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The Application of Neuroelectrophysiological Monitoring in Posterior Percutaneous Endoscopic Cervical Discectomy

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Abstract

Study design: Retrospective case analysis.

Purpose: To investigate the application of neuroelectrophysiological monitoring in Posterior Percutaneous Endoscopic Cervical Discectomy (P-PECD).

Overview of literature: There is an injury risk of nerve root and spinal cord during P-PECD. Intraoperative neuroelectrophysiological monitoring can dynamically monitor the function of the nerve roots and spinal cord, providing real-time data for the surgeon to avoid the risks during P-PECD.

Methods: A retrospective review was performed on 25 patients in an average of 45.9 years +/- 10.9 years old with single segment of cervical disc herniation between May 2018 and June 2019. All the patients underwent a P-PECD and Free-run Electromyography (f-EMG), Motor Evoked Potential (MEP), and Somatosensory Evoked Potential (SEP) were used to monitor the function of nerve roots and spinal cords in the operation. The monitoring results were recorded and analyzed.

Results: When placing operation channels and grinding vertebral plates, f-EMG displayed no obvious reactions, MEP could be induced on both sides, and bilateral SEP waveforms were stable, showing the function of nerve roots and spinal cords was normal. f-EMG detected a series of changes in the motion unit waveform on the patient's diseased side when the removal of the ligamentum flavum and the inner layer of the vertebral plate. The waveforms of f-EMG returned to normal following the surgical tools were removed from the nerve root and dural sac. The double-sided waveforms can be induced in MEP, and were stable in SEP. The true positive rate was 96% and the false negative rate was 4% during the operation. No nerve damages were found in all patients.

Conclusion: Combined applications of free-EMG, MEP and SEP can provide objective functional indicators of the nerve root and spinal cord for surgery, thereby improving the efficiency and safety of the operation.

Keywords: Percutaneous endoscopic cervical discectomy; Neuroelectrophysiological monitoring; Free-run electromyography; Motor evoked potential; Somatosensory evoked potential

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Introduction

Posterior Percutaneous Endoscopic Cervical Discectomy (P-PECD), also known as the posterior keyhole foraminotomy, is one of the minimally invasive surgical methods for the treatment of cervical spondylotic radiculopathy. Compared with traditional anterior cervical discectomy, P-PECD has the advantages of less trauma, less bleeding, faster postoperative recovery, lower cost, and retention of postoperative spinal activity [1-3]. However, due to the limited endoscopic surgery sight and the lack of obvious anatomical makers, there is a significant risk of nerve root and spinal cord injury during P-PECD [4].

Intraoperative neuroelectrophysiological monitoring can dynamically monitor the function of the nerve roots and spinal cord, which makes the positioning of nerve roots more precise. Furthermore, this monitoring offers reliable data for operator in the process of the endoscopic channel implantation and the nerve root decompression, thereby reducing nerve root and spinal

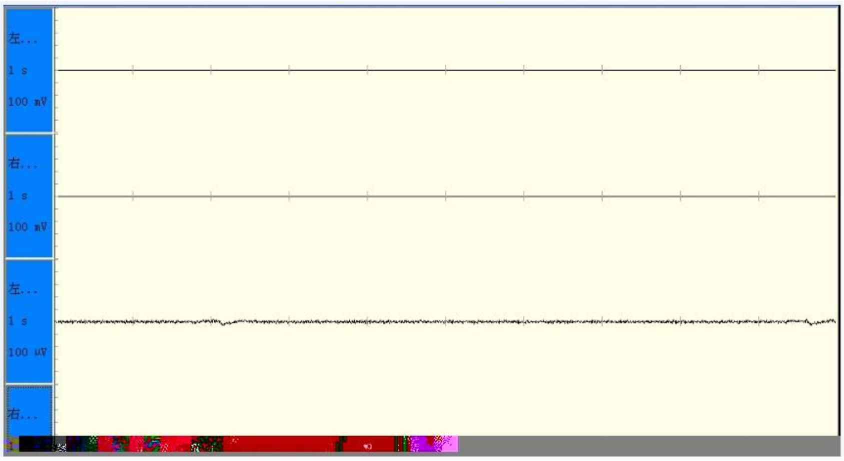

Figure 1A: No significant waveforms were observed on either side of f-EMG before surgery.

cord injury, and establishing an important foundation for surgical safety. Spinal surgery neurophysiological monitoring programs usually include Free-Run Electromyography (f-EMG), Motor Evoked Potential (MEP), and Somatosensory Evoked Potentials (SEP). f-EMG represents the real-time functional status of the nerve root motor pathway, MEP reflects the descending motor conduction pathway of the anterior spinal cord, and SEP indicates the ascending sensory conduction pathway of the posterior spinal cord.

At present, there are few reports on the application of nerve monitoring in P-PECD. In this study, we performed retrospective analysis of the data from 25 patients with single-segment cervical disc herniation who were received by our department from May 2018 to June 2019 and have had an operation of P-PECD under general anesthesia status, to investigate the application of neuroelectrophysiological monitoring in P-PECD [5-9].

Materials and Methods

Patients

This study enrolled 25 patients (14 males and 11 females) with single segment of cervical disc herniation between May 2018 and June 2019 at Department of Spinal Surgery, People's Hospital of Longhua Shenzhen, China. The average age was 45.9 years +/- 10.9 years old (ranged from 27 to 73) [6]. The clinical manifestations of all patients were radiating pain of nerve root, without the decrease of muscle strength in the nerve root dominating area and the spinal cord compression pyramidal sign. Magnetic Resonance Imaging (MRI) showed 1 case (4%) of cervical disc herniation at C3-C4, 2 cases (8%) of cervical disc herniation at C4-C5, 12 cases (48%) of cervical disc herniation at C5-C6, and 10 cases (40%) of cervical disc herniation at C6-C7. Computed Tomography (CT) confirmed that there was no obvious calcification at the site of cervical disc herniation before operation. All patients underwent the posterior PECD under general anesthesia.

Neuroelectrophysiological monitoring

Combined monitoring of f-EMG, MEP, and SEP in the operation by using an Evoked Potential Monitor (Thermo Nicolet, USA). f-EMG intraoperative monitoring of muscles in response to nerve roots in the site of the cervical disc herniation and the surgically selected cervical segment in real time. MEP with a stimulation intensity of 150V to 400V stimulates cervical vertebrae C3 and C4 which are the positive and negative electrodes and the reference electrode of each other before surgery and during key steps of operation [7]. The conduction pathway of MEP is central anterior stimulation through the spinal cord; nerve root to the contralateral target muscle receiving, thus MEP can indirectly examine the function of the spinal cord and nerve roots. The muscles monitored by MEP are the same as those of f-EMG. The stimulation site of SEP is the median nerve of the bilateral wrist, and receiving electrodes are C3' and C4', and the reference electrode is Fz. SEP with a stimulating amount of 8 mA to 15 mA is continuously stimulated throughout the surgery. The conduction pathway of SEP is median nerve stimulation along the afferent nerve through the spinal cord and thalamus to the central cerebral cortex.

Surgery

The patient was placed in a prone position after general anesthesia, and the head was fixed by the head frame so that the neck was flexed forward and the shoulders were fixed by a wide tape. Positioning the cervical segment Cx/Cy to be operated through a C-arm X-ray machine. The intervertebral space was marked in the lateral position of the cervical vertebra, and the 1/2 of zygopophysis was marked according to the site of the herniated disc in anteroposterior. The intersection of the two marking lines is the midpoint of the surgical approach incision. After routine disinfection and surgical drape, a skin incision of 1 cm was made centering on the marked point, and then the subcutaneous tissue and fascia were cut layer by layer. The guide rod was inserted into the affected side of the Cx/Cy intervertebral space under the fluoroscopy of the C-arm X-ray machine, and a working channel (retractor) was placed after confirming the position was correct. After verifying that there was no mistake in the C-arm X-ray machine, connected the imaging system, flushed the tube of aspirator and the radio-frequency electrode, and turned on the light source. The ligamentum flavum and the vertebral plate were exposed after the soft tissue in channel was cleaned with the nucleus pulposus forceps and the radiofrequency electrode. Under the endoscope, the bone and the ligamentum flavum of the lower edge of the Cx vertebral plate were removed with a burr drill and a rongeur. The radiofrequency electrode was used to stop bleeding, and the nerve root dural sac was explored and exposed, and the intervertebral disc was protruded. Using a detacher to separate the nerve root and extrude nucleus pulposus, and then a nucleus pulposus forceps was used to remove the nucleus pulposus, followed by treatment of the nucleus pulposus lesions in intervertebral disc. The radiofrequency

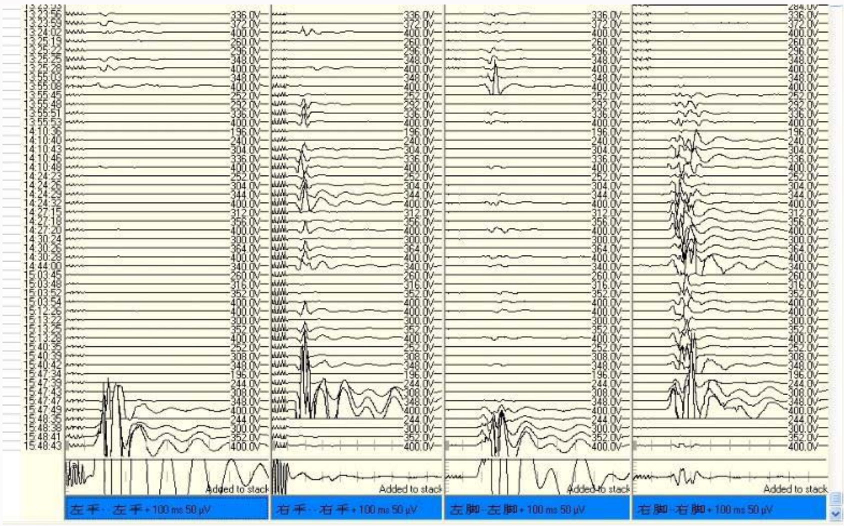

Figure 1B: MEP in patients with cervical disc herniation at C5-C6. The nucleus pulposus protruded to the left side of the center, and the stimulation sites were C3 and C4. The receiving muscles were the deltoid and biceps muscles. Four columns represented MEP in the left and right deltoid, and the left and right biceps muscle, respectively. In the initial stage of surgery for a long time, the waveforms of MEP were low due to intravenous injection of muscle relaxant. After the metabolism of muscle relaxant was completed, the MEP waveform returned to normal, and both sides of MEP could be induced after operation.

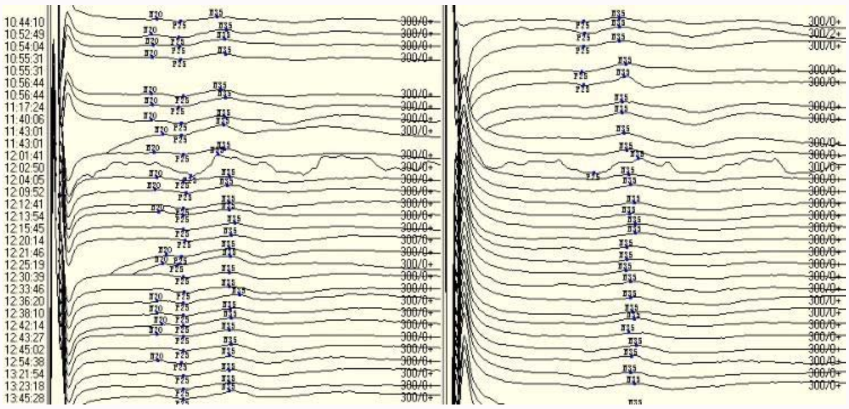

Figure 1C: SEP in upper limb of patients. The two columns represented the SEP of upper limb in the left and the right respectively. The stimulation site of SEP is the median nerve of the bilateral wrist, and receiving electrodes are C3' and C4'. The bilateral waveforms of SEP were inerratic throughout the surgery and no significant decrease and potential extension in amplitudes.

ablation electrode was used to form the annulus fibrosus and stop bleeding. Check again that the Cy nerve root was relaxed and had no entrapment. Finally, 7 mg of compound betamethasone was injected under the endoscope. After the operation, the endoscopic system and working channel were removed, and the incision was sutured and bandaged with sterile gauze [2,3].

Results

Clinical outcomes

All patients postoperatively had immediate relief of nerve root pain symptoms, good activity, and no nerve root injury and complications of spinal cord injury, and were discharged on the third day after surgery. However, one of the patients emerged numbness of the upper extremity after surgery, and numbness was significantly improved after partial nerve root closure.

Neuroelectrophysiological monitoring before surgery

All electrodes of the patients were properly connected and fixed before surgery. Before the operation has begun, no significant waveforms were observed on either side of f-EMG (Figure 1A), motor evoked potentials could be induced on both sides of MEP (Figure 1B), and the bilateral waveforms of SEP were stable (Figure 1C).

Neuroelectrophysiological monitoring during surgery

In all patients, when the nerve root, dural sac and surrounding tissues were separated by a detacher, the affected side of the f-EMG showed a series of waveform changes, and no obvious abnormalities were observed on the sound side (Figure 1D), motor evoked potential waveforms could be induced on both sides of MEP (Figure 1B), and the bilateral waveforms of SEP were stable (Figure 1C). The nerve roots and protruded nucleus pulposus of 6 patients were difficult to identify by the surgeon under the endoscope. When using the nerve detacher to separate the outer membrane, there were 5 patients with a significant change in the waveform of f-EMG (Figure 1E), and 1 patient had no obvious abnormality in f-EMG (Figure 1A), and waveforms could be induced on both sides of MEP (Figure 1B) and the bilateral waveforms of SEP were stable (Figure 1C). There was no nerve damage in all patients after operation. Therefore, the surgeon cannot rely absolutely on neurophysiological monitoring in the identification of nerve roots during surgery, and it is still necessary to

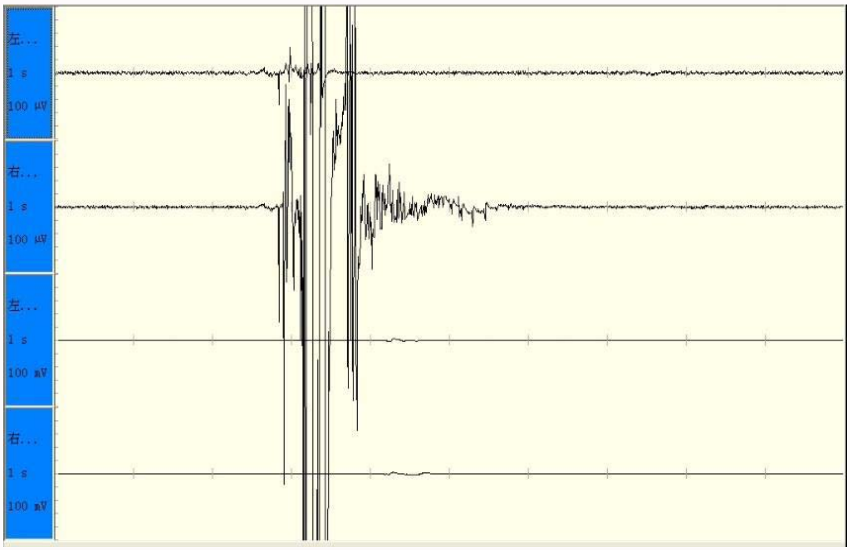

Figure 1D: Waveform of f-EMG on the affected side when the nerve roots, dural sac, and surrounding tissues were separated in a detacher during the surgery.

identify them in combination with anatomical structures.

When the surgeon removed the nucleus pulposus using a nucleus pulposus forceps and treated the nerve root adhesion tissue using the radiofrequency ablation electrode, f-EMG showed a series of waveform changes on the affected side, and no obvious abnormalities on the healthy side (Figure 1E), motor evoked potential could be induced on both sides of MEP (Figure 1B), and the bilateral waveforms of SEP were stable (Figure 1C).

There were 24 patients, when the nerve roots and surrounding tissues were separated in a detacher, the nucleus pulposus were removed by a nucleus pulposus forceps, and the nerve root adhesion tissue was treated with a radiofrequency ablation electrode, the affected side of the f-EMG showed a series of waveform changes, and no obvious abnormalities were observed on the sound side, double-sided waveforms of MEP could be induced, and the bilateral waveforms of SEP were stable. Neuroelectrophysiological monitoring suggested that the surgeon has touched the nerve or around the nerve root at this time, but the function of nerve and spinal cord was normal, and the true positive rate was 96%. When the surgeon used the nerve detacher to isolate the nerve root, there was no obvious reaction in f-EMG, and both sides of the MEP waveform could be induced, and the bilateral waveform of SEP was stable in 1 patient. All patients had no relevant neurological complications after surgery [10].

Neuroelectrophysiological monitoring after surgery

After operation, the bilateral waveforms of f-EMG recovered to rest (Figure 1A), motor evoked potential could be induced on both sides of MEP (Figure 1B), and the bilateral waveforms of SEP were stable in all patients, no significant changes compared with preoperative.

Discussion

Analysis of intraoperative combined monitoring of f-EMG, MEP and SEP

Postoperative spinal nerve root injury is the most serious complication of P-PECD, and the use of neuroelectrophysiology to continuously monitor the function of spinal cord and nerve root is an important means to reduce this complication. SEP is the earliest neurophysiological monitoring method used in spinal surgery, but it can only monitor the sensory conduction pathway on the dorsal side of the spinal cord and has a high false negative rate. MEP monitors spinal motor conduction pathway. Intraoperative monitoring using SEP and MEP can comprehensively monitor sensory and motor conduction pathways in the spinal cord and reduce false negatives rate [11]. Cervical disc herniation occurs in front of the nerve root or spinal cord, hence the nerve will be pulled or isolated and there is a risk of nerve root damage during surgery. The f-EMG can monitor the function of nerve roots in real time and reduce nerve root damage. In this study, a patient occurred concurrent radiculitis after surgery, but had a significant improvement in numbness of the affected limb after treatment of local block. A retrospective study showed that postoperative radiculitis was one of the inevitable complications, whether for simple decompression surgery or fusion surgery [12,13]. The postoperative radiculitis is mainly caused by intraoperative nerve root traction, radiofrequency ablation, excessive burning of the electrodes, and postoperative scar tissue stimulation, but its incidence is low. This study displayed that when the radiofrequency ablation electrode was used to treat the nerve root adhesion tissue, the f-EMG showed a series of waveform changes, but the bilateral waveforms of both the SEP and MEP could be induced, and there was no obvious abnormality in the amplitude. This phenomenon suggests that the process of radiofrequency electrode ablation during surgery has a stimulating effect on nerve roots. Therefore, when operating the radiofrequency electrode, the surgeon should try to reduce the stimulation of the nerve root for a long time or operate at a location away from the nerve root.

The significance of combined monitoring of f-EMG, MEP and SEP

Combined monitoring of f-EMG, MEP and SEP can monitor intraoperative spinal sensory, motor conduction pathways, and nerve root function, and reduce the risk of spinal cord and nerve root injury, and improve the safety of surgery. The bilateral waveforms of SEP were stable before operation, and the double-sided waveforms of MEP could be induced (Figure 1B and 1C). The bilateral waveforms of SEP and MEP were stable during and after operation, and no significant changes were observed, suggesting that the spinal cord

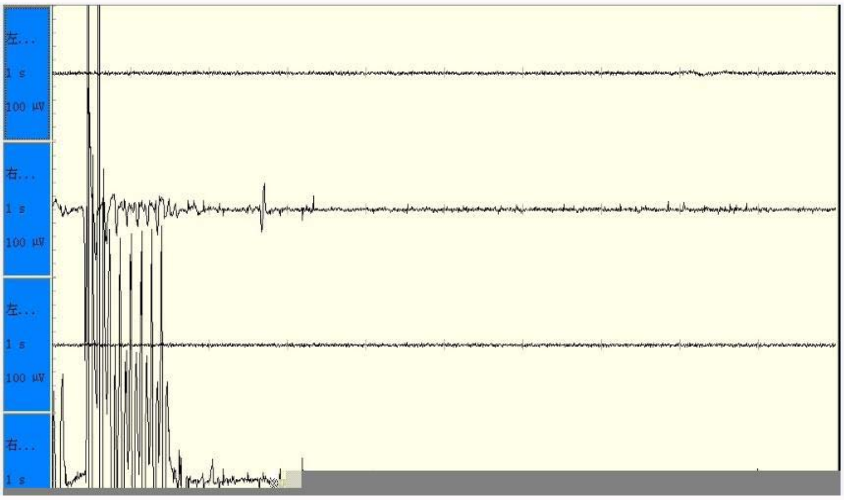

Figure 1E: Changes in a series of waveform of f-EMG were showed on the affected side when the surgeon removed the nucleus pulposus with the nucleus pulposus forceps and treated the nerve root adhesion tissue with the radiofrequency ablation electrode.

Table 1: Summary of Data for 8 Patients with Anomalous Course of Vertebral Artery at the Hybrid Fixations for Atlantoaxial Dislocation or Instability.

No.	Age /Sex	Diagnosis	JOA score (pre-op)	JOA score (post-op)	High-Riding VA	Asymmetry of BL VAs	Method of Surgery
1	61/M	AAS	12	15	+R	+ (R>L)	C1-C2 fusion, C2 margel screw (left) and lamina screws (right)
2	34/F	AAS	11	14	+R	+ (R>L)	
3	11/M	SED	10	14	+R	+ (R>L)	
4	29/M	AAS	11	15	+R	+ (R>L)	
5	77/M	AAS	11	15	+L	+ (R>L)	Occ-C2 fusion, C1 laminectomy
6	28/M	AAS	10	14	+R	+ (R>L)	
7	25/F	SED	12	15	+R	+ (R>L)	
8	34/F	AAS	9	13	+R	+ (R>L)	

VA: Vertebral Artery; BL: Bilateral; AAS: Atlantoaxial Subluxation; SED: Spondyloepiphyseal Dysplasia; L: Left; R: Right; Occ-C: Occipitocervical; FM: Foramen magnum First intersegmental artery; persistent first intersegmentalarter

function was normal during operation. The f-EMG is a real-time monitoring indicator for nerve roots, so it is straight in preoperative and postoperative rest state (Figure 1A). During the surgery, when the nerve roots and surrounding tissues were separated in a detacher, the nucleus pulposus were removed by a nucleus pulposus forceps, and the nerve root adhesion tissue was treated with a radiofrequency ablation electrode, the affected side of the f-EMG showed a series of waveform changes, and no obvious abnormalities were observed on the sound side, and waveform in the affected side returns to normal after stopping the operation.

Operating essentials of intraoperative neuroelectrophysiological monitoring and application of anesthesia

The position of puncture using the needle electrode must be the nerve root distribution area of the surgical segment. Receiving muscles in f-EMG and MEP are the same, so that the MEP conduction pathway can be monitored, and SEP can be combined to indirectly detect intraoperative nerve root and spinal cord function. Total venous anesthesia was used throughout the operation, and the muscle relaxant was used during anesthesia induction and was not used afterwards. Since inhaled sevoflurane has a synergistic effect on muscle relaxants, no inhaled drugs were used during surgery. Other anesthetics were normally used.

Analysis of the cause of false negative

There was no obvious reaction in f-EMG and both sides of the MEP waveform could be induced and the bilateral waveform of SEP was stable when the surgeon used the nerve detacher to isolate the nerve root in one of the patients in this group. The surgeon incision of the epineurium and identification of nerve roots under endoscopy, its false negative rate was 4%, and no related neurological complications were found after surgery in all patients. Postoperative statistical anesthesia records found that the patient maintained the use of the muscle relaxant rocuronium bromide and inhaled sevoflurane in larger doses during the operation. When the surgical operation was nearing the end, SEP and MEP suddenly could not monitor any waveforms in 1 patient in this group. The surgeon immediately stopped the operation when he was informed of this phenomenon. But the surgeon did not find any traces of spinal cord and nerve root damage under the microscope through identifying and examining layer by layer in the anatomical structure. Finally, the cause was found in that the stimulation box on the ground was soaked by the physiological saline used in the intraoperative operation, so that the waveforms of SEP and MEP were suddenly interrupted. Consequently, in the minimally invasive endoscopic operation of the spine, because a large amount of physiological saline is used as the medium for surgical endoscopic operation, the receiving box and the stimulation box of the neuroelectrophysiological monitoring must be fixed on the edge of the operating bed to avoid corrosion of water on the ground, thus affecting the accuracy of intraoperative monitoring results.

The shortages of this study are that PECD is only suitable for cervical spondylotic radiculopathy caused by cervical disc herniation and analysis of fewer cases. Because the P-PECD is a new type of surgery, all the operations used intraoperative neurophysiological monitoring. The conclusions still require more studies of multi-center and large-sample to provide further theoretical support (Table 1).

Conclusion

In conclusion, the combined neuroelectrophysiological monitoring of f-EMGs, MEP, and SEP has a significantly improved to the safety of P-PECD. However, in the critical steps of identifying nerve roots and protruding nucleus pulposus, the surgeon cannot rely absolutely on neuroelectrophysiological monitoring. It is still necessary for the surgeon to cut the epineurium in terms of the anatomical layer, and then remove the nucleus pulposus with a nucleus pulposus forceps when the nucleus pulposus tissue is seen. In this process, the surgeon must pay attention to the protection of nerve fibers.

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