Original Article

Short running title: The suprascapular notch cross-sectional area

Accuracy of suprascapular notch cross-sectional area by MRI in the diagnosis of suprascapular nerve entrapment syndrome – a retrospective pilot study

Jiyeon Park, MD1,2, Min-Ying Su, PhD3, and Young Uk Kim, MD, PhD3,4

1Department of Anesthesiology and Pain Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea

2Department of Anesthesiology and Pain Medicine, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea

3Department of Radiological Sciences, University of California, Irvine, CA, USA

4Department of Anesthesiology and Pain Medicine, Catholic Kwandong University, College of Medicine, International ST. Mary’s Hospital, Incheon, Republic of Korea

*Correspondence: Young Uk Kim MD, PhD

Department of Anesthesiology and Pain Medicine, Catholic Kwandong University, College of Medicine, International ST. Mary’s Hospital, Incheon, Republic of Korea. Department of Radiological Sciences, University of California, Irvine, CA, USA
Accuracy of suprascapular notch cross-sectional area by MRI in the diagnosis of suprascapular nerve entrapment syndrome: a retrospective pilot study

Running title: Suprascapular notch cross-sectional area
Abstract

**Background:** Suprascapular nerve entrapment syndrome (SNES) is a peripheral neuropathy caused by compression of the suprascapular nerve. Previous studies have demonstrated that the suprascapular notch’s morphological change is closely correlated with SNES. Thus, we thought that the suprascapular notch cross-sectional area (SSNCSA) might be a good diagnostic parameter to assess SNES.

**Methods:** We acquired suprascapular notch data from 10 patients with SNES and from 10 normal individuals who had taken shoulder magnetic resonance imaging (S-MRI) and no evidence of SNES. T2-weighted coronal S-MRI images were acquired at the shoulder. We analyzed the SSNCSA at the shoulder on the S-MRI using our image analysis program. The SSNCSA was measured as the suprascapular notch that was the most affected site in the coronal S-MRI images.

**Results:** The mean SSNCSA was 64.50 ± 8.93 mm² in the control group and 44.94 ± 10.40 mm² in the SNES group. SNES patients had significantly lower SSNCSA ($P < 0.01$) than the control group. ROC analysis showed that the best cut-off of the SSNCSA was 57.49 mm², with 80.0% sensitivity, 80.0% specificity, and AUC of 0.92 (95% confidence interval, 0.79–1.00).

**Conclusions:** The SSNCSA was found to have acceptable diagnostic properties for detecting SNES. We hope this result will help to diagnose SNES objectively.

**Keywords:** Cross-sectional area; Diagnosis, shoulder, morphological parameter; Suprascapular nerve entrapment syndrome; Suprascapular notch.
Introduction

Suprascapular nerve entrapment syndrome (SNES) is not common among patients who suffered from shoulder dysfunction. However, SNES has clinical implications because it innervates approximately 60-70% of the shoulder joint and often leads to pain over the lateral and posterior aspects of the shoulder, as well as weakness of infraspinatus or supraspinatus muscles because the suprascapular nerve innervates [1-6]. Trauma or traction injury due to repetitive overhead activities or massive rotator cuff tears occur in SNES [7-10]. The diagnosis of SNES should be differentiated from disorders of the cervical part of the spinal cord, damage to the brachial plexus, cervical discopathy or diseases of the shoulder joint, for example, damage to the rotator cuff or degeneration of the shoulder [11-13]. Thus, an exact diagnosis is important to manage SNES.

The diagnosis of SNES is typically based on physical examination, and interview [14,15]. Other additional examinations for the diagnosis of SNES include imaging modalities (ultrasonography, X-ray and computed tomography) and electromyography and assessment of the conduction velocity from the neck nerve point to the supraspinatus muscles [10,16-19]. Although electromyography is the gold standard for the diagnosis of SNES, Shoulder Magnetic resonance imaging (S-MRI) is also very useful for analysis of the pathologic abnormalities of the suprascapular notch [2]. Podgórski et al. [20] have reported that there are a lot of anatomical variations of the suprascapular notch region and the shapes of the suprascapular notch are highly diverse. In addition, the suprascapular nerve is compressed most commonly at the suprascapular notch [2]. However, few studies have investigated how suprascapular notch’s morphological change affects SNES. Moreover, no studies have examined the clinical optimal cut-off point of the suprascapular notch cross-sectional area (SSNCSA) to diagnose SNES.

Therefore, in order to assess the relationship between SNES and suprascapular notch, we made a new morphological diagnostic parameter called the SSNCSA. The SSNCSA has not yet been
analyzed for its correlation with SNES. We assumed that the SSNCSA is an important morphologic parameter in the diagnosis of SNES.
Materials and Methods

Participants

This original research protocol was approved by Institutional Review Board (IRB No.: IS21RISI0021). We reviewed electronic medical records of patients who had visited the shoulder orthopedic clinic with SNES from November 2015 to December 2020 and who had taken S-MRI within six months of the visit.

The SNES group included the patients who are diagnosed SNES by attending physicians according to their history, physical examination, and imaging modality. In addition, the final diagnosis was confirmed with electromyography. Exclusion criteria were as follows; (1) history of scapular fracture, (2) history of shoulder surgery, (3) No available S-MRI. The people who had taken the S-MRI and had no structural abnormalities in the MRI were included in the control group.

The participants were the SNES group comprising 10 patients. There were 8 (80.0%) men and 2 (20.0%) women, and the average age was 43.90 ± 15.57 years (range, 18 to 60 years) (Table 1). To contrast the SSNCSA between individuals without and with SNES, we enrolled the control group consisting of subjects who wanted to take S-MRI for accurate diagnosis. The control group included patients who had shoulder pain and wanted to undergo S-MRI. Moreover, the patients in the control group doesn’t have any abnormal findings on S-MRI. In the control group, 10 subjects (6 males and 4 females) were enrolled with a mean age of 42.70 ± 13.28 years (range, 20 to 73 years).

Imaging parameters

S-MRI was performed on a 3.0T MR unit (MAGNETOM Skyra; Siemens Medical Solutions, Erlangen, Germany) and 3T Ingina (Philips Medical Systems, Eindhoven, The Netherlands) scanners, we acquired T2-weighted coronal plane turbo spin echo images from all enrolled patients.
The following S-MR imaging sequences were used: slice plane axial, field of view of $160 \times 160$ cm, repetition time of 619.0 milliseconds, echo time 13.0 milliseconds, flip angle 35 degrees, slice thickness 3.00 mm, matrix size $512 \times 307$ pixels, number of signals averaged = 2, scan time 4 min 32 seconds, and $3 >$ echo train length.

**Image analysis**

The SSNCSA measurements were done by the 15 years experienced board-certified pain specialist who was blinded to the shoulder state. We obtained coronal T2-weighted TSE S-MR images which present the best visualization of the suprascapular nerve. We measured the SSNCSA on S-MRI (INFINITT Healthcare, Korea) through INFINITT PACS (Fig 1 A).

**Statistical analysis**

We compared the SSNCSA between the SNES and the normal subjects using independent $t$-tests. $P < 0.05$ was considered statistically significant. ROC curve analysis is used to present the diagnostic values of the SSNCSA in the diagnosis of SNES, and the diagnostic values include the cut-off points, area under the curve (AUC), specificity and sensitivity. SPSS version 22.0 (IBM Inc, USA) was used to analyze collected data.
Results

Demographic characteristics were not significantly different between groups. The average SSNCSA was 64.50 \pm 8.93 \text{ mm}^2 in the control group and 44.94 \pm 10.40 \text{ mm}^2 in the SNES group (Table 1). SNES patients had significantly lower SSNCSA ($P < 0.01$) than the control group (Table 1). The ROC analysis showed that the best cut-off value of the SSNCSA was 57.49 \text{ mm}^2, with 80.0% sensitivity, 80.0% specificity, and AUC of SSNCSA was 0.92 (95% confidence interval, 0.79–1.00) (Table 2, Fig. 2).
Discussion

The purpose of this pilot study was to find out the clinical implication of the SSNCSA in SNES. The present study showed that the SSNCSA had 80.0% sensitivity and 80.0% specificity for predicting SNES. This result demonstrated that the SSNCSA can be a meaningful predictor of SNES.

SNES is a neuropathic condition in which the suprascapular nerve is compressed along its pathway. Traumatic injuries such as clavicular fracture, scapular fracture, proximal humerus fractures, and dislocation of the acromioclavicular joint or the shoulder are common causes of suprascapular nerve damage [4,12,13,21]. Most importantly, the suprascapular nerve compression is most commonly occurred at the suprascapular notch, and symptoms and signs caused by nerve compression based on morphological changes in the suprascapular notch [2,22,23]. Structures around the suprascapular nerve are possible to compress and injure it by many mechanical factors. Direct compression in the suprascapular notch region (e.g., labral cyst, ganglion cyst, tumor) [11], continuous nerve irritation after rotator cuff injuries or inflammation of shoulder can all lead to SNES [3,24].

SNES diagnosis is based on patients’ history and physical exams while ruling out other similar pathologies including cervical radiculopathy, cervical discopathy, and various rotator cuff injuries. Imaging studies also can be used to diagnose [14,15]. Ultrasound, X-ray, computed tomography and MRI provide information on suprascapular nerve and surrounding structures helping to diagnose SNES [15,25,26]. Nerve conduction velocity and electromyography are the gold standards for SNES diagnosis [14]. However, nerve conduction velocity or electromyography cannot be performed for all patients, because the efficacy of electromyography is low. Although electromyography can confirm the nerve conduction problem or muscle weakness, it is not useful to diagnose differentially various shoulder diseases. Moreover, negative results in electromyography
cannot rule out SNES when clinical signs and symptoms are highly suspicious of SNES [14]. Therefore, MRI is more commonly taken in shoulder patients rather than electromyography, and the diagnostic criteria of MRI can be a useful tool to diagnose SNES.

The suprascapular nerve is most commonly compressed at the suprascapular notch, and anatomical variations of suprascapular notch can also increase the risk of SNES. Even though it has been reported that SNES is more likely to occur in patients with a V-shaped or narrow suprascapular notch, a significant correlation between suprascapular notch type and SNES has not been confirmed. Ürgüden et al. [9] have reported that Rangachery type 4 and 5 of the SSN may increase the risk of suprascapular nerve injury during the operation of rotator cuff tear. However, no clinical research has been performed to prove their theory. Polgúj et al. [16] have insisted that the size of the suprascapular notch is a major risk factor in SNES. [22] While there is no study to analyze suprascapular notch objectively. In other words, narrowed suprascapular notch has been considered to be a major morphologic parameter of SNES. Therefore, we thought that analyzing the cross-sectional area of suprascapular notch is the most important factor to diagnose SNES, and we designed the present study to prove the correlation of SSNCSA and SNES.

It is difficult to measure because of the bone margin of suprascapular notch as a wavy or curved contour, and multiple signal intensity within the narrowed site. Thus, the length or thickness of suprascapular notch is not a proper measurement to diagnose SNES. Instead of it, the cross-sectional area of the suprascapular notch may predict SNES effectively, because the SSNCSA, which measures the whole cross-sectional area of the suprascapular notch, represents the space of SSN limited by surrounding structures. In the end, this study demonstrated that the SSNCSA is a good morphological measurement diagnostic tool of SNES.

This research has some limitations. First, SNES has multiple causes, such as rotator cuff tear, trauma, and repetitive overhead activities. In addition, the structure around the suprascapular
nerve such as supraspinatus muscle, infraspinatus muscles, suprascapular ligament, suprascapular notch and spinoglenoid notch. However, we only focused on the suprascapular notch where the suprascapular nerve is most commonly compressed. In further studies, we will investigate other anatomical structures which affect the SNES, especially spinoglenoid notch where the suprascapular nerve is also commonly compressed. Second, there might be some errors in the measurements of the SSNCSA on S-MRI. Although we were trying to analyze this morphologic measurement method in the best plane which presents the suprascapular notch at the coronal image section, the coronal images we measured the section image could be inhomogeneous because of differences in the cutting level or angle in the S-MRI as a result of individual anatomic difference and technical errors. Third, there are several alternative imaging diagnosis tools to evaluate SNES, such as ultrasound examination, or computed tomography, but this study analyzed only the measurement of the SSNCSA on S-MRI. Fourth, functional instability was not analyzed because functional instability is subjective findings that may vary from one interpretation to another. Our goal was to provide objective morphological indicators. Fifth, a small number of population were enrolled for the study. We enrolled all patients who were diagnosed with SNES in our hospital, there were only 10 SNES patients. Although this pilot study investigated small number of patients, this is valuable because it provides the diagnostic criteria using S-MRI, especially SSNCSA. Sixth, since this is the retrospective study, the people who had the S-MRI scan and no structural abnormalities were enrolled in the control group. The control group might have shoulder pain and might not represent the normal people. In a further study, normal people should be recruited in the control group and be scanned for S-MRI prospectively, and the more accurate SSNCSA of normal people can be obtained.

Despite several limitations, we presented the diagnostic criteria using MRI for the first time, especially using SSNCSA. In addition, the present study proved that SSNCSA can be an objective
and useful diagnostic tool for SNES.

We concluded that the SSNCSA had high sensitivity (80.0%), high specificity (80.0%), and an AUC of 0.92 for diagnosing SNES. This data will strengthen the results that the SSNCSA plays a significant role in determining SNES.

**Funding**

None

**Conflicts of Interest**

No potential conflict of interest relevant to this article was reported.

**Author Contributions**

Jiyeon Park (Data curation; Investigation; Methodology; Software; Visualization; Writing – original draft)

Min-Ying Su (Writing – review & editing)

Young Uk Kim (Conceptualization; Formal analysis; Investigation; Methodology; Supervision; Writing – review & editing)

**Acknowledgements**

The authors would like to thank SoYoon Park, Jae Ni Jang, Yun-Hong Kim, and Won-Jun Choi for managing the administrative activities related to the conduct of the study.
ORCID

Jiyeon Park, https://orcid.org/0000-0002-1727-2411

Min-Ying Su, https://orcid.org/0000-0002-3069-0271

Young Uk Kim, https://orcid.org/0000-0003-4977-5272
References


17. Polguj M, Sibinski M, Grzegorzewski A, Waszczykowski M, Majos A, Topol M. Morphological and radiological study of ossified superior transverse scapular ligament as


Table 1. Comparison of the Characteristics of the Control and SNES Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control Group (n = 10)</th>
<th>SNES Group (n = 10)</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>6/4</td>
<td>8/2</td>
<td>0.355</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>42.70 ± 13.28</td>
<td>43.90 ± 15.57</td>
<td>0.855</td>
</tr>
<tr>
<td>SSNCSA (mm²)</td>
<td>64.50 ± 8.93</td>
<td>44.94 ± 10.40</td>
<td>P &lt; 0.01</td>
</tr>
</tbody>
</table>

Values are presented as mean ± SD or the numbers of patients. SNES: Suprascapular nerve entrapment syndrome, SSNCSA: Suprascapular notch cross-sectional area.
Table 2. Sensitivity and Specificity of Each Cut-off Point of the SSNCSA

<table>
<thead>
<tr>
<th>SSNCSA (mm²)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.49</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>45.79</td>
<td>50.0</td>
<td>100</td>
</tr>
<tr>
<td>48.51</td>
<td>70.0</td>
<td>100</td>
</tr>
<tr>
<td>57.49*</td>
<td>80.0</td>
<td>80.0</td>
</tr>
<tr>
<td>60.63</td>
<td>90.0</td>
<td>60.0</td>
</tr>
<tr>
<td>75.88</td>
<td>100</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*The best cut-off point on the receiver operating characteristic (ROC) curve. SSNCSA: suprascapular notch cross-sectional area.
Fig. 1. Measurement of suprascapular notch cross-sectional area (SSNCSA) (white arrow) was acquired on MR T2 weighted images.
Fig. 2. ROC curve shows that the best cut-off score for SSNCSA was 43.85 mm², with sensitivity 80.0% specificity 80.0%. SSNCSA AUC (95% Confidence interval) = 0.92 (0.79–1.00).