Multimodal intraoperative monitoring (MIOM) during surgical decompression of thoracic spinal stenosis in 36 patients

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Accepted: 7 May 2007 / Published online: 4 July 2007
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Abstract A prospective study of 36 patients who received multimodal intraoperative monitoring (MIOM) during decompression of thoracic spinal stenosis between March 2000 and December 2005 was chosen as the study design. The objective was to determine the sensitivity and specificity of MIOM techniques used for monitoring spinal cord during surgical thoracic decompression. The background data revealed that the surgical decompression for thoracic spinal stenosis is less frequent than in other regions of the spine. However, due to the relative narrow spinal canal, neurological complications could be severe. The combination of monitoring ascending and descending pathways may provide an early alert to the surgeon in order to alter the surgical procedure, and avoid neurological complications. The methods involved evaluation of intraoperative somatosensory spinal and cerebral evoked potentials and motor evoked potentials of the spinal cord and muscles that were compared with post operative clinical neurological changes. 36 consecutive patients with thoracic spinal stenosis of different aetiologies were monitored by the means of MIOM during the surgical procedure. 31 patients had true negative while one patient had false positive findings. Three patients had true positive and one patient had false negative findings. This indicates a sensitivity of 75% and a specificity of 97%. The one case of false negative findings recovered completely within 3 months. In conclusion, the MIOM is an effective method

of monitoring the spinal cord during surgical decompression of the thoracic spine.

Keywords Thoracic spine surgery · Decompression · Intraoperative monitoring · Sensitivity · Specificity

Introduction

The majority of thoracic spine surgical procedures is due to corrections of deformities where intraoperative monitoring became a well established method making the wake up test to assess the function of the spinal cord obsolete.

Thoracic stenosis of the spinal canal can occur due to degenerative changes (seldom), fracture and dislocation of bony fragments, thoracic disc herniation and finally ossification of posterior longitudinal ligament (OPLL).

Surgical procedures for decompression within the thoracic spine are technically demanding having a high risk of damage to the spinal cord. Particularly for the decompression of OPLL, lack of consensus still remains regarding the choice of operative procedure. Preventing the increase of postoperative paralysis by posterior instrumentation was shown using neurophysiological monitoring in a case with extensive cervical thoracic OPLL [3, 5]. The advancement of multimodal intraoperative monitoring (MIOM) allows by using the epidural electrodes to stimulate the spinal cord rostral of operating region and record below.

However, false negative responses in spinal cord monitoring, using spinal cord evoked potentials following spinal cord stimulation during surgery for thoracic OPLL, have been reported [2]. The 55-year-old female presented during the partial removal of the OPLL decreased ampli-

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tudes during decompression, which recovered to the control level by the end of surgery. However, after surgery the patient showed complete motor paralysis with preserved sensory function. The question is raised as to what is actually monitored within the spino–spinal-evoked potentials.

The relatively few reports on the application of multi-modal intraoperative monitoring during surgical decompression of thoracic spine document the need of further investigation because false negative findings can have drastic consequences [2].

Aim of the study

To determine the sensitivity and specificity of MIOM techniques used for monitoring of spinal cord during surgical thoracic decompression.

Materials and methods, patient population

For this study the methods of examination by applying the MIOM as well as the anaesthesia protocol have been described by Sutter et al. [4]. The intraoperative monitoring was performed by the first two authors, who are experienced neurophysiologists, specially trained in the different methods of MIOM. The patients have been selected according to the inclusion/exclusion criteria described by Sutter et al. [4] and the respective surgeon. Figure 1 gives an overview of the surgical procedures. Thirty-six patients with thoracic spinal stenosis of different aetiologies were selected for MIOM (Table 1).

The tests and their frequencies applied to the patient population with thoracic spinal stenosis are summarised in Table 2.

Fig. 1 Surgical procedures applied in our series of 36 patients undergoing decompression of thoracic spinal stenosis

Table 1 Aetiologies of thoracic spinal stenosis operated with the aid of MIOM ($n = 36$)

Diagnostic characteristics	
Congenital anomaly	2
Degenerative	11
Disc herniation	8
Fracture	11
Miscellaneous	4

Results

The surgical procedures of the 36 patients with thoracic spinal stenosis were planned and performed according to the pre-existing pathology. There were 18 males and 18 females of mean age 57.8 years (range 15.4 to 78.6 years), on average the duration of the operation was 5.1 h (range 1.7 to 12 h). There were 31 true negative cases, while one was false negative (Table 3). We have observed one false positive case (Table 4) and three true positive cases (Table 5).

Using the standard formula, the sensitivity of MIOM for decompression of thoracic spine was calculated to be 75% (95% confidence interval: 22–99%) and the specificity to be 97% (95% confidence interval: 82–99.8%).

It has to be stated that there was no severe neurological complication in the examined population.

In the examined group of 36 patients receiving MIOM during surgical decompression of thoracic spinal stenosis, we had one false negative case in a 39-year-old male with achondroplasia and multisegmental Stenosis and Kyphosis. The surgeon performed a laminectomy T9–L1 with osteotomy and corrective spondylodesis. The IOM modalities were performed accordingly with cerebro–muscular evoked potentials from vastus medialis and tibialis anterior muscles as well as continuous electromyography (EMG) of vastus medialis and tibialis anterior muscles including the neuro–cerebral evoked potentials with stimulation of the tibial nerve and two epidurally placed electrodes at T7 and L1. All evoked potentials were available, although pathological from the beginning, and did not change during the whole operation of 11.8 h duration. Postoperatively, the patient suffered an L2- and L3-radiculopathy on the left side. This case shows the difficulty of monitoring the L2 nerve root especially in a patient with very short legs due to achondroplasia explaining why we could not monitor pectineus muscle.

The one false positive case was a 69-year-old female with progressive instability and myelopathy after T12-fracture, who received decompression and corrective fusion from dorsal. During the operation of 5.8 h duration we recorded an intercurrent continuous reduction of the cerebro–muscular evoked potentials, which were thought to be due to a cerebrovascular insult. Postoperative, we

Table 2 Tests* applied to the patient population ($n = 36$) with thoracal spinal stenosis. (Tests*: Recorded muscle pairs or stimulated nerve pairs in a given modality)

Monitoring modality	Monitorings applied		Baseline recording	
	Out of 36 cases	Mean tests per patient	Normal	Abnormal/no potential
cm-EP	35 (97.2%)	2.4	11	24/0
sm-EP	9 (25%)	2	NVM	
cs-EP	13 (36.1%)	1.2	2	9/2
ss-EP	2 (5.6%)	1	NVM	
nc-EP	33 (91.7%)	1.4	12	21/0
ns-EP	13 (36.1%)	1.1	NVM	
EMG	33 (91.7%)	2.4	No spontaneous activity	
In situ stimulation.	8 (22.2%)			

cm-EP cerebro–muscular evoked potentials, *cs-EP* cerebro–spinal evoked potentials, *ns-EP* neuro–spinal evoked potentials, *nc-EP* neuro–cerebral evoked potentials, *NVM* normative value missing, *sm-EP* spino–muscular evoked potentials, *ss-EP* spino–spinal evoked potentials

Table 3 Detailed description of false negative cases in thoracic spine decompression procedures

False negative cases (thoracal database)											
Patient	Region	Pathology	Surgery	Duration	IOM modalities	IOM-baseline	IOM-changes	Neurological deterioration	Duration	Recovery	
K.D., m,	39 y	T9–L2	Achondroplasie,								
		multisegmental Stenosis and Kyphosis (SLCT)	Laminectomy T9–L1, Osteotomy and corrective Spondylodesis	11.8 h	cs _{T7,L1} -EP cm _{VM,TA} -EP s _{L1} s _{T7} -EP n _{TNC} -EP ns _{T7} -EP sm _{VM,TA} -EP EMG _{VM,TA}	All available, but pathologic	none	Radikulopathy L2,L3 left	3 Months	Completely	

Table 4 Detailed description of false positive cases in thoracic spine decompression procedures

False positive cases (thoracal database)									
Patient	Region	Pathology	Surgery	Duration	IOM modalities	IOM-baseline	IOM-changes	Expected neurological deficit	
K.G., f, 66 y	T11–T12	Progressive Instability and myelopathy after T12-fracture and vertebroplasty	Decompression and corrective fusion from dorsal	5.8 h	cmTA,AH-EP nTNC-EP EMG TA,AH	All motor and sensory EP pathological available	Intercurrent continous reduction of cm/nc-EP	Cerebro–vascular attack	

couldn't find any new neurological deficits. In the three true positive cases, described in detail in Table 5, we communicated with the surgeon immediately after onset of a significant deterioration of pre-existing pathological evoked potentials. These neurological deficits were foreseen and confirmed by the postoperative clinical examination.

Discussion

In thoracic spine decompression procedures, a close collaboration of spine surgeons and neurologists specialised in the techniques of MIOM is essential. Instant decisions are important in order to prevent neural damage.

Table 5 Detailed description of true positive cases in thoracic spine decompression procedures

True positive cases of thoracic database									
Patient	Region	Pathology	Surgery	Duration (h)	IOM modalities	IOM-baseline	IOM-changes	Neurological deterioration	Recovery
R.A., m, 44 y	T9–T10	Disc herniation	Decompression ventrolateral	6.3	cmEP ADM AH, cont EMG, ncEP MN TN	All available but pathologic	Deterioration of cmEP AH right and ncEP TN right	Deterioration of pre-existing paraparesis right	Partial recovery
G.E., m, 68 y	T11–T12	Ossified disc herniation	Decompression dorsal and ventral	6.5	csEP, cmEP TA AH, nsEP, ncEP TN	All available but pathologic	Transient loss of cmEP and csEP	Deterioration of paraparesis and partial bladder incontinence	6 months complete
B.H., m, 63 y	T11–L1	Instability and stenosis	Decompression and fusion dorsal	4	cmEP P VM TA SA, ncEP PN, cont EMG	All available but pathologic	Deterioration of cmEP and TA left	Deterioration of sensorimotor deficits L4–S1 left	2 months complete

In the literature, the few reports on intraoperative monitoring during surgical decompression of the thoracic spine are case reports.

Previous reports [1] clearly demonstrated that, for technically demanding procedures such as decompressions in the thoracic spine, a multimodal approach of monitoring is essential in order to monitor the whole functional integrity of the spinal cord. But even with the multimodal approach it is difficult to prevent every aspect of damage to the neural structures as demonstrated in the one false negative case. In the 39-year-old male with achondroplasia, it was impossible to record cerebro-muscular evoked potentials from the pectineus muscle because of the extreme shortness of the legs. Another difficulty in monitoring the thoracic spine is monitoring the nerve roots and missing a target muscle that is not innervated by multiple nerve roots. In addition, it is usually inconvenient or impossible to monitor the paravertebral muscles.

The one false negative case in our series is due to postoperative neurological deficits in nerve roots that we were not able to monitor and which recovered within 3 months. The one false positive case with reduction of all cerebro-muscular evoked potentials could probably have been prevented using a rostral entrance control.

Two of the three true positive cases recovered within 2 to 6 months, one recovered only partially.

The remaining 31 true negative cases are an expression of the surgical skill and of the good cooperation between surgeons and the neurologists alerting the surgeon whenever a significant change of evoked potentials occurred in order to adapt the procedure.

In summary, the multimodal approach to intraoperative monitoring in thoracic spine surgery proves to be a valid and reliable method to contribute to the improvement of the quality of spine surgery in the thoracic spine and to prevent or reduce neurological damage.

Acknowledgments Dr. Lote Medicus fund for the financial support of the development of MIOM at the Schulthess Clinic. Dave O’Riordan and Charles McCammon for helping with the manuscript. Anne Mannion PhD for the critical review of the manuscript. A special thanks to professor Arnaldo Benini who supported the study with his patients.

Conflict of interest statement None of the authors has any potential conflict of interest.

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