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ANATOMICALLY HIGH DIVISION OF SCIATIC NERVE AND ITS CLINICAL SIGNIFICANCE
ANATOMSKI VISOKA PODELA SEDALNOG ŽIVCA I NJEN KLINIČKI ZNAČAJ

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Abstract

Background / Aim: The sciatic nerve (SN) is a mixed nerve formed in pelvis by joining of L4-S3 anterior spinal nerve roots. SN can be under the pressure in different regions throughout its course, however, the most frequent site of impingement is under the piriformis muscle which causes occurrence of piriformis syndrome. High division of SN has its relevance considering the fact that it leads to compression of nerve resulting in piriformis syndrome. Determining the connection between anatomical parameters of pelvis and high division of SN which is considered to be one of the most common causes of piriformis syndrome in both genders. Methods: This study was conducted on 28 formalin fixed cadavers of both genders at the Institute of Anatomy in Belgrade and Department of Anatomy in St Andrews. For measuring of required dimensions, we used a ruler and a caliper. The statistical data analysis was performed in SPSS 11.0 using Mann-Whitney U test. A statistically significant difference in the values of bispinal and bituberal lines were observed. Results: A high division of SN was found on 58.33% of the male cadavers and 80% of the female cadavers. A statistically significant difference in the mean value of the bituberal line between the male and female sex was also recognised. Conclusion: Connection between the anatomical parameters of the pelvis and the level of division sciatic nerve is confirmed. Although on the basis of the results it could be assumed that people with smaller pelvic dimensions would have greater likelihood of developing a piriformis syndrome. The other factors such as biomechanics related to a wider „Q angle“ in women that could result in a higher incidence of piriformis syndrome, should also be considered.

Keywords: piriformis syndrome, histology, sciatic nerve, piriformis muscle, high division

Apstrakt

Uvod / Cilj rada: Sedalni živac (n. ischiadicus) je mešoviti živac koji nastaje u karlici od prednjih grana kičmenih (spinalnih) živaca od L4 -S3. Tokom svog puta, n. ischiadicus može biti podložan pritisku u različitim regionima, a naročito u predelu zgloba...
kuka od strane piriformnog mišića što prouzrokuje simptome piriformnog sindroma. Visoka podeša nerva klinički je značajna zbog toga što ona najčešće ima za posledicu kompresiju nerva odnosno piriformni sindrom. Ispitivanje povezanosti anatomijskih parametara karlice sa visinom podele n. ischiadicus kod oba pola, uz pretpostavku da ispitivani parametri utiču na samu podešu nerva koja se smatra jednim od glavnih uzročnika piriformnog sindroma. **Metode:** Studija je sprovedena na 28 formalinskih kadavera oba pola na Institutima za anatomiju, medicinskog fakulteta u Beogradu i St Andrews-u. Za merenje parametara dimenzija karlice korišćeni su lenjir i kaliper. Statistička obrada podataka je izvršena u programu SPSS 11.0 primenom Mann-Whitney U testa. **Rezultati:** Uočena je statistički značajna razlika u vrednosti kod bispinalne i bituberalne linije. Visoka podeša je pronađena na 58.33% od uzorka muškog pola i na 80% od uzorka ženskog pola. Takođe je pokazana statistički značajna razlika u srednjoj vrednosti bituberalne linije između muškog i ženskog pola. **Zaključak:** Veza između anatomijskih parametara karlice sa nivoom podele n. ischiadicus je potvrđena. Iako bi se na osnovu rezultata moglo pretpostaviti da će osobe sa manjim dimenzijama karlice imati veću verovatnoću da se kod njih razvije piriformni sindrom, trebalo bi uzeti u obzir i druge faktore kao što je biomehanika koja je povezana sa širim uglom m. quadriceps femorisa kod žena i ima za posledicu veću učestalost piriformnog sindroma. **Ključne reči:** piriformni sindrom, histologija, n. ischiadicus, m. piriformis, visoka podeša

**Introduction**

Sciatic nerve (SN) is the longest and the widest nerve of the human body [1]. It is a mixed nerve formed in pelvis by joining of L4-S3 anterior spinal nerve roots. At the level of the sacroiliac joint sciatic nerve can be almost 2 cm wide. The main reason for high division of sciatic nerve is its size [1].

SN exits the pelvic cavity wrapped with a single epineurium through the greater sciatic notch under the piriformis muscle. Most often, at the level of superior angle of popliteal cavity SN is divided into the terminal branches, medial tibial nerve and lateral common fibular nerve [2]. Once it enters gluteal region through the infrapiriform opening, it moves over the pelvitrochanteric muscles, covered with gluteus maximus muscle and soft tissue [3]. SN then descends between tuberosity of ischium inside, and the greater trochanter of femur, which is outside. In the thigh, SN is located posterior from adductor
magnus muscle and anterior from long head of biceps femoris muscle [3]. In this area, nerve is particularly vulnerable to injury during administration of intramuscular injections [4]. Motor branches of SN are responsible for innervation of hip and knee joint, while the sensitive branches innervate almost the entire lower leg, with the exception of the anterior inner part of the lower leg and the medial edge of the foot [2]. By achieving a close relationship with piriformis muscle SN in gluteal region can cause the occurrence of the „piriformis syndrome“ [4]. Because of common distal attachment with piriformis muscle on the greater trochanter of femur, obturator internus muscle as well as superior and inferior gemellus muscle have the ability to compensate for the loss of its function [3].

**Anatomical variations**

According to the classification of Beatons and Ansons anatomical variations of SN relative to pelvitrochanteric piriformis muscle can be classified into several types (Fig. 1.):

Type 1: Undivided nerve below undivided muscle.

Type 2: Division of nerve between and below undivided muscle.

Type 3: Division above and below undivided muscle.

Type 4: Undivided nerve between heads.

Type 5: Division between and above heads.

Type 6: Undivided nerve above undivided muscle.

Babinski and Mas also described the new anatomical variation in which common fibular nerve extends above and tibial nerve below, relative to superior gemellus muscle. All these classifications are important in surgery to determine the cause and location of nerve compression and thus determine the appropriate treatment [2]. It’s believed that divided piriformis muscle is an important cause of the piriform syndrome, because it contributes to compression and irritation of the SN that runs between its fibers [2]. Beside the piriformis muscle, it is thought that nerve compression can also be performed by obturator internus muscle (Fig.3), which belongs to the group of external rotators in hip joint, located below the SN [5]. The close contact between the tendon of obturator internus muscle and SN causes similar symptoms such as those occurring in the piriform syndrome [5]. The aim of this study is to examine the relationship between the anatomical parameters
of the bony pelvis and the height of SN division in both sexes, assuming that analysed parameters affect the SN division itself, which is considered to be one of the main causes of piriform syndrome.

**Materials and Methods**

Our study was conducted at the School of Medicine, University of Belgrade (Serbia) and School of Medicine, University of St Andrews (United Kingdom). The study was conducted on cadaveric material of the Institute of Anatomy "Niko Miljanic" in Serbia, as well as Department of Anatomy in St Andrews, where 28 cadavers were used in this study, of which 18 cadavers were male and 10 female, aged 74-86 years. These cadavers were embalmed with 10% formalin and fixed. For this research, we formed two study groups, that together comprised 56 lower extremities, with the aim of defining high and low division of SN. Distal attachment of piriformis muscle on the greater trochanter of femur was taken for boundary of division of SN. All divisions above the distal attachment of piriformis muscle are defined as high, while divisions below are defined as low. For the parameters of the bony pelvis dimensions, we took the distance between the right and left superior anterior iliac spine which we defined as a bispinal line, as well as the distance between two tuberosities of ischium that we defined as a bituberal line (Fig.2). For measuring of required dimensions, we used a ruler and caliper. An example of dissected cadavers is presented in (Fig.3). Statistical data processing was performed in SPSS 11.0 using the Mann-Whitney U test, with an accepted level of statistical significance was p <0.05, and p <0.001 for highly statistically significant result.

**Results**

Results of our research are presented in tables (Table 1. and Table 2.) and graphics (Graphic 1 and Graphic 2.). In our study we analysed 56 lower extremities (36 male and 20 female). In 38 we found high division of SN, representing 67.86% of the total sample, while a low division of SN was found in 18 cadavers, representing 32.14% of total sample. High division of SN was found in 21/36 male cadavers, which represents 58.33% of male specimen, while the same division was found in 16/20 female cadavers, which represents 80% of female specimen. The mean value of the length of bispinal line on the total cadaver sample with high division of SN was 24.38 ± 1.69, whereas the mean value of the same
parameter on the total cadaver sample with low division of SN was 30.01 ± 2.27. Comparing the two formed groups (with high and low division of SN) and using the Mann-Whitney U test, we demonstrated a statistically significant difference of mean value of bispinal line between high and low divisions (p=0.003; p<0.05). The mean value of the length of bituberal line in cadavers with high division of SN was 14.56 ± 1.05, while the same parameter in group with low division of SN was 16.38 ± 0.25. Using the Mann-Whitney U test, in comparison of the two cadaveric groups tested, a statistically significant difference in the dimension of bituberal line was obtained (p=0.004; p<0.05). In the male cadaveric group with high division of SN, the mean value of the length of bispinal line was 24.75 ± 2.36, while in female cadaveric group same parameter was 24.00 ± 0.82. After comparing two groups, we did not obtain statistical significance (p=0.88; p>0.05). Mean value of the bituberal line in the male cadaveric group was 15.38 ± 0.63, while the same parameter in female cadaveric group was 13.75 ± 0.65. Statistical analysis revealed a significant difference in the mean value of bituberal line between male and female cadaveric group (p=0.028; p<0.05).

Discussion

SN represents the nerve which is due to anatomical characteristics particularly susceptible to various forms of injury [3]. The neuropathy of this nerve is one of the most common disease in the lower extremity [3]. SN may be susceptible to the pressure in different regions, but it most commonly occurs in the area of hip joint by the piriformis muscle, causing the symptoms of „piriformis syndrome“ in patients [4]. „Piriformis syndrome“ is characterized by severe pain in the gluteal region, lower part of back, and worsening of symptoms due to prolonged sitting [7]. The reason of „piriformis syndrome“ can be caused by impaired anatomical structures during growth and development, as well as, congenital anomalies [4]. In the study [4], where the researches analyzed topographic characteristics on foetuses that are thought vary along with the foetal development of the organs. When they followed distances between infrapiriform opening and individual anatomical structures on the hip bone, it was observed that distances increased with the age, however, it was not possible to make correlation between nerve thickness in the level of the infrapiriform opening and age, which is explained by the faster development of the musculoskeletal system versus nervous system [4]. It was also noted that the distance
between tuberosity of ischium and SN, as well as the distance between greater trochanter of femur and SN at the point where SN transitions from gluteal region into the posterior femoral compartment remained unchanged relative to age [4]. The significance of these results is the fact that shows that the situation of SN in relation to the femur and pelvic bone does not change in relation to the age [4]. High division of SN is clinically significant because it most often results as nerve compression which is cause of „piriformis syndrome“ [2]. In our study, we followed relationship of high and low division of SN with pelvic parameters (bispinal and bituberal line). Division of SN into the end branches at a higher level than usual can happen anywhere in thigh or pelvis and it is relatively common phenomenon [3]. This was confirmed by our results which are showing that in 67.86% of total sample the SN was highly divided above the distal attachment of piriformis muscle on greater trochanter of femur which we have designated as the criterion for determining the level of the division. Observing the pelvic parameters of cadavers with high division of SN, it can be observed that the mean value of both parameters, bispinal line (24.38 ± 1.69) and bituberal line (14.56 ± 1.05) is less than mean value of bispinal line (30.01 ± 2.27) and bituberal line (16.38 ± 0.25) obtained in cadavers with low division of SN, which proved to be statistically significant (p< 0.05). Further analysis of obtained results by gender, we obtained the result that is statistically significant (p< 0.05) and indicates decrease in the length of bituberal line in the female cadavers. These results indicate relationship between the anatomical parameters of the pelvis with the level of SN division, such the high division is associated with smaller pelvic dimensions. It could be assumed that due to frequent high division, the person with the smaller size of the pelvis will have a higher probability to develop „piriformis syndrome“, however, other factors such as biomechanics should be considered. It is considered that „piriformis syndrome“ occurs more frequently in women with larger dimensions of pelvis than men, and main cause for that has biomechanical origin which is induced by a larger "Q angle" [6]. „Piriformis syndrome“ is up to six times more common in women than in men due to the biomechanics which is associated with a wider angle m. quadriceps femoris ( "Q angle") in women [6]. Our results may indicate the cause of the „piriformis syndrome“, primarily in individuals of the female population, because the conducted cadaveric study shows a more frequent high division of SN in women (80% of the total sample), with a statistical significant difference in the length of bituberal line, which is certainly smaller in females. There is a study which
showed that the relationship between the anatomical structures of hip bone and SN, first in the anatomical position, and than in positions which are simulating the piriformis muscle elongation test (such as 60° flexion, 30° adduction and 10° medial rotation in hip joint) [8]. In previous study, results showed that during biomechanics stretching tests infrapiriform opening becomes closer to the spine of ischium and the angle between transversal plane and SN becomes larger, and makes SN more susceptible to being „stuck“.

**Conclusion**

The results of our study show that there is a relationship between the anatomical parameters of the bony pelvis with the level of SN division. A high division of SN is associated with the smaller length of bispinal and bituberal line in both sexes and there is a more frequent high division of SN in females (80% of the total sample). Also, in females, there is a statistically significant difference in the length of bituberal line, which is smaller.

Although, the results would suggest that people with smaller pelvic dimensions are more likely to develop „piriformis syndrome“, other factors such as biomechanics, which in this case is associated with the wider „Q angle“ in women, results in a higher incidence of „piriformis syndrome“ [6].

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Figure 1. Anatomical variations of sciatic nerve (Beatons and Ansons classification). MP – piriformis muscle; SN – sciatic nerve; 1: Undivided nerve below undivided muscle; 2: Division of nerve between and below undivided muscle; 3: Division above and below undivided muscle; 4: Undivided nerve between heads; 5: Division between and above heads; 6: Undivided nerve above undivided muscle.
Figure 2. View of measurements of anatomical parameters of pelvis. 1 – superior anterior iliac spine; 2 – tuberosity of ischium; BSL – bispinal line; BTL – bituberal line.
Figure 3. High division of sciatic nerve, above the obturator internus muscle. The sciatic nerve exits the pelvis from the infrapiriform portion of greater sciatic foramen divided by attachment of obturator internus muscle in the left gluteal region: IT – tuberosity of ischium; GT – great trochanter of femur; QF – quadratus femoris muscle; CPN – common peroneal (fibular) nerve; TN – tibial nerve; OI – obturator internus muscle; P – piriformis muscle, GM – gluteus medius muscle.

Table 1. Results of the measured pelvic parameters. With asterisk is marked statistically significant difference in decrease of length of bispinal and bituberal lines in cadavers with high division of sciatic nerve (p<0.05). All measurements are presented in cm.

| High division of SN (67.86%) | Mean value | SD  |
|-----------------------------|------------|-----|
| Bispinal line               | 24.38*     | 1.69|
| Bituberal line              | 14.56*     | 1.05|
| Low division of SN (32.14%) | Mean value | SD  |
| Bispinal line               | 30.01      | 2.27|
| Bituberal line              | 16.38      | 0.25|
Table 2. Results of the measured pelvic parameters in cadavers with high division of SN. With asterisk is marked statistically significant difference in decrease of length of bituberal line in female cadavers (p< 0.05). All measurements are presented in cm.

| High division of SN in male cadavers (58.33%) | Mean value | SD  |
|-----------------------------------------------|------------|-----|
| Bispinal line                                  | 24.75      | 2.36|
| Bituberal line                                 | 15.38      | 0.63|

| High division of SN in female cadavers (80%)  | Mean value | SD  |
|-----------------------------------------------|------------|-----|
| Bispinal line                                  | 24.00      | 0.82|
| Bituberal line                                 | 13.75*     | 0.65|
Graphic 1. View of statistically significant difference (with SE) in length of bispinal and bituberal line between high and low division of SN. With asterisk is marked decrease in both parameters in cadavers with high division (p< 0.05).
Graphic 2. View of statistically significant difference (with SE) in length of bituberal line between two sexes with high division of SN. Asterisk shows decrease in length of bituberal line in females (p<0.05).

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