Ultrasonographic Visualisation of Anatomical Variations of the Supraclavicular Nerves

Abstract

Typical anatomy of the supraclavicular nerve (SCN) is described as originating from the cervical plexus and dividing into medial, intermediate, and lateral branches. The SCN is vulnerable to injury during clavicular surgery, leading to altered sensation post-operatively. There is also increasing interest in anaesthetising the SCN in shoulder or clavicular surgery. Utilising a high-frequency (20MHz) ultrasound probe, 20 healthy volunteers were scanned, giving data for 40 SCNs. For each nerve, anatomical course and branches were graphically plotted using a custom Python 3.8.12 program and Microsoft Excel. Of 40 nerves, only 19 (47.5%) demonstrated a typical course, with the rest showing considerable variability of branching patterns. Crossing branches (CBs) were found in 24 (60%) with a total of 54. Just over half (29, 54.7%) of these crossed the clavicle lateral to its midpoint, with 32 (59.6%) CBs having a diameter of ≥25% compared to that of the SCN main trunk. The distance from the mid-clavicular point at which the branches crossed the clavicle was recorded. This study demonstrated that over half the SCNs had atypical branching patterns with intra-volunteer variability. Preoperative mapping may be useful in preventing injury and subsequent numbness.

Keywords: Supraclavicular nerves, ultrasonography, anatomical variations
Introduction

Typical anatomy of nerves as described in anatomical textbooks and taught in medical schools is often an oversimplification of the actual anatomy. In practice, variation in nerve anatomy is the norm \(^1\)-\(^4\). High frequency ultrasound allows study of the anatomy of nerves in healthy volunteers without disruption to tissue planes.

The supraventricular nerve (SCN) arises from the cervical plexus and mediates sensation from the skin over the shoulder and clavicle. Recently, there has been a lot of interest in anaesthetising the SCN with local anaesthetic (LA) either in combination with low volume brachial plexus block or as an isolated block for clavicular surgery.\(^5\),\(^6\)

Improved understanding of the variation in SCN anatomy by anaesthetists will improve the safety and effectiveness of the regional anaesthesia technique.\(^7\) In addition, branches of the SCN are frequently damaged in clavicular surgery, resulting in numbness over the shoulder and clavicle.\(^8\) Better knowledge of the anatomy of this nerve could help surgeons avoid intraoperative damage.

Our aim was to use high frequency ultrasound scanning (USS) to better understand the course and anatomical variations of the SCN and its branches and compare it to standard anatomy textbook description. We also aimed to visualise this variation using a custom computer programme. Our hypothesis is that the anatomy of the SCN varies greatly from what is traditionally taught or shown in textbooks.
Materials and methods

Ethical approval was obtained from the Human Biology Research Ethics Committee (HBREC.2021.34). Twenty volunteers were recruited, and written consent obtained for USS on both sides of their neck (n=40 nerves). The following demographic and anatomical parameters for each volunteer were recorded: age, sex, height, weight, BMI, neck girth at the level of the cricoid cartilage, and clavicular length.

Volunteers were positioned supine, with their heads rotated opposite to the study side. The SCN and its branches were plotted on 2D line graphs with the x and y axes defined as shown in Figure 1. The sternoclavicular joint was considered the ‘0’ point. A line passing through this ‘0’ point from medial to lateral in the coronal plane formed the x-axis. A line passing caudal to cephalad from the ‘0’ point in the sagittal plane formed the y-axis. The SCN and its branches were plotted on x and y axes in centimetres utilising these axes.

All studies were performed with the GE Venue Fit, L4-20t-RS high frequency ultrasound probe using a nerve pre-set. The scanning was done by an anaesthetist with over 20 years of experience using ultrasound for nerve imaging and nerve blocks. The images were interpreted by two anaesthetists.

The following observations were made for each side studied:

1. SCN vertebral origin- ultrasound appearance of the transverse processes of cervical vertebra and presence of vertebral artery was used to determine the level of cervical vertebra.
2. Maximal width of SCN
3. Maximal width of SCN prior to branching.
4. Coordinates of SCN trunk and branching points along the above defined axes
5. Distance of SCN or its most medial branch from the brachial plexus at the level of the “stoplight sign” for the C5 and C6 nerve roots as observed whilst doing interscalene block.
6. Diameter of crossing-branches (CB) and their distance from the midpoint of the clavicle. These are SCN branches which cross over the clavicle to the chest wall.

The coordinates of the SCN, its branching points and other data collected as described above were input into a custom Python 3.8.12 program (https://replit.com/@NeilSardesai1/SCN-grapher#main.py). This program used the matplotlib library to generate 2D line graphs of the SCN.
Results

Demographic and anatomical parameters of 20 volunteers are summarised in Table 1.

The SCN and its branches were identified on both sides of all 20 volunteers, generating 40 sets of results. When comparing the two SCNs from the same volunteer, there was asymmetry in terms of both origin and branching pattern.

The SCN originated from the C4 nerve root in all volunteers studied except one, where the SCN originated from C5.

In 95% of sides, the SCN was clearly seen as a single trunk between the investing and prevertebral fascia, with a median diameter of 0.34 cm (range 0.13 cm-0.83 cm). In two sides (from two different volunteers), the nerve was seen to originate as separate nerves. In one case, the two origins were quite close to each other and combined into one nerve before dividing further (Figure 2b), whilst in the other case, they continued as two separate nerves (Figure 2c).

The typical textbook representations of the SCN (Figure 2a) with medial, intermediate, and lateral branches, was observed in less than half of the study sides (47.5%). Even when three branches were present, their branching pattern was different in 62.5% of cases. The number of branches also varied, with only two branches in 12.5%, and four or more in 22.5% of cases. In one side studied, only one main nerve was observed.

As shown in Figure 3, the distance of the SCN, or its most medial branch, from the roots of the brachial plexus at the “stoplight sign” was measured. The median distance was 0.75 cm (range 0.38-1.53 cm).

Ultrasound identifiable crossing branches (CBs) of the SCN were found in 60.0% of sides with a total of 54 CBs observed. The median diameter of CBs was 0.26 cm (range 0.04-0.48 cm). When comparing the diameter of the CBs to that of their main SCN trunk, 2 CBs were more than 25% of the diameter of the main SCN trunk and 14 CBs were more than 50%.

The sites where CBs crossed the clavicle were also investigated. Figure 2 illustrates the relationship of CBs to the midpoint of the clavicle. Most of the CBs (n=14, 25.9%) crossed at the midpoint. Additionally, a greater number of CBs crossed the clavicle lateral (n=29, 54.7%) to the midpoint compared to those crossing medially (n=11, 20.4%).
Discussion

Textbooks describe the supraclavicular nerve as originating from the cervical plexus, dividing into medial, intermediate, and lateral terminal branches.9,10

Anatomy of the SCN has been previously studied in cadavers to demonstrate its branching patterns. These studies showed that 97% of SCNs had medial and lateral branches, but with just under half (49%) having the traditional branching pattern of medial, lateral, and intermediate branches.8,11 Two branches (medial and lateral) were found in 40% of cadavers and three branches (medial, intermediate and lateral) were found in 60% of cadavers in a study by Van et al. 12

This traditional pattern was seen in less than 50% (47.5%) of our volunteers. However, in contrast to cadaveric studies, we found a high variation in the SCN branching pattern, even between sides of the neck within the same volunteer, which is in line with variations seen in other cutaneous nerves.13,14

The difference between cadaveric and our study could be due to limitations in cadaveric studies. There is potential for the nerves to be moved due to the dissection process, with branches being inadvertently transected or missed due to their small size. Ultrasound has the advantage of scanning live volunteers without any disruption to tissue planes. To our knowledge, this is the first reported USS study of the anatomical variations of the SCN.

This wide variation in SCN anatomy observed was illustrated using a Python 3.8.12 program (https://replit.com/@NeilSardesai1/SCN-grapher#main.py), which generated 2D diagrams to visually represent the course taken by the SCN in the neck to enable ease of comparison. This is shown in Figure 2.

The SCN mediates cutaneous sensation over the shoulder and clavicle. Recently, there has been renewed interest in blocking this nerve in combination with the low-volume interscalene approach to block the brachial plexus for shoulder surgery, or the supraclavicular approach to block the brachial plexus for clavicular surgery.5 We were able to visualise the SCN on both sides in all our volunteers using ultrasound, using a 20 MHz probe to see smaller branches of the SCN. The main trunk of SCN can be seen by commonly available ultrasound machines in the anaesthetic department and thus can be easily blocked.

The “stoplight sign” refers to the ultrasound image of three hypoechoic structures between the anterior and middle scalene muscles sought during ultrasound guided interscalene block. From our current understanding they represent the C5 cervical root and the upper and lower fascicles of the C6 cervical root.15 Local anaesthetic is injected at this level for performing an interscalene approach to the brachial plexus. This can block the SCN by spreading cephalad or superficially through the interscalene groove.16,17 In this study, the SCN or its most medial branch was located at a median distance of 0.75 cm (range 0.38-1.53 cm) from the most superficial root (C5) of the brachial plexus at the level of the “stoplight sign”. The large volumes of LA (25-30 ml) previously used in interscalene blocks often resulted in extensive LA spread, blocking sympathetic and sensory nerves. Despite the low-volume (10-15 ml) interscalene blocks currently used, LA spread may still affect the SCN and other branches from the cervical plexus, given the proximity between structures seen in some of our volunteers.
As well as its role in nerve blocks, the SCN is clinically important in clavicular surgery. A frequent complication is injury to the branches of the SCN through inadvertent transection or stretching of the nerves intraoperatively. This could lead to post operative numbness and paraesthesia, with a reported incidence of numbness following operative treatment of clavicle fractures of 10-29%. This can be due to injury to CBs or branches that pass over or through tunnels and grooves in the clavicle, fibrous and muscular structures surrounding the clavicle or entrapment of the branches subsequently in the callus. In this study, CBs were identified in 65% of volunteers, with 40% of sides studied having more than one CB. In most cases, the diameter of a CB was ≥ 25% of the main SCN trunk. It is possible that smaller branches were not identified but these may be clinically less significant.

Cadaveric study showed a high variation in the position of nerves crossing the clavicle, and as a result, the authors concluded that a clinically significant “safe zone” could not be determined. Although our results showed the most common location for the CBs to cross the clavicle was at its midpoint (25.9%), the number and location of other CBs were highly variable. Thus, any incision made to access the clavicle would risk injury to one of more of these branches.

We have demonstrated that the SCN and its branches can be successfully identified using high frequency ultrasound and have shown that there is significant variation in the anatomy of the SCN. However, there are possible limitations to our study. All volunteers were healthy and had no pre-existing trauma to the clavicle. We do not know whether the presence of a fractured clavicle, and subsequent haematoma formation, oedema and/or soft tissue swelling would make it more difficult to visualise these nerves, or to what extent trauma would distort anatomy. Since we have shown that SCN anatomy within individuals is highly variable between their sides of the neck, using the contralateral side would not be a good indicator for the anatomy on the affected side.

The swelling due to a haematoma resulting from clavicular fracture is usually located deep to the clavicle and is unlikely to impede visualisation of the nerves. Ultrasound imaging of the SCN can be attempted after the patient has been anaesthetised and positioned for surgery, thus minimising discomfort. In clinical practice, when attempts were made to preserve the SCN during clavicle surgery, the incidence of numbness was significantly reduced. However, even when the nerves are not divided, the resultant neuropraxia from stretching during surgical retraction can cause neuropathic pain. A more prudent approach would be to place the skin incision about 1 cm inferior and parallel to the clavicle. In this location, the likelihood of encountering a clinically significant nerve branch is low.

Intraosseous nerves passing through the clavicle have been reported. However, we were not able to see these branches using ultrasound, and our study may therefore have underestimated the true number of branches passing close to the clavicle.

Mapping of the SCN prior to clavicular surgery may be useful to minimise the risk of nerve damage and improve patient satisfaction after surgery.
Conclusion

Our study has successfully mapped the course of the SCN and its branches using high frequency ultrasound. We have shown that less than half of the necks studied followed the typical anatomical pattern described in textbooks, with a high degree of variability of the SCN between sides of the neck in the same volunteer.

Given the wide variation of the SCN between individuals, we feel ultrasound may have a role in pre-operative mapping of the SCN to minimise the risk of damage to these nerves during clavicular surgery.
References


Figure 1
Figure 2

(a) SCN plot for volunteer 2 (Left)
(b) SCN plot for volunteer 5 (Right)
(c) SCN plot for volunteer 3 (Right)
(d) SCN plot for volunteer 5 (Left)
(e) SCN plot for volunteer 9 (Left)
(f) SCN plot for volunteer 9 (Right)

Figure 3

X axis clavicle – distribution of crossing points as bar chart

Relation of crossing branches to midpoint of clavicle

Distance of crossing branches from midpoint of clavicle (cm)
Figure Legends:

Figure 1:
Position for scanning: Volunteer lying supine with head turned opposite to the side being scanned.
‘0’ = sternoclavicular joint.
X-axis: A line passing through ‘0’ from medial to lateral in the coronal plane
Y-axis: A line passing caudal to cephalad from ‘0’ in the sagittal plane

Figure 2:
Multiple “2D diagrams” showing considerable variability in the course and branching pattern of the SCN
2a: Typical textbook SCN showing medial intermediate and lateral branch
2b: Dual origin of SCN forming a single nerve before branching out
2c: Two separate nerves representing SCNs
2d: Multiple branches of SCN
2e: Unusual branching and course of the nerve.
2f: SCN with a CB

Figure 3:
Relation of crossing branches to midpoint of clavicle.

Figure 4:
Ultrasound image demonstrating the distance from the SCN (vertical arrow) and the roots of the brachial plexus at the level of the ‘traffic light sign’ (horizontal arrows). The brachial plexus roots are located deep to the sternocleidomastoid muscle (SCM) and between the scalenus anterior (SA) and scalenus medius (SM).
Tables

Table 1
Demographic and anatomical parameters of volunteers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>26.5 (19-68)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.75 (1.53-1.88)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70 (53-96)</td>
</tr>
<tr>
<td>BMI</td>
<td>22.6 (19.6-32.9)</td>
</tr>
<tr>
<td>Circumference of neck at the level of cricoid cartilage (cm)</td>
<td>36.35 (31-45.5)</td>
</tr>
</tbody>
</table>