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Preoperative and postoperative ultrasound elastography findings of the sciatic nerve in patients with unilateral lumbar foraminal disc herniation: a pre-test and post-test design

V. BURULDAY[1], U.O. ÇELEBI[2], M. ÖĞDEN[3], M.H. AKGÜL[4], A. DOĞAN[5], M.F. ÖZVEREN[6]

[1]Department of Radiology, Inonu University, Faculty of Medicine, Malatya, Turkey
[2]Department of Radiology, Medical Park Hospital, Ordu, Turkey
[3]Department of Neurosurgery, Kirikkale University, Faculty of Medicine, Kirikkale, Turkey
[4]Department of Neurosurgery, Yuksek Ihtisas State Hospital, Kirikkale, Turkey
[5]Department of Radiology, Kahramanmaras Sutcu Imam University, Faculty of Medicine, Kahramanmaras, Turkey
[6]Department of Neurosurgery, Medical Park Hospital, Batman, Turkey

Abstract. – OBJECTIVE: The aim of this study was to compare preoperative and postoperative findings of the sciatic nerve by using B-mode ultrasound, strain elastography (SE), and shear wave elastography (SWE) in patients with unilateral lumbar foraminal disc herniation.

PATIENTS AND METHODS: In this prospective study group, patients with complaints of foraminal disc herniation due to one level (L4-5 or L5-S1) were included. Preoperative and postoperative (one month after surgery) B-mode ultrasound, SE, and SWE findings of the affected sciatic nerve in patients who underwent unilateral spinal decompression surgery were compared. Evaluations were performed on the axial plane from the gluteal region using a convex probe of 5-9L MHz. The reference method used to assess nerve root compression was 1.5-T Magnetic Resonance Imaging (MRI).

RESULTS: A total of 20 patients (9 males, 11 females) with a mean age of 46.2±13.1 years were included. The cross-sectional area (CSA), diameter, SWE values of the sciatic nerve were significantly higher in the affected side compared to those of the non-affected side (all for $p<0.05$). Blue and blue-green were the most common color codes in the affected side while green and green-yellow-red were the most common color codes in the non-affected side. The CSA, diameter, and SWE values of the sciatic nerve decreased after the surgery in the affected side (all for $p<0.05$), nonetheless. those did not differ in the non-affected side (all for $p>0.05$).

CONCLUSIONS: Lumbar decompression surgery decreases the sciatic nerve diameter, CSA, and stiffness of the sciatic nerve.

Key Words:
Sonoelastography, Ultrasonography, Cross-sectional area, Sciatic nerve, Foraminal lumbar disc herniation.

Introduction

Lumbar foraminal disc herniation is defined as the upward migration of the degenerated disc at the neuroforaminal level[1]. Lumbar foraminal disc herniation is the most common cause of sciatica and is an important health problem that adversely affects activities of daily living and quality of life. Surgical treatment is indicated in patients who do not respond to conservative treatment and have neurological deficits[2]. There are many studies in the literature evaluating pain, mobility, quality of life, psychological status, and functional parameters before and after surgery for foraminal lumbar stenosis[3-5]. In addition, studies have been also conducted in which radiologic evaluation of nerve roots and herniation both before and after surgery was performed. However, previous studies mainly used MRI[6-8]. On the other hand, US is an increasingly used imaging technique in peripheral nerve imaging in recent years[9,10], and it has been shown that the sciatic nerve is thicker and edematous in patients with unilateral foraminal stenosis[11]. However, as far as we know, there is no study comparing sciatic nerve findings before and after surgery in patients who under-

Corresponding Author: Veysel Burulday, MD; e-mail: vedoctor@hotmail.com

went lumbar foraminal disc herniation operation by using US. Accordingly, the aim of this study was to compare preoperative and postoperative findings of the sciatic nerve by using B-mode ultrasonography, SE, and SWE in patients with unilateral lumbar foraminal disc herniation.

Patients and Methods

Study Design and Participants

The study was designed as a pre-test, post-test prospective study. Comparison was made of the preoperative and postoperative (one month after surgery) B-mode US, SE, and SWE findings of patients who were applied with spinal decompression. The inclusion criteria were unilateral lumbar radiculopathy; foraminal stenosis demonstrated on preoperative MRI and unsuccessful nonoperative treatment. The patients selected were in the age range of 18-65 years.

Sciatic nerve on the non-operated side was taken as control reference. The exclusion criteria were polyneuropathy, a previous history of trauma or surgery in the lumbosacral region, tumor-associated sciatica or piriformis syndrome. Patients were also excluded if a condition was known that would reduce the quality of the US imaging (obesity, motion restriction within the hip joint, excessive injection scar in gluteal soft tissue). The current study protocol was approved by the Local Ethics Committee (decision no: 06/03, dated: 28.02.2017). All study participants provided written informed consent.

Ultrasound Acquisitions

The B-mode and elastographic evaluations were made using a digital sonography unit with real-time tissue elastography software LOGIQ E9 (GE Healthcare). Evaluations in the axial plane of the bilateral gluteal region were made using a convex probe of 5-9 MHz. All the US examinations of all the patients were applied by the same radiologist and the findings were confirmed with cross-checking by another radiologist.

SE and SWE were performed using the technique described by Çelebi et al[11]. The patient was positioned lateral decubitus with the knee and hip in flexion. The anatomic orientation of the probe and the relevant anatomic structures are shown in Figure 1A. Using a caliper from the inner board of the perineural echogenic rim on the axial view, calculation was made with the direct tracing method of the CSA of the sciatic nerve from the same level (Figure 1B). Applying light and rhythmic compression to the probe, SE was performed from the gluteal region. Color-coding of SE was superimposed on the B-mode images and shown on the monitor. Screen images showing ideal compression (5-7 bar pressure) were evaluated according to the compression bar scale of 1-7 in the unit. Within the device memory, a digital recording was made of the SE examination for later analysis in video format. In the color code analysis, red indicates the softest texture, green a medium hard texture, and blue the hardest texture[11]. To provide better quantitative assessment, the color coding was classified as red only, yellow-red, green-yellow, green only, blue-green, and blue only, according to the data from the involved side of the patient.

The shear wave elastography examination of each patient was applied in the axial plane without compression. A single screen displayed B-mode and SWE images simultaneously (Figure 2-3). Using the digital video format of the device,

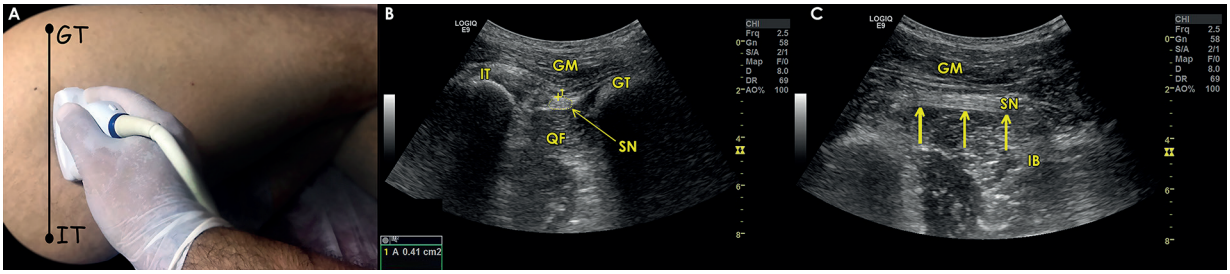

Figure 1. (**A**) Image showing the probe position and anatomic orientation. B-Mode ultrasound image shows the sciatic nerve (**B**) gluteal approach sonographic appearance in axial plane (CSA was measured 41 mm^2) (**C**) gluteal approach sonographic appearance in longitudinal plane. Abbreviations: GT: Great trochanter, IT: Ischial tuberosity, GM: Gluteus maximus, QF: Quadriceps femoris, SN: Sciatic nerve (*arrows*), IB: Ischial bone).

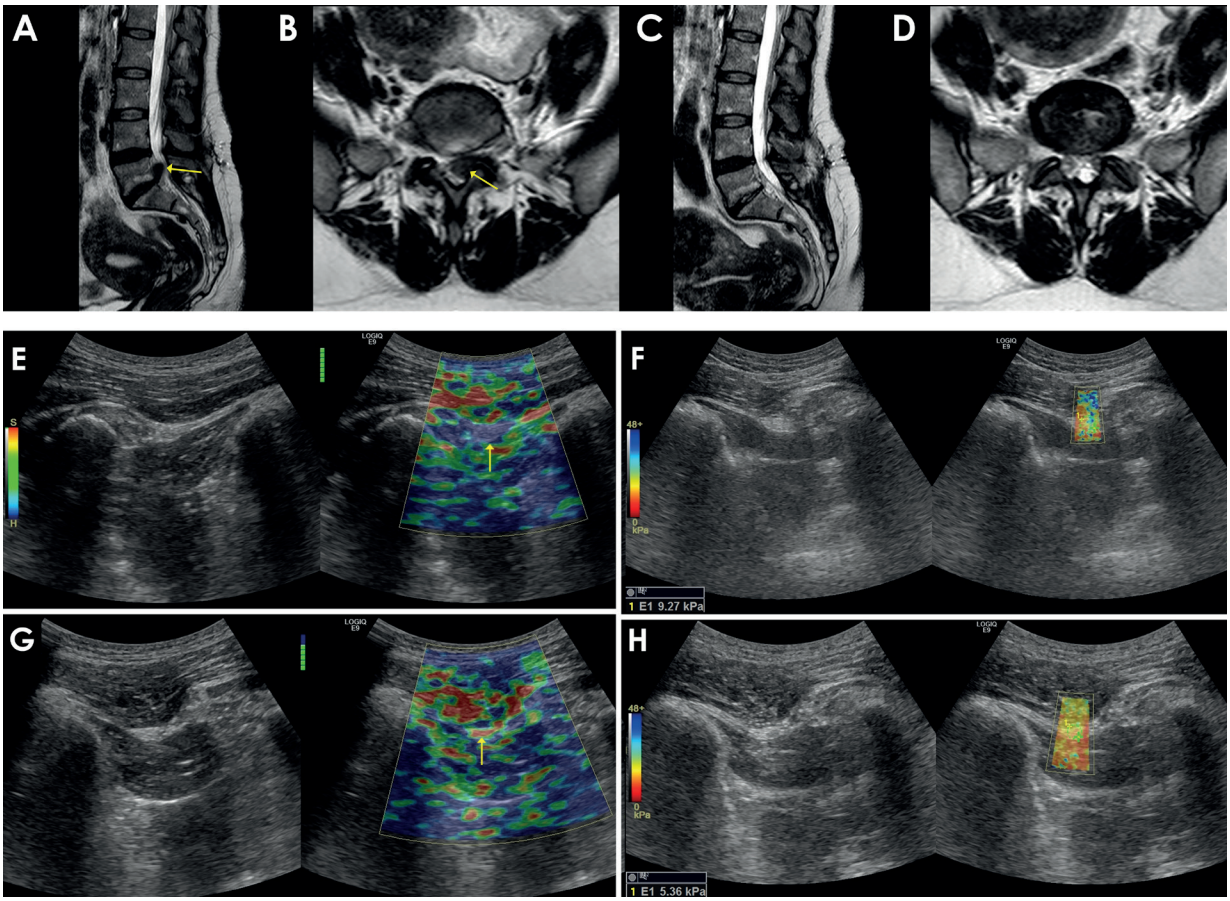

Figure 2. A 46-year-old female patient with left foraminal stenosis level of L5-S1. **A-B,** MRI T2W (A-sagittal, B-axial view) images show cranial migration of disc extrusion at L5-S1 level *(arrows)* in the preoperative period. **C-D,** On the control MRI T2W (C-sagittal, D-axial view) images one month after surgery, disc extrusion was not seen, and the patient's clinical complaints were recovered. **E,** The left sciatic nerve (preoperative period) shows a blue color coding with SE and **F,** The SWE value (preoperative period) was measured as 9.27 kPa. **G,** The left sciatic nerve (postoperative period) shows a yellow-red color coding with SE and **H**, The SWE value (postoperative period) was measured as 5.36 kPa.

the SWE evaluation was recorded and stored for further analysis. Sciatic nerve hardness was analyzed quantitatively and expressed as kilo Pascal (kPA). Three measurements were taken of a circular region of interest at 2-4 mm intervals of each sciatic nerve and the mean values were calculated for use in the statistical analysis.

MRI Protocol

In the study, the assessment of foraminal level in diagnosed lumbar disc herniation was made according to the MRI-based description recommended by the NASS, the American Society of Spine Radiology, and the American Society of Neurology[12,13]. Comparisons were made of the preoperative and postoperative MRI findings of patients applied with spinal decompression (Figure 2-3).

Nerve roots and herniation were visualized using a 1.5 Tesla MRI unit (Philips MRI Systems®) with the use of a spine surface coil. The routine lumbar MRI evaluation protocol was as follows: Sagittal T1-weighted imaging (T1-WI) (relaxation time [TR], 400-700 ms; echo time [TE], 8 ms, slice thickness / gap: 4 mm / 1 mm). Axial T2-WI (TR, 2000-5000 ms; TE, 120 ms, slice thickness / gap: 4 mm / -). Sagittal T2-WI (TR, 2000-5000 ms; TE, 120 ms, slice thickness / gap: 4 mm/1 mm).

Statistical Analysis

Statistical analyses were performed using SPSS (SPSS version 20.0, IBM®, Armonk, NY, USA) software. Descriptive statistics were stated as number, percentage, mean, and standard devia-

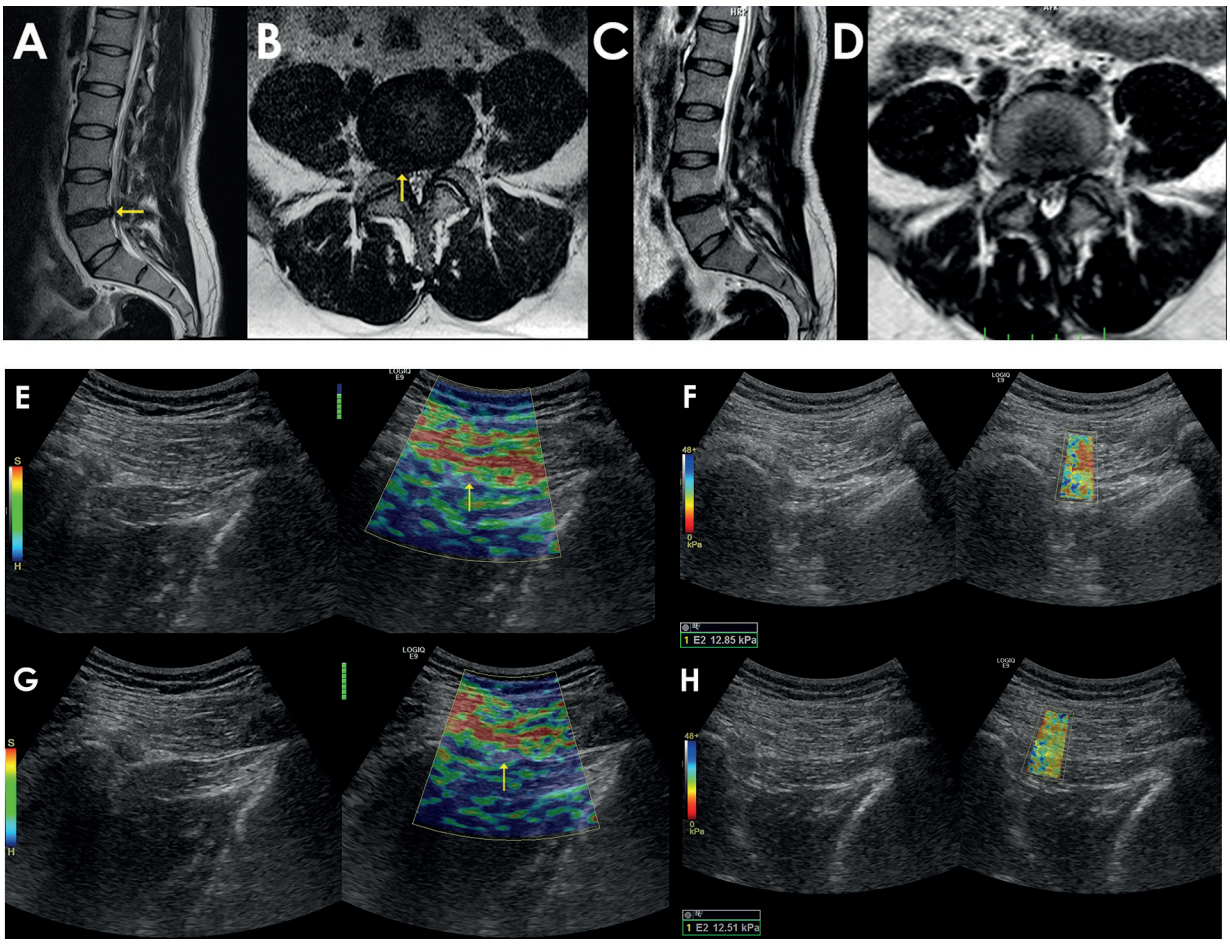

Figure 3. A 41-year-old male patient with right foraminal stenosis level of L4-5. **A-B,** MRI T2W (A- sagittal, B-axial views) images show the foraminal disc protrusion at L4-5 level (arrows) in the preoperative period. **C-D,** On the control MRI T2W (C-sagittal, D-axial views) images one month after surgery, disc protrusion was unchanged, and the patient's clinical complaints were persisted. **E,** The left sciatic nerve (preoperative period) shows a blue color coding with SE and **F,** The SWE value (preoperative period) was measured as 12.85 kPa. **G,** The left sciatic nerve (postoperative period) shows a blue color coding with SE and **H,** The SWE value (postoperative period) was measured as 12.51 kPa.

tion values. Preoperative and postoperative CSA, diameter, and SWE findings were compared with the Wilcoxon Signed Rank Test. CSA, diameter, and SWE findings of the affected and non-affected sides were compared with the Mann-Whitney U-Test. Categorical variables were compared with the Chi-square test. A value of $p<0.05$ was accepted as statistically significant.

Results

A total of 20 patients (9 males, 11 females) with a mean age of 46.2±13.1 years (range 21 to 64 years) were included. Comparison of the preoperative CSA, diameter, SE and SWE values of the sciatic nerve of the affected and non-affected sides are shown in Table I. The CSA, diameter, SWE values of the sciatic nerve were significantly higher in the affected side compared to those of in the non-affected side. Blue and blue-green were the most common color codes in the affected side while green and green-yellow-red were the most common color codes in the non- affected side.

Preoperative and postoperative ultrasonography findings of the affected and non-affected sides are shown in Table II and Table III. The CSA, diameter, and SWE values of the sciatic nerve decreased after the surgery in the affected side, nonetheless those did not differ in the non-affected side. Clinical improvement was not achieved in only 1 of 20 patients. Similarly, postoperative CSA, SE and SWE values of this patient did not improve.

Table I. Preoperative comparison of the ultrasound parameters of the involved and non-involved side.

Variables	Involved (N = 20)	Non-involved (N = 20)	*p*-value
CSA (mm^2)	46.25 ± 4.3	37.20 ± 3.3	0.000
Diameter (mm)	6.27 ± 0.62	5.79 ± 0.64	0.026
SWE (kPA)	12.54 ± 3.5	6.13 ± 1.53	0.000
Strain Elastography			0.000
- Blue	7 (35)	0 (0)	
- Blue-Green	9 (45)	1 (5)	
- Green	2 (10)	8 (40)	
- Green-yellow-red	2 (10)	7 (35)	
- Yellow-red	0 (0)	2 (10)	
- Red	0 (0)	2 (10)	

• Bold *p*-values denote significance. • CSA: Cross sectional area, SWE: Shear Wave Elastography.

Discussion

In the present study we aimed to compare the sonoelastography findings and CSA of the sciatic nerve before and one month after the surgery, to the best of our knowledge, for the first time in the literature. We have two main findings according to our results. First, patients with unilateral sciatica have thicker and stiffer sciatic nerves in the affected side compared to the non-affected side. Second, lumbar decompression surgery decreases the sciatic nerve diameter, CSA, and stiffness of the sciatic nerve.

As for the imaging of the lumbar spine and nerve roots, computed tomography (CT) and MRI are very useful to visualize the segment of herniation, its severity (protrusion, extrusion, etc.), and anatomic localization (central, posterolateral). Yet, CT and MRI are confined to the lumbosacral region and do not demonstrate sciatic nerves in the lumbar spine protocol images[10,11]. On the other hand, US is a convenient imaging tool to visualize sciatic nerve due to its several advantages such as ease of application, lack of ionizing radiation, easy applicability, and wide availability, low cost, and high spatial resolution. Recently sonoelastography, a non-invasive method to quantify of the softness and harness of the tissue, has been reported for the detection of the changes of sciatic nerves[14,15]. There are mainly two methods of elastography as the SE and SWE. Although SE demonstrates tissue deformation with compression applied by the physician, in SWE the shear waves are produced by the transducer and their speed is measured[16]. In our study, to achieve more valid and reliable results, we have used both SE and SWE methods.

When the nerve fibers are compressed or entrapped, nerve circulation deteriorates, venous congestion occurs, and nerve inflammatory changes occur. For this reason, we typically expect the peripheral nerves to become edematous and thicker, just proximal to the entrapment region. We also expect a decrease in nerve echogenicity due to edema. If the entrapment is mild, we expect to see some structural changes such as de-

Table II. Preoperative and postoperative comparison of the ultrasound parameters of the involved side.

Variables	Preoperative (N= 20)	Postoperatve (N = 20)	*p*-value
CSA (mm^2)	46.25 ± 4.3	39.80 ± 4.5	0.000
Diameter (mm)	6.27 ± 0.62	5.91 ± 0.61	0.001
SWE (kPA)	12.54 ± 3.5	7.82 ± 2.8	0.000
Strain Elastography			0.000
- Blue	7 (35)	1 (5)	
- Blue-Green	9 (45)	0 (0)	
- Green	2 (10)	6 (30)	
- Green-yellow-red	2 (10)	11 (55)	
- Yellow-red	0 (0)	0 (0)	
- Red	0 (0)	2 (10)	

• Bold *p*-values denote significance. • CSA: Cross sectional area, SWE: Shear Wave Elastography.

Table III. Preoperative and postoperative comparison of the ultrasound parameters of the non-involved side.

Variables	Preoperative (N= 20)	Postoperatve (N = 20)	*p*-value
CSA (mm^2)	37.20 ± 3.3	38.00 ± 2.99	0.173
Diameter (mm)	5.79 ± 0.64	5.74 ± 0.50	0.419
SWE (kPA)	6.13 ± 1.53	5.99 ± 1.3	0.279
Strain Elastography			0.659
- Blue	0 (0)	0 (0)	
- Blue-Green	1 (5)	1 (5)	
- Green	8 (40)	5 (25)	
- Green-yellow-red	7 (35)	10 (50)	
- Yellow-red	2 (10)	2 (10)	
- Red	2 (10)	3 (15)	

CSA: Cross sectional area, SWE: Shear Wave Elastography.

generation of the nerve, along with axonal changes if the damage is severe and longer, while only the myelin fibers are damaged[9,17]. As a matter of fact, Kara et al[10] found that the subjects with unilateral sciatica have thicker sciatic nerves compared to healthy subjects in their study. They used B mode imaging in their study and measured the CSA of sciatic nerve with direct tracing method. Similarly, we have performed CSA measurement with direct tracing method and nerve diameter measurement. Similar to the results of Kara et al[10] we found that the sciatic nerve diameter was increased compared to the non-herniated side. With decompression surgery, we expect the nerve circulation to recover and the structural changes that have taken place in the nerve to heal. For this reason, we expect to reduce the CSA, diameter and SWE results of the sciatic nerves after surgery according to our hypothesis. The results of our study supported our hypothesis.

Limitations

We have some drawbacks to this study. First, the lack of a control group comprising foraminal stenosis patients who did not undergo surgery is the main limitation. Since the herniation can be regressed spontaneously so some structural changes can be seen in the sciatic nerve. Lack of evaluation of intra-rater and inter-rater reliability is another limitation. Last, the patients could be evaluated regarding the pain and functional parameters so that radiological and clinical improvements could be compared.

Conclusions

In the light of our first and preliminary results, patients with unilateral sciatica have thicker and stiffer sciatic nerves in the affected side compared to the non-affected side. Second, lumbar decompression surgery decreases the sciatic nerve diameter, CSA, and stiffness of the sciatic nerve. Further studies concerning the comparisons of ultrasonographic, and clinical improvements are awaited.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Informed Consent

Informed consent was obtained from all the participants.

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