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Prevention and prediction of postoperative bowel bladder disorder using an anal plug electrode with Tc-MsEP monitoring during spine surgery

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ABSTRACT

A retrospective study was performed to examine the efficacy of intraoperative monitoring of the external anal sphincter (EAS) muscle-evoked potential after a transcranial muscle-action potential (Tc-MsEP) in spinal cord surgery, and to evaluate alarm points for EAS waveform deterioration related to postoperative bowel bladder disorder (BBD). BBD is caused by damage to the hypogastric, pelvic, and pudendal nerves and leads to a significant reduction in quality of life. Intraoperative Tc-MsEP monitoring using the EAS is common to prevent neurological deficit, but the relationship of BBD with intraoperative monitoring of the EAS has not been examined. Waveform derivation from the EAS using a plug-type surface electrode was investigated in 123 spine surgeries in which Tc-MsEP was recorded intraoperatively outside the anal sphincter. An acceptable baseline waveform from the EAS was detected in 105 of the 123 cases (85.3%). Preoperative BBD was present in 16 cases, postoperative BBD occurred in 8 cases, and intraoperative waveform deterioration from the EAS was detected in 25 cases. The derivation rate was significantly lower in cases with preoperative BBD compared to those without BBD (62.5% vs. 88.9%, $p<0.01$). Waveform deterioration from the EAS had a sensitivity of 100%, specificity of 93.0%, positive predictive value of 50%, and negative predictive value of 100% for detection of postoperative BBD. All postoperative BBD was detected with an EAS amplitude decrease to <30% of baseline. Therefore, in spine surgery, a Tc-MsEP intraoperative EAS amplitude decrease to <30% of the control waveform may be useful for prediction of postoperative BBD.

Keywords: external anal sphincter, intraoperative spinal cord monitoring, Tc-MsEP, bowel bladder disorder, spinal surgery

INTRODUCTION

Bladder and rectal function are influenced by the hypogastric, pelvic and pudendal nerves.

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Damage to these nerves may result in serious loss of excretory function and significant reduction of quality of life. Bowel bladder disorder (BBD) occurs relatively commonly after spinal surgery for conditions such as spina bifida and spinal cord tethered syndrome. Intraoperative monitoring of the external anal sphincter (EAS) was first reported in the 1970s[1] and monitoring of transcranial muscle-action potentials (Tc-MsEPs) using the EAS is now widely performed in spinal surgery to prevent intraoperative neurological deficit.[2-12] However, the relationship of BBD with intraoperative monitoring of the EAS has not been examined. Therefore, the purpose of this study was to examine the significance and characteristics of use of an anal electrode in Tc-MsEP spinal cord monitoring and to evaluate the incidence of postoperative BBD and alarm points for EAS waveform deterioration.

MATERIAL AND METHODS

Patients

The subjects were 123 patients with recorded Tc-MsEPs outside the anal sphincter during spine surgery at our hospital. The study was approved by our Institutional Review Board (IRB No. 354-3) and each patient provided informed consent before enrollment. There were 57 males and 66 females, and the mean age at surgery was 49.2 years (range 8-86 years). There were 34 cervical cases (27.6%), 54 thoracic cases (43.9%), and 35 lumbar cases (28.5%) (Table 1). Details of diagnoses are shown in Table 1. Waveform derivation from the EAS in intraoperative Tc-MsEP was investigated based on a change in amplitude compared to the control waveform, and the relationship with occurrence of postoperative BBD was examined. A total of 2036 muscles were chosen for monitoring and acceptable baseline Tc-MsEP responses were obtained

Table 1 Characteristics of the patients.

Item	Number or mean ± SD (n=123)
Background	
Age (years)	49.2±18.3
Female	66
Region of spine	
Cervical	34
Thoracic	54
Lumbar	35
Diagnosis	
Spinal tumor (cervical, thoracic)	33
OPLL, OYL	20
Lumbar degenerative disease	17
Scoliosis (idiopathic, congenital)	14
Lumbar intradural extramedullary tumor	11
Cervical spondylosis myelopathy	5
Tethered cord syndrome	4
Cervical involvement in rheumatoid arthritis	3
Others	16

OPLL, ossification of posterior longitudinal ligament; OYL, ossification of yellow ligament.

from 1814 (89.1%). Bladder bowel function was based on JOA scores before and after surgery, with a decline of >1 point defined as postoperative BBD.

Anesthetic management and general conditions during surgery

A minimal benzodiazepine dose was used as preanesthetic medication to avoid possible suppression of waveform latency and amplitude. Propofol (3-4 mg/kg), fentanyl (2 mg/kg), and vecuronium (0.12-0.16 mg/kg) were administered for induction, and anesthesia was maintained with propofol (50-100 μg/kg/min), fentanyl (1-2.5 μg/kg/h), and vecuronium (0.01-0.04 mg/kg/h). Concomitant hypotensive anesthesia was given as appropriate with continuous PGE1 and a short-acting β1 blocker (landiolol). Patients were maintained in a normothermic state and the temperature was raised in the event of possible intraoperative spinal damage. End-tidal CO_2 was maintained in the reference range throughout surgery. For intraoperative body temperature monitoring, a catheter with a vesical temperature sensor was used. Hemodynamic data were electronically recorded with invasive arterial BP monitoring. Systolic blood pressure was measured during surgery and was determined at the time of waveform deterioration.

Stimulation and recording methods

A MS120B (Nihon Kohden, Tokyo, Japan) was used to perform transcranial stimulation. The stimulation parameters were 5 stimuli in a row at 2-ms intervals, a constant biphasic current of 200 mA for 500 μs, a 50-1000 Hz filter, and a 100-ms epoch time with ≤20 recorded signal responses. The stimulated point was 2 cm anterior and 6 cm lateral from the Cz location over the cerebral cortex motor area. Using the Neuromaster MEE-1232 ver. 05.10 (Nihon Kohden, Japan), which is expandable to 32 channels, muscle action potentials were recorded from the upper and lower extremities via a pair of needle electrodes 3 to 5 Tc-MsEPs apart. The bilateral trapezius, triceps, deltoid, biceps, brachioradialis, abductor digit minimi, extensor carpi ulnaris, adductor longus, quadriceps femoris, hamstrings, tibialis anterior, gastrocnemius (GC), and abductor halluces (AH) were used as target muscles. For anal sphincter muscles, a 2-channel surface plug-type electrode was applied to the EAS (Figure 1). Tc-MsEP data from these muscles were used for analysis. Multimodal monitoring was used in all cases, with a particular combination of brain stimulated spinal cord evoked potentials (D-wave) and somatosensory evoked potentials. Free running electromyography (EMG) from all the above muscles was monitored throughout

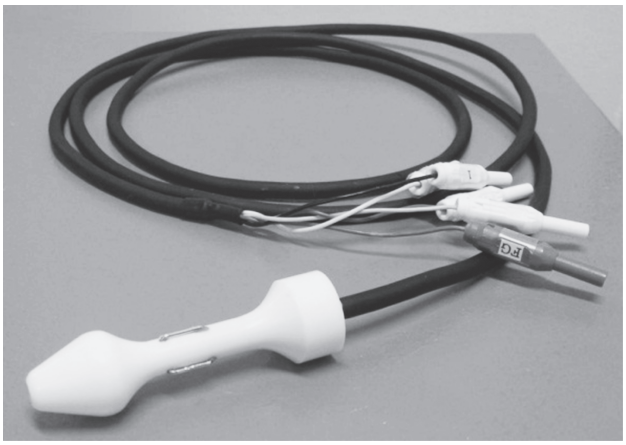

Fig. 1 Surface plug-type electrode for the external anal sphincter (Nihon Kohden Co., Ltd).

the operation.

Statistical analysis

Significance was assessed by Student t-test or Fisher exact test at $P < 0.05$. Data analysis was performed with SPSS ver. 22 for Windows (IBM, Chicago, IL, USA).

RESULTS

An acceptable baseline waveform from the EAS was detected in 105 of the 123 surgeries, giving a derivation rate of 85.3%. The waveform derivation rate for each disease is shown in Figure 2. Preoperative BBD was present in 16 cases, postoperative BBD occurred in 8 cases, and intraoperative waveform deterioration from the EAS was detected in 25 cases. The derivation rate was significantly lower in cases with preoperative BBD compared to those without BBD (62.5% vs. 88.9%, p<0.01). (Table 2). Waveform deterioration from the EAS had a sensitivity of 100%, specificity of 93.0%, positive predictive value (PPV) of 50%, and negative predictive value (NPV) of 100% for prediction of postoperative BBD (Table 3).

Deterioration rates compared to the control waveform in cases with and without BBD are shown in Figure 3. Cases with postoperative BBD all had decreases of intraoperative amplitude to <30% of the control waveform, with a significant difference between the groups (51±12% vs. 17±10%, p<0.01) (Figure 3).

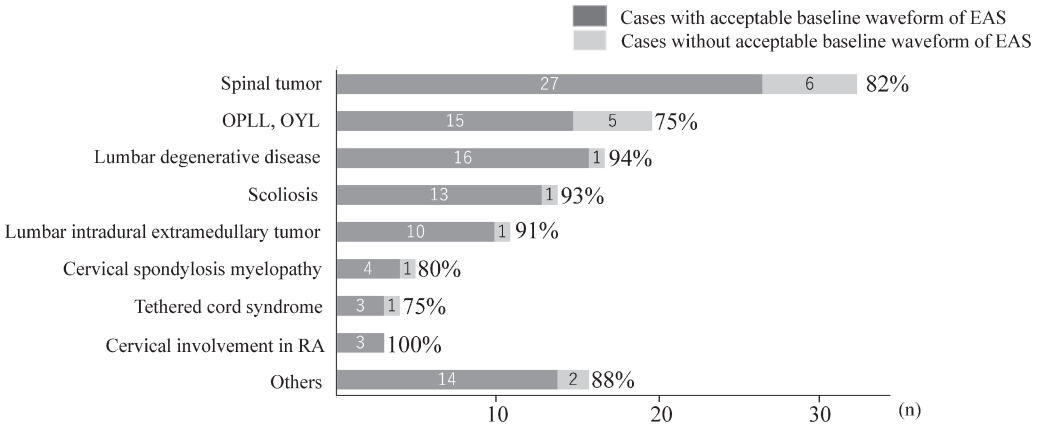

Fig. 2 Waveform derivation rate for each disease.
OPLL, Ossification of posterior longitudinal ligament; OYL, Ossification of yellow ligament; RA, Rheumatoid arthritis.

Table 2 Derivation rate of transcranial muscle-action potential (Tc-MsEP) of the external anal sphincter (EAS) in cases with and without preoperative bladder bowel disorder (BBD).

	With BBD (n=16)	Without BBD (n=107)	Total (n=123)
Waveform derivation rate	62.5% (10/16)	88.9%* (95/107)	85.3% (105/123)

* P=0.001 for cases with BBD vs. without BBD.

Table 3 Relationship of postoperative bowel bladder disorder (BBD) with waveform deterioration from the external anal sphincter (EAS).

	Postoperative BBD		
	Present	Absent	Total
Waveform deterioration (+)	8	8	16
Waveform deterioration (-)	0	107	107
Total	8	115	123

Note: sensitivity = 100%, specificity = 93.0%, positive predictive value (PPV) = 50%, negative predictive value (NPV) = 100%.

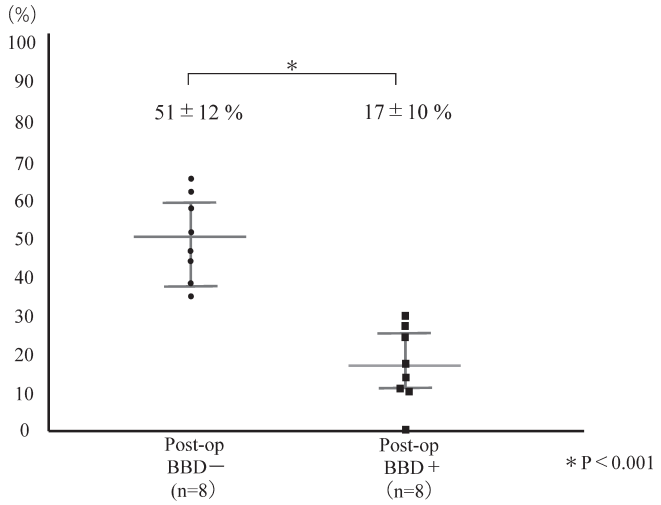

Fig. 3 Deterioration rates compared to the control waveform in cases with and without postoperative bowel bladder disorder (BBD).
Note: There was a significant difference in rates between the two groups ($p<0.01$).

Illustrative case

The patient was an 8-year-old girl with tethered cord syndrome due to lipoma. She had frequent urination and bladder and rectal leakage disorder without motor deficiency of the lower limbs. She underwent surgery with untethering and lipoma resection. In surgery, the dura of S2-S4 was highly adherent to the lipoma. After exfoliation of the lipoma, an abnormal wave appeared in the sphincter on free run EMG, so lipoma resection was abandoned. Peeling in the caudal direction outside the epidural duct and cut off of the caudal end thread were performed. At that time, waveforms deteriorated for the left TA, GC, AH and sphincter, and right quad and sphincter (Figure 4). The EAS waveform decreased to 3.0 μV (29.1% of the control) on the left and to 5 μV (23.8% of the control) on the right. Subsequently, waveform recovery was not apparent. Postoperatively, there was no motor deficiency, but BBD worsened and intermittent urination has occurred for 6 months.

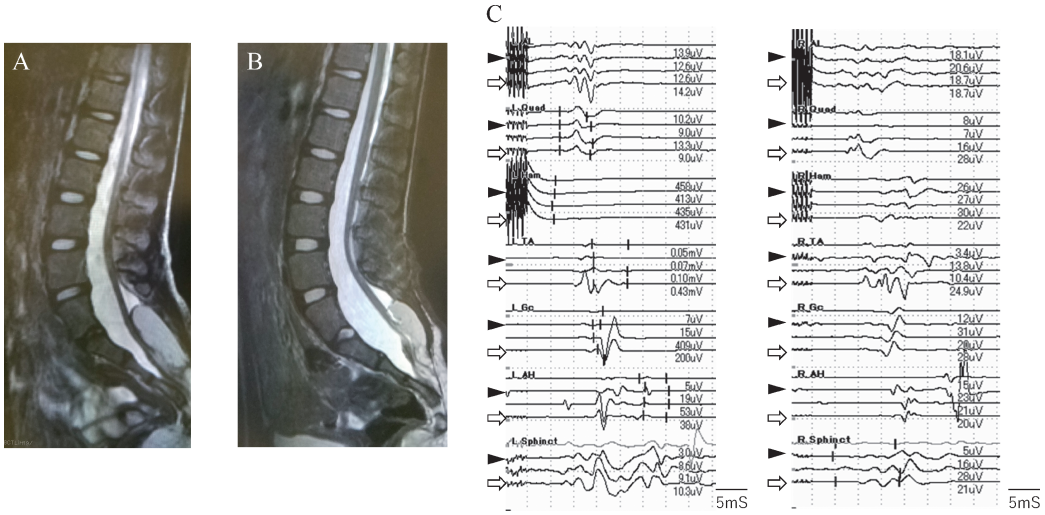

Fig. 4

(A) An 8-year-old girl with tethered cord syndrome due to lipoma shown in preoperative sagittal T2-weighted MRI.

(B) In surgery, peeling in the caudal direction outside the epidural duct and cut off of the caudal end thread were performed, as shown in postoperative sagittal T2-weighted MRI.

(C) In surgery, acceptable baseline waveforms were obtained in transcranial muscle-action potential (Tc-MsEP) (open arrow).

Note: During surgery, waveforms deteriorated for the left TA, GC, AH, and sphincter, and right quad, and sphincter (arrowheads). Finally, the external anal sphincter (EAS) waveform decreased to 3.0 μV (29.1% of the control) on the left and by 5 μV (23.8% of the control) on the right.

DISCUSSION

Intraoperative spinal cord monitoring is important for performance of safe spinal surgery to avoid a neurological deficit. Somatosensory evoked potentials (SSEPs), spinal cord evoked potentials after brain stimulation (Br-SCEP, D wave), free-running EMG, spinal cord evoked potentials after stimulation of the spinal cord (Sp-SCEP) or the peripheral nerve (Pn-SCEP), and Tc-MsEP have been used for this purpose.

In 1953, Floyd and Walls described EMG using a surface electrode placed on the skin of the anus.[2] Thereafter, various electrophysiological tests on bladder rectal function have been developed. Intraoperative monitoring of the EAS has been used since the 1970s, and many institutions currently perform Tc-MsEP including the EAS for prevention of intraoperative paralysis in spinal surgery. The EAS is dominated by pudendal nerve branches from S2 to S4, forming a reflex arc. Even at rest, an action potential is present, and this potential is suppressed by bearing down reflectively, with resultant discharge of feces. These features are not seen in other interosseous muscles. The action potential at rest is lost with damage to the posterior funiculus, leading to difficulty in contraction of the anal sphincter.[3]

In our series, the waveform derivation rates from the EAS were 86.6% in patients without BBD (71/82 cases), and acceptable baseline Tc-MsEP responses from all muscles were obtained at a similar rate of 89.1% (1814/2036 muscles). The diseases with low waveform derivation rates were ossification of posterior longitudinal ligament (OPLL), ossification of yellow ligament (OYL), and spinal tumor. These diseases are likely to be accompanied by postoperative paralysis,

and Tc-MsEP monitoring is strongly recommended.[10,11] The amplitude is strongly influenced by the number of muscle fibers at the tip of the electrode[4] and the amplitude for the EAS in Tc-MsEP is similar to that of the biceps;[5] thus, these are comparable to our results. However, the false positive rate was 50% (8/16 cases), which is relatively high and could be due to features peculiar to the surface-type plug electrode.[8]

Several reports have suggested a relationship of postoperative paralysis with waveform deterioration to <30% of baseline,[9-11] but this has not been examined for the EAS. In our series, all 8 cases with postoperative BBD had amplitude decreases to <30% of baseline, which suggests that the alarm point for BBD in Tc-MsEP of the EAS is similar to that in previous reports.[9-11]

This study has several limitations, including the small number of cases and variable diagnoses and surgical lesions, which reduces the power of the statistical analysis. Second, 2-channel plug-surface type electrodes were used for EAS detection, which might have reduced the waveform detection rate and increased the false positive rate, since a needle-type electrode is superior to a surface electrode in EMG of the EAS.[8] The surface electrode is less invasive and can be repeatedly used without difficulty, but use of a needle-type electrode may result in improved waveform detection.

Within these limitations, this is the first study to examine the relationship of postoperative BBD with intraoperative monitoring of the EAS during spinal surgery.

All postoperative BBD could be detected with amplitude decreases to < 30% of baseline. Intraoperative waveform deterioration of the EAS was predictive of postoperative BBD with a sensitivity of 100%, specificity of 93.0%. PPV of 50%, and NPV of 100%. Therefore, we suggest that intraoperative monitoring of the EAS in spine surgery could be useful for prediction of postoperative BBD.

CONFLICT OF INTEREST

None of the authors have a conflict of interest. Funding was from institutional sources only.

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