어깨위신경의 초음파 소견: 신경 전도 검사를 위한 최적의 위치

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Ultrasonographic Findings for the Suprascapular Nerve: Identifying the Optimal Site for Nerve Conduction Study

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Objective: It is difficult to obtain reliable electrodiagnostic results by stimulating the suprascapular nerve (SSN) at Erb's point. We used ultrasound to determine the best location to evoke compound muscle action potentials (CMAPs) during electrical stimulation of the SSN.

Method: We observed the anatomic location of the SSN using ultrasonography (USG) and its relationship to the surrounding structures. Also, we compared the electrodiagnostic results for the SSN between the conventional nerve conduction study (NCS) technique and USG-guided NCS.

Results: The CMAP amplitude of the SSN in the USG-guided technique was significantly larger than that in the conventional technique ($p < 0.05$). The intensity of current stimulation was also significantly lower in the USG-guided technique than in the conventional technique ($p < 0.05$). The optimal site for electrical stimulation was a point 7.5 cm lateral from the sternal end (a point 43.0% of the total length of the clavicle from the sternal head of the clavicle) and 2.28 cm above and perpendicular to that point.

Conclusion: This study identified the location of the SSN in the supraclavicular region and provides an optimal site for stimulation of the SSN. USG-guided NCS could help to reduce patient discomfort and increase test accuracy.

Key Words: nerve conduction study, suprascapular nerve, ultrasound

Introduction

The suprascapular nerve (SSN) arises from the upper

trunk of the brachial plexus, or its posterior division, with contributions from the C5, C6, and occasionally the C4 nerve roots.¹ It supplies motor branches to the supraspinatus and infraspinatus muscles and is also believed to provide sensory innervation to the coracohumeral ligament, the coracoclavicular ligament, the subacromial bursa, and the posterior shoulder capsule.^{2,3} There are a number of mechanisms that can be responsible for injury to the SSN. These can include

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traction injury, repetitive activities, or compression of the nerve from a space-occupying lesion including ganglion cysts or rotator cuff tears. In addition, ossification of the transverse scapular ligament or spino-glenoid notch, or Parsonage-Turner syndrome could also result in suprascapular neuropathic symptoms.⁴⁻¹¹

The gold standard for diagnosis of SSN injury is the electrodiagnostic test, including needle electromyography (EMG) and the nerve conduction study (NCS).¹²⁻¹⁶ Although several published studies have reported normative values, the variability of compound muscle action potentials (CMAP) exists for the SSN, and the criteria for interpretation can vary between different centers or practitioners.^{12,15} Technical errors or operator dependency also are issues with these tests, and therefore, lower test reliability. One of the reasons for such technical errors is that the electrical stimulation point for the SSN is quite ambiguous.^{12,15} Erb's point, or a point above the clavicle where the brachial plexus is located, is visually unclear and can be difficult to identify because it depends largely on various factors including the subject's body weight or neck posture. Increasing the stimulation intensity at Erb's point may induce volume conduction in other nerves, leading to misdiagnosis. Moreover, repetitive electrical stimulations or high intensity currents during electrical stimulation at Erb's point could result in patient discomfort.

Ultrasonography (USG) has been reported to be a useful imaging method for the assessment of many disorders affecting nerves.¹⁷⁻²⁰ USG could be a useful method for the precise localization of the SSN.²¹⁻²⁴ The purpose of this study was to determine the best SSN location for evoked CMAPs during nerve conduction tests using ultrasound. We hypothesized that the results obtained from the USG-guided NCS could give more accurate information for the SSN and alleviate the discomfort caused to patients by conventional NCS. Not only will these results provide the most appropriate location for SSN stimulation, but are also ex-

pected to broaden our knowledge of SSN sonographic findings.

Materials and Methods

1) Subjects

Twenty healthy volunteers over 19 years old were recruited. Exclusion criteria included a history of cervical radiculopathy, any disease which results in peripheral polyneuropathy (e.g., diabetes, chronic alcohol use), any trauma around the neck and shoulder, or family history of hereditary neuropathy. Healthy volunteers were included from the community via local advertisement, and all subjects signed written informed consent. This study was approved by the Institutional Review Board of Korea University Guro Hospital.

2) Conventional NCS

Conventional NCS was performed according to the study of Lee et al.²³ The stimulation point of the SSN is a point 2 or 3 cm above the clavicle and beyond the posterior border of the sternocleidomastoid at the level of the transverse process of the sixth cervical vertebra. The subject's neck was rotated to the opposite side of stimulation. The surface E1 electrode was placed several centimeters lateral to the medial border of the scapula and 2 to 3 cm below the scapular spine. The E2 surface electrode was positioned 2 cm more distal to the stimulating cathode. The examiner obtained the CMAP of the SSN with supramaximal stimulation. Then the examiner found the minimal intensity of current required to elicit maximal SSN CMAP. The NCS was performed using the Viking-Quest electrodiagnostic system (Nicolet Biomedical, Madison, WI, USA). Skin temperature was maintained above 32°C. Recordings were obtained with the following equipment settings: sensitivity, 5 mV per division; sweep speed, 1 ms per division; and bandwidth 20 to 3,000 Hz.

3) Ultrasound examination

Ultrasound was performed using the HD 15 Ultrasound System (Philips, Bothell, WA, USA). Each subject was lying in the supine position. The neck was fully rotated toward the contralateral side. The C5 and C6 nerve roots were identified in the axial plane and when continued downward, we found that these two roots formed the upper trunk of the brachial plexus. We found the site where the SSN was best observed lateral to the upper trunk (Fig. 1). After the cross-sectional area (CSA) of the SSN was confirmed at that location, we then marked the position on the skin surface. We measured the vertical distance and the horizontal distance to describe the relationship between the clavicle and the SSN (Fig. 2). The vertical distance was measured as the shortest distance from the marked point to the clavicle in the surface anatomy. The horizontal distance was measured from the sternal end of the clavicle to the vertical end, which is the intersection of the clavicle and the perpendicular line from the marked point to the clavicle. The horizontal distance ratio was also calculated as the relative ratio of the horizontal distance to the total length of the clavicle. The total length of the clavicle was measured from the sternal end to the acromial end. The

Fig. 1. The important landmarks for confirmation of the suprascapular nerve using ultrasonography are the omohyoid muscle (OM) and the scalene muscle (SM). The arrow marks the suprascapular nerve in the fascia layer under the OM in close relation to the brachial plexus indicated by the round circle.

skin depth was measured from the skin to the SSN.

4) Ultrasound-guided NCS

The USG-guided NCS was stimulated using the cathode placed at the marked position found by the USG. The E1 and E2 electrodes were placed at the same locations as for conventional NCS. In our study, the examiner obtained the SSN CMAP with supra-maximal stimulation. Then the examiner found the minimal intensity of current required to elicit maximal SSN CMAP.

5) Statistical analysis

Data were analyzed using SPSS 20.0 for Windows (IBM SPSS Inc., Armonk, NY, USA). The mean values and standard deviation of the measurements were calculated. To compare CMAP amplitude and current intensity at the stimulation between the conventional and USG-guided techniques, a paired t-test was performed. Results were considered statistically significant if the p value was < 0.05.

Fig. 2. The vertical distance (VD) was measured as the shortest distance from the marked point (*) to the clavicle in the surface anatomy. The horizontal distance (HD) was measured from the sternal end of the clavicle to the vertical end. The total length of the clavicle was measured from the sternal end to the acromial end.

Results

Demographics of 20 healthy volunteers are as follows. The mean age and BMI were 31.6 ± 8.78 years and 22.87 ± 2.17 kg/m², respectively ($n = 20$). The male to female ratio was 2.33.

Table 1 shows the SSN electrodiagnostic results using the two techniques. The mean values for CMAP amplitude using the conventional technique and the USG-guided technique were 5.47 ± 0.92 mV and 5.95 ± 1.09 mV. The CMAP amplitude of the SSN in the USG-guided technique was significantly larger than that of the conventional technique ($p < 0.05$). The mean value of the minimum intensity for maximal CMAP in the conventional NCS and USG guided NCS was 62.30 ± 11.10 mA and 50.46 ± 9.83 mA, respectively. The intensity of current stimulation was also significantly lower in the USG-guided technique than that of the conventional technique ($p < 0.05$).

SSN was identified in all of the participants using USG. The mean value of SSN CSA was 2.43 ± 0.59 mm². The SSN was located 7.5 ± 0.73 cm from the sternal end to the acromial end, which was $43.0 \pm 3.35\%$ of the horizontal ratio. The vertical distance from the clavicle was 2.28 ± 0.50 cm. The mean value of depth from skin was 6.79 ± 1.89 mm (Table 2).

Discussion

We successfully demonstrated the anatomical location of the SSN in this study. The USG-guided technique, in which we performed electrical stimulation at the position localized using ultrasonography, evoked a statistically significantly larger SSN CMAP than the conventional technique. This indicates that the CMAP

obtained with the conventional nerve conduction technique may have resulted from insufficient stimulation. Therefore, we found it necessary to perform SSN nerve conduction at the position we have identified to obtain more accurate results.

NCS is a safe and non-invasive test in which side effects have not been reported, but the electrical stimulation during NCS causes severe discomfort for patients. In many cases, even though NCS is necessary, some patients refuse the test due to this discomfort. In this study, the mean values of the minimal current intensity for maximal SSN CMAP were significantly lower using the USG-guided NCS than the conventional NCS. This result supports that the USG-guided technique can be more easily applied to patients who cannot tolerate the discomfort of high intensity electrical stimulation.

The sonographic findings identified in the current study not only supported the findings identified in the previous studies, but also provided new findings on the SSN. Bilfeld et al. evaluated SSN accessibility using USG in 4 cadavers and 30 healthy volunteers.²⁵ They reported that the SSN in the supraclavicular portion had been easier to identify than in the scapular portion, and a segment of the SSN between these two portions was not visible. The present study identified the SSNs located in the supraclavicular region in all 20 healthy volunteers and found that this area could be the recommended location for USG-guided SSN block. Siegenthaler et al. assessed the SSN using

Table 1. Nerve Conduction Data for the Suprascapular Nerve

Parameters (n = 20)	Conventional NCS*	USG-guided NCS*
Amplitude (mV)	$5.47 \pm 0.9^{**}$	$5.95 \pm 1.09^{**}$
Intensity (mA)	$62.30 \pm 11.10^{**}$	$50.46 \pm 9.83^{**}$

Values are mean $\pm$ standard deviation.

$^{**}p < 0.05$.

Table 2. Ultrasonographic Data for the Suprascapular Nerve

Parameters (n = 20)	Value
CSA (mm ²)	2.43 ± 0.59
Clavicle (cm)	17.45 ± 1.13
VD (cm)	2.28 ± 0.50
HD (cm)	7.5 ± 0.73
HD ratio (%)	43.0 ± 3.35
Skin depth (mm)	6.79 ± 1.89

Values are mean $\pm$ standard deviation.

Vertical distance (VD): the shortest distance from the marked point to the clavicle, Horizontal distance (HD): horizontal distance from the sternal head of the clavicle to the vertical end, HD ratio: ratio of horizontal distance to the total length of the clavicle

USG.¹⁸ They performed USG on 60 healthy volunteers and found that evaluating the SSN using USG is better in the lateral cervical region than at the level of the scapula and that the omohyoid muscle is a reliable anatomical landmark. Battaglia et al. studied the relationship between the SSN and omohyoid muscle in 33 healthy volunteers.²¹ The omohyoid muscle and the SSN tend to course together as they travel distally. In our study, the SSN was also located near the omohyoid muscle. Based on the present study and many other studies, the omohyoid muscle is an important anatomic landmark for USG-guided SSN block. However, it is difficult to identify the omohyoid muscle via surface anatomy, which makes it difficult to utilize as a landmark during nerve conduction studies. We found the SSN stimulation site on the skin surface, 7.5 cm lateral to the sternal end of the clavicle and 2.28 cm vertical to the vertical end. The location information confirmed in this study can help clinicians deliver accurate stimulation to the SSN during nerve conduction studies. Laumonerie et al.'s study included 30 healthy volunteers and 5 cadavers.¹ The diameter of the SSN at the level of its origin averaged 1.33 mm (1~9 mm). In the current study, SSN CSA was measured in the supraclavicular area. Considering that recent USG studies prefer CSA to the diameter of the nerve as a measurement of nerve sonographic findings, the CSA values for the SSNs confirmed in this study may be more useful for sonographic studies. Laumonerie et al. also measured the depth of the skin surface to the SSN, and the mean depth was 5.12 mm (2.7~10.6 mm). Our findings suggest the mean depth is 6.79 mm. The skin depth presented in the above findings was less than 1 cm, so this should be kept in mind when using USG guided SSN blocks; the needle approach should be shallow.

This study is the first to suggest the usefulness of a USG-guided NCS technique for the SSN. Recently, USG guided NCS has been studied for various peripheral nerves. Boon et al. investigated the USG-guided lateral femoral cutaneous nerve (LFCN) NCS technique

in a population of normal subjects, of whom 50% had a body mass index within the obese range (> 27.5).²⁶ They found that responses were obtained in at least 92% of subjects using either of the techniques, and 92% of normal subjects had $< 60\%$ interside variability using the USG guided technique. Park et al. also studied the utility of a USG-guided LFCN NCS technique.²⁷ In that study, the SNAP amplitude of the LFCN using the USG-guided technique was significantly larger than that of conventional NCS. Kim et al. studied the USG-guided NCS for the superficial peroneal nerve.²⁸ They suggested the optimal recording position in the NCS for the superficial peroneal nerve was one-third medial to the lateral malleolus for the intermediate dorsal cutaneous nerve and just lateral to the midpoint of the intermalleolar line for the medial dorsal cutaneous nerve. Evangelopoulos et al. studied electrode positioning for the saphenous NCS using USG.²⁹ They concluded that SNAP amplitudes of the recorded sensory nerve action potentials were higher with the ultrasound-guided needle electrode recordings than with surface recordings. The present study also confirmed that the USG-guided technique evoked better CMAP values than the conventional technique. We suggest using the USG guided technique if it is difficult to obtain accurate results using conventional NCS or to determine the stimulation location at the surface.

This study has some limitations. First of all, since the volunteers enrolled in this study included few obese individuals, a study including more obese people could reveal different results for the SSN nerve conduction or sonographic findings. Secondly, the number of subjects enrolled was relatively small. Therefore, future studies that include larger samples are recommended. In this study, we did not evaluate inter-observer reproducibility because one sonographer performed all sonographic examinations for the study. Lastly, we did not include a patient with SSN neuropathy. Thus, we cannot assure the utility of the USG-guided technique in patients with SSN neuropathy. Future evaluations should identify the utility of

USG-guided stimulation by including patients with SSN neuropathy.

Our study contributes to identifying the location of the SSN in the supraclavicular region and provides an optimal site for SSN stimulation. This also could help relieve patient discomfort during such examinations. Further studies that include a large number of patients with SSN neuropathy are recommended to replicate and expand our findings.

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