Evaluation of the Neurosensory Function of the Medial Meniscus in Humans

Baransel Saygi, M.D., Yakup Yildirim, M.D., Nadire Berker, M.D., Demet Ofluoglu, M.D., Evrim Karadag-Saygi, M.D., and Mustafa Karahan, M.D.

Purpose: Menisci are known to have receptors mainly concentrated at the anterior and posterior horns. Although they are purported to send afferent impulses to the central nervous system, this function has not been thoroughly evaluated. The purpose of the study was to investigate whether stimulation of the menisci initiates a cortical response. The reaction of the end organ to the reflex arc is also evaluated. **Type of Study:** Prospective case series. **Methods:** Fourteen patients with normal medial menisci were included in the study. Different parts of the knee joint (the posterior horn and the body of the medial meniscus, the medial femoral condyle, the capsule, and the joint space) were electrically stimulated by a probe during arthroscopy. The cortical response was monitored with somatosensory-evoked potentials (SEPs). The compound muscle action potentials (CMAPs) of the semimembranosus, quadriceps, and biceps femoris muscles were also monitored with electroneuromyography (ENMG). **Results:** Among the stimulated parts, only the posterior horn of the meniscus produced cortical responses. No response was obtained with stimulation of the medial femoral condyle, the body of the medial meniscus, the capsule, or the joint space. Stimulation of the posterior horn of the medial meniscus produced a measurable amount of CMAP latency for the semimembranosus muscle, but not for the quadriceps and biceps femoris muscles. **Conclusions:** Stimulation of the posterior horn of the medial meniscus produces reproducible cortical SEPs and results in ENMG-verified response of the semimembranosus muscle where no response of the semimembranosus muscle is detected with stimulation of the other parts of the knee. **Clinical Relevance:** The knowledge that only the horns of the medial meniscus have mechanoreceptors in the medial compartment of the knee helps to understand patients' signs and symptoms in medial compartment disease. **Key Words:** Meniscus—Somatosensory evoked potentials—Electroneuromyography—Neurosensory—Semimembranosus.

A systematic sensory-motor synergy has been proposed around the anatomic structures of the knee including the ligaments, antagonistic muscle pairs and sensory mechanoreceptors in the ligaments, the capsule, and the associated muscles.[1] Among them, anterior cruciate ligament (ACL) has been the commonly investigated structure owing to its importance in knee stability.[1,2] Histologic studies have defined presence of mechanoreceptors in the ACL.[3] An ACL-hamstring reflex arc via the receptor afferents was reported that excites the hamstrings but simultaneously inhibits the quadriceps with stressing of the ACL.[1] The existence of similar mechanoreceptors was also defined for menisci in anatomic and histologic studies.[4-6] The mechanoreceptors might be expected to provide reflex sensory information with stimulation. However, activation of the menisci mechanoreceptor, whether initiated as a cortical response and a reflex arc similar to ACL receptors, had not been evaluated before.

The aim of the present study was to monitor the cortical response of the reflex arc with stimulation of

From PTT Hospital (B.S.), Department of Orthopaedic Surgery, Istanbul, Turkey; Acibadem Hospital (Y.Y.), Department of Orthopaedic Surgery; Istanbul, Turkey; Department of Physical Medicine and Rehabilitation (N.B., D.O., E.K.-S.) and Department of Orthopaedic Surgery (M.K.), Marmara University, Istanbul, Turkey.

Address correspondence and reprint requests to Baransel Saygi, M.D., Oguzhan Cad Celik Sok No. 10-9, Adatepe-Maltepe, Istanbul, Turkey. E-mail: baranselsaygi@superonline.com

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the mechanoreceptors at the posterior horn of the medial menisci. Somatosensory-evoked potentials (SEPs) were used to monitor the cortical component of the reflex arc. Reaction of the end organ to the cortical reflex was evaluated with electroneuromyography (ENMG). The hypothesis is that stimulation of the mechanoreceptors located at the posterior horn of the menisci has the capacity to initiate a cortical response and also cause a meniscus muscle reflex arc that has an effect on mobility of the menisci. Any event interfering with the mechanoreceptor mechanism may alter the meniscus mobility.

METHODS

Fourteen patients with normal medial menisci were studied during arthroscopy of the knee for other conditions. Electrophysiological studies were conducted by an ENMG-SEP machine (Medelec/TECA Sapphire, Surrey, England). The patients were anesthetized by use of a narcotic (alphentanyl) and a hypnotic (propofol). Inhalation anesthetic agents were avoided because of their depressant effects on cortical responses.[2] Muscle relaxants were also avoided so as not to affect the ENMG results. No local anesthesia was used.

SEPs

SEPs are defined as the cortical potentials evoked in response to mechanical or electrical stimulation of peripheral nerves of the lower or upper extremities.[7] They monitor peripheral nerve and posterior column proprioception and abnormalities are associated with disorders of joint positions, stereognosis, and vibration.[2] Waves are labeled by polarity (P, positive; N, negative) and latency (expressed in milliseconds).

Posterior Tibial Nerve SEP Responses: In all of the cases, the posterior tibial nerve was stimulated in the electrophysiology laboratory with a square current wave of 0.2 ms in duration at an intensity of 10 mA and a frequency of 2.0 pps. Trials were performed 3 times and superimposed to ensure consistency and also to confirm that the posterior tibial nerve SEPs were within normal limits.

Medial Meniscus SEP Responses: Medial meniscus SEP recordings were monitored during arthroscopy. The middle part of the posterior third (posterior horn) of the medial meniscus was electrically stimulated by a flush-tip monopolar electrode probe placed through the anteromedial portal. The probe is Teflon coated to its tip (Medelec). The stimulus thus comes only from the extreme tip of the probe, is localized to posterior horn of the medial meniscus, and does not spread through the synovial fluid or to other structures of the knee. Electrolyte-free resection fluid (5% mannitol in water) was used during the surgery to prevent intra-articular conduction.

The stimulus used was a wave of 0.2-ms duration at an intensity of 10 mA and a frequency of 2.0 pps. The response was recorded over a bandwidth of 20 to 200 Hz for a duration of 200 ms (Fig 1). Trials were performed 3 times. For each trial, 342 epochs were averaged and superimposed to ensure consistency.

Cortical response was monitored by an electrode inserted subcutaneously into the scalp at the CZ position of 10/20 (according to the international encephalography system) with FZ reference. The medial femoral condyle, the body of the meniscus, the capsule, and the joint space (through the resection fluid within the joint) were also stimulated in addition to the posterior horn of the medial meniscus.

ENMG Study

Medial Meniscus Muscle Reflex: The ENMG study to evaluate the meniscus muscle reflex arc was recorded during the arthroscopy. A concentric needle-recording electrode was inserted into the motor point of semimembranosus muscle to record the compound muscle action potential (CMAP). The ground electrode was placed at the posteromedial part of the knee between the stimulation and recording electrodes. The

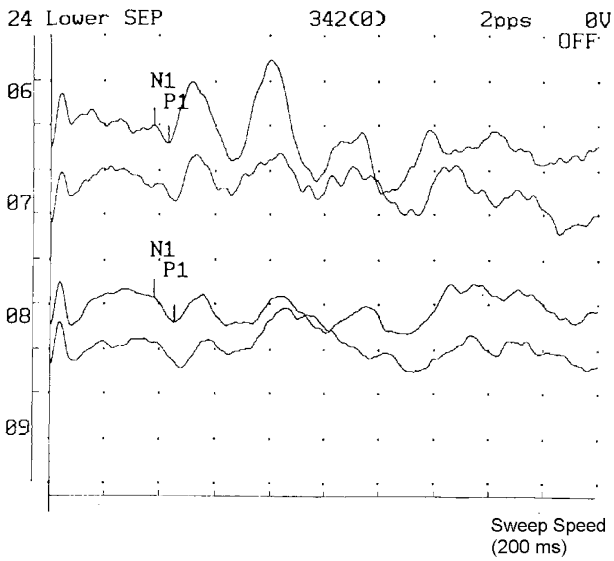

FIGURE 1. SEP response of case 10 obtained during the procedure. N1 is the first negative latency of each wave and P1 is the first positive latency of each wave.

stimulus used was a wave of 0.1 ms duration at an amplitude of 1 mV and a frequency of 1.0 pps. The response was recorded over a bandwidth of 2 to 200 Hz at a sweep speed of 50 ms.

The posterior horn and the body of the medial meniscus, the medial femoral condyle, and the joint space were stimulated by the probe and the CMAP of the semimembranosus muscle was recorded for each. The recording electrode was then inserted into the motor point of the quadriceps and biceps femoris muscles. The posterior horn of the meniscus was stimulated with the identical wave pattern for recording the CMAP for the quadriceps and biceps femoris muscles.

RESULTS

The medial menisci of 14 patients were found intact during arthroscopy. Stimulation of the posterior horn of the meniscus produced a cortical SEP response with a mean latency (and standard deviation) of P1: 53.9 ± 7.7 and N1: 44.7 ± 6.3 ms. Mean latency (and standard deviation) of the posterior tibial nerve SEP was P2: 44.2 ± 5.0 and N2: 38.1 ± 3.5 ms (Table 1). No cortical SEP response was obtained with stimulation of the medial femoral condyle, body of the medial meniscus, capsule, and joint space.

Mean CMAP latency (and standard deviation) to the semimembranosus muscle with stimulation of the posterior horn of the medial meniscus was 18.0 ± 1.0 ms (Table 2). Mean CMAP amplitude (and standard deviation) was 5.9 ± 0.5 mV. CMAP response was not obtained for semimembranosus muscle with stimulation of the body of the medial meniscus, medial femoral condyle, and joint space. No CMAP response was detected for the quadriceps and biceps femoris muscles with stimulation of the posterior horn of the meniscus.

TABLE 1. *SEP of the 14 Subjects Showing the Posterior Tibial Nerve and Posterior Horn of the Medial Meniscus*

	LATENCY (milliseconds)			
Case	P1	N1	P2	N2
1	51.7	40.6	40.4	34.4
2	59.4	54.3	45.0	38.6
3	56.4	41.1	46.1	36.3
4	49.2	39.1	41.2	35.9
5	75.4	59.9	60.4	49.2
6	57.8	48.8	42.7	39.3
7	48.1	38.4	40.9	37.6
8	52.3	43.4	43.4	38.1
9	51.1	41.2	44.1	37.7
10	45.2	37.8	42.8	35.9
11	50.8	44.4	40.9	38.1
12	49.8	43.2	41.3	37.1
13	60.5	47.7	43.6	39.8
14	47.5	46.7	47.0	36.4

NOTE. P1, N1: Latency results of posterior horn of medial meniscus. P2, N2: Latency results of posterior tibial nerve.

TABLE 2. *ENMG Results*

Case	Amplitude (mV)	Latency (ms)
1	6.4	18.6
2	6.1	17.9
3	4.9	16.0
4	5.9	18.1
5	6.4	18.6
6	6.0	17.2
7	5.7	19.7
8	6.2	18.0
9	5.9	16.7
10	5.8	18.9
11	6.2	18.2
12	6.3	18.5
13	4.7	19.1
14	5.8	16.9

DISCUSSION

Histological examinations revealed the presence of neural and sensory receptors in the meniscus. Although menisci are purported to input afferent impulses to the central nervous system via the receptors,[6,8] the linkage has not yet been elucidated.

In the current study, stimulation of the posterior horn of the medial meniscus produced measurable amounts of cerebral cortical–evoked potentials. However, no reaction was detected with stimulation of the body of the meniscus and other parts of the knee joint. This confirmed the presence of electrically sensitive receptors localized to the posterior horn of the medial meniscus. Because the probe was Teflon coated and exposed only at its very tip, the small intensity of the stimulus applied does not allow spread of the stimulus.[2] The absence of response to electrical stimulation in other parts of the knee joint, including the synovial fluid, indicates that the stimulus remained localized to the area where it was used.

In histologic studies, the presence of Pacinian and Ruffini corpuscles together with free nerve endings have been reported[4,6,9] that are indicative of sensory function of the menisci. They were mainly identified in the outer one third of the vascular perimeniscal

tissue, being heavier at the horns. Absence of neural elements in the inner part of the meniscus[5,6] is in accordance with the current study in which no cortical response was obtained with stimulation of the body of the meniscus.

Together with the cortical response, the end organ of the reflex arc was also evaluated. ENMG was used for this purpose. The recording electrode was inserted into the motor unit of semimembranosus muscle, which has an extensive connection with the coronary ligament of the medial meniscus.[10] The semimembranosus muscle has 5 distal expansions. The first is the oblique popliteal ligament. The second attachment is to the posterior capsule and posterior horn of the medial meniscus. It is this part that pulls the medial meniscus posteriorly with knee flexion. The third part inserts to the periosteum of the collateral ligament. The direct head attaches to the posterior medial tibia and the distal portion inserts into the periosteum of the medial tibia.[10,11] In the study of Kaplan,[10] faradic stimulation applied to the semimembranosus muscle at the motor point produced backward pull of the medial meniscus. Although an active connection between the semimembranosus muscle and the medial meniscus was defined, in the Kaplan study, the nature and the mechanism were not clearly outlined. In the current study, the presence of a reflex arc between the medial meniscus and semimembranosus muscle was proven. Stimulation of the posterior horn of the meniscus produced an ENMG-verified response of the semimembranosus muscle. This shows that activation of the posterior horn receptors leading to semimembranosus contraction may aid posterior movement of the medial meniscus other than passive displacement by the condyles of the femur.[10,12] Stimulation of the other parts of the knee, including the body of the meniscus, did not produce any CMAP for semimembranosus muscle. No ENMG response was detected with stimulation of the posterior horn when the recording electrode was inserted into the quadriceps and biceps femoris muscles. This is evidence of the presence of a unique reflex arc between the posterior horn of the medial meniscus and the semimembranosus muscle.

After a tear of the medial meniscus and subsequent partial arthroscopic meniscectomy, there were defined abnormalities in limb motion and muscle activation profiles.[13] This finding has been difficult to explain because arthroscopy is a relatively minor procedure. Excision of the posterior horn of the meniscus, which is the frequent site of the lesion together with the neurosensory receptors, may be a cause of a decrease in the muscle control of the knee joint after arthroscopy. Similarly, tearing of the posterior horn may contribute to the inhibition of the activation of the semimembranosus muscle, which may change the internal joint forces and meniscus mobility.

In the current study, the anterior horn of the meniscus, which is also known to be rich of receptors, was not stimulated. Its stimulation may also produce another cortical response and a reflex arc similar to the posterior horn. This needs further investigation.

Although we have used electrical stimulus, the sensory stimulus in the knee is mechanical. However, electrical stimulation is another tool and is a step in studying and determining the sensory function of the meniscus in humans.[2]

CONCLUSIONS

This study provides direct evidence that stimulation of the posterior horn of the meniscus produced reproducible cortical SEPs and resulted in ENMG-verified response of the semimembranosus muscle. Mechanical stimulation of the posterior horn receptors during flexion or rotation of the knee joint may result in an activity similar to electrical stimulation, which causes semimembranosus muscle contraction that pulls the medial menisci backward. This activity may prevent menisci from squeezing during movement of the knee joint. Therefore, more precaution must be taken to preserve as much of the posterior horn of the menisci as possible while performing meniscectomy. Similarly, interfering with the semimembranosus function (i.e., harvesting as a graft) may also impair meniscus mobility because this muscle is the end organ of the meniscus reflex arc.

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