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Neural Complications of Surgical Treatment of Adolescent Idiopathic Scoliosis: a Single Center Experience

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Abstract

Objective: Adolescent idiopathic scoliosis surgery presents a challenge to anesthetist due to the extensive nature of the surgery and the constraints on anesthetic techniques of intraoperative neurophysiological monitoring of the spinal cord.

Intraoperative neurophysiological monitoring combining both somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs) have become a standard of care by preventing neurologic sequela and lesions of the spinal cord.

The objective of this article was to assess the incidence of neural complications in surgical treatment of adolescent idiopathic scoliosis surgery in a single institution and investigate possible factors associated with it.

Methods: Medical records of 216 patients who underwent adolescent idiopathic scoliosis surgery with posterior spinal fusion were retrospectively reviewed from January 2009 to October 2013. Patients were monitored using electrophysiological methods including SSEPs and transcranial electric MEPs simultaneously.

Results: Neurophysiologic monitoring changes were seen in 5 patients (2.3%): 4 (75%) women and 1 (25%) men. Out of the 5 patients with significant signal alert, 3 patients presented changes in Tc-MEPs and 2 patients in Tc-MEPs and SSEPs. 3 patients presented intraoperative significant changes in neurophysiologic signals that improved following corrective actions by surgeons and correction of hemodynamic parameters by anesthesiologists with no postoperative neurologic deficits; 2 did not show any reversal of the signals after systemic intervention and developed postoperative neurologic deficits consisting of transient paraparesis (0.92%).

Conclusion: This study indicates that early detection of neurophysiological changes using a multimodal approach with SSEPs and Tc-MEPs affords the surgical team an opportunity to perform rapid intervention to prevent injury progression or the possibility to reverse impeding neurologic sequela.

Keywords: Spinal surgery; Intraoperative neuromonitoring; Evoked potentials; Adolescent idiopathic scoliosis

Introduction

Adolescent idiopathic scoliosis surgery presents a challenge to the anesthetist due to the extensive nature of the surgery and the constraints on anesthetic techniques of intraoperative neurophysiological monitoring of the spinal cord.

Iatrogenic spinal cord injury is the most feared complication of scoliosis surgery for both parents and adolescents that are submitted to this type of surgery. However, instrumented spinal fusions are essential to halt progression and ameliorate the symptoms. Derotation of the spinal column causing direct injury to the spinal cord or impinging on the vasculature are the mechanisms most often related to the iatrogenic injury during scoliosis procedures [1,2].

The incidence of major neurologic injury following surgery for spinal deformity has been reported in the most recent literature to range from 0.26% to 0.73% in the idiopathic cases. Some previous studies pointed out different neural complication rates, some of them reported rates as high as 17% [3,4].

The type of procedure, curve magnitude, type of instrumentations, combined approach and decreased spinal cord perfusion due to hypotension and/or significant hemorrhage are important factors associated with neural complications [5].

Maneuvers such the Stagnara wake-up test, were implemented until the 70s to detect and correct problems before they became irreversible [6]. The complications and limitations associated with this test (single surgical moment evaluation, accidental extubation, gas embolism, fracture of the ribs) required other methods of neural evaluation during scoliosis surgery.

Intraoperative neurophysiological monitoring combining both somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs), has become a standard of care by preventing neurologic sequelae and lesions of the spinal cord [7].

The aim of this study was to assess the incidence of neural complications in surgical treatment of adolescent idiopathic scoliosis surgery and investigate possible factors associated with it.

Methods

From January 2009 to October 2013, 216 medical records of patients who underwent adolescent idiopathic scoliosis surgery with posterior spinal fusion were reviewed. This study was approved by the institution review board.

We obtained data from the patient's clinical history, anesthetic chart, monitoring reports as well as perioperative notes, in order to determine a temporal relationship between the intra-operative events and the changes observed in the neurophysiologic monitoring. Demographic and important clinical data was also obtained including age, gender, height, weight and body mass index. Preoperative neurological status and preoperative curve type and Cobb angle were obtained from the outpatient clinical notes.

The type of anesthesia performed (total intravenous anesthesia or balanced anesthesia) was decided by the anesthesiologist in charge of each procedure. The effect of the drugs used on the neural complications encountered was evaluated statistically.

Neurophysiologic monitoring

In our institution, since 2009, experienced surgical neurophysiologists have been monitoring spinal cord function with use of a standardized multimodality technique. SSEPs are cortical responses elicited by peripheral nerve stimulation (posterior tibial nerve). In the potentials acquired the waves N30, N40 and N50 were analyzed.

Transcranial MEPs (Tc-MEPs) apply a stimulus at a cortical level. A bridge between C3´/C4´ (International 10/20 System) was used during stimulation. The electrodes were in place for monitoring from muscles that were linked to the roots/spine level likely to be injured during the procedure.

Relevant neurophysiological change (significant alert) was defined as a reduction in amplitude (unilateral/bilateral) of ≥ 50% SSEPs and ≥ 60% for transcranial electric MEPs when compared with baseline. When the decrease in amplitude was > 80% a wake-up test was performed.

Statistical analysis

Categorical variables were presented as number of patients and percentages, and were compared using Fischer's exact test. Continuous variables were presented as median and interquartile range, and compared using the non-parametric Mann-Whitney test. Statistical significance was defined as p- value < 0.05.

To test the association between study variables and outcome (changes in SSEPs or Tc-MEPs), odds ratio (OR) and 95% confidence intervals (95% CI) were used. The statistical analysis was performed using Stata version 12.

Results

A total of 216 patients were included, with approximately 88% of women. The mean age of the patients was 15.1 years old. Demographic data is presented in Tables 1 and 2.

		Patients with neuromonitoring changes (n=5)		**Patients without neuromonitoring changes (n=211)**		**p-value**
		Number	%	Number	%	
Gender	Female	3	75.0	186	88.2	0.386
	Male	1	25.0	25	11.9	
Scoliosis	Dorsal	1	25.0	144	68.9	0.077
	Lombar	1	25.0	35	16.8	
	Dorsolombar	2	50.0	30	14.3	
Anesthesia	AGB	2	50.0	131	62.1	0.637
	AGIV	2	50.0	80	37.9	

Table 1: Demographic and clinical and data.

	Patients with neuromonitoring changes (n=5)		**Patients without neuromonitoring changes (n=211)**		**p-value**
	Median	interquartile range (Q1-Q3)	Median	interquartile range (Q1-Q3)	
Age	15.5	14.5-19.0	15.0	14.0-19.0	0.386
ASA	1.0	1.0-2.0	1.0	1.0-2.0	0.727
Cobb Angle (º)	60.7	52.3-63.1	55.7	45.9-68.2	0.821
Number of screws	16.0	14.5-17.0	16.0	13.0-17.0	0.798
Number of levels fused	10.0	9.0-10.0	9.0	7.0-10.0	0.317
Surgery duration	242.5	237.0-254.5	198.0	173.0-215.0	0.003
Anesthesia duration	320.0	308.0-344.0	270.0	243.0-291.0	0.005

Table 2: Clinical and surgical data.

A total of 211 did not show any signal alert and had no postoperative deficit. The significance of the cases with non-significant alert (reduction in amplitude of >50% SSEPs and <60% for transcranial electric MEPs) was uncertain and the hemodynamics of these patients was maintained but no surgical interventions were undertaken. No new postoperative event, sensory or motor, was detected in these patients.

Neurophysiologic monitoring changes were seen in 5 patients (2.3%): 4 (75%) women and 1 (25%) men (P=0.386) (Table 3). Out of the 5 patients with significant signal alert, 3 of the patients presented changes in Tc-MEPs and 2 patients in Tc-MEPs and SSEPs. Only 3 patients presented intraoperative significant changes in neurophysiologic signals that improved after corrective actions by surgeons and correction of hemodynamic parameters by anesthesiologists. These patients did not show any postoperative neurologic deficits.

Sex (M -male; F-female)	Cobb Angle (°)	Neuromonitoring changes	Stage of surgery	Time after the beginning of surgery (minutes)	Stagnara Wake-up-test	Intraoperative intervention	Postoperative outcome
M	55.5	MEPs	After corrective maneuvers	150	Yes	Instrumentation removed	No deficits
F	44.5	MEPs and SSEPs	After insertion of material	115	No	Instrumentation removed	Transient neurologic deficits
F	61.2	MEPs	After corrective maneuvers	106	No	Corrective actions	No deficits
F	66.0	MEPs	After corrective maneuvers	105	Yes	Instrumentation removed	Transient neurologic deficits
F	65.0	MEPs and SSEPs	After corrective maneuvers	116	No	Corrective actions	No deficits

Table 3: Intraoperative changes and clinical outcomes (MEPs: motor evoked potentials; SSEPs: somato-sensitive evoked potentials).

However, out of the 5 patients that developed neurophysiologic changes, 2 did not show any reversal after systemic intervention and developed postoperative neurologic deficits consisting of transient paraparesis (0.92%). Only 1 of these patients had changes in Tc-MEPs and SSEPs simultaneously. Cause-effect relationship was detected in all cases: 4 patients after deformity correction and 1 patient after material insertion. 3 patients required removal of the instrumented material. The patients who showed neurologic deficits after surgery had their instrumentation removed. In the first patient the intraoperative intervention did not have any effect on the neurophysiological parameters and the patient awoke with paraparesis postoperatively, which improved over a period of several months but still with clinical evident deficits. The second patient also had postoperative paraparesis, but the intraoperative removal of the material showed significant improvement in the Tc-MEPs signal. The neurologic deficits resolved after a few weeks with the patient regaining all neurologic and motor functions.

As expected the surgery duration was higher in the neural complications group: 242.5; 237.0-254.5 vs.198.0; 175.0-215.0 (median; interquartile range).

Discussion

The use of electrophysiologic monitoring during spine surgery is a well-established and widely used technique. In 1992, the Scoliosis Research Society issued a position statement regarding the use of neurophysiologic monitoring during spinal surgery. They concluded that, "A substantial body of research has demonstrated that neurophysiologic monitoring can assist in the early detection of complications, and can possibly prevent postoperative morbidity in patients undergoing operations on the spine" [8]. Nowadays, there is no question about neurophysiologic monitoring being a standard of care in the surgical treatment of several spinal deformities [9].

Neurologic deficit is one of the most severe risks of scoliosis treatment and its incidence varies among different studies. In our study the incidence of neural complications after adolescent idiopathic scoliosis surgery was 0.92%. As mentioned previously, this incidence is slightly above from what is stated in the most recent literature.

The goal of neurophysiologic monitoring is rapid detection of any neurological insult that can result in neurological deterioration during surgical intervention on the spine and prompt early intervention to reverse the insult and avoid adverse sequels. Timely detection of impending spinal cord damage is paramount [10-12].

Our study supports that multimodality neuromonitoring of spinal cord sensory and motor function, during adolescent idiopathic scoliosis surgery is feasible and provides useful neurophysiologic information to reverse the neurological insult.

There is very low evidence from the literature supporting unimodal SSEPs or Tc-MEPs as a valid diagnostic test for measuring intraoperative neurologic injury. However, there is high evidence that multimodal neuromonitoring is sensitive and specific for detecting intraoperative neurologic injury [2,13].

In this study, only the Tc-MEPs or both SSEPs and Tc-MEPs were altered in patients with significant signal changes. The differential sensitivities of Tc-MEPs and SSEPs to evolving spinal cord injury may be related to differences in the neural pathways that mediate these responses and to the mechanisms of spinal cord injury [12].

Spinal cord sensory and motor pathways are physically separated from each other and have separate vascular supplies (i.e. anterior and posterior spinal arteries). It is possible that selective ischaemia of the anterior spinal cord region may manifest as a loss of motor-evoked potential amplitude in the absence of concurrent change in SSEPs. Moreover, the vascular supply to the motor pathways is also less redundant than is the supply to the posterior sensory columns, adding to this vulnerability. Since most neurologic injuries during scoliosis surgery appear to be related to ischaemia, Tc-MEPs are more likely to change under these conditions than SSEPs. Prolonged hypotension can result in spinal cord vascular injury. Tc-MEPs are particularly sensitive to blood pressure changes and can be used quite effectively to titrate the degree of hypotensive state that the spinal cord will withstand [10].

We can conclude that SSEPs monitoring complements Tc-MEPs monitoring by being sensitive to injury limited to the posterior sensory columns.

Consensual change of SSEPs and Tc-MEPs responses may have a worsened prognostic significance in terms of possible postoperative clinical impairment. As presented in this study, one of the patients that had intraoperative alterations in both Tc-MEPs and SSEPs had a severe neurologic injury with transient paraparesis in postoperative period, requiring several months to partially recover her sensory and motor functions.

The majority of evoked potentials changes in this study were related to insertion, adjustment or removal of the instrumentation during correction of the scoliosis deformity. Placement of instrumentation and subsequent derotation can result in impingement on the vasculature of the spinal cord or direct compression of neural structures, resulting in ischaemia [1,14,15].

The wake-up test remains mandatory when only SSEPs are used for intraoperative monitoring purpose due to the possibility of isolated lesion of corticospinal tract in the presence of unmodified SSEPs responses. However, the wake-up test can also be used as a supplement to SSEPs and Tc-MEPs when needed [13]. In our study the decision to perform the wake-up test in one of the patients was a multidisciplinary decision. This patient did not have any neurologic deficit in the postoperative period. Some authors even say that the maneuver per se might improve spinal cord function, once awakening a patient requires cessation of the surgery, reduction of the pharmacologic load which leads to a rise in blood pressure and improvement in spinal cord perfusion [12].

Complications related to patient positioning are a well-documented cause of iatrogenic injury for surgical procedures in general and has been shown to correlate with changes in SSEPs and/or Tc-MEPs [16,17]. In our series there was no neurologic injury related to poor patient positioning.

Limitations and strengths of the study

The present study has some limitations: it is a retrospective, non-randomized study. However, it is a study that evolves a large population of patients with similar demographic characteristics, operated by the same surgical team and in a single institution.

Conclusion

Intraoperative monitoring of somatosensory and motor evoked potentials is a reliable method to provide information regarding spinal cord integrity during spinal deformity surgery. A multimodal approach with SSEPs and Tc-MEPs has been a standard of care in scoliosis surgery, assessing the entire spinal cord functionality in real time.

This study indicates that early detection of neurophysiological changes affords the surgical team an opportunity to perform rapid intervention to prevent injury progression or the possibility to reverse impeding neurologic sequelae.

We conclude that intraoperative neuromonitoring is a potentially valuable tool for the optimization of outcome in complex spinal surgery.

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