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Gender, BMI and side-to-side differences in spinal accessory nerve conduction from the upper and middle components of the trapezius muscle

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ABSTRACT

Introduction: There is a variety of testing methods described in the literature for the spinal accessory nerve (SAN). This study aims to evaluate side-to-side, gender, and BMI differences with surface recording from the upper and middle trapezius using a standard distance to the upper trapezius.
Methods: Subjects underwent bilateral SAN conduction testing with the active recording electrodes over the superior border of the upper trapezius, midway between the acromion and the C7 spinous process, and over the middle trapezius 3 cm medial to the vertebral border of the scapula.
Results: Mean latency values were 2.17 ± 0.22 msec and 3.14 ± 0.40 msec for the upper and middle trapezius, respectively. Mean amplitude values were 8.02 ± 2.2 mV for the upper trapezius and 3.96 ± 1.77 mV for the middle trapezius. The mean side-to-side latency difference was 7.8% for the upper and 9.5% for the middle trapezius, while the mean side-to-side amplitude difference was 18.2% for the upper and 37.6% for the middle trapezius. BMI had a significant inverse effect on upper and middle trapezius amplitudes such that both males and females with lower BMI had larger amplitudes. There was a significant gender difference for upper and middle trapezius latency with faster latency values observed in females.
Conclusions: SAN conduction with surface recording from the upper and middle trapezius is well tolerated. Side-to-side differences may be the best way to evaluate both amplitude and latency, so bilateral testing is essential in light of anatomical variation and BMI effects on amplitude.

1. Introduction

The spinal accessory nerve (SAN), or cranial nerve XI, is often injured during surgical procedures of the posterior triangle of the neck and can also be affected due to sporting injuries, trauma or lesions within the cranial cavity (Axibal et al., 2017; De Lima et al., 2011; Dumitru and Zwarts, 2002; Hsu et al., 2004; Kennelly, 2012; London et al., 1996; Stino and Smith, 2018; Van Tuijl et al., 2006; Bodack et al., 1998; Al-Ajmi et al., 2015). Idiopathic spinal accessory nerve injury and SAN impairment related to compression from backpacks has also been reported (Sergides et al., 2010; Coulter et al., 2015). Spinal accessory nerve injury frequently produces shoulder pain with atrophy of the trapezius and/or sternocleidomastoid. The patient also presents with weakness in shoulder abduction and an aching type of pain in the area of the trapezius (London et al., 1996; Chang et al., 2011). Spinal accessory nerve conduction may help to identify cranial lesions as well as brachial plexopathies and can be used to help assess prognosis of spinal accessory nerve injuries (Kennelly et al., 2012).

The spinal accessory nerve has a cranial and a spinal component. The cranial root arises from 3 to 6 small rootlets in the caudal portion of the nucleus ambiguous at the level of the medulla oblongata (Tubbs et al., 2014). The spinal component of the spinal accessory nerve is derived from the lateral part of the anterior horn of the spinal cord with several branches originating from the individual C1-5 spinal nerve rootlets which travel in a cephalad direction sequentially fusing with each individual superior segment to form the spinal accessory nerve (Tubbs et al 2008, 2014). This nerve continues superiorly, entering the cranial cavity through the foramen magnum, and travels with cranial nerve X (Vagus) nerve in

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the cranium to exit the cranial cavity through the jugular foramen (Tubbs et al., 2014; Cesmebasi and Spinner, 2015). The SAN then splits after exiting the skull into internal and external rami. The internal ramus joins the vagus nerve branches that contribute to the pharyngeal plexus. The external ramus is larger and supplies the sternocleidomastoid and trapezius muscles (Tubbs et al., 2014). Once in the neck, the spinal accessory nerve is joined by additional nerve fibers from the C1-4 levels through a communication with the cervical plexus. These cervical plexus fibers are proposed to preferentially provide the motor supply to the sternocleidomastoid (C1-2) and trapezius muscles (C3-4) (Tubbs et al., 2014). Dumitru and Zwarts (2002) and Olarte et al. (1977) however, asserted that the upper trapezius is supplied by the spinal accessory nerve and that cervical fibers from the cervical plexus supply only the middle and lower trapezius (Dumitru and Zwarts, 2002; Olarte et al., 1977). Soo et al. (1990) proposed that the motor supply to the upper and middle trapezius is more often from the accessory component, while the lower trapezius is supplied from the cervical plexus (Soo et al., 1990). Kierner et al. (2001), however, reported that the nerve supply to the lower part of the trapezius is supplied by a branch of the spinal accessory nerve and that the middle and upper trapezius are supplied by both the spinal accessory nerve and by muscular branches from the cervical plexus (C2-C4) (Kierner et al., 2001).

Standard techniques should make assessing the relatively superficial spinal accessory nerve fairly straightforward. However, there is a range of assessment methods described in the literature. The spinal accessory nerve is superficial posterior to the sternocleidomastoid muscle at the midpoint of this muscle, making this an ideal place for stimulation of the nerve (Dumitru and Zwarts, 2002). Cherington (1968) described surface stimulation of the spinal accessory nerve at this point with surface recording electrodes placed over the upper trapezius muscle 5 cm lateral to the C7 spinous process (Cherington, 1968). Fahrer et al. (1974) described surface stimulation in the same location as Cherington, with needle recording from the upper, middle and lower trapezius muscles (Cherington, 1968; Fahrer et al., 1974). Petrera and Trojaborg (1984) reported needle recording from the upper, middle and lower trapezius with near nerve needle stimulation in the same location as Cherington and Fahrer using a patient population (Cherington, 1968; Fahrer et al., 1974; Petrera and Trojaborg, 1984). Green et al. (1985) reported latency values for the upper, middle and lower trapezius using surface stimulation at the same posterior sternocleidomastoid position with surface (bar) recording electrodes located at a distance of 5 cm lateral to the C7 spinous process for the upper trapezius. They positioned the recording electrode at the midpoint of the distance between the spine of the scapula and the corresponding spinous process for the middle trapezius, and two finger breadths from the spinous process in line with the inferior vertebral border of the scapula for the lower trapezius (Green and Brian, 1985). Cherington (1968) Petrera and Trojaborg (1984) and Green et al. (1985) did not report amplitude values (Cherington, 1968; Petrera and Trojaborg, 1984; Green and Brian, 1985). Chang et al. (2011) recorded spinal accessory nerve conduction values from a group of 20 non-symptomatic subjects using similar electrode arrangements as Green et al., and did report amplitude values (Chang et al., 2011; Green and Brian, 1985). No standardized distances were reported for spinal accessory nerve recording (Fahrer et al. 1974; Chang et al., 2011; Cherington, 1968; Petrera and Trojaborg, 1984; Green and Brian, 1985). Patient positioning has also been variable, with Kennelly (2006) reporting supine positioning with the head elevated and rotated 45° to the opposite side (Kennelly, 2006). Petrera did not report patient positioning; Green et al. tested patients in a prone position, and Chang et al. (2011) reported testing in a seated position (Chang et al., 2011; Petrera and Trojaborg, 1984; Green and Brian, 1985).

Prior published studies have not analyzed side-to-side, gender, or BMI differences. The described techniques have also not reported any standard distances. This study aims to evaluate potential side-to-side, gender and BMI differences in spinal accessory nerve conduction values, with recordings from the upper and middle trapezius using a standardized distance to the upper trapezius.

2. Methods

The Belmont University Institutional Ethics Committee approval (number 290) was obtained for procedures on human subjects and written informed consent was obtained from each subject. This study complied with the 2013 Declaration of Helsinki. Sixty nine participants were tested bilaterally for a total of 138 spinal accessory nerves tested. The mean age of subjects was 24.7 ± 3.6 years. 21 males and 48 females between the ages of 20 and 42 years old, participated in the study. Participants were further categorized into low and high BMI groups, with low BMI being defined as ≤24.9, and high BMI defined as >24.9. The males were split fairly evenly into BMI categories, with 10 males in the low, and 11 males in the high BMI group. There were 33 females in the low, and 15 females in the high BMI group.

The subjects were healthy individuals who underwent an upper quarter screen. Subjects were excluded if they had a history of diabetes, thyroid, liver or kidney pathology or a history of upper extremity injury or cervical nerve root pathology. The Cadwell Wave EMG Machine, Cadwell Corporation (Kennewick, WA), was used to record the nerve conduction values. The gain was set at 5000μV per division with a sweep speed of 5 ms/Div. Latency markers were placed at the onset of the negative deflection from baseline, and the amplitude was measured from baseline to peak.

Subjects underwent bilateral spinal accessory nerve conduction testing with recording from the upper and middle trapezius in a seated position. A reference ground electrode was placed over the C7 spinous process with active recording electrodes placed at a point on the upper trapezius at the upper border of the muscle, midway between the acromion and the C7 spinous process (approximately 5–7 cm lateral to the C7 spinous process). The reference electrode was located in a bar electrode 2 cm lateral to the active electrode on the upper trapezius. Middle trapezius recording was accomplished with the active electrode placed 3 cm medial to the vertebral border of the scapula at the level of the scapular spine. The reference electrode for the middle trapezius was also located in a bar electrode 2 cm distal to the active electrode, along a line formed at a 45° angle toward the border of the scapula. The recording electrode placements are shown in Fig. 1. After placement, a supramaximal stimulus was delivered with a duration of 100 μs along the posterior aspect of the sternocleidomastoid 8 cm proximal to the active recording electrode for the upper trapezius (see Fig. 1). Latency and amplitude was recorded, while surface skin temperature was monitored and maintained above 32 °C. Each recording was completed twice and the results were averaged. Waveforms are shown in Fig. 2.

The mean and standard deviation, as well as mean and percent difference between sides were calculated. Normal ranges were calculated to include upper and lower limits of normal for all parameters assessed using the mean ± 2 SD and a mean percent side-to-side difference + 2 SD. A two-way analysis of variance (ANOVA) was used to analyze gender and BMI differences. Significance was set at $P \leq 0.05$. Data were analyzed using SPSS (Statistical Package for the Social Sciences, version 22.0, SPSS Inc., Chicago, IL).

3. Results

The mean latency and amplitude values with standard

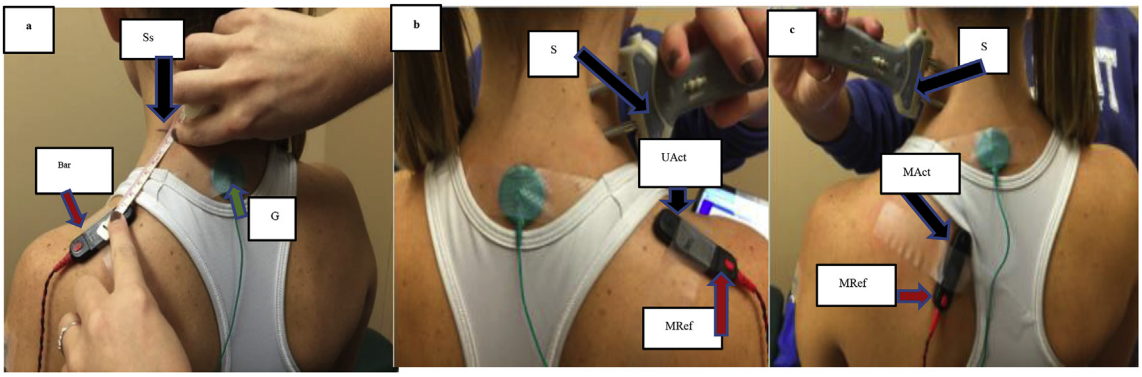

Fig. 1. Upper and middle trapezius electrode placement. A. Stimulus site was established at 8 cm proximal to the active recording electrode posterior to the sternocleidomastoid muscle. The ground electrode was placed at the C7 spinous process, while the active and reference recording electrodes were embedded in the bar electrode with the reference electrode placed at a fixed distance of 2 cm distal to the active recording electrode. B. Upper trapezius recording with active electrode placed over the upper border of the upper trapezius muscle at a point midway between the acromion and the C7 spinous process. C. Middle trapezius recording with the active electrode placed 3 cm medial to the vertebral border of the scapula at the level of the scapular spine. Key: G = ground electrode, Bar = bar electrode, S = stimulator, Ss = stimulator site, UAct = upper trapezius active recording electrode, URef = upper trapezius reference recording electrode, MAct = middle trapezius active recording electrode, MRef = middle trapezius reference recording electrode.

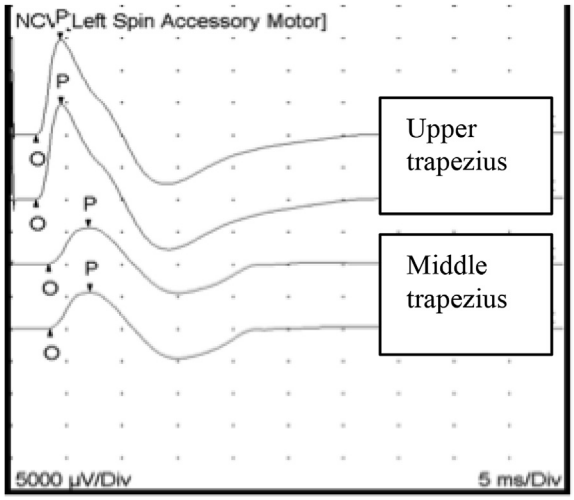

Fig. 2. Spinal accessory waveform with recording from the left upper and middle trapezius. Two recordings were made to confirm the waveform and the average of the two was documented. Key: O = onset, P = peak.

deviations and upper/lower limits of normal for all limbs (both right and left) are presented in Table 1. Side-to-side percent differences in upper and middle trapezius latency were 7.80% and 9.55% respectively. Side-to-side percent differences in upper and middle trapezius amplitude were 18.20% and 37.63% respectively (see Table 2).

There was a significant gender difference (0.001, 0.000) for upper and middle trapezius latency respectively, but no BMI effect and no interaction between gender and BMI for latency. Upper and middle trapezius latency values were faster for females (see Fig. 3). BMI had a significant effect on both upper (P = 0.00) and middle trapezius (P = 0.03) amplitudes while gender had a significant effect only on upper trapezius amplitudes (P = 0.00). There was no interaction between gender and BMI for amplitude. Males appeared to have a greater upper trapezius amplitude than females regardless of BMI status (see Table 3). Both males and females with lower BMI had larger upper and middle trapezius amplitudes than their high BMI counterparts (see Fig. 4).

Table 1
All subjects (N = 138 limbs) means, SD, upper/lower limits of normal for distal latency and amplitude. The overall upper/lower limits of normal are defined as (mean ± 2 SD).

Muscle	Latency (msec)	Amplitude (mV)
Upper trapezius	2.17 ± 0.22, 2.61	8.02 ± 2.20, 3.62
Middle trapezius	3.14 ± 0.40, 3.94	3.96 ± 1.77, 0.42

Table 2
Side-to-side differences all subjects (mean, SD, percent difference).

Muscle	Latency (msec)	Amplitude (mV)
Upper trapezius	7.80 ± 5.8, 19.4%	18.20 ± 15.7, 49.6%
Middle trapezius	9.50 ± 8.25, 26.0%	37.63 ± 3.14, 43.91%

4. Discussion

The upper and middle trapezius latency values found in this study were similar to those of Green et al. (1985) who reported 2.1 ± 0.2 and 3.0 ± 0.2 msec for the upper and middle trapezius latency values respectively, and within the range of those reported by Cherington (1968) (1.8–3.0 msec) (Cherington, 1968; Green and Brian, 1985). However, the present study used a standard 8 cm distance from stimulation site to recording site in the upper trapezius, which differs from previous descriptions of spinal accessory nerve conduction (Dumitru and Zwarts, 2002; Chang et al., 2011; Cherington, 1968; Petrera and Trojaborg, 1984; Green and Brian, 1985; Kennelly, 2006). Chang et al. (2011) did not report latency values, but did report amplitudes and used a technique similar to that of the present study in a seated position for a series of 20 non-symptomatic individuals. Chang et al.'s amplitude values for the upper and middle trapezius were 11.6 ± 3.5 mV and 5.9 ± 1.9 mV, respectively and were larger than the amplitudes for mean upper and middle trapezius in this study (Chang et al., 2011). This difference in amplitude values may in part be due to their placement of the reference electrode over the acromion while in the present study the reference electrode was 2 cm distal to the recording electrode fixed in a standard bar electrode. Chang et al. (2011) demonstrated a large variability about the mean in amplitude values in a similar fashion to the present study's amplitude findings and BMI was not reported. It is also possible that the present study's sample contained more subjects with greater BMI than did that by Chang et al. (2011) (Chang et al., 2011).

The current study's upper trapezius latency values fall within

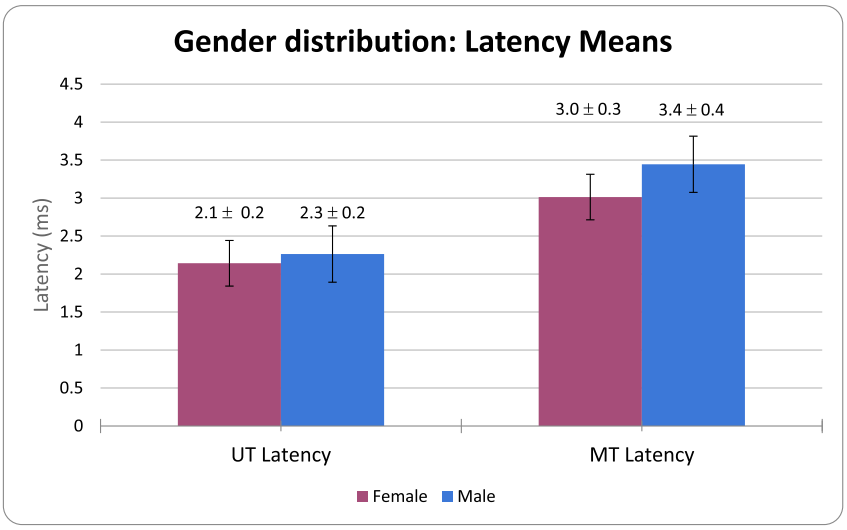

Fig. 3. Gender effect for latency values. There was a significant gender effect for upper trapezius (P = 0.001) and middle trapezius (P = 0.000) latency values.

Table 3
Amplitude (mV) mean and SD for gender and BMI categories.

	BMI category	Males	Females
Upper trapezius	Normal	10.18 ± 2.28	7.84 ± 1.51
	High	8.27 ± 2.62	6.78 ± 2.12
Middle trapezius	Normal	4.43 ± 2.27	4.15 ± 1.49
	High	3.79 ± 1.94	3.36 ± 1.72

the normal range of 20% difference between sides as described by Buschbacher (2009). The upper limit for middle trapezius latency differences was 26% in the current study, which somewhat exceeds Bushbacher's comparative normal latency guidelines (Buschbacher et al., 2009). The current study identified an upper limit of 43.9% for the upper trapezius and 49.6% for the middle trapezius amplitudes, which is within the normal guideline of up to 50% difference between sides (Dumitru and Zwarts, 2002; Buschbacher et al., 2009; Bromberg and James, 1998; Kimura, 2013).

The current study found shorter (faster) latency values in the female participants when compared with the male participants. This finding is similar to that of Bahrami et al. who also reported faster spinal accessory nerve latency values in female subjects and identified a higher surface skin temperature in their female subjects (Bahrami et al., 2004). This may be due to a higher core body temperature for the females. The current study did monitor and maintain skin temperature above 32 °C but did not record individual temperatures, so this remains a conjecture. The current study had a large proportion of female subjects and therefore one might anticipate that would result in shorter upper trapezius normal latency values when compared with other normal value studies containing a high percentage of male subjects. This is difficult to fully assess since Chang et al. (2011) did not report latency values and neither Cherington (1968) or Green and Brien (1985) reported subject gender. We did find a shorter upper trapezius latency than Bahrami et al. (2004) who had an even gender distribution in their pool of 60 subjects. However, this comparison is also challenging because we used a standard 8 cm distance from the stimulation to the upper trapezius recording sites which differs from the previously mentioned studies (Cherington, 1968; Green and Brian, 1985; Bahrami, 2004; Chang, 2011).

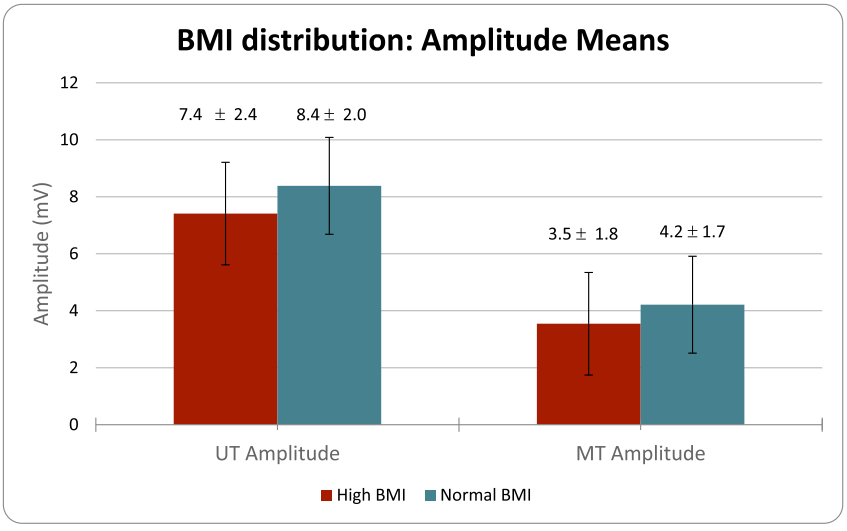

Fig. 4. BMI effect for amplitude values. There was a significant BMI effect for both upper trapezius (P = 0.000) and middle trapezius (P = 0.033) amplitude values.

Anatomical variability may also lead to challenges in performing and interpreting spinal accessory nerve conduction with recording from the trapezius. Laughlin et al. (2011) identified the presence of a surface recorded upper trapezius response in patients who had complete SAN transection identified surgically (Laughlin et al., 2011). Additionally, there were cases of complete SAN transection with normal EMG examination of the trapezius. They hypothesized that cervical plexus fibers may supply the trapezius so that nerve conduction and EMG testing of the trapezius should not be used exclusively to rule out the possibility of complete SAN transection which may have occurred following surgical procedures in the neck at a proximal level (Laughlin et al., 2011). This type of anatomic variability may also correspond with variability in amplitude recording. In addition, the current study did find that BMI had an inverse relationship with both upper and middle trapezius amplitudes so that a smaller amplitude value may be expected in those with higher BMI.

Spinal accessory nerve conduction studies may have technical limitations, particularly in those with higher BMI, such that an absolute normal value for amplitude may not be appropriate and a side-to-side difference may be necessary. Excessive stimulation of the spinal accessory nerve may also lead to technical challenges. Laughlin et al. (2011) found surface spinal accessory nerve compound motor action potentials (CMAPs) present in patients with surgically identified transected SAN lesions in the posterior triangle (Laughlin et al., 2011). These CMAPs had shorter latency values on the involved side when compared with the non-symptomatic side, which according to Laughlin et al. (2011), may be due to overstimulation producing a volume conducted response from neighboring cervical plexus branches (Laughlin et al., 2011). It may be advisable to also record from the sternocleidomastoid in cases of possible proximal trauma to the spinal accessory nerve.

Spinal accessory nerve conduction with recording from the trapezius remains a valuable tool particularly for assessing distal trauma which may occur from sporting activities and compression about the shoulder such as in backpack or rucksack compression type of injuries. In fact, Al Ajmi et al. (2015) noted a significant decrement in amplitude with surface recording from the trapezius in a case of SAN schwannoma (Al Ajmi et al., 2015). Bodack et al. (1998) noted prolonged trapezius latencies and motor unit changes with needle electromyographic sampling of the trapezius in SAN injury associated with whiplash injury (Bodack et al., 1998). Stino et al. (2018) reported that the sternocleidomastoid is sometimes spared in SAN injury following cervical lymph node dissection making assessment of the trapezius important in these cases as well (Stino et al., 2018).

4.1. Limitations

The present study investigated mostly young adult subjects, so the results may not apply to older individuals or to the very young.

4.2. Conclusion

SAN conduction with surface recording from the upper and middle trapezius is well tolerated, and can be used to assess both SAN and cervical plexus injuries. Individuals with a higher BMI may have a lower recorded amplitude, and females may have a slightly shorter latency value.

4.3. Clinical relevance

- Side-to-side differences may be the best way to evaluate spinal accessory nerve amplitude and latency.
- Anatomic variation may impact nerve conduction findings, and best practice would be to avoid overstimulation of the spinal accessory nerve to prevent current spread to the cervical plexus fibers.
- Recording from the sternocleidomastoid, would be helpful to fully assess proximal SAN pathology.

Declarations of interest

None.

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