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Advancing Healthcare Innovation: Multidisciplinary Collaboration and Translational Research

Determinants influencing intraoperative neuromonitoring quality during cervical spine treatment: A systematic review

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Abstract The functional integrity of the nervous system is monitored using a method known as Intraoperative Neuromonitoring (IONM) during surgical operations. Utilizing devices positioned on the patient's skin or within their muscles, IONM normally entails monitoring the electrical activity of nerves or muscles. The surgical technique used during the cervical spine treatment can influence the quality of IONM. Surgeons who are experienced in IONM and have a good understanding of the anatomy and physiology of the cervical spine are more likely to obtain accurate and reliable IONM signals. The signals are transmitted to a monitoring system that provides real-time feedback to the surgical team. This feedback can alert the team to potential nerve damage, allowing them to make adjustments to the surgical technique or take other steps to protect the nerves. Patient factors such as age, medical history, and comorbidities can influence the quality of IONM. For instance, patients with pre-existing neurological conditions or those who are elderly may have a higher risk of neurological damage during the surgery, which can affect the quality of IONM. The use of IONM for Anterior Cervical Spinal Surgery (ACSS) has been widely researched across a number of medical reference sources. Research on behind cervical surgery were neglected to take into consideration.

Keywords: Motor Evoked Potential, Risk of Bias (Rob), Intraoperative Neuromonitoring (IONM), Electrophysiological Monitoring, Anterior Cervical Spinal Surgery (ACSS), Meta-Analysis

1. Introduction

The integrity of the nervous system is monitored during surgical operations using a method called intraoperative neuromonitoring (IONM). During cervical spine treatment, IONM can help detect and prevent neurological complications that may arise during the procedure. Certain individuals continue to dispute the use and expense of IONM as its usage during spine surgery increases steadily (Laratta et al 2018). With anticipating spinal cord damage and alerting the surgical team in time in a prompt, remedial action (such as stabilizing vital signs, changing the course of the surgery, or aborting it), IONM assures the standards and protection of treatments (Udelsmanet al 2020). Throughout the previous ten years, IONM has seen a triple growth in use. Substantial batches of neuromonitoring activities occurrence and cause could be identified, which might help with attempts to enhance the quality of the data. The National Quality Strategy (NQS) requires being consistent with these program (Leiter et al (2020)). Effective extraction of neuromonitoring data could make it simple to get out a thorough assessment of treatment effectiveness, particularly the importance of neuromonitoring position for consequences connected to the NQS patient safety goal. Because quality assessments are often related to settlement, organizations could be more excited to gather this data (Goodrumet al 2020). Although more interest in extracting performance metrics from Electronic Health Records (EHRs), this is presently not practical because unstructured information, such as records for neuromonitoring, is available in unrestricted symbols, which necessitates laborious human study analysis (Karhade 2020). Natural language processing (NLP) has been developed in response to the difficulty of effectively extracting important information from enormous amounts of unstructured text data in electronic health records. Iatrogenic injuries can have a significant impact on patients' health and well-being, and can sometimes result in long-term or permanent harm. Preventing iatrogenic injuries requires a multifaceted approach that includes improving communication among healthcare providers, implementing evidence-based guidelines and protocols, and encouraging patient engagement and empowerment. Healthcare providers must also prioritize patient safety and take steps to minimize the risk of iatrogenic injuries through careful monitoring and attention to detail. Including iatrogenic harm from unintentional durotomies and other injuries (Han et al 2019). Digital copies of patients' medical records are preserved electronically and made available to authorized healthcare practitioners as electronic health records (EHRs). Health-related data including a patient medical history, prescriptions, test results, allergies, and imaging tests are frequently included in electronic health records (EHRs). Despite these advancements, there are currently no methods for automatically collecting and characterizing neuromonitoring data from electronic health records (Halsey et al 2020). EHRs may have certain disadvantages as well, including issues with data security and privacy, the possibility of data entry errors, and the expense of setting up and maintaining an EHRs system. It is important for healthcare providers to carefully evaluate the benefits and risks of EHRs and to take steps to ensure that patient data is protected and that the system is used effectively to improve patient care. The monetary effects for any supporting technology on the provision of medical services must be properly understood as expenses grow. With increased emphasis on enhancement in function and metrics for outcomes, spine surgeons are entrusted with performing very delicate surgeries (Guiroyet al 2020). The incidence rate of preoperative neurological impairments has, however, risen, according to information from elective surgical patients between 1999 and 2011, which contradicts the previous statement.

Neurological deficiencies may have major financial costs. The use of IONM was created to reduce this danger, although its efficacy has frequently been disputed (Charalampidis et al 2020). Numerous articles supporting or criticizing the usefulness of IONM have been written, however there is no clear agreement or advice (Siddharth and Shylaja 2021). Numerous supporters contend that IONM is crucial despite promptly intraoperative diagnosis because it provides an extra defense against lawsuits. Research found that although IONM enhanced patient care, it only applied to teaching hospitals and more wealthy metro areas (Hatef et al 2020). Levin et al (2019) examined the individual techniques, their anatomical and physiological bases, and their use in spinal surgery as trustworthy indicators of functional injury, their limitations, and their application to particular minimally invasive surgical procedures, such as the lateral transposes access for underbody fusion and the divergent trajectory for cortico-pedicular screws. To determine if present is connection between subsequent its clinical importance, they looked back at instances where IONM signals during spine surgery showed a considerable difference. The severity of the spine condition is one of the primary determinants of treatment options. For example, a minor spine injury may only require rest and physical therapy, while a more severe injury may require surgery. Age and overall health can play an important position in influential the best course of treatment. Older patients or those with other health problems may be more at risk for complications during surgery, and may need to explore non-surgical options. The type of spine condition can also impact treatment decisions. Some conditions, such as herniated discs, may respond well to conservative treatments such as physical therapy or chiropractic care, while other conditions such as spinal tumors or fractures may require surgery. Funaba et al (2022) examined the individual techniques, their anatomical and physiological bases, and their use in spinal surgery as trustworthy indications of functional injury, their limitations, and their usage to particular surgically surgical procedures, such as the lateral transposes access for antibody fusion and the divergent trajectory for cortico–pedicular screws. To assess the effect of IONM departure disposal, medical expenditures, and hospital-based obstacles, a multivariate analysis with modifications for patient a factor was utilized (George et al (2019)).IONM is particularly useful in surgeries that involve the spine or brain, as these areas are particularly sensitive and complex. By monitoring the electrical signals generated by the nervous system during the surgery, IONM can help to identify any potential damage or changes that may occur. This allows the surgical team to make adjustments or take corrective actions as needed to help minimize the risk of complications. Jesse et al (2022) evaluated IONM's functionality and the effects it had on patients after surgery functional outcomes. There were 86 consecutive SM patients who underwent surgery. Functional results following surgery might vary based on a number of variables, including the procedure's kind, the patient's age and general health, and its extent. Patients' overall health and age can also impact functional outcomes. Older patients or those with other health conditions may take longer to recover and may have a harder time regaining function after surgery. In this situation, the objective was to create a computational approach that could be used to extensive initiatives to enhance quality. Throughout this study IONM quality can be affected by cervical spine surgery approach. Experienced IONM surgeons who understand cervical spine architecture and physiology are more likely to get accurate and dependable signals. A monitoring system sends signals to the surgical team in real time.

The study is divided into four sections: Section 2, which deals with materials and methods, Section 3, which offers the findings and analysis, and Section 4, which deals with the conclusion.

2. Materials and Methods

To discover papers that focused on IONM usage for ACSS, a thorough search of Medline, Embase, SCOPUS, was conducted. Cervical AND monitoring, Neuromonitoring AND cervical, Neuromonitoring AND intra-operative cervical, Electrophysiology AND cervical monitoring, among the search criteria used are Cervical AND sensorial recalled prospective and Cervical AND motor induced possibilities (Wilent et al 2020). The study methods were used into the search strategy development. After examining every pertinent report, it was decided to further analyze the references of the publications chosen for evaluation in order to find research that had not been found during the first database search. Research describing the usage of IONM for anterior cervical spine surgery ACSS was included. Experiments involving non-spinal surgical treatment, cranial surgery, or surgery on the posterior cervical spine were disqualified. In addition, reports of incidents, research that exclusively used spinal cord evoked potential, that failed to give patient outcome, was disregarded (Wi et al (2020)).

2.1. Retrieval of data

Data was gathered from studies that matched both of the eligibility requirements. This information was taken from every study: study year, study category, level of documentation, demographics, surgery type, indication for surgery, neuromonitoring modality type, neuromonitoring conscious requirements, and possibility of neurological wound, IONMsensitivity, false positive rate, specificity, and false negative rate shows in Table 1. Neurologic damage, which is characterized as any indication of deterioration in preoperative neurologic condition compared to the beginning, was the main outcome measure that was employed (Jorge et al 2019).

Table 1 Sensitivity and Specificity.

Reference	Number of Patients	Total Incidence of Neurologic Injury (%)	Neurologic Injury Risk with IONM (%)	Neurologic Injury Risk Without IONM (%)	Sensitivity	Specificity	False Negative	False Positive
Wilent et al (2020)	119	3 (2.5)	NR	NR	0.33	0.96	0.67	0.04
Wi et al (2020)	Total:1445 Corpectomy: 483	Total:2(0.01) Corpectomy: 2 (0.4)	NR	NR	1.00	0.82	0.00	0.18
Jorge et al (2019)	1039	1 (0.09)	1/577 (0.17)	0/462 (0)	0.00	0.99	1.00	0.01
Di Martino et al (2019)	163	1 (0.6)	NR	NR	0.67	0.98	0.33	0.02
Rao et al (2021)	57	2 (3.5)	NR	NR	0.67	0.96	0.00	0.04
Asquini et al (2021)	508	12 (2.4)	NR	NR	0.77	1.00	0.23	0.00

2.2. Evaluation of the study' methodological strength and data category

Using the established criteria, levels of probability is awarded to each research displayed in Table 2.The standard of every manuscript submitted was assessed utilizing the Methodological Index for Nonrandomized Studies (MINORS) standards (Di Martino et al (2019)). This criterion has already been proven to have strong examine-retest, both inside and outside validity, and interobserver reliability. Using a method developed by the Systematic Statistical Evaluation Group, risk of bias (RoB) of comparison study evaluated. Research was deemed to have a low RoB if they complied with at the criteria. The research was classified as having a high RoB if five out of the twelve criteria were satisfied. RoB was assessed for noncomparative research using this also altered 5-point assessment score.

Table 2 Data and demographics.

Reference	Study Type	Evidence Level	Surgery Dates	Mean Age, Yrs. Range)	% Male	Number of Institutions	Type of Surgery	Indication for Surgery
Wilent et al (2020)	Retrospective	IV	23 month period	46 (24–82)	NR	1	ACD Fonly	R,M,T,Tu,O
Wi et al (2020)	Retrospective	IV	2000–2004	NR	NR	1	ACD Fonlyand ACDF + Corpectomy	R,M,T,Tu,O
Jorge et al (2019)	Retrospective	III	1995–2004	NR	NR	1	ACD Fonly	R,T,Tu,O
Di Martino et al (2019)	Retrospective	IV	1995–2002	48.6 (14–84)	NR	1	ACDFonly	R,M,T,O
Rao et al (2021)	Retrospective	IV	2007–2010	47.6 +/– 11.1	NR	1	ACDF+Corpectomy	R, M
Asquini et al (2021)	Retrospective	IV	1994–2004	55.7 (NR)	52.8	1	ACDF+Corpectomy	R,M,O

2.3. Data Analysis

The data were analyzed the random-effects framework with inverted variable loading. The study estimates 95% confidence intervals (CI). Several experiments' results were evaluated using 95% CIs and related forest areas. The likelihood of neurological damage in operations utilizing anterior cervical discectomy with fusion (ACDF) with IONM was assessed using a meta-analysis (Rao et al 2021). The incidence of injury in the research calculated by dividing the total quantity of difficult neurologic proceedings by patient crowd. Usingan I^2 values, disparity of the studies within meta-analysis collection was evaluated. The sensitivity and specificity of IONM was assessed with bivariate analysis (Asquiniet al 2021). It was decided to assess the sensitivity and specificity of unmoral IONM using mixed-effect regression. It is deemed statistically important when the *P* value was ≤ 0.05.

3. Results and Discussion

According to an article evaluation, 60 researches were eliminated because they were not relevant to the spine, and 32 additional researches were also removed. Following a thorough assessment of another study their explanations were removed to expose the final research shown in Figure 1 that satiated all inclusion and exclusion requirements. In three investigations, the only conditions that qualified for ACSS were myelopathy or radiculopathy being while a select group of patients receiving treatment for infections, tumors, injuries, or an osseous behind prospective ligaments were included in the other research (Karpathiotakis et al 2020).

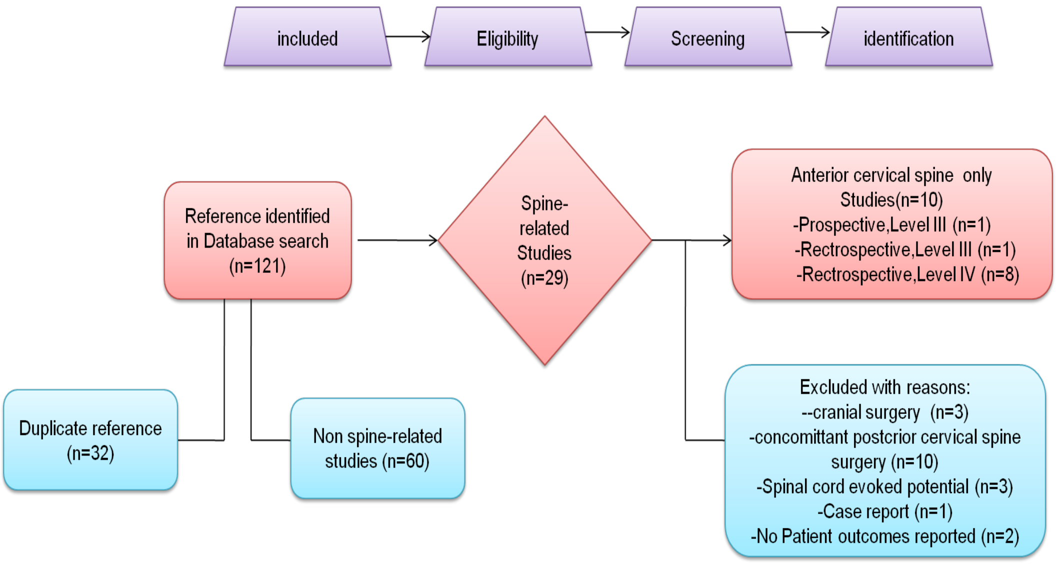

Figure 1 Included studies' process.

3.1. Quality Evaluation of the Included Studies

The Standard Deviation (SD) of the MINORS scores from the IONM study ranges from 9 to 11, with an average of 9.63. The MINORS study yielded results with scores ranging from 14 to 18, an average of 16, Based on a 2.83 standard deviation. Despite the low RoB of the documents in this investigation, they all had poor methodological quality (Nasi et al 2020). Overall, there were 26,357 patients. In one study, a national database with 22,768 patients was employed. The studies gave mean patient ages, resulting in a subjectively indicate age of 51.3 years, with an average age of 14 to 86 years of age. As shown in Table 3. The study found that the patient groups were 52%22 and 45% male, respectively (Fei et al 2022).

Table 3 Assessment of Non-comparative study Quality and Bias Risk

Risk of Bias	Reference	MINORS Score
Low	Wilent et al (2020)	10/16
Low	Wi et al (2020)	9/16
Low	Jorge et al (2019)	14/24
Low	Di Martino et al (2019)	9/16
Low	Rao et al (2021)	9/16
Low	Asquini et al (2021)	10/16

3.2. Monitoring Technique

In the investigations that included Somatosensory Evoked Potentials (SSEP) monitoring, the ulnar or median nerves were used to monitor the upper extremities, while the tibial or peroneal nerves were used to monitor the lower extremities. One research monitored the SSEP just on the upper extremities (Sanderset al 2020). The SSEP monitoring method was not reported in two trials. According to Table 3, an essential role concern was defined as a 50% decline in frequency or an increase in delayed over three trials, a 30% to 50% loss in amplitude over the study, and a 60% drop in intensity (Baro et al 2021)). This study utilized the absence of 50% intensity drop; another used an absence of 60% intensity reduction over 10 minutes; and a third used an indeterminate, significant intensity fall, as shown in Table 4.

Table 4 Neuromonitoring Information.

Reference	Monitoring Modality	Type of Monitoring	SSEP Nerve	SSEP Alert Criterion: Amplitude Decrease	SSEP Alert Criterion: Latency Increase	MEP Muscle Group	MEP Alert Criterion: Amplitude Decrease
Wilent et al (2020)	Multimodal	SSEP and MEP	U, Ti	30%–50%	NR	APB, DI, TA, AH	50%
Wi et al (2020)	Multimodal	MEP, SSEP and EMG	NR	60%	NR	D,Tr,ECR,DI,TA,AH	60% (10 min)
Jorge et al (2019)	Unimodal	SSEP	M,U,Ti,P	50%	10%	NR	NR
Di Martino et al (2019)	Unimodal	SSEP	M,Ti	NR	NR	NR	NR
Rao et al (2021)	Multimodal	SSEP and MEP	M, U, Ti	50%	10%	APB, TA, AH	Significant reduction
Asquini et al (2021)	Unimodal	SSEP	M,U,Ti,P	50%	10%	NR	NR

3.3. Risk of Neurological Injury

A total undefined possibility of adverse outcome of 0.19% was produced by 49 neurological injury events in 26,357 subjects throughout trials (Zhang 2022). According to Figure 2, the overall estimated possibility of neurological impairment after ACSS was 0.64%. The studies' I^2 value of 81.07% and Q value of 47.5366 both showed extreme heterogeneity. Figure 3 compares the weighted risk of neurological impairment in the analysis that examined an appropriate cohort of patients receiving ACDF alone to corpectomies, which was 1.02%. Examined was the potential of neurological impairment in ACDF patients with IONM (Suresh et al 2021). As shown in figure 4, there was a statistically significant variation between these individuals' probabilities of experiencing neurological impairment with IONM.

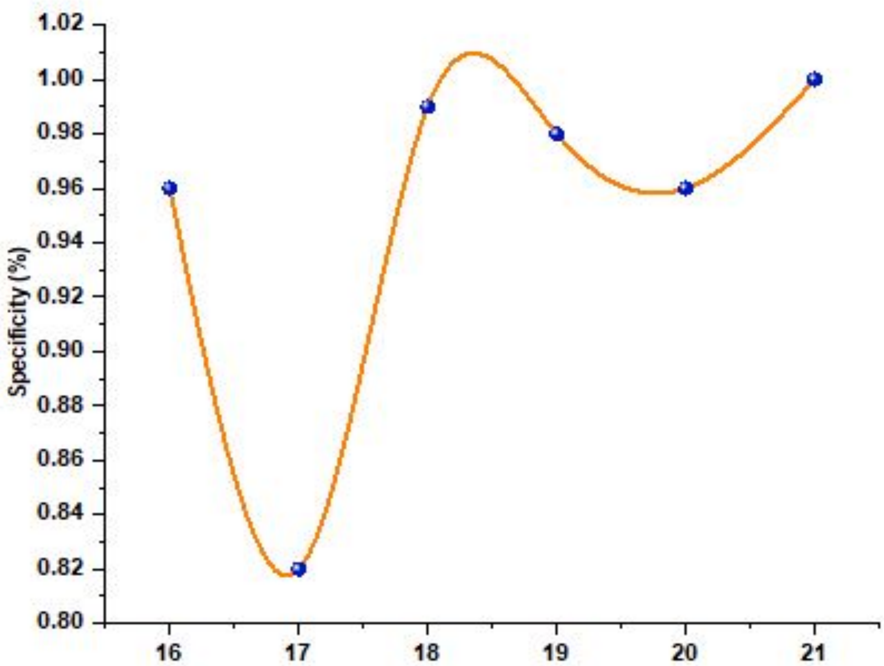

Figure 2 Neurological Injury specificity.

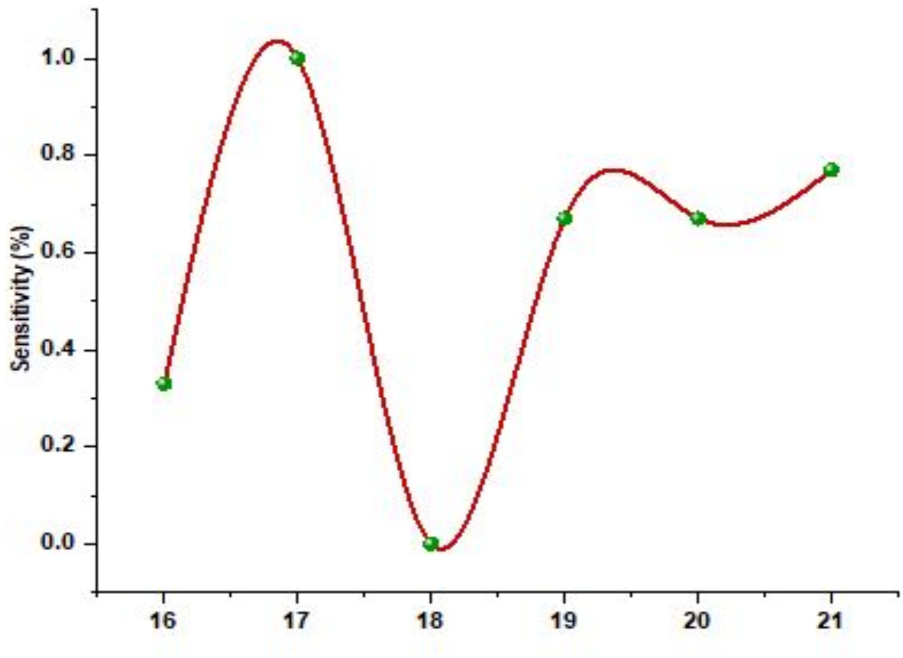

Figure 3 Neurological Injury sensitivity.

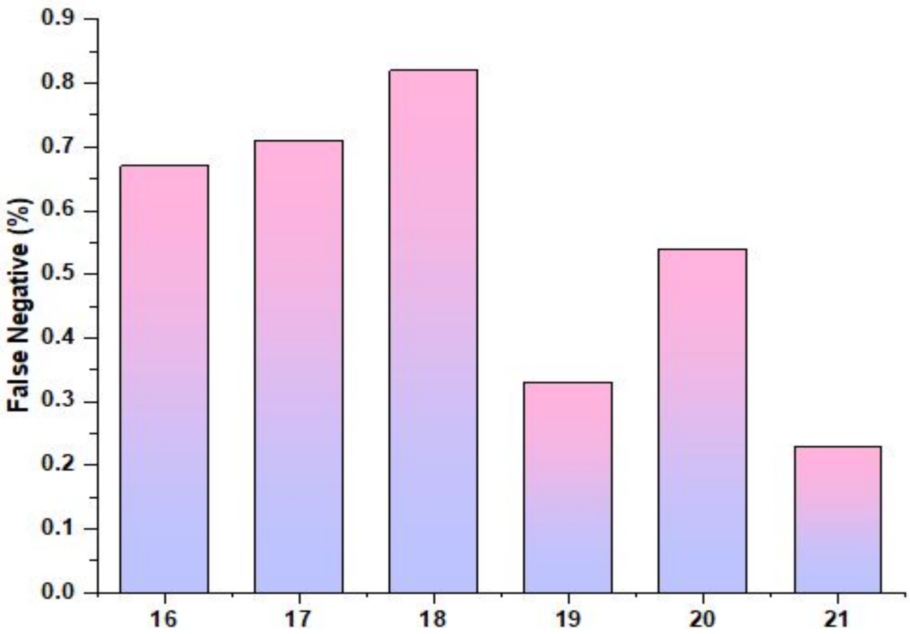

Figure 4 Neurological Injury False negative.

3.4. Intraoperative Neuromonitoring (IONM) Sensitivity and Specificity

The study provided available data on sensitivity and specificity. The bivariate analysis's findings are shown in Figure 5, with the study's overall sensitivities and specificities for ACSS being 71% and 98%, respectively (Ichino et al (2019)).24.2% and 99.6%, respectively, were the combined positive and negative prognostic ratings. For IONM in ACSS. The results for multimodal and immoral IONM are displayed in Figure 6 together with the findings from the bivariate evaluation that was used to aggregate the six trials with full sensitivity and specificity data (Toki et al (2022)). The unmoral and multimodal IONMs both have excellent specificity. The sensitivities for both modalities were decreased, and the sensitivities for morally defective individuals differed statistically significantly.

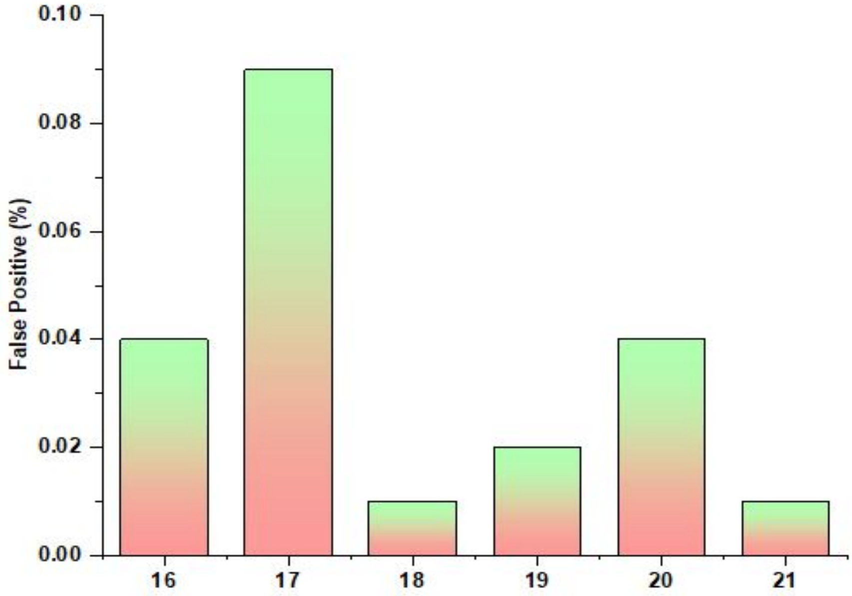

Figure 5 Neuromonitoring false positive intraoperatively

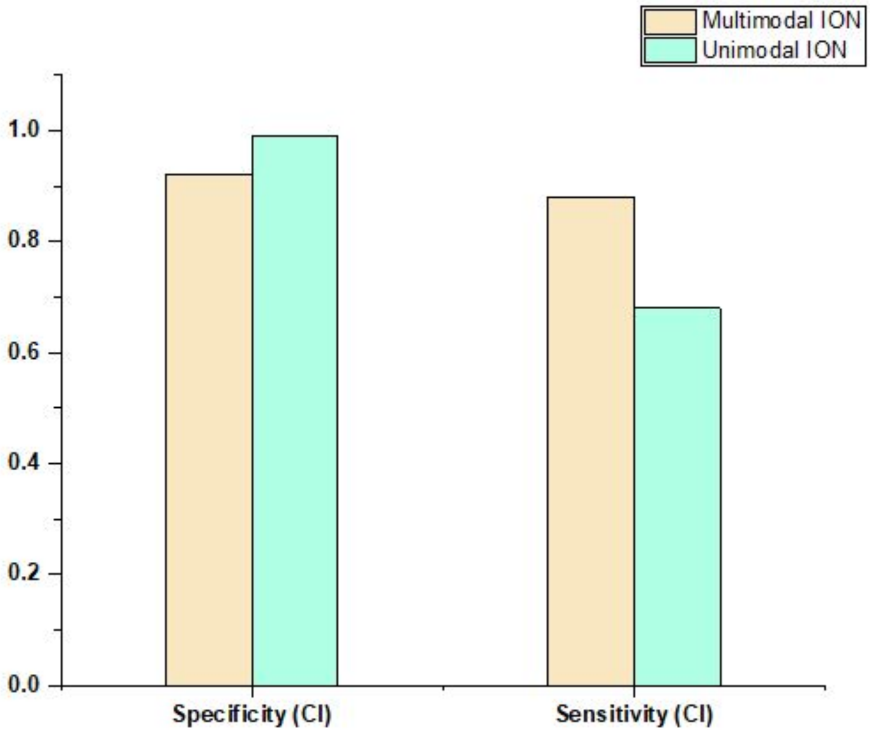

Figure 6 comparison of specificity and sensitivity

4. Final considerations

ACSS, there is a small chance of neurological damage. With or without IONM usage, there is no change in the risk of neurological impairment for ACDFs. Unmoral IONM may reduce subclinical intraoperative alarms since it has a greater specificity than multimodal IONM. This meta-analysis has intrinsic limitations since it is vulnerable to the combined flaws of the included studies. Unfortunately, prospective research and randomized controlled trials do not have a substantial body of data. An appropriate group to apply the results of this research to be difficult to determine since studies often include precise demographic information. Surgery for trauma, tumors, and infections was included in some studies; these reasons often have a poorer prognosis and have distinct risks for cerebral harm than degenerative disorders do. Despite these drawbacks, the study offers crucial aggregate data, highlighting critical areas for further investigation that will help in guiding decisions about the indications for IONM in ACSS. For spinal procedures, intraoperative neuromonitoring has been employed since the 1970s. The Stanger wake-up test was the sole method available for intraoperative evaluation of neurologic function prior to the widespread usage of IONM. The use of IONM in various spine procedures, such as tumor removal, deformity correction, trauma, and degenerative spine surgery, has increased recently. A significant body of research demonstrates that IONM may help with the early diagnosis of neurological damage brought on by spinal cord traction, compression, or ischemia during deformity maintenance. There is disagreement about the best neuromonitoring method to utilize for cervical spine procedures like ACDF and the regular use of IONM.

Ethical Considerations

Not Applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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