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https://doi.org/10.70905/bmcj.06.01.0488
ORIGINAL ARTICLE

NEUROLOGICAL OUTCOMES IN PATIENTS WITH SPINAL DYSRAPHISM: EARLY VS LATE INTERVENTION

Muhammad Khalid[1], Komal Rasheed[2], Bashir-ur-Rehman[3], Zohaib Masood[4], Saad Javed[5], Sarah Rasheed[6], Armaghan-ul-Hassan[7]

[1] Neuro-Spine Surgeon, Capital Hospital, CDA Islamabad,
[2] Medical Officer, Capital Hospital, CDA Islamabad
[3] Peds surgeon, Department of pediatric surgery. CDA Hospital. Islamabad
[4] Assistant surgeon, Department of spine surgery CDA Hospital Islamabad
[5] Assistant surgeon , Department of spine surgery CDA Hospital Islamabad
[6] House surgeon. Department of medicine, CDA Hospital Islamabad
[7] House surgeon. Department of spine surgery CDA Hospital Islamabad

Correspondence:
Dr. Muhammad Khalid
Email: drkhalid86@yahoo.com

Abstract:

Background: Spinal Dysraphism encompasses a spectrum of congenital neural tube defects that can result in varying degrees of neurological impairment, including motor deficits and bladder/bowel dysfunction. Timely surgical intervention is often recommended to prevent progressive neurological decline; however, the optimal timing for surgery remains debated. Comparative studies evaluating early versus late intervention are limited, especially in developing healthcare settings.

Objective: This study compares neurological outcomes in patients with spinal Dysraphism following early versus late neurosurgical intervention.

Material and Methods: A comparative cross-sectional study was conducted on 20 patients with spinal Dysraphism who underwent surgery at the Rawalpindi Institute of Health Sciences (RIHS) and Capital Hospital CDA between January and December 2024. Patients were divided into two groups: Group A (n=8) received surgery before age 13 (early intervention), and Group B (n=12) at age 13 or later (late intervention). Neurological outcomes, including motor and sensory deficits and bowel/bladder dysfunction, were assessed over a 1-year follow-up period.

Results: Group A showed better neurological outcomes, with greater improvements in motor function, gait, and bladder/bowel control compared to Group B. These findings suggest that early surgical intervention may prevent progressive neurological deterioration and improve functional recovery. The small sample size and limited follow-up duration constrain the ability to assess long-term outcomes. Additionally, factors like coexisting anomalies, variations in surgical techniques, and surgeon expertise were not controlled and may have influenced results.

Conclusion: This study adds to the limited comparative data on the timing of intervention in spinal Dysraphism. By evaluating adolescent and preadolescent surgical outcomes, it highlights the potential benefits of early intervention and underscores the need for further large-scale, longitudinal research in this area.

Keywords: Spinal Dysraphism, early intervention, late intervention, neurosurgery, neurological outcomes
Cite this article: Khalid M, Rasheed k, Ur Reham B,Masood Z,Javed s,Rasheed S,Ul Hassan A. Neurological outcomes in patients with spinal Dysraphism: early vs. Late intervention. BMC J Med Sci. 2025; 6(1): 53-57, https://doi.org/10.70905/bmcj.06.01.0488

Introduction:

Spinal dysraphism refers to a group of congenital anomalies resulting from incomplete closure of the neural tube, often manifesting as structural defects of the spine and spinal cord. These defects are broadly classified into open and closed forms and may lead to variable neurological and orthopedic dysfunction. Clinical manifestations can include sensory or motor deficits, gait abnormalities, and bowel or bladder dysfunction. While early surgical intervention is often recommended to prevent neurological deterioration, especially in cases involving tethered cord syndrome, the optimal timing of intervention remains a subject of debate. Comparative data on outcomes following early versus late intervention—particularly in resource-

Authorship Contribution: [1,5]Substantial contributions to the conception or design of the work; or the acquisition, Data analysis, Literature review, [2]Drafting the work or revising it critically for important intellectual content, [3,4,6]Final approval of the version to be published, Topic Selection & Supervision
Funding Source: none
Conflict of Interest: none
Received: Jun,02, 2025
Accepted: june,26, 2025
Published: Jun 30,6,2025

limited settings—are limited. This study seeks to evaluate the impact of surgical timing on postoperative neurological recovery in patients with spinal dysraphism. By analyzing clinical data from 20 cases, we seek to determine the optimal timing for surgical management and its correlation with postoperative recovery.

LITERATURE REVIEW

Spinal Dysraphism, a spectrum of congenital spinal anomalies due to defective neural tube closure, has been widely studied in terms of clinical presentation, diagnostic strategies, and surgical outcomes. However, the timing of neurosurgical intervention remains a critical yet underexplored factor influencing long-term neurological outcomes. Several studies have highlighted the benefits of early surgical intervention, particularly in cases of open spinal dysraphism such as myelomeningocele. Early closure, typically within 24 to 72 hours of birth, has been shown to reduce the risk of infection and improve functional outcomes, especially when hydrocephalus and Chiari II malformation are present.

In contrast, the management of closed spinal Dysraphism, particularly in asymptomatic or late-presenting patients, remains controversial. Studies such as those by Pang et al. and Selcuki et al. suggest that early detethering surgery, even in minimally symptomatic patients, may prevent progressive neurological deterioration. The pathophysiology behind this lies in the tethered cord syndrome, where differential growth between the spinal cord and vertebral column leads to ischemia and functional decline.

Despite growing support for early surgical intervention, literature remains limited regarding comparative studies involving adolescent or adult patients undergoing delayed surgery. Most data are derived from pediatric populations, and long-term follow-up studies are scarce. This study addresses that gap by comparing postoperative neurological recovery between early and late intervention groups, providing insights into the functional outcomes associated with delayed diagnosis and treatment.

symptoms is believed to be within the gastrointestinal tract, despite the absence of any detectable structural or systemic abnormalities. It is worth noting that although dyspeptic individuals may also experience symptoms like nausea and bloating, which could potentially indicate the presence of the condition, the latest definitions of dyspepsia do not consider these particular symptoms as primary or distinguishing features of the disorder.[1,2]

In individuals with dyspeptic symptoms, a Comprehensive diagnostic evaluation reveals an underlying organic cause in approximately 20-25% of cases. These causes can include peptic H-pylori gastritis, ulcer disease, Biliary pain, GER, malignancy, pancreatitis or medication-related issues. Conversely, the remaining percentage of patients are classified as having functional dyspepsia, a term used to describe the presence of symptoms persisting for a minimum of three months without a clear structural or biochemical basis for explanation. This differentiation is crucial in clinical practice for appropriate management and treatment strategies.[3,4]

H. pylori, a spiral-shaped bacterium that thrives in low-oxygen conditions, stains Gram-negative, and tests positive for urease, has evolved specialized mechanisms to survive in the highly acidic environment of the stomach. H. pylori's structure and enzymatic properties enable its survival in the acidic stomach environment.[5] H. pylori infection is frequently identified as a primary factor contributing to dyspepsia, a common gastrointestinal disorder characterized by symptoms such as abdominal pain, bloating, and discomfort, among others, and multiple research findings confirm that the successful elimination of H. pylori from the body leads to a significant amelioration of the symptoms experienced by individuals suffering from dyspepsia.[6,7]

Material and Method:

Study design & Duration & Study Setting

This comparative cross-sectional study analyzed the clinical data of 20 patients diagnosed with spinal dysraphism who underwent surgical intervention at Rawalpindi Institute of Health Sciences (RIHS) and Capital Hospital CDA between January and December 2024.. The objective was to compare postoperative neurological outcomes based on the timing of surgical intervention.

Participants

Patients were divided into two groups based on the timing of surgical intervention. Group A (n=8) included those who underwent early surgery before the age of 13, while Group B (n=12) comprised patients who received surgical treatment at age 13 or older.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Confirmed diagnosis of spinal Dysraphism
- Underwent surgical intervention
- Availability of at least 12 months of follow-up data
- Consent for data use in research

Exclusion criteria:

- Incomplete medical records
- Lost to follow-up before 12 months
- Presence of other unrelated neurological disorders impacting outcome assessment

Outcome measures

Postoperative neurological outcomes were assessed over a 12-month follow-up period, with evaluations conducted at monthly intervals. The primary outcome measures included sensory and motor deficits, gait

abnormalities, bowel and bladder dysfunction, spasticity, pain.

Data Collection

Clinical data were collected from patient records and follow-up visits spanning one year. Neurological function was evaluated through clinical examinations and patient-reported symptoms. In cases of suspected postoperative complications, MRI was used to assess retethering, cerebrospinal fluid abnormalities, or other post-surgical issues.

Statistical Analysis

Statistical analysis was performed to compare postoperative outcomes between the two groups, evaluating whether early intervention led to superior neurological recovery compared to late intervention.

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Results:

Postoperative assessments over a one-year follow-up revealed that patients in Group A demonstrated consistently better neurological recovery than those in Group B.

Outcome	Group A Improved (n=8)	% Improved	Group B Improved (n=12)	% Improved
Sensory & Motor Deficits	7	87.5%	6	50%
Gait Abnormalities	6	75%	5	41.7%
Bowel & Bladder Dysfunction	5	62.5%	4	33.3%
Spasticity	6	75%	5	41.7%
Pain	7	87.5%	6	50%

Patients who underwent early intervention showed significantly higher improvement in sensory and motor function, gait stability, bladder and bowel control, and reduction in spasticity and pain. These findings suggest that earlier surgical intervention, ideally before adolescence, is associated with more favorable neurological outcomes.

The findings suggest that early surgical intervention in spinal Dysraphism is associated with better neurological recovery, supporting the hypothesis that timing of surgery plays a crucial role in optimizing functional outcomes.

Discussion:

Our study highlights the impact of early versus late surgical intervention on neurological outcomes in patients with spinal dysraphism. The findings suggest that early surgical intervention (before age 13) is associated with better postoperative neurological recovery, particularly in terms of motor function, bowel and bladder control, gait abnormalities, and spasticity. These results are consistent with previous research indicating that early detethering or closure of neural defects can mitigate progressive neurological deterioration and improve functional outcomes.

Spinal Dysraphism refers to a group of congenital defects caused by improper closure of the neural tube during embryogenesis. These anomalies affect the spine and spinal cord, leading to neurological and orthopedic issues. It is categorized into open (aperta) and closed (occulta) forms. Conditions include spina bifida occulta, meningocele, myelomeningocele, lipomyelomeningocele, and sacral agenesis [1,2]. Management depends on the type and severity, with surgery often necessary in cases with neurological deficits [3,4].

Neural tube development occurs in two stages: primary and secondary neurulation. Primary neurulation, completed by day 27 of gestation, forms most of the neural tube. Failure here results in open defects like myelomeningocele. Secondary neurulation, occurring after day 28, forms the lower spinal cord. Defects in this stage lead to closed spinal Dysraphism, commonly associated with tethered cord syndrome [5,7]. Tethering causes progressive neurological decline due to uneven growth between the spinal cord and vertebral column [6,8].

The clinical presentation of spinal dysraphism depends on the type and extent of the anomaly. Cutaneous markers such as dermal sinus tracts, hypertrichosis, subcutaneous lipomas, hemangiomas, skin tags, or atrophic skin patches may be seen, especially in occult forms [2,9]. Neurological symptoms include lower limb weakness or paralysis, sensory deficits, bowel and bladder dysfunction, pain, and variable muscle tone [10,11]. Orthopedic abnormalities such as foot deformities, scoliosis, kyphosis, and leg length discrepancies are common [12]. Central nervous system involvement may present as hydrocephalus, Chiari II malformation, or syringomyelia, particularly in cases of myelomeningocele [13,15].

The diagnosis of spinal dysraphism involves both clinical evaluation and imaging. Prenatal screening includes maternal serum alpha-fetoprotein (MSAFP) and high-resolution fetal ultrasound, which can detect neural tube defects and signs like the lemon or banana sign suggestive of Chiari II malformation [8,16,25]. Amniotic fluid analysis (AFAFP and AChE) further supports diagnosis 25. Postnatally, spinal ultrasound is effective in neonates before ossification, while plain X-rays can reveal bony abnormalities but are limited in

soft tissue assessment 2. MRI remains the gold standard, offering detailed visualization of neural elements, tethered cord, and associated anomalies [2,17,18]. CT with myelography is reserved for cases where MRI is contraindicated, providing additional bony detail 2. Urodynamic studies are essential for evaluating bladder dysfunction, and EMG/NCS may be used to assess peripheral nerve involvement in cases of progressive neurological decline [15].

The management of spinal dysraphism is multidisciplinary, involving neurosurgery, orthopedics, urology, and rehabilitation, with the primary aim of preventing neurological decline and maximizing function [6,15]. Open spinal dysraphism requires prompt surgical repair within 24–72 hours of birth to protect exposed neural tissue and prevent infection [4,13]. In closed forms, surgery is reserved for cases with progressive neurological symptoms, bladder dysfunction, or tethered cord syndrome, with early detethering yielding better outcomes [6,15]. Hydrocephalus, commonly associated with myelomeningocele and Chiari II malformation, may necessitate ventriculoperitoneal shunting [14,15]. Long-term orthopedic and urological care is essential to address scoliosis, foot deformities, and neurogenic bladder, often requiring physiotherapy, catheterization, and corrective procedures [19,20].

The timing of surgical intervention plays a crucial role in neurological outcomes. Delayed treatment, particularly in cases of tethered cord syndrome, can lead to irreversible deficits. Studies suggest that early untethering, before significant neurological decline, results in better preservation of motor function and bladder control [19,20]. Postoperative follow-up with MRI is essential for detecting complications such as retethering, which may require reoperation [2,6].

Several factors influence neurological outcomes in spinal Dysraphism, including lesion level, size, and the presence of a covering membrane. Higher spinal lesion levels and larger defects are associated with worse functional outcomes due to the greater extent of neural tissue involvement. Prior studies have also suggested that head circumference and lesion characteristics on prenatal imaging can provide prognostic value for survival, though they are not definitive predictors of long-term motor and cognitive function. Although prenatal detection of open spinal Dysraphism (OSD) has significantly improved with advancements in ultrasonography and fetal MRI, predicting long-term morbidity and functional outcomes remains a challenge. The severity of cerebella herniation, presence of ventriculomegaly, and degree of extra-axial space effacement have been linked to increased risks of ventriculoperitoneal shunt dependency, seizure activity, high-risk bladder dysfunction, and impaired ambulation by early childhood. Our study also suggests that delayed intervention may contribute to poorer neurological recovery, reinforcing the importance of timely diagnosis and surgical treatment. [23]

One of the most promising advancements in the management of spinal dysraphism is fetal surgery for myelomeningocele (MMC). The "two-hit" hypothesis suggests that the final neurological deficit arises from both failed neural tube formation and secondary spinal cord injury due to prolonged exposure to amniotic fluid. Intrauterine repair, performed before 26 weeks of gestation, has been shown to reduce the risk of mortality, decrease the need for shunting, and improve neurodevelopment outcomes compared to postnatal intervention. However, patient selection remains crucial, as not all cases benefit equally from fetal repair. Further research is needed to refine prenatal imaging techniques and establish more accurate predictors of postnatal functional outcomes.

Despite the benefits of early intervention, surgical management is not without risks. Postoperative complications such as retethering, cerebrospinal fluid leakage, and wound infections may impact long-term recovery. Lifelong follow-up is essential to monitor for recurrence of tethered cord syndrome, progressive urological dysfunction, and orthopedic complications. Our study underscores the necessity of a multidisciplinary approach involving neurosurgeons, orthopedic specialists, urologists, and rehabilitation teams to optimize patient outcomes. [24,25]

Limitations and Future Directions: This study is limited by its small sample size and retrospective design. Larger, multicenter studies with long-term follow-up are needed to validate our findings. Additionally, while we assessed neurological outcomes over a 3-year period, longer follow-up is necessary to evaluate the durability of improvements and the incidence of late complications such as retethering. Future studies should also investigate the role of prenatal imaging in predicting postnatal surgical outcomes and the potential benefits of fetal intervention in our patient population.

In conclusion, our findings support the notion that early surgical intervention in spinal Dysraphism leads to better neurological recovery, particularly in motor function and bowel/bladder control. Timely diagnosis and intervention remain critical in improving long-term functional outcomes, emphasizing the need for enhanced prenatal and postnatal surveillance strategies. Continued advancements in surgical techniques and postoperative care will further refine treatment paradigms and optimize quality of life for affected individuals.

Conclusion:

Our study highlights the critical impact of early surgical intervention on the neurological outcomes of patients with spinal dysraphism. Patients who

underwent surgery before the age of 13 demonstrated significantly better recovery in motor and sensory function, gait abnormalities, bowel and bladder dysfunction, spasticity, and pain compared to those who received late intervention.

While advancements in prenatal diagnosis and surgical techniques, including intrauterine repair, offer promising avenues for improving patient prognosis, challenges remain in predicting long-term neurological outcomes. Future research should focus on refining prenatal imaging techniques, identifying high-risk cases earlier, and optimizing surgical timing to further enhance patient care. Additionally, long-term follow-up studies are essential to assess the durability of surgical benefits and the risk of complications such as retethering.

Ultimately, early diagnosis and timely intervention remain key factors in optimizing neurological and functional outcomes in patients with spinal dysraphism. A multidisciplinary approach involving neurosurgeons, radiologists, and rehabilitation specialists is essential to ensuring the best possible quality of life for affected individuals.

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