducibility. The modified McCormick scale was developed for spinal cord disease and is not specifically validated across all dysraphic phenotypes [17]. Binary bladder status cannot distinguish changes in continence, residual urine, catheterization requirements, or urodynamic function, and detailed postoperative bowel outcomes were unavailable. Anatomical indicators overlapped, and procedures were selected according to clinical need, limiting comparisons between lesion and operative groups. No multivariable adjustment was performed; baseline disability, lesion type, and surgical selection remain potential confounders. Greater baseline disability also provides more opportunity for grade improvement. No standardized urodynamic, quality-of-life, school participation, or long-term retethering data were available. The absence of a nonsurgical control group prevents estimation of surgical effectiveness. These limitations restrict generalizability, and the study supports description and hypothesis generation rather than independent prediction or causal inference. Prospective studies should use predefined short- and long-term assessment intervals, standardized neurological, bladder, and bowel measures, urodynamic evaluation, and surveillance for retethering and reoperation.

Conclusions

Recorded modified McCormick grades were unchanged or improved in most patients on postoperative day 10 in this heterogeneous spinal dysraphism cohort. These early functional grade changes do not establish durable neurological recovery. Associations with baseline characteristics, lesion anatomy, and surgical procedures were unadjusted and should not be interpreted as independent predictors, evidence of comparative procedural effectiveness, or causal treatment effects. Minimal change in binary bladder involvement does not exclude changes in bladder function. Prospective studies with defined follow-up intervals and standardized neurological, bladder, bowel, and quality-of-life outcomes are needed to evaluate sustained recovery.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Mitrajit Sharma, Pankaj Pawar, Waseem Ahmad, Vishnu Vardhan, Ravi Ranjan, Chayanika Choudhury

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Ethics Committee of King George's Medical University, Lucknow issued approval XXI-PGTSC-IIA/P47. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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