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Original Article

Electrophysiological Characteristics of the Pediatric Femoral Nerve and Their Use in Clinical Diagnosis

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ABSTRACT

OBJECTIVE: To explore the electrophysiological characteristics of the pediatric femoral nerve at different ages. **METHODS:** Surface electrodes were used to detect femoral nerve conduction in 163 healthy children aged 0-14 years recruited to this study and divided into six age groups. Based on the range of normal values obtained, the diagnosis of 22 patients with suspected femoral nerve injury was confirmed. **RESULTS:** We obtained normal values for pediatric femoral nerve motor and sensory conduction in all age groups, including proximal and distal compound muscle action potential latencies, proximal compound muscle action potential amplitude and duration, motor conduction velocity, F-wave latency, and sensory conduction velocity. We measured proximal compound muscle action potential in all children in all age groups. The manifestation of femoral nerve injury in the 22 patients was primarily a clear decrease or absence of compound muscle action potential amplitude or a lengthened latency. Electromyographs revealed that 104 muscle parts were involved in the nerve function, in which 59 parts were found to be abnormal (56.73%). **CONCLUSIONS:** The development of pediatric femoral nerve mainly began after 1 years old and continued to 14 years old. The proximal latency and compound muscle action potential amplitude of the pediatric femoral nerve have clinical value. Detection of the femoral nerve is important in the diagnosis of lower limb monoplegia, especially for acute flaccid paralysis associated with nonpolio enterovirus infection.

Keywords: pediatric femoral nerve, nerve conduction, lower limb monoplegia, acute flaccid paralysis, injury

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Introduction

The femoral nerve arises from the dorsal divisions of the ventral rami of the second, third, and fourth lumbar nerves. It descends through the fibers of the psoas major muscle after separation from the lumbar nerves and passes down between the psoas major muscle and iliacus muscle behind the iliac fascia. The nerve then runs beneath the inguinal ligament, into the thigh from the lateral border of the femoral artery, and splits into an anterior and a posterior division. The anterior division branches 2-3 cm below the inguinal ligament, where the anterior cutaneous branch is distributed in the anteromedial surface of the thigh, whereas the muscular branch dominates the sartorius and pectineus. The posterior division dominates the quadriceps femoris muscle and develops into the saphenous nerve entering the surface of the knee, leg, and foot.[1-3]

Femoral nerve palsy is characterized by disorders of corresponding cutaneous sensations and muscle movements. Clinical manifestations include knee extensor and hip flexor weakness, an absence of knee jerk, and sensory disturbance of the anterior thigh and medial crus. In recent years, cases of femoral nerve palsy have been reported at home and abroad,[1-5] but a systematic review of the

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disorder has yet to be published. In China, little research has been conducted on normal pediatric femoral nerve conduction.

In this study, between 2005 and 2012, we used surface electrodes to examine femoral nerve conduction in 163 healthy children aged 0-14 years, along with motor and sensory conduction; we also explored how the electrophysiological characteristics of the femoral nerve changed from birth to the age of 14. In the second part of the study, based on the range of normal values obtained in the first part of the study, we confirmed the diagnosis in 22 children clinically suspected of suffering from femoral nerve injury or lesion.

Materials and Methods

Subjects recruited for the study

The study was approved by the Ethics Committee of the Children's Hospital affiliated to Chongqing University of Medical Sciences. Informed consent from the subjects or their legal guardians was obtained via signed consent forms.

Apart from the 22 patients clinically suspected of having femoral nerve injury or lesion, all subjects were children with no possible femoral neuropathy, including children with traumatic unilateral upper extremity injuries but with a healthy contralateral one and children from a hearing screening. Consent of the parents was obtained before inspection of the subjects' limbs.

Subjects were divided into two groups according to the research objectives. The normal group contained 163 healthy children aged 0-14 years divided into six age groups: 0-3 months old, 3-6 months old, 6 months to 1 year old, 1-3 years old, 3-6 years old, and 6-14 years old. The clinical group was made up of 22 cases of children suspected of having femoral nerve injury who had visited our hospital between 2005 and 2012 whose diagnoses were confirmed after clinical follow-up. This group included 12 patients with acute flaccid paralysis associated with nonpolio enterovirus (NPEV) infection, three with femoral fracture, one with pelvic trauma, two with femoral pseudoaneurysm, one with iliacus hematoma, and patients with Guillain-Barré syndrome (GBS). The first nerve conduction test was carried out 3 to 7 days after paralysis, at an average of 4.6 days (median); the clinical review was performed after 3 weeks to 3 months at an average of 6.1 weeks (median). The first electromyograph (EMG) test was carried out 2-8 weeks after onset. This article mainly focuses on the first test results.

Twelve patients with NPEV-infected acute flaccid paralysis were clinically diagnosed in this article. We completed the relevant electrophysiological examinations and selectively performed head magnetic resonance imaging (MRI), spinal MRI, and cerebrospinal fluid examinations as well as cerebrospinal fluid/blood/stool enterovirus nucleotide acid detections (multiplex real-time polymerase chain reaction examination). Therefore, possible acute disseminated encephalomyelitis was excluded in 12 patients. In the 12 patients with acute flaccid paralysis associated with NPEV infection,[6,7] seven were male and five were female; their ages spanned 3-36 months with an average age of 16.7 months; including one patient with tetraplegia, two with triplegia, two with diplegia, and seven with monoplegia of lower limb, all with acute flaccid paralysis. Three patients had received the polio vaccine before onset, and two patients had a neonatal perianal abscess. In seven patients, nonpolio enteroviruses polymerase chain reaction examinations were positive in stool cultures and/or cerebrospinal fluid, including enterovirus 71 polymerase chain reaction (+) in six patients and Coxsackievirus A16 polymerase chain reaction (+) in one patient. Five patients that had abnormal MRI signals showed nontransverse spinal cord injuries and evidence of spinal cord inflammatory lesions that were mainly in the cerebrospinal fluid. Spinal MRI scans suggested that four patients with spinal lesions had identical T1 and long T2 signals of discontinuous patches and spots; one patient had identical T1 and long T2 signals in the cord and showed patchy mildly abnormal enhancement on their enhanced spinal MRI scans. These findings were consistent with characteristic enterovirus findings of more selective damage with lumbar and cervical enhancement.

The diagnosis of GBS was made on the basis of the diagnostic guidelines for GBS in China.[8]

The patients with femoral fractures, pelvic trauma, femoral pseudoaneurysm, and iliacus hematoma all had the clinical manifestation of monoplegia of the lower limb on the damaged side.

Testing methods

Electroneuronography

Electroneuronography (ENoG) of the femoral nerve was performed with a Keypoint multifunction neural potentiometer (Dandy, Denmark). All electroneurographs were recorded with a disc electrode and stimulated with a saddle electrode, including the motor conduction, F wave, and sensory conduction.[9]

To measure motor conduction velocity (MCV), the recording electrode was placed at the interior of the rectus femoris, with the reference electrode at the superior border of the patella, whereas the ground electrode was positioned between the recording point and stimulation point. The proximal stimulation point was at the lateral border of the inguinal femoral artery and distal stimulation point at the distal femoral nerve below the rectus femoris. Because of the deep position of the femoral nerve, the stimulation electrode was fixed firmly in position when stimulated. The F wave was recorded at the proximal stimulation point. The stimulus intensity started at 1 mA and gradually increased to the supramaximal value using a square wave direct current. When femoral nerve injury is clinically suspected, the comparison of both sides is necessary, so the distance between the stimulation point and recording electrode must be equal for the muscle action potential amplitude of each side to be compared.

To determine sensory conduction velocity, the recording point was fixed at the lateral border of the inguinal femoral artery pulse, with the reference point 3 cm from the proximal recording electrode and the stimulation point at the distal rectus femoris. The stimulus intensity started at 1 mA, before being gradually increased to the supramaximal value with continuous superposition approximately 30-100 times to obtain a reliable value for the sensory nerve action potential (SNAP).

ENoG was performed on those children suspected of having a femoral neuropathy. In children with suspected femoral neuropathy, in addition to the femoral nerve, the tibial and fibular nerves should also be examined. If the upper limbs are involved, the median and ulnar nerves should be included in the medical examination. In the clinical subjects in this study, motor conduction, F wave, and sensory conduction were all measured.

EMG

EMGs were obtained for those children suspected of having a femoral neuropathy. The test was performed using a Keypoint multifunction neural potentiometer (Dandy, Denmark). All EMGs were recorded with a concentric needle electrode. Rectus femoris, vastus intermedius, vastus medialis, and vastus lateralis in the lower limbs on the affected or healthy side were examined in three to five sections of muscle for each patient. The concentric needle electrode was placed over the muscle belly and used to take measurements from different directions and at different levels to observe the spontaneous electrical activity under the resting state (namely, positive sharp wave and fibrillation potential, also called denervation potential) as well as the recruitment reaction under light or heavy contraction of each muscle.[10]

Measurements were performed while the children were asleep after having been administered chloral hydrate. The room temperature was 22-26°C and the skin temperature was >30°C.

Calculations and statistical analysis

All data are presented as the mean ± standard error of the mean. Statistical analysis was performed with a one-way analysis of variance test with Bonferroni's corrections and a two-tailed independent samples t-test, using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL). The level of statistical significance was defined as a P value of less than 0.05.