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Intraoperative Neuromonitoring Auxiliary Significance of DNEP for MEP-positive Event During Severe Spinal Deformity Surgery

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Study Design: This was a retrospective analysis.

Objective: The objective of this study was to assess the intraoperative neuromonitoring auxiliary significance of descending neurogenic–evoked potential (DNEP) for motor-evoked potential (MEP) during severe spinal deformity surgery when MEP-positive event occurs.

Summary of Background Data: MEP detection is the most widely applied neurological monitoring technique in spinal deformity surgery. MEP is quite vulnerable to anesthesia, blood pressure, and other intraoperative factors, leading to a high false-positive rate of MEP (3.2%–45.0%), which has greatly interfered with the surgical process. At present, the widely used "presence-or-absence" alarm criteria of MEP is not enough to solve the problem of false positive of MEP.

Methods: A total of 205 cases undergoing severe spinal deformity correction were retrospectively studied. Overall, 74 MEP-positive cases were classified as 2 subgroups: DNEP (+) and DNEP (−) groups. The MEP recovery, wake-up test, and Frankle grade were used to assess the neurological functions. The perioperative and long-term neurological outcomes were assessed.

Results: There were significant differences in preoperative scoliosis angle and kyphosis angle between DNEP (−) and DNEP (+) groups. Patients in DNEP (−) group showed more MEP improvement (81.5%), compared with the DNEP (+) group (53.2%). The Wake-up test showed 59.3% motor function deficit cases in DNEP (−) group, which was lower than the 87.2% in DNEP (+) group. More patients in DNEP (−) group had normal nerve function (Frankel level E) than those in DNEP (+) group immediately after surgery, as well as at follow-up.

Conclusions: MEP-positive cases with intraoperative DNEP (−) showed superior prognosis after severe spinal deformity surgery. Intraoperative DNEP could be regarded as an important quantitative tool to assist MEP to monitor neurological injury and can serve as a temporary substitution monitoring technique after MEP is lost.

Key Words: severe spinal deformity surgery, intraoperative neuroelectrophysiological monitoring, motor-evoked potentials, descending neurogenic–evoked potentials, neurological prognosis

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Ischemic injury of the spinal cord is one of the severe complications during spinal deformity surgery, especially in the surgery for severe rigid spinal deformity. Nonetheless, complex screw placement, osteotomy, and correction maneuvers have markedly increased the risk of spinal cord ischemia injury, leading to postoperative neurological deficit. Previous studies demonstrate that the incidence of postoperative neurological complications is 4.0%–21.2%.[1–5] The surgeons need to immediately identify the real neurological injury events during the high-risk surgical procedures (such as screw insertion, osteotomy, and correction) of severe rigid spinal deformity surgery so that they can take immediate standardized measures (like intraoperative intervention or methylprednisolone pulse therapy) to avoid the postoperative neurological injury.[6] Consequently, intraoperative neurophysiological monitoring (IONM), including motor-evoked potential (MEP), somatosensory-evoked potential (SSEP), and descending neurogenic–evoked potential (DNEP), have been commonly applied as a real-time neurological monitoring technique in spinal deformity surgery, to detect the neurological injury during the operation.[7,8]

MEP detection is the most widely applied and effective neurological monitoring technique in spinal deformity surgery, and even in the whole spinal surgery. MEP contributes to detect the descending motor system integrity, including both lateral and anterior corticospinal tracts, which are sensitive to ischemia. Various studies have demonstrated the neuromonitoring effectiveness of MEP application during spinal deformity surgery.[9–11] However, MEP detection is quite vulnerable to anesthesia, blood pressure, and other intraoperative factors during the neurological

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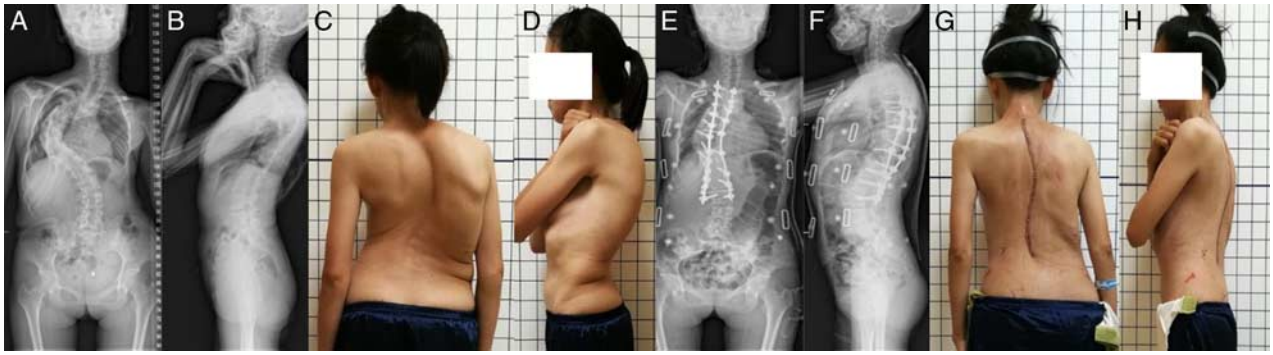

FIGURE 1. A 27-year-old woman with a severe and stiff scoliosis (A–D). She was treated with a long posterior reconstruction from T2 to L2 with 1-level grade 5 osteotomies at T8 (E–H).

monitoring process, leading to a high false-positive rate of MEP (3.2%–45.0%),[12–17] which has greatly interfered with the surgical process. The incidence of false-positive events may occur if neurological deficits are judged based on MEP alone even with the "presence-or-absence" approach. The false-positive events of MEP will increase the unnecessary surgical procedures and extend the operation time due to the presence of potential confounder for the false-positive results, thus adding to the potential risk of nerve injury. At present, the widely used "presence-or-absence" alarm criteria of MEP is not enough to solve the problem of false positive of MEP. On this account, other intraoperative predictors of spinal cord ischemia should be identified to monitor spinal cord injury as a supplement to MEP monitoring and reduce the false-positive events of IONM.

DNEP, the third neurological monitoring method in addition to MEP and SSEP, has been demonstrated to be of high sensitivity and specificity to injury of the spinal cord during spinal deformity surgery, especially in patients with severe scoliosis and neuromuscular scoliosis. Compared with MEP, DNEP is less affected by intravenous anesthetics, blood pressure, and other intraoperative factors.[12,18] DNEP application may avoid the interference of MEP false-positive events during the surgical process.[19,20] However, little is known about the auxiliary value of DNEP for MEP during spinal deformity surgery. Change in the intraoperative DNEP may allow for the accurate judgment of positive events of MEP during scoliosis surgery.

This study aimed to retrospectively analyze the data from 205 cases undergoing severe thoracic 3-column spinal osteotomy correction in our center and to evaluate prospectively the accuracy of intraoperative DNEP change in estimating the positive events of MEP during severe thoracic 3-column spinal osteotomy correction.

METHODS

Clinical Data

From May 2008 to February 2017, a total of 205 severe thoracic 3-column spinal osteotomy correction cases treated in our center were retrospectively analyzed in this study (Fig. 1). All operations were monitored intraoperatively by combining MEP, SSEP, and DNEP. The cases were enrolled with the following inclusion criteria: (1) patients receiving severe thoracic deformities surgery with MEP-positive event; (2) patients with no preoperative neurological deficits (Frankel grade E); (3) patients with complete IONM data and follow-up data of neurological function (>1 y); (4) patients whose baseline of intraoperative MEP and DNEP were successfully detected. Overall, 74 cases with MEP change were enrolled, meanwhile, in which some cases were false-positive events, while others suffered from neurological impairment to various degrees. The false-positive event criteria were as follows: (1) there was no correlation of intraoperative evoked potentials events and surgical procedures, with recovery only after observation or routine treatment; (2) No recovery or incomplete recovery of MEP amplitude after routine treatment when there was no corresponding postoperative neurological injury. To more accurately analyze the prognostic value of intraoperative DNEP degeneration (<80% DNEP amplitude) in the presence of MEP degeneration, patients were divided into 2 subgroups, namely, DNEP (−) (n=27) (Fig. 2) and DNEP (+) (n=47) groups (Fig. 3). Afterward, the postoperative neurological functions and other related factors were compared within each group. Table 1 shows the clinical characteristics of the MEP-positive patients.

Anesthesia

General anesthesia for spinal deformity correction was conducted as described in a previous study[21] To avoid the interference of inhalation anesthesia on MEP, total intravenous anesthesia was used during the whole surgery. Propofol of 1.5–2 mg/kg, 3–5 μg/kg of fentanyl, and 0.15–0.2 mg/kg of cisatracurium were routinely used for anesthesia induction. Then, the anesthesia was maintained using remifentanil (0.2–0.5 μg/kg/min) and propofol (5–6 mg/kg/h). Nondepolarized muscle relaxants were used to assist in tracheal intubation during anesthesia induction, and then no muscle relaxant was used during the whole course (only at the exposure stage, if necessary), to reduce the inhibitory effect of muscle relaxants on the MEP.

Standardized Intraoperative Procedures for MEP-positive Patients

The specific procedures were as follows when MEP changes: (1) To stop the operation intraoperatively and elim-

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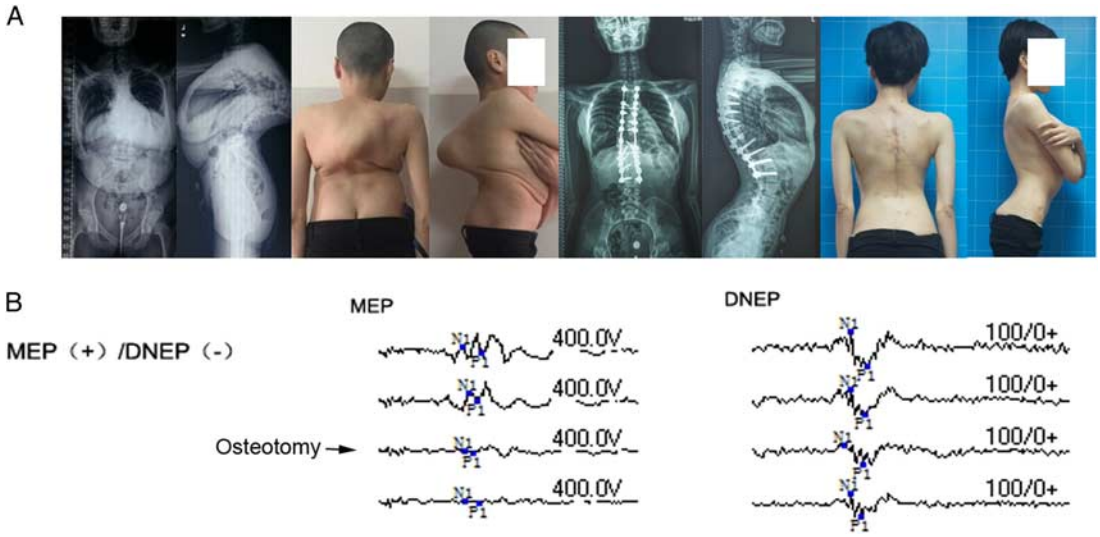

FIGURE 2. Case in [MEP(+)/DNEP (+)] group. Views of a 20-year-old case with severe and rigid spinal deformity with normal spinal cord function (Frankel level E) before operation. A, She was treated with a long posterior reconstruction from T1 to L4 with 1-level grade 6 osteotomies at T9–T10. B, When T9–T10 vertebral column resection was performed, the MEP and DNEP amplitude of both lower limbs disappeared and did not recover after the operation. Results of the wake-up test: no movement of both lower limbs. Postoperative immediate spinal cord function reduced to Frankel level B and tended to be normal (Frankel level E) at postoperative 9 months. DNEP indicates descending neurogenic–evoked potential; MEP, motor-evoked potential.

inate the equipment failure (including electrode needle and thread falling off); check the current anesthesia and physiological states (such as anesthetic potency, muscle relaxants, inhalation gas, and blood pressure); and properly increase the blood pressure and reduce the anesthesia depth. (2) To intravenously inject high-dose methylprednisolone when monitoring events persist. (3) To check the tension of spinal cord tissue and decompress the tension properly if necessary. A Wake-up test was performed if monitoring events persist. (4) If the wake-up test was positive, terminate immediately the high-risk op-

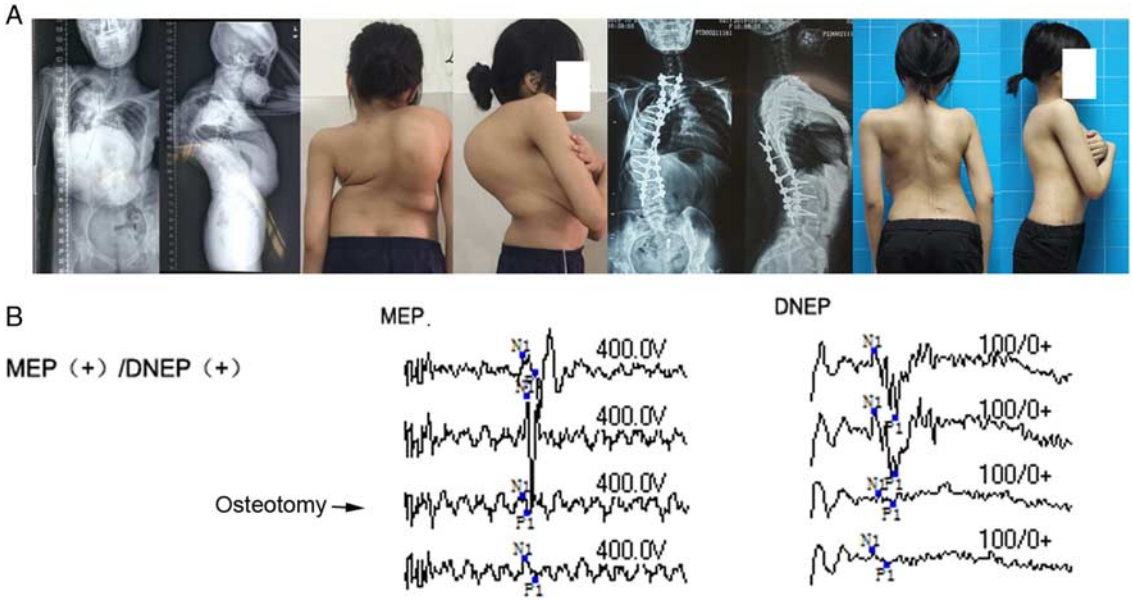

FIGURE 3. Case 2 in [MEP(+)/DNEP (–)] group. Views of a 28-year-old case with severe and rigid spinal deformity with normal spinal cord function (Frankel level E) before operation. A, She was treated with a long posterior reconstruction from T2 to L3 with 1-level grade 6 osteotomies at T10–T11. B, When T10–T11 vertebral column resection was performed, the MEP amplitude of both lower limbs disappeared, while DNEP existed. The electrophysiological signal was not improved until the end of the operation. Results of the wake-up test: no movement of both lower limbs. Postoperative immediate spinal cord function tended to be normal (Frankel level E). DNEP indicates descending neurogenic–evoked potential; MEP, motor-evoked potential.

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TABLE 1. The General Data of Patients With Intraoperative MEP Variations

Characteristics	Mean ± SEM
No. MEP events	74/205
Age (y)	22.30 ± 1.02
Sex (male/female)	73:132
Preoperative angle of scoliosis (deg.)	120.82 ± 2.21
Preoperative angle of kyphosis (deg.)	115.62 ± 3.21
MEP recovery	47/74
Wake-up test (+)	38/74
Neurological deficit	40/74
False-positive rate of MEP	10/74
Neurological deficit (d)	
Immediately after operation	40/74
Postoperative 3 d	32/74
Postoperative 7 d	29/74
Postoperative 1 mo	20/74
Postoperative 6 mo	10/74
Postoperative 12 mo	2/74
Bleeding volume (mL)	2982.97 ± 346.69
Operation time	512.26 ± 17.99
Etiology of MEP events	Screw insertion (11), osteotomy (44), correction (19)

MEP indicates motor-evoked potential.

eration, loosen the internal fixator, and an O-arm examination was performed if necessary. (5) To perform laminectomy and decompression on the areas where spinal cord compression might exist if the monitoring events still existed; in the meantime, to remove the internal fixation while maintaining the spinal stability until MEP amplitude was improved. (6) If the MEP amplitude remained unimproved, the serious neurological complication should be identified and the operation should be terminated immediately.

IONM Alarm Criteria and Assessment of Postoperative Neurological Complications

In the present study, MEP alarm was set as following: when MEP amplitude disappeared in unilateral or bilateral lower extremities, repetitive or increased stimulation intensity could not be recorded after excluding the nonoperative factors (including anesthesia, blood pressure, and instruments), and the MEP amplitude was not restored within 10 minutes.[22] The significance level of the DNEP alarm was set at over 2 averaged trials with an 80% reduction in primary DNEP amplitude or >10% extension in the response latency compared with baseline level (Fig. 4).[6] A routine wake-up test was performed immediately after surgery. The clinical neurological function was evaluated at immediately after surgery, 3 days, 7 days, 1, 6, and 12 months postoperatively. The spinal cord function was assessed according to the Frankel grading method.

Statistical Methods

The demographical and clinical data of MEP-positive patients were summarized by descriptive statistics. The independent t test and χ^2 test were utilized using SPSS 19.0 (SPSS Inc., Chicago, IL), with an α level of 0.05.

RESULTS

Severe Thoracic 3-column Spinal Osteotomy Correction Cases

A total of 205 severe thoracic 3-column spinal osteotomy correction cases were enrolled from our center during the study period. As shown in Table 1, 74 of these 205 cases had met the inclusion criteria. Among all the 74 MEP-positive cases, 47 achieved MEP improvement intraoperatively, and 40 had neurological deficit postoperatively with a high false-positive rate (13.5%, 10/74) of MEP. Then, the neurological outcomes of MEP-positive patients were assessed immediately after surgery, as well as at 3 days, 7 days, 1, 6, and 12 months postoperatively. Most patients with neurological impairment tended to be normal (Frankel level E) during the postoperative neurological rehabilitation, but 2 cases had a neurological deficit at 1-year follow-up after surgery. The MEP-positive events mainly occurred at the screw insertion (n = 11), osteotomy (n = 44), and correction (n = 19) stages of surgery. The intraoperative blood loss was 2982.97 ± 346.69 mL.

Prognostic Significance of Intraoperative DNEP Change

To more clearly analyze the prognostic significance of intraoperative DNEP change (<80% DNEP amplitude) in the presence of MEP degeneration with a high false-positive rate (13.5%, 10/74), 74 MEP-positive cases were divided into 2 subgroups, namely, DNEP (−) group (n = 27) and DNEP (+) group (n = 47). As shown in Table 2, there were

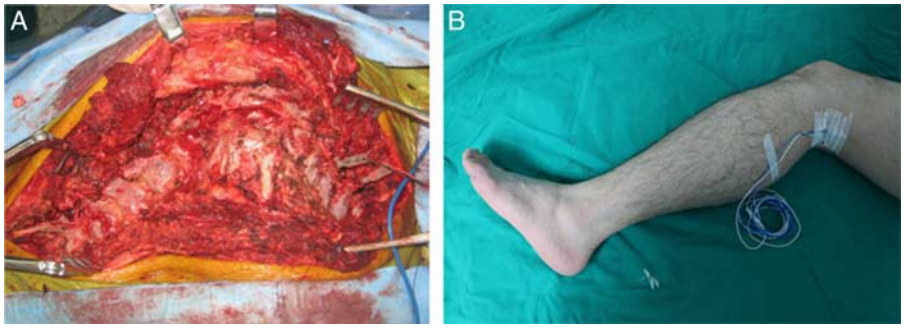

FIGURE 4. A, Two 15 mm JO-5 spinous process stimulation electrodes were directly inserted into the adjacent spinous process at the rostral end of the surgical incision. B, Recording electrodes are usually placed in the peripheral nerve conduction pathway (tibial nerve or common peroneal nerve) in the popliteal fossa to collect signals.

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TABLE 2. The Demographic and Operative Data for Both Groups

Parameters	Mean ± SEM		
	DNEP (−) (N = 27)	DNEP (+) (N = 47)	*P*
Age (y)	21.78 ± 2.11	22.60 ± 1.06	0.702
Sex (male/female)	11:16	20:27	0.879
Preoperative angle of scoliosis	115.00 ± 3.35	124.17 ± 2.81	0.045
Preoperative angle of kyphosis	105.15 ± 5.13	121.64 ± 3.90	0.013
MEP recovery	22/27	25/47	0.015
Wake-up test (+)	8/27	30/47	0.005
Neurological deficit			
Immediately after operation	10/27	30/47	0.026
Postoperative 3 d	5/27	27/47	0.001
Postoperative 7 d	4/27	25/47	0.001
Postoperative 1 mo	1/27	19/47	0.001
Postoperative 6 mo	0/27	10/47	0.010
Postoperative 12 mo	0/27	2/47	0.277
False-positive rate of MEP	10/27	0/47	0.000
Bleeding volume	2041.43 ± 290.78	3556.09 ± 496.52	0.013
Operation time	484.73 ± 29.49	527.49 ± 22.61	0.258
Etiology of MEP event	Screw insertion (6), osteotomy (19), correction (2)	Screw insertion (5), osteotomy (25), correction (17)	—

DNEP indicates descending neurogenic–evoked potential; MEP, motor-evoked potential.

significant differences in preoperative scoliosis (115.00 ± 3.35 vs. 124.17 ± 2.81 degrees) and preoperative angle of kyphosis (105.15 ± 5.13 vs. 121.64 ± 3.90 degrees) between DNEP (−) and DNEP (+) groups. In addition, the MEP events in DNEP (−) group mainly occurred at osteotomy (70.4%, 19/27), screw insertion (22.2%, 6/27), and correction (7.4%, 2/27) stages. Meanwhile, the MEP events in DNEP (+) group mainly occurred at osteotomy (53.2%, 25/47), correction (36.2%, 17/47), and screw insertion (10.6%, 5/47) stages. Furthermore, DNEP (+) group suffered from a greater blood loss (3556.09 ± 496.52) than that in DNEP (−) group (2041.43 ± 290.78) ($P = 0.013$). The above results indicated that the DNEP (+) group was linked with higher surgical risk compared with the DNEP (−) group. In DNEP (−) group, 81.5% (22/27) patients achieved MEP improvement, which was significantly different from that in DNEP (+) group (53.2%, 25/47). In the wake-up test, 29.6% (8/27) cases in DNEP (−) group showed motor function deficit, which was less than the 63.8% (30/47) in DNEP (+) group. The neurological outcomes were assessed immediately after surgery, as well as at 3 days, 7 days, 1, 6, and 12 months postoperatively. According to our findings, the 2 groups tended to be normal (Frankel level E) during the postoperative neurological rehabilitation. Nonetheless, more patients in DNEP (−) group had normal neurological function than in those in the DNEP (+) group immediately after surgery, as well as at 3 days, 7 days, 1, and 6 months postoperatively. The above results indicated that patients with DNEP (−) had much less severe neurological impairment than those with DNEP (+) in the presence of MEP degeneration. In addition, there were more false-positive MEP events in DNEP (−) group (37.0%, 10/27). However, there was no false-positive MEP event in the presence of DNEP, indicating that DNEP application might avoid the interference of MEP false-positive events.

DISCUSSION

The neurological deficit remains one of the most devastating complications in spinal surgery, especially in severe rigid spinal deformity surgery. Complex screw insertion, correction maneuvers, and osteotomy markedly increase the risk of spinal cord ischemia injury, leading to postoperative neurological deficit. Previous studies demonstrate that the incidence of postoperative neurological complications is 4.0%–21.2%.[1–4] Intraoperative MEP monitoring has been widely used in spinal deformity surgical procedures, to monitor the neurological deficit. Lenke et al[2] found that the incidence of MEP-positive events in vertebral column resection patients was as high as 20%, and that of postoperative neurological deficit was about 5.7%. According to Kelly et al,[4] the total incidence of neurological complications following 3-column osteotomy was 9.9%, while that after vertebral column resection was 15.8%. Severe thoracic deformity has increased the risk of neurological injury since the thoracic spinal cord is sensitive to ischemia, narrower spinal canal, and more rigid scoliosis, resulting in higher rates of intraoperative monitoring events and neurological complications.

Nonetheless, MEP is highly sensitive to various factors during the intraoperative monitoring process, including the minor degree of motor tract deterioration.[23,24] Therefore, the incidence of false-positive events is quite high if the neurological deficits are judged based on MEP alone. At present, the widely used "presence-or-absence" alarm criteria of MEP is not enough to solve the problem of false positive of MEP. MEP detection is quite vulnerable to anesthesia, blood pressure, and other intraoperative factors that affect oxygen delivery to the spinal cord (such as hypotension, hypoxia, and anemia) during the neurological monitoring process, leading to a high false-positive rate of MEP (3.2%–45.0%),[12–16] which interferes with the surgical process. Compared with intravenous anesthesia, the inhalational anesthetic method appears to exert a more inhibitory effect on MEP amplitude.[25–27] Compared with intravenous anesthesia, lower and more variable MEP waveforms are noted under inhalational anesthesia, which need higher stimulus intensity to obtain.[28] Kim et al[29] reported the 9.6% MEP false-positive events in 52 cases during cervical surgery with an anesthetic scheme containing propofol infusion, isoflurane, and nitrous oxide, which exhibited higher body mass index and longer operation time. Longer operation time in false-positive MEP cases may be involved in the condition of "anesthetic fade" in which the MEP threshold tends to raise.[26] Low MEP waveform that requires a maximal stimulus to gain is prone to lose for that increased stimulus fails to make up for increasing threshold during the long operation. Shida et al[30] demonstrated that

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the evoflurane anesthetic method resulted in lower MEP amplitude (< 50 mV) compared with intravenous anesthesia and indicated that the administration of sevoflurane may contribute to false-positive MEP events. It has been reported that these false-positive neuromonitoring changes can be induced by unstable blood pressure.[18] True-positive findings of MEP during congenital spinal deformity correction in children under age 4 years are rare and low MEP amplitude are common.[31] The anesthesia and other systemic factors, with inconsistent intraoperative monitoring methods, lead to potential false-positive events of MEP during the surgery. In this study, among these 205 cases undergoing severe rigid thoracic deformity surgery, 36.10% (74/205) had MEP-positive events, including 54.05% (40/74) with neurological complications, with a high false-positive rate of MEP (13.5%, 10/74). Besides, the false-positive events of MEP will increase the unnecessary surgical procedures and extend the operation time due to a potential confounder for false-positive results, thus significantly increasing the potential risk of neurological injury. Consequently, more intraoperative predictors of spinal cord ischemia should be identified to judge the false-positive events of MEP.

DNEP, the third neurological monitoring method in addition to MEP and SSEP, has been noted to be of high sensitivity and specificity to spinal cord injury during spinal deformity surgery, especially in patients with severe scoliosis and neuromuscular scoliosis. Our experience showed that the intraoperative DNEP change allowed for the accurate judgment of MEP-positive events during the scoliosis surgery. Our work aimed to assess the intraoperative neuromonitoring auxiliary significance of DNEP change in MEP-positive cases during severe thoracic deformity resection. The immediate and long-term postoperative neurological outcomes were evaluated among 2 subgroups, namely, intraoperative DNEP (+) and DNEP (−) groups. According to our findings, MEP-positive cases having intraoperative DNEP (−) during spinal deformity surgery were associated with a superior prognosis of neurological recovery in comparison with that in DNEP (+) group. DNEP application may avoid the interference of MEP false-positive events during the surgical process.[19,20] To investigate the auxiliary significance of intraoperative DNEP for MEP-positive events, the spinal cord recovery outcomes were rigidly followed up (such as immediate and long-term postoperative outcomes). Our results showed that intraoperative DNEP (−) patients following the spinal deformity surgery were associated with a superior prognosis for neurological recovery in comparison with that in DNEP (+) group in MEP-positive cases. Besides, the intraoperative MEP recovery rate in DNEP (−) group was higher than that in DNEP (+) group. Furthermore, the intraoperative blood loss in DNEP (−) group was lower than that in the DNEP (+) group. All these results indicated that patients in DNEP (−) group had much less severe neurological impairment than those in DNEP (+) in MEP-positive cases. Thus, intraoperative DNEP change exerted a vital part to assist MEP in predicting spinal cord recovery in the severe thoracic deformity surgical procedure. There were more false-positive events of MEP in the DNEP (−) group (37.0%, 10/27), while there was no false-positive event of MEP in the presence of DNEP, showing that DNEP application might avoid the interference of MEP false-positive events. DNEP could serve as a temporary substitution monitoring technique to detect neurological events after MEP is lost. On the premise of the high false-positive rate of MEP, our study provided a precise approach that showed a great auxiliary role for MEP to assess neurological complications during severe spinal deformity surgery in MEP-positive cases. This work helped the surgeons to identify the severity of the neurological injury and assist the surgical team in selecting the most appropriate surgical procedure, including proper anesthesia and operation, wake-up test, and even suspension of the operation. Meanwhile, severe spinal deformity osteotomy was associated with an increased risk of neurological injury, and the spinal cord injury site could be located by moving the DNEP electrode along the spinous process during the operation, to immediately identify the etiology of IONM alarm during the surgery, thereby selecting the most appropriate surgical procedure.[32]

What is the reason for the above observations? The pathways monitored by DNEP remain a source of controversy. It has been reported that DNEP signals can be used to detect the somatosensory and motor tracts.[33] Another view is that DNEP represents the sensory descending spinal cord conduction tract rather than the motor tract, and are not a reliable indicator to detect the motor tract.[34] Our experience is more inclined to support the former view. DNEP monitoring has a better effect than traditional SSEP monitoring on recognizing the injury to the spinal cord with high sensitivity (100% vs. 51%).[35] The combined application of SSEP, MEP, and DNEP accurately detected permanent neurological deficit in 99.6% of 3436 cases during spine surgery and decreased the total number of permanent neurological deficit to 6.[36] The author suggested that there was only 1 case (of the total 74 deficits) whose DNEPs failed to estimate the occurrence of postoperative neurological deficit.[36] Furthermore, the sensory and motor pathways are anatomically adjacent to each other in the spinal cord. Consequently, sensory tract injury reflected by DNEP partially reflects the severity of motor pathway injury. Meanwhile, the lower false-positive rate is helpful to reduce the interference of MEP sensitivity to surgery.[19,20] Compared with MEP, DNEP is less affected by intravenous anesthetics, blood pressure, and other intraoperative factors.[12,18] Another view is that the ischemic tissues in the spinal cord were free from necrosis, instead, neurological functional recovery was temporarily limited during surgery, and the DNEP signal was still monitored while MEP was lost. MEP amplitude was reversible through standardized operation, including decompression and increasing the arterial supply. We concluded that DNEP remained a useful secondary test of spinal cord function, and it served as a supplement to MEP monitoring. On the basis of all the above factors, we consider

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that DNEP could be regarded as an important quantitative tool to assist MEP to establish an effective and reproducible protocol to monitor neurological injury during severe spinal deformity surgery. This may assist the surgeons in selecting the optimal surgical intervention, thus achieving the optimal treatment outcomes.

Prior articles suggest that intraoperative MEPs can sensitively and specifically detect the corticospinal tract integrity in terms of their function.[37,38] Some specific points should be noted. First, it is important to judge the prognosis for surgical patients when MEP is lost. Second, standardized intraoperative procedures for MEP-positive events are of crucial importance to prevent and improve postoperative neurological function injury. In this study, an electrophysiological approach was established to assist MEP to monitor neurological injury and evaluate the postoperative neurological prognosis for severe spinal deformity patients. Thus, intraoperative DNEP is able to assist the surgical team in reducing the incidence of postoperative neurological deficit and offer the reliable factor to predict the postoperative neurological recovery when intraoperative MEP is lost. DNEP application may avoid the interference of MEP false-positive events during the surgical process. DNEP negative cases have much less severe neurological impairment than in DNEP-positive cases in the presence of MEP degeneration. When MEP disappears and DNEP exists, we can consider a 1-stage operation. When both evoked potentials continue to disappear, suggesting a high risk of spinal cord injury, we may consider temporary fixation and second-stage surgery. Meanwhile, our surgical team has established standardized intraoperative procedures for MEP-positive cases during the surgery. Therefore, our study suggests that DNEP combined with MEP, together with the standardized intraoperative procedures, can better improve the postoperative neurological outcomes after severe spinal deformity surgery. However, due to the limitation of our work, it still needs further research with large sample data to verify and the monitoring mechanism of DNEP needs further study.

CONCLUSIONS

DNEP could be regarded as an important quantitative tool to assist MEP to establish an effective and reproducible protocol to monitor neurological injury during severe spinal deformity surgery. MEP-positive cases with DNEP (−) during severe spinal deformity surgical procedure are associated with superior prognosis in immediate and long-term neurological functional recovery. Intraoperative DNEP can serve as a temporary substitution monitoring technique for MEP in MEP-positive cases, which assists the surgeons in selecting the optimal surgical intervention to achieve the best surgical outcomes.

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