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Research Article

Evaluation of the Conduction of the Pudendal Nerve Using Magnetic Stimulation: A Study in Healthy Volunteers and a Description of Clinical Case

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Abstract

Introduction: Magnetic stimulation is painless, non-invasive, has a narrow range of contraindications, and when applied, the frequency of obtaining motor responses (M-responses) from the pelvic floor muscles approaches 100%. However, there is currently no clear technical algorithm for the use of magnetic stimulation in the study of pudendal nerve conduction. The aim of this work is to study the conduction of the pudendal nerve using magnetic stimulation and registration of M-responses from different muscles of the perineum.

Materials and Methods: We examined 66 healthy volunteers aged 21 to 69 years (mean age 39.3 ± 14.4 years), including 45 men and 21 women. Three comparison groups were formed: the first group included subjects whose potentials were withdrawn from the right bulbocavernosus muscle (BCM), the second - from the left, and the third - from the external anal sphincter (EAS). To study the conduction of the pudendal nerve, we used a Neuro-MS/D magnetic stimulator and a Neuro-MEP-4 electroneuromyograph (Neurosoft, RF). In the presence of M-responses, the value of their latency was estimated. A patient with suspected pudendoneuropathy was considered as a clinical example.

Results: There were no statistically significant differences between the groups in terms of the latency of M-responses, including gender and age. The latency of M-responses in the recording potentials from the right and left BCM was 5.37 ± 2.20 ms (95% CI 4.65 - 6.10 ms), recording potentials from the from EAS was 6.13 ± 2.99 ms (95% CI 5.07-7.20 ms).

Discussion: Recording potentials from the right and left BCM allows assessing the conductance separately for each of the pudendal nerves. Currently, there are no unambiguously accepted normative indicators for the values of the latency of the M-responses of the pelvic floor muscles. The value of the latency of the M-responses of BCM obtained by us by the method of magnetic stimulation were 5.37 ± 2.20 ms. The value of the latency of the M-responses during registration of potentials with the EAS with surface ejection electrodes was equal to 6.13 ± 2.99 ms. The proposed method makes it possible to diagnose damage to the pudendal nerve when imaging methods (ultrasound, MRI) are not informative.

Conclusions: Diagnostic magnetic stimulation and the proposed method of applying surface recording electrodes to the pelvic floor muscles greatly simplify the study of pudendal nerve conduction in patients with suspected pudendoneuropathy. The normative indicators of the latency of M-responses were determined when the potentials were withdrawn from different muscles of the perineum within the framework of this technique.

Keywords: *Pudendal Nerve; Magnetic Stimulation; Bulbocavernous Reflex; Neuropathy of the Pudendal Nerve, Pudendal Neuralgia, Pelvic Floor*

Introduction

The pudendal nerve (S2-S4) is mixed; it innervates the muscles and skin of the perineum, the urethra, and the corpora cavernosa [1,2]. The most common forms of pudendoneuropathies (pudendal neuropathies, neuropathies of the pudendal nerve) are compression-ischemic (tunnel) and traumatic [3]. Less commonly, diabetic, dysmetabolic and dysimmune mechanisms form the basis of the pathogenesis of pudendal neuropathy [4,5]. The possibility of an isolated lesion of the pudendal nerve in herpes infection is discussed [3]. In the clinical picture of tunnel pudendoneuropathies, pain prevails. According to the Nantes Diagnostic Criteria (2006), pain syndrome in pudendal neuropathy is characterized by neuropathic pain in the area of innervation of the pudendal nerve, mainly in the sitting position; pain does not interfere with sleep, is not accompanied by an objective decrease in tactile sensitivity, and stops after diagnostic blockade [3,6]. The Nantes criteria characterize only the pain component of pudendoneuropathies. However, clinical signs of pudendal neuropathy are also hypalgesia in the area of pudendal innervation and dysfunction of the perineal sphincters. As the generally accepted methods of neurophysiological assessment of the function of the pudendal nerve, two main ones can be distinguished: stimulation electroneuromyography of the pudendal nerve and needle myography of BCM and EAS [3,7]. The disadvantages of techniques with the use of electrical stimulation are pain, discomfort for the patient when the lead electrodes are inserted into the rectum or vagina, as well as the low frequency of obtaining M-responses even in healthy subjects. Needle myography is dangerous by injury to the structures of the perineum and invasiveness [7]. An alternative way to study the function of the pudendal nerve is diagnostic magnetic stimulation. Magnetic stimulation is painless, non-invasive, has a fairly narrow range of contraindications, when applied, the frequency of obtaining M-responses suitable for analysis approaches 100% [7]. The generally accepted criterion characterizing the conduction of the pudendal nerve is the value of the terminal latency of the received M-response. At the same time, the published domestic and foreign literature lacks a clear technical algorithm for magnetic stimulation of the pudendal nerve and generally accepted normative indicators of the latency of M-responses of the pelvic floor muscles, which requires further study [8,9]. The purpose of this work is to study the conduction of the pudendal nerve using magnetic stimulation and registration of M-responses from different muscles of the perineum.

Materials and Methods

We examined 66 healthy volunteers aged 21 to 69 years (mean age 39.3 ± 14.4 years), of which 45 were men and 21 were women. The inclusion criteria for the study were: the absence of complaints characteristic of pudendal neuropathy, the absence of neurological, gastrointestinal, gynecological, urological diseases, pelvic injuries and operations on the pelvic organs in history, normal physical (including neurological) examination. The exclusion criteria were the presence of complaints characteristic of pudendal neuropathy, deviations from the norm identified in the objective status, age under 18 and over 70, and refusal to participate in the study. The patients were examined from February 2018 to April 2021. Three comparison groups were formed: the first group included subjects whose potentials were withdrawn from the right BCM, the second - from the left, and the third - from EAS. In the presence of M-responses, the value of their latency was estimated. A patient with suspected pudendoneuropathy was considered as a clinical example.

To study the conduction of the pudendal nerve, we used a Neuro-MS / D magnetic stimulator combined with a Neuro-MEP-4 electroneuromyograph (Neurosoft, RF). The center of a circular inductor with a diameter of 15 cm was applied at the level of the spinous processes of the II-IV sacral vertebrae along the midline so that the current in the inductor coil was directed counterclockwise for the right side and clockwise for the left side. Stimulation was carried out until an M-response suitable for analysis was obtained. The magnetic field strength was set to 100% (2.2 - 2.6 T). Potentials were withdrawn in two ways: with EAS and with right and left BCM. In the first case, the active abduction electrode was placed on the EAS, and the reference electrode on the inner surface of any thigh. In the second case, the active electrode was placed alternately on the right and left BCM, the reference electrode was attached to the inner surface of the thigh of the same name. Disposable self-adhesive plate electrodes ("Fiab", Italy) were used as withdrawal electrodes.

Statistical data processing

The results were processed using the SPSS Statistics 26 software package. Quantitative data were checked for normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk tests. To identify statistically significant differences in normally distributed data, we used one-way ANOVA followed by a posteriori test (Bonferroni correction) and T-test for independent samples. The results were presented as M ± SD (where M is the mean, SD is the standard deviation). $P < 0.05$ was taken as the critical level of significance.

Respect for patients' rights and bioethics rules

All patients signed informed consent to participate in the study. The study protocol was approved by the Biomedical Ethics Committee of the Federal State Educational Institution of Higher Education "PIMU" of the Ministry of Health of Russia.

Results

In all examined healthy volunteers, we managed to register the M-responses of the studied muscles. When studying the conduction of the pudendal nerve, the following results were obtained on the values of the latency of M-responses (Table 1).

Muscle which the M-response was recorded	Indicator		
	Latency, ms		Absolute latency values, ms
	M±SD	95% CI	
Right BCM	5,37±2,46	4,18-6,55	2,51-9,53
Left BCM	5,38±1,97	4,43-6,33	2,25-10,30
EAS	6,13±2,99	5,07-7,20	2,12-11,40

Table 1: *Comparison of the values of the latency of the M-responses of the muscles of the perineum, depending on the location of the evacuation of potentials in healthy volunteers.*

M - arithmetic mean, SD - standard deviation, CI - confidence interval, BCM - bulbocavernous muscle, EAS - external anal sphincter.

The value of the latency of the M-responses in the derivation of potentials from the right and left BCM totaled 5.37 ± 2.20 ms (95% CI 4.65 - 6.10 ms). There were no statistically significant differences in gender, age, values of the latency of M-responses between the studied groups of patients when the potentials were diverted from the right and left BCM and EAS (Table 2 and 3).

Muscle which the M-response was recorded	Sex	Indicator		
		Latensy, ms		Absolute latency values, ms
		M±SD	95% CI	
Left and right BCM	Male (n=45)	5,41±2,39	4,49-6,34	2,25-10,30
	Female (n=21)	4,80±2,13	3,28-6,33	0,94-8,73
EAS	Male (n=45)	6,81±3,35	5,09-8,53	2,25-11,4
	Female (n=21)	5,42±2,47	4,10-6,73	2,12-10,70

Table 2: *Values of the latency of the M-responses of the muscles of the perineum depending on the sex of healthy volunteers.*

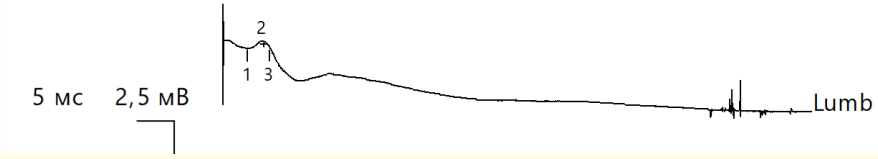
M - arithmetic mean, SD - standard deviation, CI - confidence interval, BCM - bulbocavernous muscle, EAS - external anal sphincter.

Muscle which the M-response was recorded	Age group, years	Indicator		
		Latensy, ms		Absolute latency values, ms
		M±SD	95% CI	
Left and right BCM	21-35 (n = 20)	4,07 ± 2,52	4,89 - 7,25	2,51 - 10,30
	36-45 (n = 16)	4,53 ± 1,14	2,72 - 5,34	3,50 - 6,99
	46-55 (n = 13)	4,86 ± 2,80	2,41 - 6,32	2,25 - 7,54
	55-69 (n = 17)	4,53 ± 1,06	3,77 - 5,29	3,18 - 6,48
EAS	21-35 (n = 20)	6,47 ± 1,38	3,67 - 5,27	2,12 - 6,61
	36-45 (n = 16)	4,08 ± 1,45	3,77 - 5,40	2,65 - 9,40
	46-55 (n = 13)	5,05 ± 2,83	1,53 - 8,57	2,25 - 9,39
	55-69 (n = 17)	6,55 ± 1,87	4,90 - 7,20	3,28 - 9,70

Table 3: *Значения величин латентности М-ответов мышц промежности в зависимости от возраста здоровых добровольцев. M - arithmetic mean, SD - standard deviation, CI - confidence interval, BCM - bulbocavernous muscle, EAS - external anal sphincter.*

Examples of M-responses obtained from a healthy volunteer are shown in figure 1.

a) place of superposition of the discharge electrode: right m. Bulbocavernosus
result: the latency of the M-response 4.90 ms



b) the place of application of the lead electrode: left m. Bulbocavernosus
result: the latency of the M-response of 4.23 ms

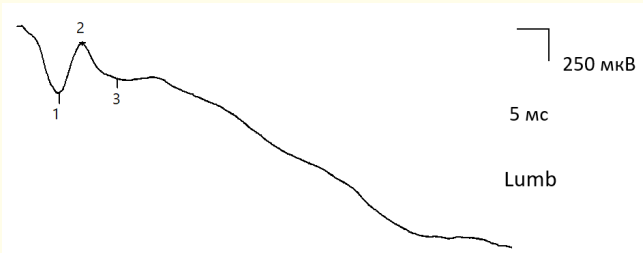
c) the place of application of the lead electrode: m. Sphincter ani
result: latency 2.05 ms

Figure 1: *Examples of M-answers obtained from a healthy volunteer.*

Clinical case

Patient U., 31 years old. Was inpatient treatment in the urological department with a diagnosis of «Chronic pelvic pain of the type of vaginal and urethral pain syndrome.» She complained of a burning sensation in the urethra, aggravated at the end of the act of urination, shooting pains in the vagina, more to the left, aggravated by intercourse, urine leakage with tension (uses pads). The nature of work is sedentary, mental. Considers herself sick for about 3 months, she was treated by a urologist and gynecologist at the place of residence without effect. Physical examination data. Examination by a gynecologist: "The external genital organs are formed correctly, according to the female type. Per vaginum - painful palpation, mainly in the area of the sacrospinous ligaments, more on the left, soreness in the neck of the bladder. « In the neurological status: painful hypesthesia in the area of innervation of the pudendal nerve on the left, anal and bulbocavernous reflexes are reduced. On the diagnostic questionnaire of neuropathic pain DN4, 5 points were scored. Additional laboratory and instrumental studies. No clinically significant abnormalities were found in laboratory blood and urine tests. According to ultrasound of the internal genital artery (transperineal access): the blood flow of the main type on both sides, the course of the arteries is rectilinear, the linear blood flow velocity is not reduced (21.4 cm / s on the right and 19.3 cm / s on the left), the diameter of the artery on the right is 1, 4 cm, on the left - 1.1 cm. Targeting MRI of the pudendal nerve canal (Alcock's canal): the pudendal nerves and adjacent structures were unremarkable. When conducting magnetic stimulation with the derivation of potentials from BCM and EAS, the data presented in table 4 were obtained. Examples of the received M-responses are presented in figure 2.

a) place of superposition of the discharge electrode: right m. Bulbocavernosus
Result: latency 6.09 ms



b) the place of superposition of the discharge electrode: left m. Bulbocavernosus Result: 15.65 ms latency

c) the place of superposition of the discharge electrode: m. Sphincter ani
Result: latency 4.23 ms

Figure 2: *The obtained M-responses of the muscles of the perineum during magnetic stimulation of the pudendal nerve in patient U. 31 years old before treatment.*

Indicator	Muscle which the M-response was recorded		Muscle which the M-response was recorded
	Right BCM	Left BCM	EAS
Latency, ms	6,09	15,65	4,23
Reference interval of latency value, ms	5,37±2,20		6,13±2,99

Table 4: *Indicators of the latency of the M-responses of the muscles of the perineum during magnetic stimulation of the pudendal nerve in patient U. 31 years old before treatment.*

BCM - bulbocavernous muscle, EAS - external anal sphincter.

It follows from table 4 that the latency of the M-response in the derivation of potentials from the left BCM of patient U. 31 years old was 15.65 ms. These results exceed the standards we obtained for the latency of M-responses during the withdrawal of potentials from these muscles; it was concluded that there was a violation of conduction along the left pudendal nerve. Thus, the instrumental data obtained by the method of diagnostic magnetic stimulation of the pudendal nerve in patient U. 31 years old are consistent with the clinical picture and the data of an objective examination. The patient was refined with the neurological diagnosis "Compression-ischemic neuropathy of the left pudendal nerve, persistent severe chronic pain syndrome" (ICD-10 code G58.8 "Other specified mononeuropathies"). A course of treatment (NSAIDs, amitriptyline, gabapentin, psychotherapy, low-intensity laser therapy and hyperbaric oxygenation) was carried out with control of the condition after 4 months. The indicators of magnetic stimulation after treatment are presented in table 5.

Indicator	Muscle which the M-response was recorded		Muscle which the M-response was recorded
	Right BCM	Left BCM	EAS
Latency, ms	6,11	13,31	4,28
Reference interval of latency value, ms	5,37±2,20		6,13±2,99

Table 5: *Indicators of the latency of the M-responses of the muscles of the perineum during magnetic stimulation of the pudendal nerve in patient U. 31 years after treatment.*

BCM: bulbocavernous muscle, EAS - external anal sphincter.

Against the background of the treatment, the values of the latency of M-responses during the derivation of potentials from the left BCM decreased (13.31 ms versus 15.65 ms), which may indicate an improvement in the conduction of the left pudendal nerve. Subjectively, the patient noted that she began to feel better, the burning sensation in the urethra decreased, the shooting pains in the vagina became less, and the control over urinary retention improved somewhat.

Discussion

Until now, there have been no studies of pudendal nerve conduction using magnetic stimulation conducted on a sufficiently large sample of patients. The article describes the use of magnetic stimulation in the study of the conduction of the pudendal nerve, namely, the peripheral part of the efferent pathway to the muscles of the pelvic floor. To study the conduction of the pudendal nerve, you can use the derivation of potentials from the EAS, as well as from the right and left BCM. The latter presupposes lateralization of M-responses, that is, it makes it possible to evaluate the conductance along each of the genital nerves separately, when necessary. The absence of statistically significant differences between the studied groups in the latency of M-responses during the derivation of potentials from BCM and EAS can be explained by the fact that the difference in the distance from the site of stimulation to each of these muscles is insignificant.

Currently, there are no unambiguously accepted normative indicators for the values of the latency of the M-responses of the pelvic floor muscles. The value of the latency of BCM M-responses obtained by us was 5.37 ± 2.20 ms, which is consistent with the previously published data of Ghezzi A., *et al.* (1991). The latency of M-responses in the derivation of potentials with EAS was 6.13 ± 2.99 ms and was twice as high as in previously published studies. The latter can be explained by the use of different types of discharge electrodes (needle, intraanal or superficial cutaneous) and, accordingly, different degrees of contact of the electrodes with the muscle under study. In previously published works, potential removal from the EAS was carried out using needle and intraanal electrodes. In our study, for the first time, surface abduction electrodes with EAS were used, which simplifies the study of the conduction of the pudendal nerve and does not bring discomfort to the patient. A clinical example illustrates the value of the proposed method in diagnosing a lesion of the pudendal nerve. In our opinion, diagnostic magnetic stimulation can be considered as the method of choice in the diagnosis of pudendal neuropathies.

This method is especially important in the absence of ultrasound and / or MRI signs of vaso-neural conflict between the internal genital artery and the pudendal nerve in the Alcock canal. Timely diagnosis and therapy of pudendal neuropathy in most cases avoids surgical interventions on the pudendal nerve. In earlier studies, magnetic stimulation was most often performed transcranially and translumbally with the capture of the central and peripheral motoneurons. Our technique with the location of the magnetic inductor at the level of II-IV sacral vertebrae allows us to exclude the involvement of spinal motor neurons and to assess the function of only the peripheral part of the neuromotor apparatus.

Conclusions

Diagnostic magnetic stimulation and the proposed method of applying surface abduction electrodes to the pelvic floor muscles greatly simplify the study of pudendal nerve conduction in patients with suspected pudendoneuropathy. In this work, the normative indicators of the latency of the M-responses of the bulbocavernous muscles and the external anal sphincter during magnetic stimulation of the ventral sacral roots are determined. We recommend using the obtained standards in clinical practice to assess the conduction of the pudendal nerve.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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