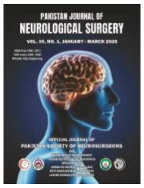

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Original Research

Role of Intraoperative Neuromonitoring for Meningomyelocele Repair

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ABSTRACT

Objectives: To determine the impact of multimodal intraoperative neuromonitoring on post-meningomyelocele repair-neurological outcome in patients receiving meningomyelocele repair.

Material and Methods: This retrospective comparative study included 50 patients who underwent primary meningomyelocele repair. The patients were separated into the IONM group (n= 42) and the non-IONM group (n= 8). In a limited number of cases, multimodal neuromonitoring was used and consisted of the following measurements: somatosensory evoked potentials, motor evoked potentials, electromyography, and the bulbocavernosus reflex measurement. The major resultant effect was the occurrence of new postoperative neurological deficits. The statistical analysis was conducted in SPSS, and $p < 0.05$ was assumed to be significant.

Results: The proportion of neurological impairments postoperatively was significantly less in the IONM than the non-IONM group (7.1% vs. 37.5, $p < 0.01$). Intraoperative alerts were witnessed in 21.4 percent of observed cases, and a timely surgical change was made. The lack of IONM had been linked with increased chances of neurological worsening (RR = 5.3). There were no differences in the length of operation and blood loss.

Conclusion: This retrospective cohort of multimodal intraoperative neuromonitoring was linked to a reduced incidence of postoperative neurological loss and can potentially become an effective addition during meningomyelocele repair.

Keywords: Meningomyelocele, Intraoperative Neuromonitoring, Spinal Outcome, Spinal Dysraphism.

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INTRODUCTION

Meningomyelocele repair is associated with a high risk of postoperative neurological impairment because of the dysplastic neural tissue manipulation. Neural pathway functional assessment by intraoperative neuromonitoring (IONM) is real-time; nevertheless, its application during meningomyelocele repair is not uniform. Meningomyelocele is the most severe and the most prevalent type of open neural tube defects, as it is caused by the inability of the neural tube to close in the initial stages of embryogenesis.[1] Although prenatal screening, perinatal treatment, and surgical interventions have improved, meningomyelocele is linked with a high rate of neurological morbidity and disability, such as motor weakness, sensory impairments, bowel and bladder issues, and musculoskeletal anomalies.[2] The surgical repair is still considered to be the most important aspect of managing it, and the main targets of the intervention are the preservation of the unexposed neural tissue, the prevention of infection, and the maintenance of the current levels of neural functioning.[3]

Though surgical repair is obligatory, the manipulation of dysplastic neural elements, roots of nerves, and other tissues exposes patients to a significant risk of iatrogenic neurological injury.[4] The problem of postoperative neurological deterioration is one of the most significant, especially in the case of children with a comorbidity in the form of hydrocephalus, scoliosis, and neurogenic bladder.[5] Even minor traumas during the operation may cause an irreversible functional impairment, and that is why it is necessary to develop certain strategies to increase neural protection during surgery. The concept of intraoperative neuromonitoring (IONM) has gained progress in the neurosurgical practice in order to offer real-time functional evaluation of the neural pathways in the course of performing surgeries.[6] Multimodal IONM methods, such as somatosensory evoked potentials (SSEP), motor evoked potentials (MEP), electromyography (EMG), and the bulbocavernosus reflex (BCR), provide an opportunity to detect the compromise of the neural status early to change surgical manipulations before the appearance of irreversible damage.[7] IONM has been reported to be effective in minimizing the occurrence of postoperative neurological deficit in spinal deformity surgery, resection of intramedullary tumours, and tethered cord release.[8]

Nonetheless, there is still no consistency in the implementation of IONM during the repair of meningomyelocele in men, and it is not always applied, especially in the low-and-middle-income healthcare environment. This imprecision can be attributed partly to a scarcity of resources in terms of neuromonitoring, technical issues in children, and an absence of strong comparative data that establishes an evident clinical advantage. Available literature appraising IONM in meningomyelocele surgery is usually limited to a small sample size, diverse monitoring guidelines, or no non-monitored control group.[9]

Moreover, the maintenance of sacral neural circuits controlling bladder and bowel control is of close significance to patients with meningomyelocele, because the decline of these areas postoperatively may have a strong negative effect on the quality of life in the long term. Some of the advanced neuromonitoring modalities (BCR, pudendal nerve SSEPs, and sphincter EMG) are promising in evaluating the integrity of sacral roots, but their clinical utility in meningomyelocele repair has not been widely assessed.[10]

Considering that meningomyelocele surgery has a high risk of neurological morbidity, and intraoperative neuromonitoring may serve as a protective intervention, additional outcome-related studies should be considered. The current research seeks to determine the relevance of intraoperative neuromonitoring on the neurological outcome of patients during the postoperative period after repairing a meningomyelocele. Further, this paper evaluates the efficacy of different neuromonitoring modalities and how they can be used to minimize neurological losses as a result of surgery.

MATERIALS AND METHODS

Study Design and Setting

This research was done in the form of a retrospective comparative observational study in the Department of Neurosurgery, Hayatabad

Medical Complex, Peshawar. This study was approved by the Institutional Review Board of MTI-HMC/KGMC Hayatabad, Peshawar (Approval No: 2702). The period under study was a group of patients who were surgically repaired for meningomyelocele over the specified time. Data collection was pre-approved by the Institutional Review Board (IRB), and the study was performed within the professional ethics. Parents or legal guardians gave informed consent regarding surgery and the use of information.

Study Population

The study involved 50 patients who had meningomyelocele repair. The patients were neonatal age to adolescent age. All cases were diagnosed clinically and radiologically.

Inclusion Criteria

All patients who have undergone primary surgical repair of open meningomyelocele and have full perioperative and postoperative neurological records.

Exclusion Criteria

Individuals who had undergone closed spinal dysraphism, revision surgery, in addition to patients undergoing incomplete neuromonitoring or follow-up data, and patients with severe systemic illness preventing neurological evaluation.

Patient Grouping

Two groups of patients were formed depending on the utilization of the intraoperative neuromonitoring:

- IONM group: 42 procedures (84%).
- Non-IONM group: 8 procedures (16%).

Neuromonitoring was made based on facility availability and the availability of technical capability during surgery.

Preoperative Evaluation

Every patient was thoroughly assessed in the preoperative stage, neurological examination oriented on the motor power, sensory status, and sphincter functioning in the case of their necessity. Comorbidities like neurogenic bladder, scoliosis, and hydrocephalus were also recorded. Spinal MRI and cranial imaging were reviewed in order to monitor the level of lesion and related abnormalities.

Surgical Technique

All meningomyelocele repairs were done under general anesthesia and under the usual principles of microsurgery. Surgical goals were ensuring that the dissection of the neural placade was accurate, that functional neural tissue was preserved, that the dural opening was water-tight, and that there was sufficient coverage of the soft tissue. Certain emphasis was placed on reducing the traction and manipulation of neural structures.

These guidelines are designed to help reduce cases of undue stress and complications associated with surgery.

Intraoperative Neuromonitoring Protocol

Multimodal IONM was utilized in situations when intraoperative neuromonitoring was adopted. Watching forms were as follows:

- The somatosensory evoked potentials (SSEP).
- Motor evoked potentials (MEP).
- The electromyography (EMG) is free-run and triggered.
- BCR monitoring of selected cases.

Recordings were taken at the baseline after anesthesia was induced. Constant observation was ensured during the surgical operation. Any notable changes in amplitude or latency increase were reported immediately to the operating surgeon, and surgical manipulations were altered accordingly to avoid neurological injury.

Anesthetic Management

Neuromonitoring signals were preferred to be maintained by the use of total intravenous anesthesia (TIVA) in monitored cases. The neuromuscular blocking agent was not used after the intubation to enable the effective recording of MEP and EMG.

Outcome Measures

The major effect was the occurrence of new postoperative neurological deficits, which were any new motor weakness, sensory deficit, or worsening of the bladder function not existing before the surgery. Long-term bladder and bowel functional outcomes beyond the early postoperative period could not be consistently assessed due to the retrospective nature of follow-up.

The Outcomes were Secondary and Included:

Occurrence rate of intraoperative neuromonitoring alerts, application of various neuromonitoring modalities, and operative duration and estimated blood loss were present.

The neurological evaluation of the postoperative period was conducted in the immediate postoperative period and at follow-up.

Statistical Analysis

The Statistical Package of the Social Sciences, version 22.6, was used to carry out the statistical analysis. Continuous variables were evaluated on normality and are given in the format of mean and standard deviation, whereas the categorical variables are given in terms of frequency and percentages. Proper statistical tests in terms of the type of variables and the sample size were used to make comparisons between the intraoperative neuromonitoring (IONM) group and the non-IONM group. Continuous variables (age, operating time, and estimated blood loss) were compared with independent sample t-tests, but Fisher's exact test was used with the use of categorical variables (gender distribution, comorbidities presence, and postoperative neurological deficits) because of a small sample of the non-IONM group.

The relationship between the application of intraoperative neuromonitoring and the postoperative neurological outcomes was further measured by means of relative risk (RR) and absolute risk reduction (ARR) and their respective 95 percent confidence intervals (CIs). The figure that was obtained was divided by the absolute risk reduction to get the number needed to treat (NNT). All comparisons were calculated using two-tailed p-values, and a p-value below 0.05 was regarded as statistically significant.

For baseline characteristics presented in Table 1, p-values were calculated using independent sample t-tests for continuous variables and Fisher's exact test for categorical variables.

RESULTS

Demographic and Baseline Characteristics

Fifty patients received an operation on meningomyelocele. The average age of the study participants was 6.8 3.2 years (neonate to adolescents). The proportion of female and male patients in the population of the study was 28 and 22, respectively. Hydrocephalus (24%), scoliosis (22%), and neurogenic bladder (30) were the most common comorbidities.

Stratification of patients based on the intraoperative neuromonitoring (IONM) use was as follows:

- **IONM group:** 42 procedures (84%).
- **Non-IONM group:** 8 procedures (16%).

Primary Outcome: Postoperative Neurological Deficits

The rate of occurrence of new postoperative neurological deficits was significantly reduced in patients who had surgery with IONM. One out of every 7.1 patients in the IONM group developed a new neurological deficit, but 1 out of every 37.5 patients in the non-IONM group had postoperative neurological worsening ($p < 0.01$, Fisher's exact test).

Deficits that were observed were motor weakness, sensory impairment, and bladder dysfunction.

Table 1: *Baseline Characteristics of Study Population.*

Variable	Total (n = 50)	IONM (n = 42)	Non-IONM (n = 8)	p-value
Age (years), mean ± SD	6.8 ± 3.2	6.7 ± 3.1	7.1 ± 3.4	0.62
Gender (F/M)	28 / 22	24 / 18	4 / 4	0.88
Hydrocephalus (%)	12 (24%)	10 (23.8%)	2 (25%)	0.91
Scoliosis (%)	11 (22%)	9 (21.4%)	2 (25%)	0.67
Neurogenic bladder (%)	15 (30%)	13 (31.0%)	2 (25%)	0.74

Note: p-values were calculated using independent sample t-tests for continuous variables and Fisher's exact test for categorical variables.

These neurological outcomes were assessed in the immediate postoperative period and during short-term follow-up; standardized long-term functional evaluation of bladder and bowel outcomes was not available for all patients.

Table 2: *Postoperative Neurological Deficits.*

Group	Procedures	Deficits	Deficit Rate
IONM	42	3	7.1%
Non-IONM	8	3	37.5%
Total	**50**	**6**	**12%**

Risk Analysis

Lack of intraoperative neuromonitoring was linked to a high probability of developing postoperative neurological deterioration. Relative risk (RR) of occurrence of new neurological deficit in the non-IONM group relative to the IONM group was 5.3 (95% CI: 1.716.5; $p < 0.01$). The absolute risk reduction (ARR) of the intraoperative neuromonitoring usage was 30.4 percent, which equals a number needed to treat (NNT) of 4, i.e., one postoperative neurological deficit was thwarted in every four patients who encountered it.

Secondary Outcomes: IONM Alerts and Modality Performance

Multimodal intraoperative neuromonitoring (SSEP, motor evoked potentials, EMG, and bulbocavernosus reflex) was shown to have a better intraoperative neural compromise detection than single-modality monitoring.

In 9 procedures (21.4), there were IONM alerts. The sensitivity in all modalities was between 40 and 80 percent, whereas the specificity was between 88 and 92 percent. The false-negative was only recorded once.

There were inconsistencies in the reporting of the operative time and estimated blood loss. In cases where data were available, the mean operative duration was between 90 and 180 minutes, and the estimated blood loss was between 50 and 150 mL, with no statistically significant differences being found between the IONM and no-IONM groups.

Table 3: *Modalities Used in Meningomyelocele Repair.*

Modality	Cases Monitored	Sensitivity (%)	Specificity (%)	Clinical Role
SSEP	35	40–70	85–90	Sensory pathway integrity
MEP	42	70–80	88–92	Motor pathway monitoring
EMG	42	–	–	Sacral root irritation
BCR	15	–	–	Bladder/anal sphincter function

Additional Statistical Analysis

The lack of intraoperative neuromonitoring was also linked with a significantly high rate of neurological degradation in the postoperative period.

- Relative Risk (Non-IONM vs IONM): 5.3.
- Absolute Risk Reduction: 30.4%.
- Number Needed to Treat (NNT): 4.

Multimodal neuromonitoring is more sensitive in terms of keeping motor pathways intact than single-modality monitors. New modalities, such as pudendal nerve SSEPs and urinary bladder EMG/MEPs, can also lead to increased sacral neural pathways protection.

Operative Parameters

Table 4: *Operative Parameters (Reported in Subset of Patients).*

Parameter	IONM	Non-IONM	p-value
Operative Time (min)	120 ± 30	115 ± 35	0.74
Blood Loss (mL)	85 ± 25	90 ± 30	0.68

Table 5: *Additional Statistical Analysis*

Measure	Estimate	95% Confidence Interval	p-value
Deficit Rate – IONM	7.1%	2–18%	–
Deficit Rate – Non-IONM	37.5%	14–69%	–
Relative Risk (Non-IONM vs IONM)	5.3	1.7–16.5	**< 0.01**
Absolute Risk Reduction	30.4%	12–49%	**< 0.01**
Number Needed to Treat (NNT)	4	–	–

Note: p-values for relative risk and absolute risk reduction were derived using Fisher's exact test based on postoperative neurological deficit rates. Confidence intervals were calculated at the 95% level.

DISCUSSION

This paper examined how the concept of intraoperative neuromonitoring (IONM) can decrease postoperative neurological losses in meningomyelocele repair. The results reveal that the new neurological deficits of those patients who were monitored using multimodal IONM are significantly lower than those of patients who were not monitored (7.1% vs. 37.5%, p < 0.01). These findings are in agreement with the research conducted by Zanin L et al, (2025, which found that IONM lowers neurological harm in high-risk spinal operative procedures.[11] Likewise, a multimodal IONM study by Egyptian Rheumatology and Rehabilitation by El-Wakil W et al, (2023) revealed that the use of intraoperative monitoring to minimize the occurrence of postoperative neurological dysfunction and enhance functional postoperative outcomes in complex spine surgery and spinal cord surgery.[12]

Multimodal intraoperative neuromonitoring (IONM) in our paper also caused a reduction in postoperative neurological deficit after repair in meningomyelocele (7.1% vs. 37.5, p 0.01). This is in line with the pharmacovigilance systematic review by Alvi et al, (2025), which stated that motor evoked potentials (MEPs) are highly sensitive and somatosensory evoked potentials (SSEPs) are highly specific, and that a combination of the two in multimodal monitoring is a comprehensive evaluation of neural activity.[13] The interoperability between MEPs and SSEPs enables predicting a lack of intraoperative integrity, as well as resorting to surgical intervention in time, and is characterized by safeguarding neurological functions. The results of these studies justify the application of multimodal IONM in complex spinal surgery to ameliorate patient outcomes.

Sacral monitoring, which included the use of bulbocavernosus reflex (BCR) and EMG, helped in measuring the pathways that govern bladder and bowel activities. Nevertheless, while intraoperative preservation of sacral reflexes was documented, the present study was not designed to determine whether this translated into durable long-term bladder and bowel functional independence. This corresponds to the research of Choi J et al, (2022) that demonstrated that postoperative autonomic outcomes can be predicted with the help of sacral monitoring.[14] Besides, Silverstein et al, (2024) found that BCR and EMG monitoring can potentially preserve urological and sphincter functions in the case of the application of the traditional modalities.[15]

The immediate feedback that is offered by IONM enables the surgeons to make alterations to intraoperative maneuvers as the neural compromise is identified. The results of the study conducted by Squintani G et al, (2025) showed that timely reaction to monitoring alerts was effective in stabilizing the neurological functioning in tethered cord surgeries.[16] Similarly, Udayakumaran et al, (2021) highlighted that IONM can be used as a diagnostic technique as well as an active protective measure during the delicate neural dissections.[17]

The IONM and non-IONM groups were similar in terms of their operative parameters, such as the surgical duration and estimated blood loss. This implies that multimodal monitoring would not add a risk to operations. Similar results were obtained by Chen BJ et al, (2025), who found that IONM may be applied to complex surgeries of the spine without loss of efficiency and safety of patients. [18]

Although these are good outcomes, there are a number of limitations that need to be addressed. The study was retrospective, and the non-IONM group was not large; therefore, the study might not be very generalizable. Secondary outcome evaluation is also prone to incomplete records of operative parameters. Future perspective and multicentered research to have a standardized monitoring protocol and long-term follow-up are required to validate these findings (Liu T et al, 2022).[19]

It is not clear whether or not the benefit that was seen in this retrospective cohort would continue to be seen in a prospective, forward-looking population. To confirm reproducibility, evaluate benefit durability, and cost-effectiveness, a prospective study with a standardized multimodal IONM protocol using pre-established neurological and urological outcome measures is needed. These studies would give more convincing support to the common practice of IONM use in the repair of meningomyelocele.

There are significant limitations of this study. Its retrospective nature is also associated with a selection bias, and the non-IONM cohort is too small (n=8) to have sufficient statistical power and might overestimate effect estimates. Thus, it is impossible to presume causality, and the results should be viewed as hypothesis-forming and not conclusive. These limitations define the necessity of prospective, sufficiently powered studies that would use standardized neuromonitoring protocols.

CONCLUSION

This research shows that multimodal intraoperative neuromonitoring (IONM) is very effective in avoiding cases of postoperative neurological deficits, and only 7.1% of patients under monitored conditions experienced new deficits as opposed to 37.5% of the patients who were not monitored. Motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) were specifically useful to monitor intraoperative neural compromise, whereas the electromyography (EMG) and the bulbocavernosus reflex (BCR) were useful in the maintenance of sacral autonomic activity, such as the management of the bladder and bowel. The results endorse that real-time responses provided by IONM can enable timely modification of surgical movements that will protect the nervous system much better without extending the duration of surgery and reducing the bleeding. Although these results show that multimodal IONM may provide some kind of protection during meningomyelocele repair, before it can be sternly recommended, it must be examined through prospective longitudinal studies.

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Additional Information

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Human Subjects: Informed consent was obtained from all participants included in the study.

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AUTHORS CONTRIBUTIONS

Sr.#	Author's full name	Intellectual Contribution to Paper in Terms of:
1.	***Tabraiz Wali Shah***	Study concept, methodology design, literature review, and referencing.
2.	***Mushtaq***	Data collection, statistical analysis, and result interpretation.
3.	***Shahid Ayub***	Final review and referencing support.
4.	***Sohaib Ali***	Manuscript writing, editing, and quality assurance.