Short Communication

Utilization of electromyography during selective obturator neurotomy to treat spastic cerebral palsy accompanied by scissors gait

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Selective obturator neurotomy is a commonly used neurosurgical intervention for spastic cerebral palsy with scissors gait. Here we report the use of surface electromyography to assess the accuracy and effect of selective obturator neurotomy procedures. Selective obturator neurotomy was carried out on 18 patients while using intraoperative electromyography. Contractions of adductor muscles were recorded by electromyography before and after neurotomy and assessed using root mean square and integrated electromyography tests. Passive and voluntary movements were recorded for all patients. Our results show that adductor spasms and adductive deformity of hip were improved in all patients with spastic cerebral palsy. Adductor muscle spatiality was improved significantly, confirmed by a significant decrease in the values of root mean square and integrated electromyography in both passive and voluntary movements after surgery. We show that electromyography is an effective tool for accurately and safely targeting nerve tracts during selective obturator neurotomy. Thus, we demonstrate a valuable noninvasive method to objectively evaluate the effect of treatment in spastic cerebral palsy patients.

Keywords

Spastic cerebral palsy; selective obturator neurotomy; electromyography

1. Introduction

Cerebral palsy is a diverse group of disorders caused by permanent but not progressive damage in the developing brain. Muscle spasms constitute one of the most common manifestations of cerebral palsy (Bell et al., 2002). There are multiple methods to treat spastic cerebral palsy, the primary goal being to reduce muscular tension and eliminate spasticity. Most patients are treated with medication and physical rehabilitation (Abbruzzese, 2002). Other remedies rely on selective obturator neurotomy (SON), including focal injection of botulinum toxin, focal application of alcohol or phenol, and intrathecal injection of baclofen (Ploumis et al., 2014). Botulinum toxin type A, in conjunction with appropriate physical therapy, is used against focal dystonia and rigidity in hemiplegic spasticity (Yan et al., 2018).

Standard treatment approaches, however, tend to be reversible and often inevitably require surgical intervention (Emery, 2003). One of the most effective surgical approaches introduced in 1972 was selective peripheral neurotomy (Kwon and Kim, 2009). SON and selective tibial neurotomy can both be classified as selective peripheral neurotomy. SON was first performed to treat the spasticity of hip adductors in 1887 while selective tibial neurotomy was performed in 1912. Selective posterior rhizotomy was first conducted by Foerster in 1908 to treat spastic cerebral palsy, specifically in the lower limb (Sindou, 2003). These surgical methods were proven to be safe and to obtain considerable improvements in muscle power, severity of spasticity, range of joint movement and functional disability (Davids, 2010; Park and Johnston, 2006; Saintyves et al., 2011).

In recent years, intraoperative electromyography (EMG) has been used during surgical operations to help surgeons select targeted nerve bundles and determine the degree of bundle resection. This has greatly increased the precision of surgical procedures and prevented excessive denervation (Patikas et al., 2005; Sitthinamsuwan et al., 2013). The therapeutic effect of this intervention in spastic cerebral palsy patients is traditionally assessed via gross motor function measurement (GMFM), modified ashworth scale (MAS), and passive range of motion (PROM). However, these assessments are difficult to quantify accurately and insufficient as a measure of therapeutic effect. It was recently shown that surface EMG is an effective noninvasive method to objectively evaluate the clinical therapeutic effect of spastic cerebral palsy stiff knee gait (Wang et al., 2011). The values of integrated electromyogra-

phy (iEMG) and root mean square (RMS) show a positive correlation with muscle force and muscle tension, making them robust and reliable tools for assessment (Farina et al., 2014; Onishi et al., 2000; Wang et al., 2011).

Thus, our study applied intraoperative EMG to identify nerve bundles for surgical resection in patients with spastic cerebral palsy with scissors gait. We then tested the use of surface electromyography (sEMG) to assess the therapeutic effects of our approach.

2. Materials and methods

2.1 Patient selection

This study was carried out in the Provincial Hospital affiliated with Shandong University and Liaocheng People's Hospital from July 2016 to October 2017. Eighteen patients were selected based on criteria approved by the international cerebral palsy conference (Rosenbaum et al., 2006). The only symptomatic and clinical manifestations considered were scissors gait and coxa vara, respectively. All patients had an IQ score over 60 measured by wechsler intelligence scales and could follow the test procedures. All patients could walk independently and had no pathological changes in their hips. Written informed consent was obtained from all patients. This work was approved by the ethics committee of Liaocheng People's Hospital (No. 2016051).

2.2 sEMG recordings

Data collection was carried out using ME6000 T8 sEMG. RMS and integrated EMG (iEMG) were calculated via synchronized video and joint angle meter. RMS was used to depict mean change in the electro-discharge of muscle and nerve within a certain time, which is the root mean square value of all amplitudes during this time. iEMG was deemed the total area under the curve in a given time frame of signals by regulated filtering.

2.3 Preoperative assessment

A special test was performed on each patient one day before surgery. The method of testing was taught to the patients, following which they were given sufficient time to become familiar with the testing process. Patients were directed to lie down on the exam table and relax their muscles. The recording electrode was fixed on the most prominent part of the adductor region in the same direction as muscle fibers. Grounding wires were placed at the midpoint of reference electrode and recording electrode, approximately 20 mm from the measurement point. Patients were tested during both passive and voluntary movements. First the hip joint was examined at maximum possible adduction for 3-5 sec followed by 10-15 sec of rest. Patients were then asked to extend their hip joint for 3-5 sec followed by 10-15 sec of rest. An Ag/AgCI surface electrode was used, and collection was carried out using a ME6000 T8 sEMG (H145340, Shanghai Huanxi Medical, China). The following parameters were used: a sampling rate of 1000Hz, input impedance $< 5G$, amplified 1000 times. The tests were repeated three times, with iEMG and RMS calculated for each.

2.4 Surgical process

The patient was directed to lie down in a supine position with flexed knees and maximum possible abduction of hip joints. All patients received general anesthesia. A longitudinal 3-4 cm incision was made below the pubic crest near the site of origin of the adductor longus muscle and reaching the anterior branch of the obturator nerve. The space between adductor longus and adductor brevis was separated. The anterior branch of the obturator nerve was exposed. Electrical stimulation was provided distinctly to obturator, gracilis, and adductor longus muscles.

Performing microsurgery, the nerve epineurium was spliced, and the nerve was divided into 2 to 3 bundles. Then each bundle was electrically stimulated, and compound muscle (motor) action potential (CMAP) was recorded. CMAP represents and idealizes the summation of action potentials in a group of muscle fibers simultaneously contracting in the same region. CMAP or M wave was produced from nerve conduction, which causes the contraction of innervated muscles. The highest amplitudes of triggered CMAP and the strongest muscle contraction nerve bundle were chosen for denervation. After every resection, the proximal targeted nerve was stimulated, and CMAP recorded. When two nerve bundles showed the same high amplitudes, they were both operated upon. Following the operation, at least one bundle was protected. Bipolar coagulation was used to coagulate the proximal stumps of the resected fascicle, while an artificial cerebral dura mater patch was used to pack the postoperative nerve bundles. Lastly, the incision was closed layer by layer.

2.5 Postoperative care

Patients were taught to maximally stretch their thighs until three days postoperatively; on day 4 they were allowed to stand with help. Muscle strength was tested similar to pre-operation tests on the seventh day.

2.6 Rehabilitation

Rehabilitation plans designed by a kinesiotherapy included relevant exercises and orthotic devices. Functional electrical stimulation was also applied to patients for 6 months, following which evaluation tests were administered to each patient.

Table 1. RMS and iEMG values of adducts from pre-operation, post-operation, and post-rehabilitation measurements. Data are described as mean $\pm$ SD. $^*P < 0.05$ (compared to pre-operation value)

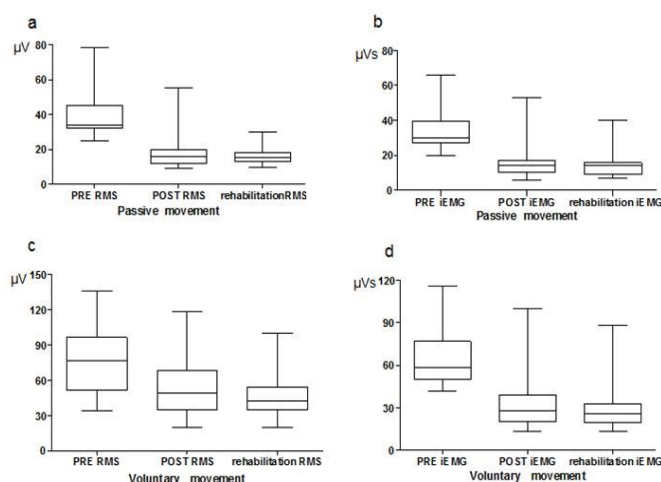| Parameter	Pre-operation data	Post-operation data	Post-rehabilitation data
voluntary movement RMS (μV)	38.34 ± 9.90	$17.62 \pm 8.45^*$	$16.19 \pm 4.70^*$
voluntary movement iEMG (μVs)	33.78 ± 9.90	$15.25 \pm 8.46^*$	$13.94 \pm 6.50^*$
Passive movement RMS (μV)	75.68 ± 27.7	$53.53 \pm 23.47^*$	$46.50 \pm 17.57^*$
Passive movement iEMG (μVs)	65.71 ± 20.05	$30.84 \pm 16.12^*$	$28.09 \pm 13.86^*$

Figure 1. RMS and iEMG values from measurements taken pre-operation, post-operation, and post-rehabilitation. The upper and lower limits of the blocks respectively represent the highest and the lowest values in the data set. Data are described as mean ± SD. *$P < 0.05$ (compared to pre-operation value).

2.7 Data analysis

Statistical analyses, including mean and standard deviations, were performed using SPSS 25.0. One-way ANOVA with Bonferroni's correction was used to compare the means of three or more groups. The probability of $P < 0.05$ was deemed statistically significant.

3. Results

3.1 Evaluation of surgery outcomes

Following surgery, all patients displayed gait improvement, achieving nearly normal gait. Patients with pre-operative hip adduction (angle of adductor < 15°) showed an improved range of hip motion and angle of adductor greater than 30°. Compared with pre-operative spasms in the adductor muscle, patients with adducts deformity showed clear improvement after treatment period. Similarly, as shown by Fig. 1a,b, all patients displayed the ability to walk independently before the operation, and scissor's gait was the only manifestation of symptoms. After neurotomy and rehabilitation, patients displayed considerable improvements, up to the ability to walk normally.

3.2 RMS and iEMG values

RMS and iEMG values decreased significantly after surgery when compared to pre-operation ($P < 0.05$). However, the values for these tests did not show a significant difference between post-operation and post-rehabilitation (Table 1 & Fig. 1).

4. Discussion

Cerebral palsy attributed to non-progressive disturbances occurring in the developing fetal or infant brain. Developing brain injury may occur in the uterus, around the time of delivery, post-neonatal period or early childhood. The disturbance often results from infection, hypoxia, hypotension or stroke, with the

subsequent inflammatory cascade following the original insult (Wimalasundera and Stevenson, 2016). As known, cerebral palsy has no cure and few disease-modifying interventions; symptom management is the mainstay of treatment. Although cerebral palsy is defined as a non-progressive brain injury or lesion, the musculoskeletal pathology of extremities is progressive in the development of children, accompanied by contracture, bone torsion and joint instability (Chalkiadis et al., 2016). Children with cerebral palsy may undergo surgery to correct deformity and improve function. In recent years, surgical treatments for this disease have used intraoperative EMG to select targeted nerve bundles and determine the degree of neurotomy. This technique has expectedly increased the accuracy of resection (Sitthinamsuwan et al., 2013; Tomita et al., 2011). In this study, 18 children with cerebral palsy underwent peripheral neurotomy with selective obturator neurotomy, employing intraoperative EMG in the surgical process. As such, the extent of resection mainly depended on changes in CMAP. This method increased objectivity in decision-making as to the extent of surgery.

Rehabilitation is a basic and effective method in cerebral palsy treatment. Comprehensive rehabilitation can improve motor function, speech skills, behavior and cognition, social communication, and adaptive social capacity of children with cerebral palsy (Song et al., 2018). Suitable orthotics play an important role in improving hip and knee control, enhancing stability in joint movement, correcting infantile abnormal posture, and preventing muscle contractures (Majnemer et al., 2014; Novak, 2014). As such, our rehabilitation plan used commonly employed orthoses (including arch support, ankle-foot orthoses, orthopedic footwear, etc.) to correct malformations and maintain good posture.

SPN can decrease spasticity directly and build a tonic balance between agonist and antagonist muscles. However, postoperative recovery can build muscular strength and range of motion, largely depending on postoperative rehabilitation. The complete rehabilitation plan should be carried out in stages with flexibility. Early rehabilitation focuses on passive activity and assistant training. Medium-term rehabilitation emphasizes balance training and load-bearing muscle enhancement. Later rehabilitation aims to improve motor coordination. Thus, an integrated systemic treatment should follow a model based on 'rehabilitation' → 'surgery intervention' → 'postoperative rehabilitation' (Cassidy et al., 2016; Icagasioglu et al., 2015; Reid et al., 2015).

The assessment of therapy in spastic cerebral palsy patients has traditionally depended on gross motor function measurement (GMFM), modified ashworth scale (MAS), and passive range of motion (PROM). GMFM represents the established medical standard, while MAS and PROM reflect muscle strength and muscle tension (Cheng et al., 2012; Shin et al., 2012). However, MAS and PROM are difficult to quantify accurately and are insufficient indicators of therapeutic effect. Hence, we utilized sEMG signal analyses to assess patients' nervous and muscular function. iEMG and RMS values showed positive correlation with muscle force and muscle tension. RMS is used to describe average changes within a certain time and is considered the most reliable parameter in time domain analyses to assess the magnitude of force produced. During voluntary movements, RMS and iEMG values typically reflect changes in muscle force. However, during passive

movements, they reflect the degree of muscle tension. Our study utilized sEMG, demonstrating its value for therapeutic assessment of spastic cerebral palsy patients before and after neurosurgical treatment.

Our study analyzed the success of EMG application in 18 spastic cerebral palsy patients with scissor gait. We demonstrated that utilizing intraoperative EMG improves the accuracy of neurotomy while sEMG is a valuable tool for assessment of neurosurgical treatment. Thus, our study used new approaches to verify the effectiveness of selective obturator neurotomy.

5. Conclusion

In conclusion, the utilization of intraoperative EMG enhances the accuracy of surgical operation, and sEMG offers a precise and objective assessment of muscular strength following neurotomy in cerebral palsy patients.

Acknowledgment

Conflict of interest

The authors declare no conflict of interest.

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