

## Follow Up of Sciatic Nerve Stiffness in Patients with Deep Gluteal Syndrome, Underwent Surgery

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### Abstract

The current studies with the preliminary results show the relevance of sciatic nerve stiffness in patients with deep gluteal syndrome (DGS). The research focus was to determine the degree of nerve entrapment relative on nerve stiffness. The study was cases based, according to a smaller country population. Neurological examination, MRI of spine and pelvis and electromyography (EMG) were performed. Our focus was to follow up sciatic nerve characteristics and stiffness in patients shortly after surgery, compared with data more than one year later. The sciatic nerve was scanned by ARFI (strain) elastography during knee movements in patients with DGS, without surgery (89). In 54 patients surgical treatment was indicated, while 24 of them underwent surgery. One year later follow up was performed in 21 patients, underwent surgery. The results were based on tissue response to ARFI by color elastogram and stiffness ratio. The sciatic nerve diameter and stiffness were followed after surgery, with the absence of neurological symptoms (nerve recovery), and one year later ( $p < 0.01$ ). Sciatic nerve recovery after surgery, performed by diameter and stiffness ratio, was marked ( $r = 0.881$ ), relative to these one year later ( $r = 0.579$ ). The correlation between MRI and EMG findings and ARFI nerve stiffness values in patients scheduled for surgery was high ( $r = 0.963$ ), as well as in those one year later ( $r = 0.749$ ). The overall specificity of method was 83.8%; sensitivity was 78.4% with accuracy of 83.9%. ARFI elastography (by strain) was useful tool in decision making for surgery and in follow.

**Keywords:** Sciatic nerve; Deep gluteal syndrome; Strain Elastography; ARFI; Surgical Procedures; ROC Analysis

### Abbreviations

pts.: patients; DPS: Deep Gluteal Syndrome; ARFI: Acoustic Radiation Force Impulse

### Introduction

It is well known that peripheral nerves tighten and relax during limb movements with changes in nerve stiffness. That was used in understanding various nerve diseases such as deep gluteal syndrome (DGS) [1]. The pain originates from the hip joint and the buttock

region. Sciatic nerve is positioned underneath the gluteus maximus muscle deep in gluteal region, running between the ischial tuberosity and the greater trochanter of the thigh bone, near the top of the posterior capsule of the hip joint (ball and socket). The nerve may become irritated or inflamed in this tissue. During normal joint movement, the sciatic nerve is flexible enough to stretch and slide with moderate strain or compression. In case of abnormal movements, it may become entrapped or compressed, causing pain. In addition, trauma, injuries or repetitive motions could be causes of pain as well. Sciatic nerve roots emerge from the lumbar plexus within the pelvis and exit through the sciatic notch inferior to the piriformis muscle. Although sciatic nerve is in connection with the superior gluteal and inferior gluteal nerves, the quadratus femoris and the obturator internus, some authors believe that deep gluteal syndrome is a result of sciatic nerve compression caused by piriformis muscle [2,3]. Symptoms vary and may include pain and numbness down the leg [3,4] and they worsen when sitting or standing [4]. Neurological examination, pelvic MRI and electromyography (EMG) are often necessary [5,6]. Acoustic radiation force impulse (ARFI), a low-frequency ultrasound pulse, can be used to create the displacement of tissue [7]. ARFI elastography of sciatic nerve was applied [8-14] with an aim to develop diagnostic possibilities and improve therapeutic modalities. Full testing of sciatic nerve during limb movements are in the focus of interest. Some authors have noticed sciatic nerve tightening with knee or ankle movements [8,11]. The morphological changes of the sciatic nerve during knee extension movement and knee flexion movement have been observed.

### Aim of the Study

The aim of the study is to show the relevance of ARFI elastography (by strain) in nerve stiffness assessment establishing the degree of nerve entrapment in the process of surgical decision making and the follow up. It has to be noted that anyone was consistent to follow up patient shortly after surgery and in a relatively prolonged period of one year later.

### Materials and Methods

The sciatic nerve was scanned by strain elastography using ARFI during knee movements in symptomatic persons with deep gluteal syndrome (143) during last three years (from 2015 to 2018). The patients were divided into two groups: group A - without indications for surgical treatment (89) and in group scheduled for surgery (54). The recovery of sciatic nerve was followed up in 24 (out of 54) patients who underwent surgery (group B). Monitoring was done relatively shortly after surgery and one year later. The imaging was performed at the gluteal region. The borders of the deep gluteal space are defined by the following: posteriorly, the gluteus maximus, anteriorly, posterior acetabular column, hip joint capsule and proximal femur, laterally, lateral lip of linea aspera and gluteal tuberosity, medially, sacrotuberous ligament and falciform fascia, superiorly, inferior margin of the sciatic notch, inferiorly, proximal origin of the hamstrings at ischial tuberosity [1]. It is important to know that the greater sciatic foramen is an opening in the posterior of human pelvis. It is formed by the sacrotuberous and sacrospinous ligaments and the piriformis muscle passes through the foramen and occupies most of its volume. The greater sciatic foramen is wider in women than in men. The foramen contains seven nerves, with sciatic nerve being the most important one which passes through the infrapiriform foramen (Figure 1). Therefore, the region of interest (ROI) was on the sciatic notch below the piriformis muscle (Figure 2). The structures passing above the piriformis are superior gluteal nerve and superior gluteal vessels. Structures passing below the piriformis are inferior gluteal nerve, inferior gluteal vessels, sciatic nerve, posterior cutaneous nerve of the thigh, nerve to obturator internus, nerve to quadrates femoris, internal pudendal vessels and pudendal nerve. The sciatic nerve was typically visualized at a depth of 6cm, depending on the field of view. By Ultrasonography sciatic nerve was visualized as a hyperechoic, slightly flat oval striped structure. The results by strain elastography using ARFI were presented by color elastograms and relative strain ratio. Nerve excursions were measured during knee extension and flexion test (Figure 3). During extension the performed arc of active knee movement was 150 to 180 degree, during flexion the performed arc of active knee movement was 45 to 60 degree.

The sciatic nerve was scanned using ultrasound elastography equipment (Toshiba Aplio 300 and Aplio i 800). The strain elastography using ARFI was performed by linear probes (5 to 10 and 8 to 14 MHz). In strain elastography the ARFI pulse replaces the patient or probe movement in order to generate stress on the tissue. This technique may be less user dependent than the manual compression technique.

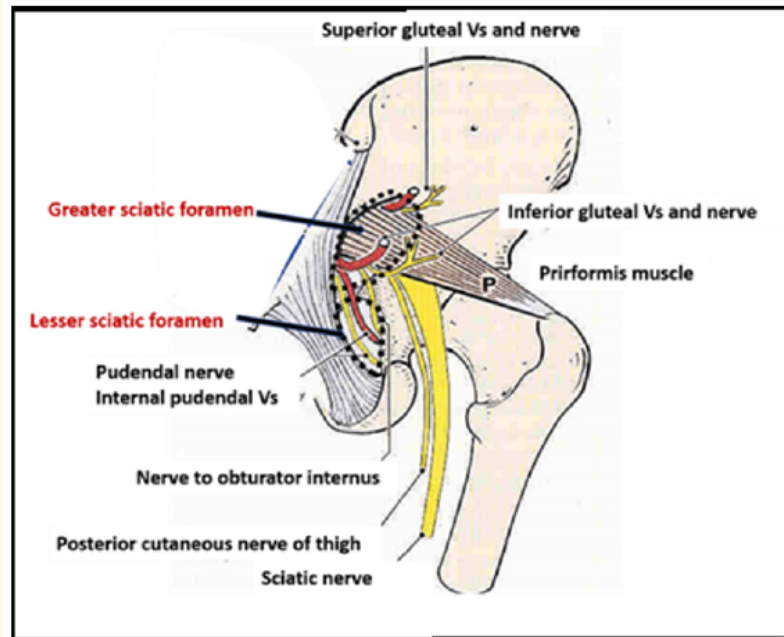


Figure 1: The greater sciatic foramen. <http://www.anatomyqa.com/anatomy/lower-limb/greater-and-lesser-sciatic-foramen/>.



Figure 2: The imaging was performed at the gluteal region. The region of interest (ROI) was on the sciatic notch below the piriformis muscle.



**Figure 3:** Nerve excursions were measured during knee extension and flexion test.

ARFI image can be created by analyzing tissue emplacement. The technique is qualitative (it provides a relative measure of the tissue stiffness in the field of view). The power of ARFI push pulse is limited by guidelines on the amount of energy that can be put into live body, thus limiting the depth of tissue displacement [7]. Methods have been developed that utilize impulsive, harmonic, and steady state radiation force excitations for monitoring the tissue response within the radiation force region of excitation (ROE) and generating images with relative differences in tissue stiffness by acoustic radiation force impulse (ARFI). The tissue displacement resulted in color elastogram, and the calculation of stiffness ratio (SR) was between different regions of interest (ROI) (Figure 4).

The obtained data were analyzed using SPSS software (version 22.0 for Windows). The measures of central tendency (arithmetic mean, median), measurements of variability (standard deviation) and relative numbers (structural indicators) were used. The Pearson linear correlation coefficient was used for the analysis of dependence. Statistical hypotheses were tested at the level of statistical significance (alpha level) of 0.05. Finally, ROC analysis was performed.

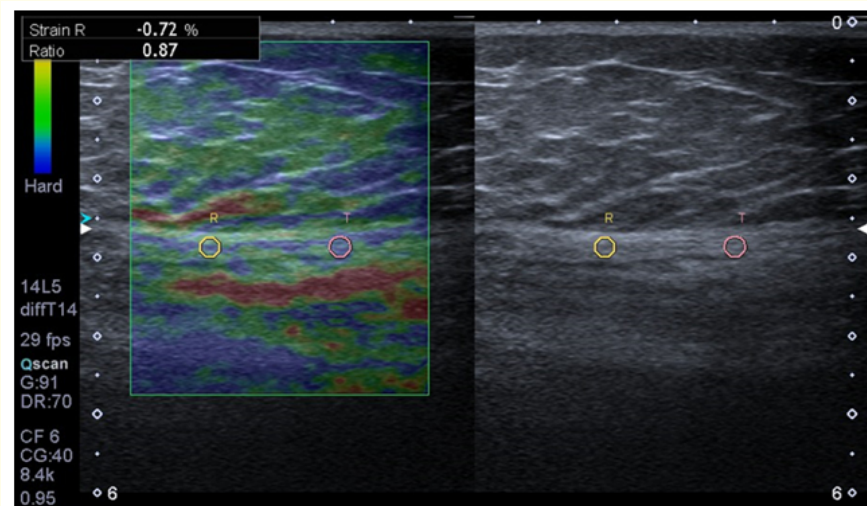


Figure 4: Color elastograms, presented from red to blue (from soft to hard zones).

### Results and Discussion

The patients with DGS, previously clinically examined and performed by MRI and EMG, were divided according to indications for surgical treatment. In 89 patients surgery was not indicated, whereas 54 were scheduled for surgical treatment. However, 24 patients underwent surgery (Table 1). Regarding the age of patients, there was a statistical significance ( $p < 0.05$ ) between patients without surgical indications and those who underwent surgery (51.5 to 43.5).

The examined patients with DGS were predominately female (47), while surgical treatment was applied equally to both male and female (Table 1). In surgical decision making MRI findings and electromyography test were decisive (Table 1). Nevertheless, it is important to point out that sciatic nerve ultrasound examination and ARFI elastography test were congruent (Table 1-3).

Group of Patients	Age	Sex (male/female)	Patients with neurological symptoms of abnormal reflexes or motor weakness	MRI of spine and pelvis (nerve lesion/examined)	Electromyography (EMG) (nerve lesion/examined)
A. Pts. with DPS without surgery (89)	51.5 ± 8.1	35/54	89/89	18/43	45/89
B. Pts. with DPS (underwent surgery - 24)	43.5 ± 5.7	12/12	24/24	23/24	24/24
C. Pts. with DPS (underwent surgery) 21/24 in follow up	41.8 ± 6.1	9/12	12/21	7/21	9/21

Table 1: Diagnostics of the subjects with sciatic nerve lesions.

Group of Patients	Age (y.)	Sex (male/female)	$\bar{x}$	sd	min	max	p-value
A. Pts. with DPS, without surgery (89) - knee extension	51.5 ± 8.1	35/54	5.96	0.69	4.3	7.3	< 0.01
A. Pts. with DPS, without surgery (89) - knee flexion	51.5 ± 8.1	35/54	4.46	0.65	2.9	6.1	
B. Pts. with DPS, underwent surgery (24) - knee extension (before/after surgery)	43.5 ± 5.7	12/12	4.99/8.05	0.7/0.5	3.7/7.3	6.5/8.9	< 0.01
B. Pts. with DPS, underwent surgery (24) - knee flexion (before/after surgery)	43.5 ± 5.7	12/12	3.90/4.65	0.72/0.24	2.6/4.3	5.4/5.1	
A. Pts. with DPS, underwent surgery, in follow up (21/24) - knee extension	47.7 ± 8.6	9/12	6.82	0.51	5.7	8.7	< 0.01
A. Pts. with DPS, underwent surgery, in follow up (21/24) - knee flexion	47.7 ± 8.6	9/12	4.47	0.34	3.6	5.7	

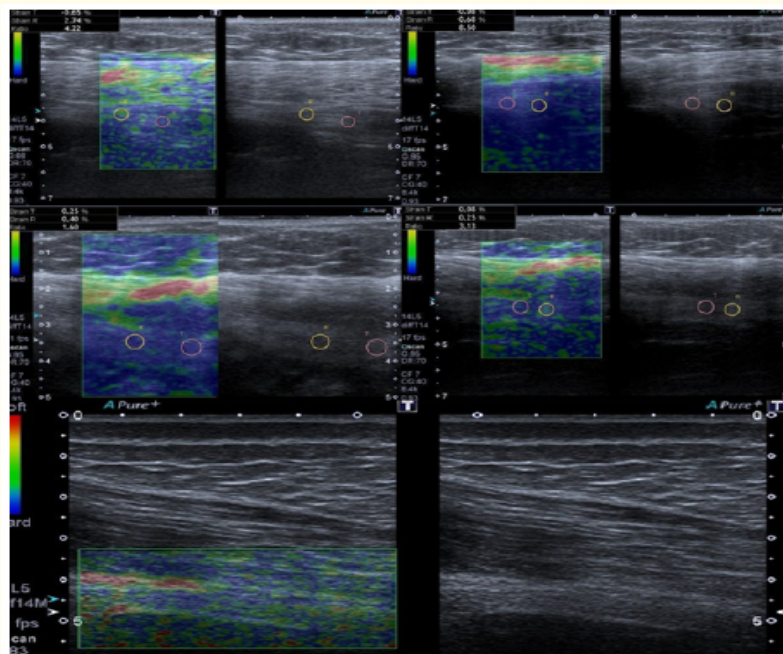
Table 2: Diameter of sciatic nerve (mm).

Group of Patients	Age (y.)	Sex (Male/Female)	$\bar{x}$	sd	min	max	p-value
A. Pts. with DPS, without surgery (89) - knee extension	51.5 ± 8.1	35/54	5.02	1.34	1.6	7.8	< 0.01
A. Pts. with DPS, without surgery (89) - knee flexion	51.5 ± 8.1	35/54	10.27	2.26	3.7	13.4	
B. Pts. with DPS, underwent surgery (24) - knee extension (before/after surgery)	43.5 ± 5.7	12/12	7.32/1.32	1.50/0.48	5.1/0.7	11.7/2.0	< 0.01
B. Pts. with DPS, underwent surgery (24) - knee flexion (before/after surgery)	43.5 ± 5.7	12/12	11.97/4.07	2.01/0.74	6.5/2.9	15.7	
C. Pts. with DPS, underwent surgery, in follow up (21/24) - knee extension	47.7 ± 8.6	9/12	3.25	0.88	1.1	5.2	< 0.01
C. Pts. with DPS, underwent surgery, in follow up (21/24) - knee flexion	47.7 ± 8.6	9/12	6.76	1.74	3.8	8.7	

Table 3: The relative differences of sciatic nerve stiffness by ARFI (SR – Stiffness Ratio).

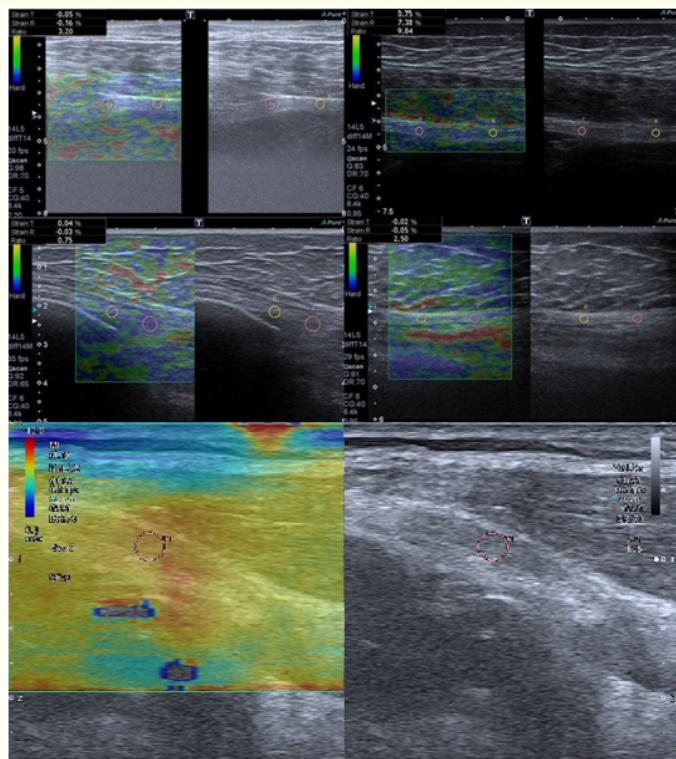
The results provided by ultrasonography and strain elastography using ARFI were presented by sciatic nerve diameters and by color elastogram and relative stiffness ratio (SR) (Tables 2 and 3) (Figure 4). Nerve excursions were measured during knee extension and flexion test (Figure 3). The color imaging were not statistically significant for groups A and B, (patients without indication for surgery and those underwent surgery), due to non-standardized color elastograms and unreliable color images in a certain number of cases. In contrast, the relative differences of sciatic nerve stiffness measured during knee extension and flexion test and recorded by ARFI showed results in good correlation with neurological symptoms of abnormal reflexes or motor weakness, EMG findings of severe nerve lesions and MRI findings of various processes and nerve lesions. Statistically high diameters of sciatic nerve changed in patients with deep gluteal syndrome during knee movements (Table 2). In knee flexion movements sciatic nerve diameters in group A and B (without indication for surgical treatment and those underwent surgery) were statistically significantly lower ( $p < 0.01$ ) than in extension movements. In a relatively short period after surgery, sciatic nerve recovery (with the absence of neurological symptoms) was remarkable in follow up

(in group B), regarding the nerve diameters in knee extension ( $p < 0.01$ ), while not so significant during knee flexion movements ( $p < 0.05$ ). Significance of nerve stiffness was found during knee movements in groups A and B (patients without indications for surgery and those underwent surgery). In patients with DGS (89), who had been not scheduled for surgery (group A), the relative differences of sciatic nerve stiffness recorded by ARFI was  $5.02 \pm 1.34$ SR in knee extension movements, but it was significantly higher ( $p < 0.01$ ) during knee flexion movements  $10.27 \pm 2.26$  SR (Table 3). What is more, in patients with DGS, underwent surgery (group B), the relative differences of sciatic nerve stiffness, before and after surgery, recorded by ARFI were highly significant, as well in extension and flexion movements ( $< 0.01$ ) (Table 3). In follow up after surgery (group B) values decreased from 7.32 to 1.32SR during extension, while movements decreased from 11.97 to 4.07SR during flexion. There no published results in follow up sciatic nerve stiffness during prolonged period of one year or more. Therefore, obtained data are important to show real recovery of sciatic nerve. The slight decrease of sciatic nerve diameter measured during prolonged period comparably to values obtained during short period of follow after surgery (in extension 6.82 according to 8.05SR, and in flexion 4.47 to 4.65SR), have shown presence of problems in recovery, with the return of neurological symptoms. MRI and EMG findings in some patients (6/21 and 7/21) confirmed that statement. Sciatic nerve stiffness ratio (1.32 to 3.25SR in extension, according 4.07 to 6.76SR, in flexion) were more indicative and statistically confirmed ( $< 0.01$ ) (Figure 5 and 6).



**Figure 5:** Case 1. The sciatic nerve stiffness before and after surgery and in follow up one year later.

*Case 1 - A 39-year-old female patient with neurological symptoms of abnormal reflexes, pelvic MRI with a compression on the left sciatic nerve by an ovarian cyst and a moderate nerve lesion by EMG. The decision was made that, since there were no indications for the surgical release of the sciatic nerve, but she was to undergo a surgery for the ovarian cyst. Relatively high differences of sciatic nerve stiffness were confirmed by ARFI elastography during knee extension and flexion movements (4.22SR and 8.50SR) (above to the left and right). The undefined contour of sciatic nerve and the differences of sciatic nerve diameters in knee movements have been well l-recognized. She underwent a surgery which led to the release of sciatic nerve (1.60SR in extension and 3.13SR in flexion movements) (below to the left and right). However, one year later the sciatic nerve tightened up (3,12SR in extension and 5,23 in flexion).  
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**Figure 6:** Case 2. The sciatic nerve stiffness before and relatively in shortened period after surgery, as well as in prolonged period of follow up.

Case 2 - A 48-year-old male patient with neurological symptoms of motor weakness, MRI of lumbar spine with lesion of right sciatic nerve roots and a severe nerve lesion by EMG. Relatively high differences of sciatic nerve stiffness were confirmed by ARFI elastography during knee movements (3.20SR in extension, 9.84SR in flexion) before surgery (above to the left and right), with significant decrease after surgery (0.75SR in extension and 2.50 in flexion) (below to the left and right). The increase of sciatic nerve stiffness was observed one year later (in extension 2,13SR, in flexion 4,34SR). Department of Diagnostic Radiology, Clinical Hospital Center “Dr Dragisa Misovic – Dedinje”, Belgrade.

The Pearson linear correlation coefficient was used for the analysis of dependence (Figure 7). In follow up, the correlation coefficient of sciatic nerve diameter was significantly high during knee flexion ( $r = 0.646$ ) in patients who had undergone surgery (group B). The correlation coefficient of sciatic nerve stiffness ratio during knee movements in patients without surgery (group A) was significant ( $r = 0.683$ ). The correlation of dependence between diameters and stiffness ratio in group A (without surgery) was significant ( $r = 0.671$ ). The highest significant correlation coefficient was noticed in the analysis of dependence between diameters and stiffness ratio in group B - patients who had undergone surgery ( $r = 0.881$ ). A very high correlation was observed between MRI and EMG findings and ARFI nerve stiffness values in patients scheduled for surgery ( $r = 0.963$ ), as well as in correlation between sciatic nerve diameters and MRI and EMG findings ( $r = 0.833$ ). A relative high correlation was observed in follow up during prolonged period, looking at sciatic nerve diameter and nerve stiffness ( $r = 0.579$ ), as well as with MRI and EMG findings ( $r = 0.749$ ).



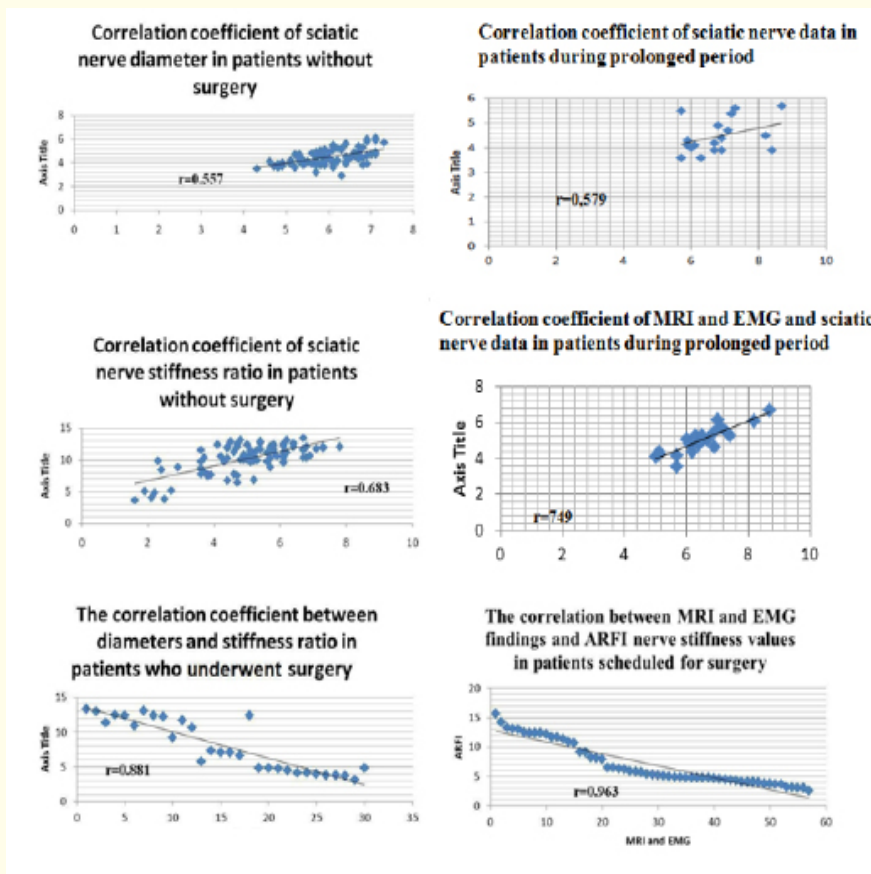


Figure 7: The correlation coefficients.

In order to calculate ROC analysis it was important to operate by cut off values (the value used to divide continuous results into categories: typically positive and negative). In group of healthy subjects (57) nerve stiffness during extension movements was  $1.45 \pm 0.58SR$ , with calculated cut off ( $\bar{x} \pm 2 SD$  - usual standard to cover more than 90% of healthy population)  $2.61SR$ , whereas it was  $4.28 \pm 0.68SR$  during flexion, with cut off  $5.64SR$ . By ROC analysis (Table 4) overall specificity of ultrasound elastography was 83.8%, sensitivity was 78.4%, with accuracy of 83.9% [8,9]. The positive predictive value was 76.6%, while the negative predictive value was 91.4%.

	%		%
Specificity of Sciatic nerve during knee extension	85.8%	Accuracy (%)	83.9%
Specificity of Sciatic nerve during knee flexion	82.1%	True Positive Values	76.6%
	Overall 83,8%	True Negative Values	91.4%
Sensitivity of Sciatic nerve during knee extension and flexion	78,4%		

Table 4: The operating characteristics by ROC analysis.

In our study, which investigated patients with DGS, ARFI elastography test showed high and very useful operating characteristics according to ROC analysis [8,9]. This can be explained by shortening of sciatic nerve diameter, particularly during knee flexion. During such a movement, the nerve was tense, and the stiffness ratio rose markedly. Ultrasonography detected entrapment and shortening of sciatic nerve in patients indicated for surgical treatment and the US findings were explicitly correlated with MRI and EMG findings of nerve lesions. It was obviously manifested by diameters of sciatic nerve and by relative differences of sciatic nerve stiffness. The fibrous bands with nerve entrapment in patients with deep gluteal syndrome significantly decreased the diameter of sciatic nerve in extension, as well as flexion movements, as a result of nerve tightening [12,13]. It was observed that movements resulted in increased nerve stiffness, particularly prominent during knee flexion movements (Figure 5 and 6). The fact remains that MRI and EMG confirmed nerve injuries. Color elastograms were presented by colors, from red to blue (from soft to hard zones) and did not turn out to be particularly helpful (Figure 4), due to lack of their standardization (there no published results). The obtained images, however, created a possibility for color elastograms to be very useful in some cases, especially in ARFI elastography estimation of the sciatic nerve (Figure 5 and 6).

Strain elastography using ARFI showed good performance in follow up of the patients who underwent surgery with regard to the diameter and stiffness ratio. The evidently based recovery of sciatic nerve diameter and stiffness shortly after surgery, was partially annulled one year later. Sciatic nerve recovery shortly after surgery was presented with the absence of neurological symptoms. The diameter and stiffness ratio was marked, relative to this one year later. The correlation between MRI and EMG findings and ARFI nerve stiffness values in patients scheduled for surgery was high, as well as in that one year later. The overall specificity, sensitivity with accuracy decreased during prolonged period of follow up. Looking at MRI and EMG findings pelvic compression process and the accrual of nerve fibrous strips were diagnostically evident in follow up one year later.

The prevalence of female population was represented by clinically confirmed cases. There were no significant differences in sciatic nerve diameter with regard to the age. It showed the importance of intraneural stiffness, especially observed in symptomatic patients with morphological changes of the nerves and the surrounding fibrous processes (MRI). Therefore, the positioning of ROI was important.

The limits of strain elastography using ARFI depend on the applied techniques, the depth of sciatic nerve and the field of view. The ARFI elastography of sciatic nerve in patients with deep gluteal syndrome was predominantly performed as preoperative decision test (Figure 5 and 6). Upon surgical exploration of the sciatic nerve, a fibrotic tendinous scar beneath the piriformis was found and released. The resection was done from trochanter's attachment, by separating joint tendon from m. piriformis and m. obturator internus, and by releasing n. peroneus and n. tibialis from fibrous bands and surrounding muscles [14-17]. However, in prolonged period of follow up it was show that sciatic nerve tightened up with increase of stiffness ratio due to pathological processes [18,19].

### Conclusion

The variation of the sciatic nerve is challenging for diagnostic and therapeutic procedure in many clinical and surgical cases. Quick ultrasound detection of the sciatic nerve makes surgical approaches more precise and effective, with a better outcome.

Strain elastography using ARFI seem to be a sensitive and accurate diagnostic procedure (ROC analysis) based on the assessment of nerve stiffness. This procedure could provide us with crucial information about the degree of nerve stiffness. It is a non-invasive, easily performed, reproducible and relatively inexpensive method, very useful in the process of surgical decision making. It has to be a prolonged period of follow up to obtain useful information for further decision making.

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