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ORIGINAL COMMUNICATION

A Standardized Protocol for Needle Placement in Suboccipital Muscles

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The objective of this study was to assess the safety and accuracy of using common anatomic landmarks to guide the placement of needle electrodes into suboccipital muscles. Atrophic changes in suboccipital muscles have been reported in some patients who have tension-type headaches, and in some patients who have headaches resulting from whiplash-type injuries. These atrophic changes most likely result from disuse or denervation. Needle electromyography is a definitive technique for determining the cause of muscle atrophy, but requires that needle electrodes be inserted into the muscle. Suboccipital muscles present a challenge to the electromyographer in that they are physically small and are located in close proximity to one another. Atrophied muscles with fatty replacement and the presence of critical structures such as the vertebral artery further complicate the procedure. Using a standardized protocol, three investigators attempted blind needle insertions into each of the suboccipital muscles of eight embalmed cadavers. A dissector then assessed targeted muscle penetrations, final resting positions of the wires, and their proximity to critical structures. Eighty-one percent of 181 attempted insertions penetrated the targeted muscles: 83% for the rectus capitis posterior minor, 83% for the rectus capitis posterior major, 94% for the obliquus capitis superior, and 63% for the obliquus capitis inferior muscles, respectively. It was concluded that readily palpable external landmarks can be used to safely and reliably guide the insertion of needle electrodes into three of the four pairs of suboccipital muscles. Clin. Anat. 21:501–508, 2008.

Key words: anatomy; electromyography; suboccipital; cervical; muscles; whiplash

INTRODUCTION

Head and neck disorders, resulting in head and neck pain, present some of the most common problems seen in medical practice. These can be difficult to treat because the cause of the head and neck pain is often not evident. Atrophic changes in suboccipital muscles at the level of spinal segments C1 and C2 have been reported in some patients who have tension-type headaches (Fernández-de-Las Peñas et al.,

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2007), and in some patients who have headaches resulting from whiplash-type injuries (Hallgren et al., 1994; McPartland et al., 1997; Andary et al., 1998; Elliott et al., 2006). While it is not clear how atrophic changes in these muscles might result in head and neck pain, it may be significant that these two groups of idiopathic head and neck pain patients share a common pathology. The functional implications of atrophic changes in suboccipital muscles are unknown, but it is suspected that alterations in proprioceptive activity from these muscles may account for both a decrease in head and neck repositioning accuracy and changes in head and neck positioning patterns (Revel et al., 1991; Heikkila and Astrom, 1996; Feipel et al., 2006). Ruling out a primary myopathic disorder, atrophy of suboccipital muscles may result from inhibition and/or disuse, or they may be neurogenic in nature. Since there is a significant difference in these two muscle disorders, it is important to be able to determine the cause of atrophy. Needle electromyography (EMG) would enable a physician to differentiate between these two muscle disorders, but has not been routinely performed, partly because of the absence of a standardized protocol for the safe and reliable insertion of needle electrodes into suboccipital muscles.

The four suboccipital muscles are the rectus capitis posterior minor (RCPMi), the rectus capitis posterior major (RCPMa), the obliquus capitis inferior (OCI), and obliquus capitis superior (OCS) muscles. The RCPMi arises from the posterior tubercle on the posterior arch of C1 and inserts on the occipital bone inferior to the inferior nuchal line and lateral to the midline. The RCPMa arises from the posterior edge of the spinous process of C2 and inserts on the occipital bone inferior to the inferior nuchal line and lateral to the RCPMi muscles. The OCI arises from the lateral surface of the spinous process of C2 and inserts on the inferior surface of the transverse process of C1. The OCS arises from the superior surface of the transverse process of C1 and inserts on the smaller lateral impression between the superior and inferior nuchal lines on the posterior aspect of the occipital bone (Moore, 1992).

While the four suboccipital muscles can be functionally classified as extensors and rotators, their small size, relative to larger muscles that act in parallel with them, minimizes their contribution to motion (Nitz and Peck, 1986). A parallel combination of muscles (PCM), i.e., smaller muscles acting across joints in parallel with much larger muscles, occurs often in humans. These smaller muscles typically have an average of 3.76 times as many spindles per gram of tissue as do their large counterparts, with the greatest absolute value of spindle density occurring in the suboccipital muscles of the cervical spine (Peck et al., 1984). In addition to stabilizing the respective joints around a neutral position, it has been suggested that these small muscles provide significant proprioceptive input to the CNS that is directly related to position and motion of the head (Abrahams, 1977).

The preferred way to perform an electrodiagnostic examination of the suboccipital muscles would be to use needle electrodes (Weiss et al., 2004). However, this procedure is accurate only to the extent that the physician is able to reliably place the needle into the correct muscle. The suboccipital muscles present a challenge in that they are physically small, are located in close proximity to one another, and have similar and poorly documented actions, making it difficult for a patient to recruit them in isolation. Atrophied muscles with fatty replacement present an additional challenge. In addition to being physically smaller than a normal muscle, the electromyographer cannot always rely upon insertional activity to determine when the needle has been inserted into the atrophied muscle (Haig et al., 2003). The presence of critical structures such as the spinal cord and the vertebral artery further complicates the procedure and further emphasizes the need for a standardized protocol to guide the placement of needles.

METHODS

Cadavers

The cervical regions of 11 embalmed cadavers, prepared by the Division of Anatomy & Structural Biology, were used in this study. Three of the cadavers were used to develop a standardized protocol that could be used to guide placement of needle electrodes into the four suboccipital muscles. Using this standardized protocol, three investigators attempted blind needle insertions into each of the four suboccipital muscles in each of the remaining eight cadavers. The age, cause of death, premorbid weight, and height of the cadavers were not obtained. However, bodies varied randomly with regard to these parameters. The ages were estimated to be between 75 and 85 years. None of the specimens were considered to be heavily muscled or obese. The selection consisted of 6 males and 5 females. The cadavers were embalmed in a standard manner using formalin. The cadavers had been stored in the supine position for a significant period of time. This, along with tissue texture changes produced by the embalming process, made palpation of boney landmarks, insertion of needles, and repositioning of joints different, and probably more difficult, than would be experienced with living subjects.

Reference Points and Lines

To standardize the protocol, a number of reference points and lines were established by consensus (see Fig. 1). The locations of the external occipital protuberance (inion) and the spinous process of C2 were palpated and marked. Since the spinous process of C2 was used as a reference point for an approximation of the location of several other structures, the investigators not only attempted to palpate this structure, but they also attempted to confirm its location with a needle probe. A line drawn between the inion (see Fig. 1, Point A) and the spinous process of C2 (see Fig. 1, Point B) was used to define the anatomical midline of the posterior cervical spine.

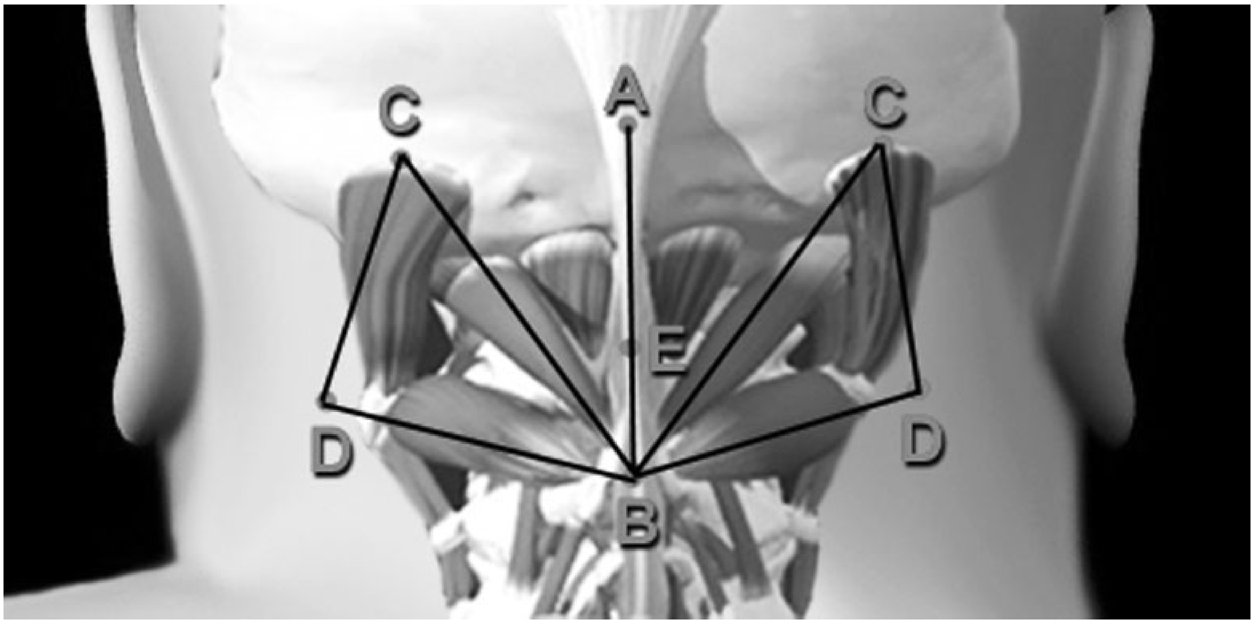

Fig. 1. Reference points and lines (Reproduced with permission, copyright Primal Pictures Ltd.).

The posterior arch of C1 (see Fig. 1, Point E) was approximated by marking a point on the midline that was 2/3 of the distance between the inion and the spinous process of C2, measured from the inion.

The lateral impression between the superior and inferior nuchal lines on the posterior aspect of the occipital bone was palpated and used as an approximation of the point of insertion of the OCS muscle (see Fig. 1, Points C). An alternative method was to mark the intersection of the superior nuchal line and a line drawn from the spinous process of C2 at a 45-degree angle from the midline (see Fig. 1, Line B → C).

A point 1 cm below the inferior border of the tragus was identified as a first approximation of the location of the lateral process of C1 (see Fig. 2). Another point at the same height as this point and 3 cm medial to the posterior medial border of the mastoid process was used as the final approximation of the location of the lateral process of C1 (see Fig. 1, Points D).

A line drawn from points D → C was used to approximate the location of the long axis of the OCS muscle (see Fig. 1). A line drawn from points D → B was used to approximate the location of the long axis of the OCI muscles. A line drawn from points B → C was used to approximate the location of the long axis of the RCPMa muscles.

Technique For Protocol Testing

A technique for needle localization of muscles in the lumbar spine in cadavers has been previously described (Haig et al., 1993). It involves inserting a thin wire into a hypodermic needle, and then inserting the needle into the target muscle. The tip of the

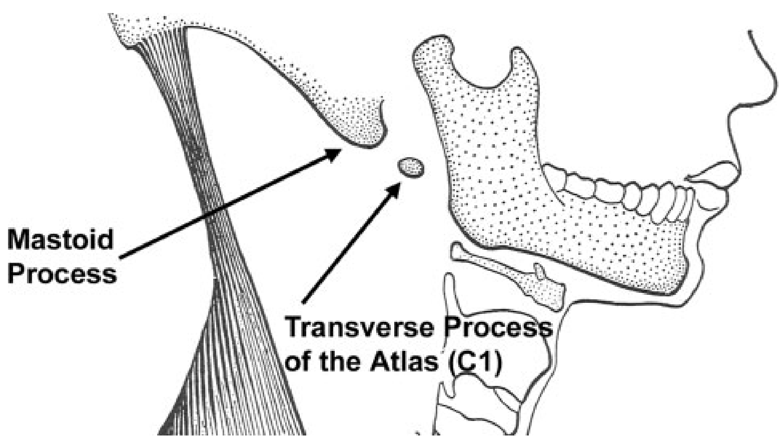

Fig. 2. Approximation of the lateral process of C1.

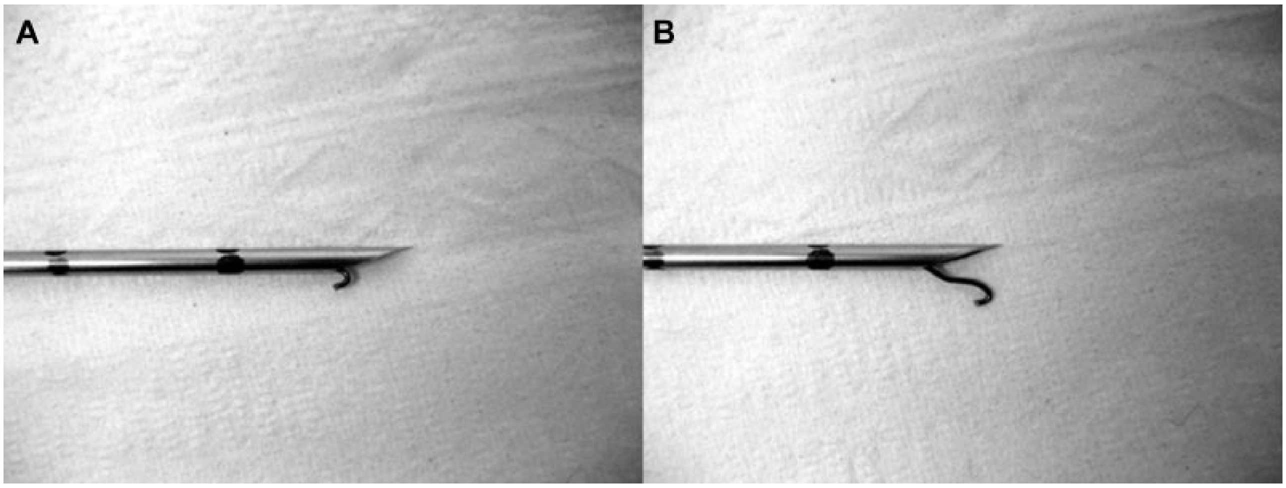

Fig. 3. **A:** Reference wire in needle. **B:** Reference wire released from needle.

wire is bent to form a ''hook'' (see Fig. 3A). Once the desired location within the muscle is reached, the needle can be withdrawn, leaving the wire hooked within the muscle. A dissector can then trace the path of the wire and the final resting place of the tip of the wire. For the current study, a standard 15-gauge hypodermic needle, 79 mm in length was used. While wires can be placed in very thin needles, this needle size was used because the stiffness minimized bending in tissue planes. A 110-mm length of 0.406 mm spring tempered music wire was used for the hooked reference wire. The hook in the wire was bent so that it would spring out and be securely lodged within the muscle when released from the lumen of the needle (see Fig. 3B). Two investigators (RCH and JJR) used this technique. An advantage in using the hooked-wire technique was that it allowed the dissector to record both the location of the hooked tip of the wire and the path that the needle had followed. Another advantage was that a label, containing the initials of the investigator and the name of the targeted muscle, could be applied to the protruding end of the wire. A weakness of this technique was that the investigator was not able to pull back the needle for a second attempt without the hooked wire being released and captured within a muscle.

The third investigator (MTA) used a 15-gauge needle and syringe to inject red latex (0.5 cc) into the target muscles (Haig et al., 1991). An advantage to using the latex injection technique was that the investigator could insert the needle, pull back and then reinsert the needle, much like an electromyographer might need to do with a patient. A weakness of the latex injection technique was that it only left a record of the final location of the tip of the needle and not its path of insertion. Consequently, while it can be determined that the investigator (MTA) hit a target muscle, it is impossible to know for certain that the intended muscle was hit.

Since it would have been impractical to blind the dissector to the intended location of the inserted wire, the research protocol was not blinded. Each investigator attempted to make an insertion into each of the eight muscles. Immediately following each insertion, a label, containing the initials of the investigator and the name of the targeted muscle, was applied to the protruding end of the wire. The order was rotated for each cadaver. While the same landmarks and insertion points were used, each investigator determined their line and angle of insertion independently. After allowing two days for the latex to cure, an experienced dissector (AJW), different from the three investigators, carefully dissected the cervical spine down to the suboccipital muscles to determine the locations of the latex and the locations of the tips of the hooked wires, using techniques described in the Appendix. An injection was judged to be a ''hit'' if the latex adhered to a surface of the muscle or was contained within the muscle. A hooked wire was judged to be a ''hit'' if the wire was lodged within the muscle (see Fig. 4). The position of a ''miss,'' for both techniques, was recorded as superior, inferior, medial, lateral, posterior, and/or anterior relative to the targeted muscle.

Final Study Protocol

For each of the following four protocols, the final action taken after insertion of the needle was to release the wire from the needle and retract the needle, leaving the wire in the targeted muscle. A similar procedure was followed for injection of latex into the targeted muscle.

Rectus Capitis Posterior Minor Muscles (RCPMi)

The needle was inserted, with the bevel positioned caudad, at a point 1 cm lateral to the midline at the level of the approximation of the posterior arch of C1 (see Fig. 5, Points 1). The needle was directed cephalad and angled approximately 80 degrees from an imaginary line drawn parallel to the surface of the skin in the midsagital plane. The needle was inserted until bone (occiput) was reached and withdrawn slightly.

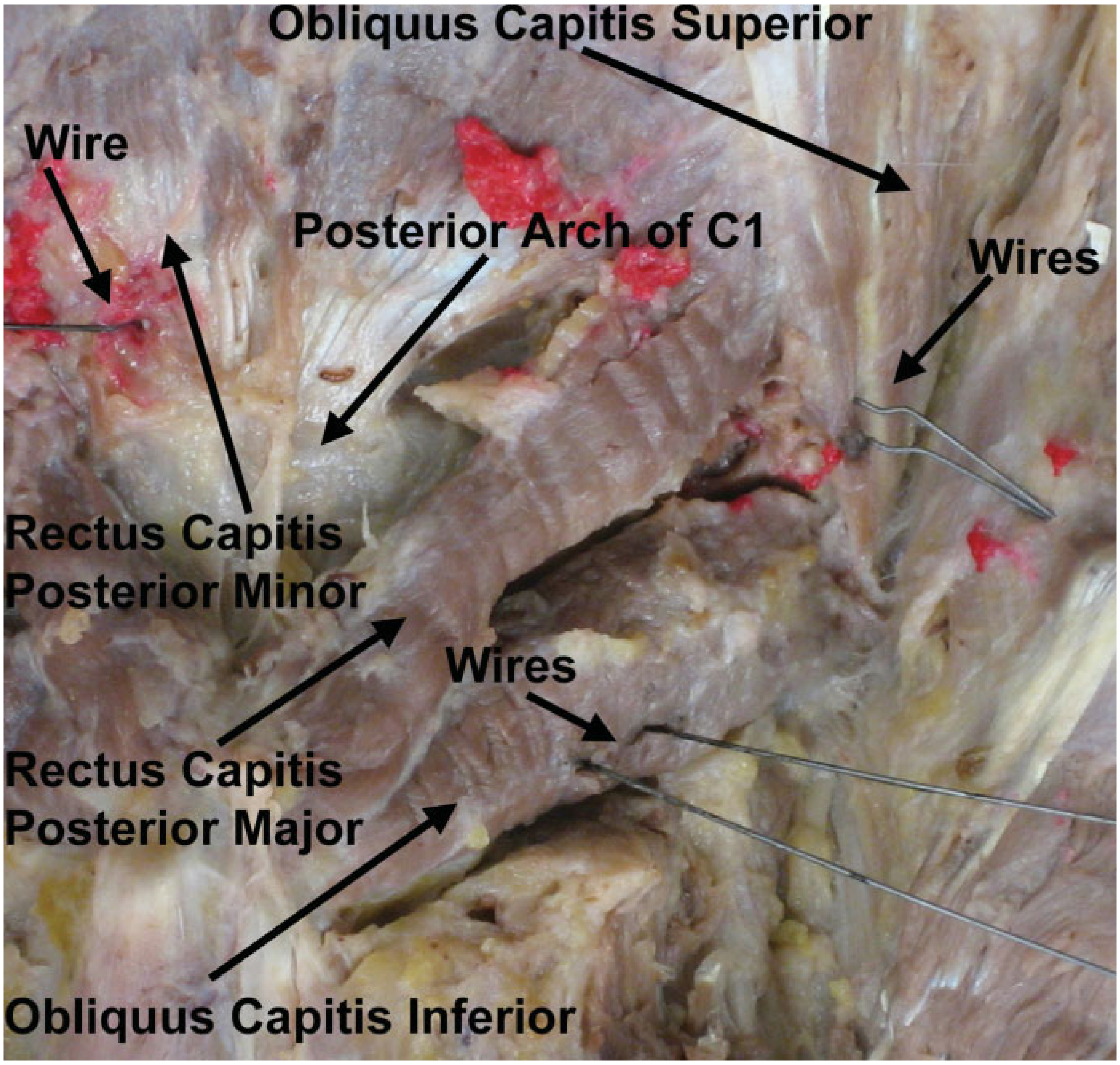

Fig. 4. Dissected specimen showing location of hooked wires.

Rectus Capitis Posterior Major Muscles (RCPMa)

The needle was inserted, with the bevel positioned caudad, at a point 2 cm lateral to the midline at the level of the approximation of the posterior arch of C1 (see Fig. 5, Points 2). The needle was directed lateral and cephalad along the approximation of the long axis of the RCPMa muscle, and angled approximately 80 degrees from an imaginary line drawn parallel to the surface of the skin and along the approximation of the long axis of the RCPMa muscle. The needle was inserted until bone (occiput) was reached.

Obliquus Capitis Superior Muscles (OCS)

The needle was inserted, with the bevel positioned caudad, at Points 3 (see Fig. 5)—Note that Points 3 in Figure 5 and Points D in Figure 1 are one and the same. The needle was directed medial and cephalad along the approximation of the long axis of the OCS muscles and angled approximately 45 degrees from an imaginary line drawn parallel to the surface of the skin and along the approximation of the long axis of the OCS muscle. The needle was inserted until bone (occiput) was reached.

Obliquus Capitis Inferior Muscles (OCI)

The needle was inserted at a point 4 cm from the approximation of the spinous process of C2 (see Fig. 5, Points 4) with the bevel positioned caudad. The needle was directed medial and caudad along the approximation of the long axis of the OCI muscle and angled approximately 90 degrees from an imaginary line drawn parallel to the skin and along the approximation of the long axis of the OCI muscle. The needle was inserted until bone (C2) was reached, or until the needle had reached a depth of no more than 4–5 cm.

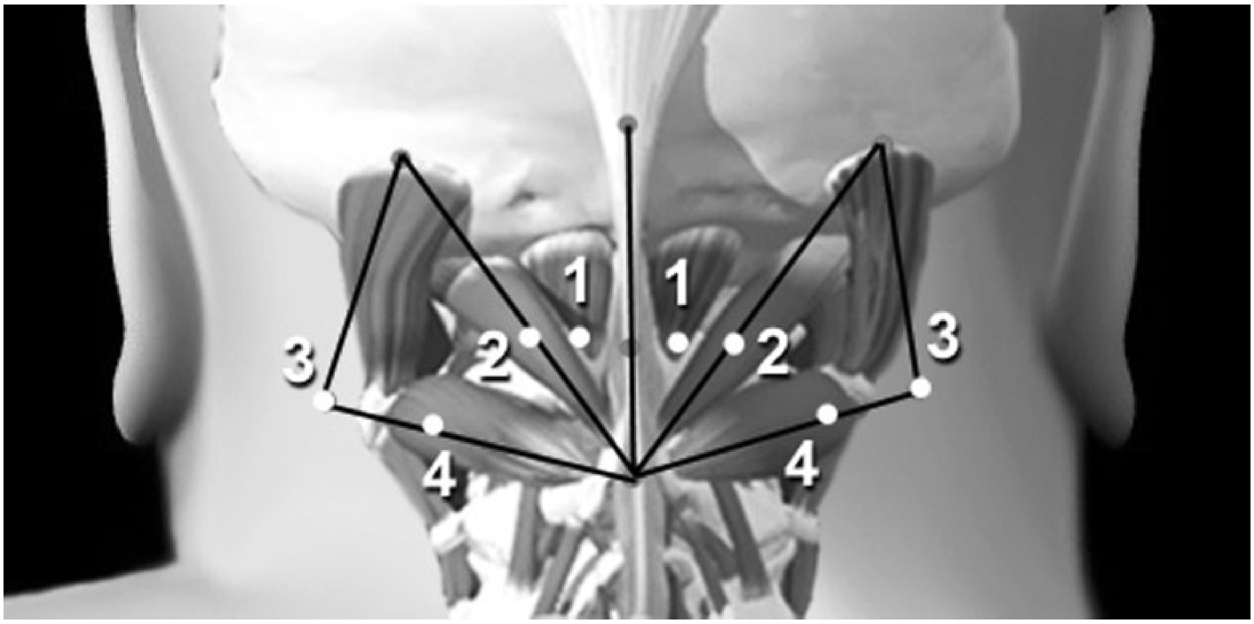

Fig. 5. Insertion points (Reproduced with permission, copyright Primal Pictures Ltd.).

RESULTS

Using a standardized protocol based upon common anatomic landmarks, three investigators attempted blind needle insertions into suboccipital muscles in eight embalmed cadavers. There were a total of 181 attempts: 46 attempts to place a needle into the pair of RCPMi muscles, 42 attempts for the pair of RCPMa muscles, 47 attempts for the pair of OCS muscles, and 46 attempts for the pair of OCI muscles. There could have been a total of 192 attempts. One investigator (JJR) was unable to schedule for one cadaver, accounting for 8 of the 11 missing data points. The same investigator forgot to make 1 attempt to place a hooked wire into a RCPMa muscle. One investigator (MTA) failed to inject enough latex out of the syringe to fill the needle and also mark the insertion point on two RCPMa muscles. None of the 181 attempts resulted in contact with or insertion into a critical structure such as nerve roots, blood vessels, the vertebral artery, or the spinal column.

The success rate for the three investigators, based upon these 181 attempts, averaged 80.6% (95% CI: 74.8%, 86.4%). This compares favorably with the 81% accuracy for attempts to insert wires into multifidi of the lumbar spine reported by Haig et al. (1991). We consider a success ratio greater than 65% to be clinically significant. The three investigators who attempted the insertions varied in their levels of experience. RCH had no experience beyond what might have been gained from his time spent in developing the protocols. MTA is a board certified electromyographer who performs EMGs on a regular basis. JJR has had physical medicine resident training in electromyography, but does not perform EMGs on a regular basis. Individually, the three investigators had a success rate of 79.7%, 83.9%, and 78.2%, respectively.

DISCUSSION

To our knowledge, this is the first study to quantify the safety and accuracy of using common anatomic landmarks to guide placement of needle electrodes into suboccipital muscles. We obtained individual accuracies of 83% for the RCPMi, 83% for the RCPMa, 94% for the OCS, and 63% for the OCI muscles. Many factors, such as physician experience and/or morphological variance among patients, may negatively impact accuracy of needle placement using this protocol. Other factors, such as additional documented anatomical landmarks, as well as changes in needle insertion techniques, may serve to increase accuracy.

There is always the question of how well a study that is performed on cadavers will translate over into living subjects. We suspect that palpation of boney landmarks will be easier on live patients than it is on embalmed cadavers. Younger, living subjects also might be expected to have greater variation in overlying splenius capitis, sternocleidomastoid, semispinalis, and superior trapezius muscles, and additional amounts of subcutaneous fat. However, using the occiput as a boney landmark to guide the depth of needle insertion for three of the suboccipital muscles should significantly help to reduce the impact of soft tissue variation among subjects. During each attempt to insert a needle into the either the RCPMa, RCPMi, or OCS muscles, all three investigators were able to hit the occiput before retracting the needle and leaving it lodged in the respective muscle.

The OCI muscle was the most problematic of the four muscles. During the development phase of the protocol, the needle insertion points for the OCI muscles were initially defined to be located 2 cm away from point B (see Fig. 1) and along the approximated lines of action of the OCI muscles. However, using these insertion points resulted in a tendency for investigators to cross over the midline and insert the needle into the contralateral muscle. For the final protocol, the needle insertion points, measured relative to point B, were moved from 2 to 4 cm. This resulted in a significant increase in accuracy. To compensate for variations in the size of subjects, the final protocol for the OCI muscles specified that the needle be inserted until bone (C2) was reached, or until the needle had reached a depth of no more than 5 cm, when using an insertion angle of 90 degrees relative to an imaginary line drawn tangential to the skin.

Accurate identification of the location of the spinous process of C2 was found to be a necessary prerequisite for successful insertion of needles into the OCI muscles. On subject no. 2889, we incorrectly identified the location of the spinous process of C2 at a point approximately 1 cm superior to the actual location. The result was that all six attempts to place needles into the OCI muscles in this cadaver were failures. However, incorrectly identifying the location of the spinous process of C2 by this amount did not seem to affect the accuracy of insertions into the other muscles. On subject no. 2894, we incorrectly identified the location of the spinous process of C2 by approximately 3 cm superior to its actual location. The consequence was that all six attempts to place needles into the RCPMa, RCPMi, and OCI muscles in this cadaver were failures. Even though incorrect identification of the location of the spinous process of C2 on subject nos. 2889 and 2894 reduced our overall accuracy for the RCPMi, RCPMa, and OCI muscles, it did not seem to affect the accuracy of insertions into the OCS muscles.

The authors consider the vertebral arteries to be the critical structures that are most at risk. Our measurements suggest that the protocols help ensure that the path of a needle will be at least 2 cm away from contacting a vertebral artery. The spinal column is considered to be a lesser risk, primarily because the protocols rely upon either an implicit limit to the depth of insertion (4–5 cm for the OCI muscles), or the occipital bone to limit the depth of insertion for the RCPMi, RCPMa, and OCS muscles. While there seems to be few reported incidents where diagnostic electromyography has resulted in complications such as hematoma, phlebitis, or temporary neuropathic pain, it is reassuring to know that there appears to be little risk of hitting a critical structure, such as the spinal cord or the vertebral arteries, even when the location of a critical landmark such as the spinous process of C2 is misjudged by as much as 3 cm. In spite of this, the authors emphasize that it is important to access the risks and benefits associated with the insertion of needles into cervical structures.

CONCLUSIONS

This study documents techniques, using readily palpable external landmarks, which can be used to safely and reliably guide the insertion of EMG needle electrodes into the four pairs of suboccipital muscles. This may be helpful for localization of EMG needle electrodes for diagnostic purposes in patients with head and neck pain, and suboccipital muscle atrophy identified on MRI. While it may be coincidental, it is intriguing that atrophic changes within suboccipital muscles have been reported in some patients who have tension-type headaches and in some patients who have headaches resulting from whiplash-type injuries. On the basis of the results of this study, future work will focus upon determining the prevalence and etiology of muscle atrophy in whiplash injury patients who are experiencing head and neck pain.

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APPENDIX: DISSECTION TECHNIQUES

1. A midline incision was made superficial to the cervical vertebral spinous processes, beginning at C7 and continuing to the occipital bone.
2. The skin was removed, working from the spinous processes laterally to the mastoid process. The skin was removed in a piecemeal fashion to allow preservation of wire placement. When working near a wire, an incision was made to the nearest border of the skin flap, and the surrounding skin reflected, with the wire passing through the incision. The skin was then removed.
3. The underlying subcutaneous tissue was removed, exposing the trapezius muscle.
4. The trapezius muscle was bisected medially, detached from its superior attachment, and incised medial to lateral from the spinous process of C7 to a point determined to allow ample reflection. The muscle was then reflected laterally. While reflecting the trapezius muscle, incisions were made beginning at each wire and continuing to the medial border of the trapezius. This allowed the wires to pass through the incisions, as the muscle was being reflected laterally.
5. The underlying fascia was then removed, allowing identification of the semispinalis capitis and splenius capitis muscles.
6. Next, the splenius capitis muscle was reflected laterally
   a. Incisions were made through the muscle at the superior nuchal line of the skull and at C7. These incisions did not completely detach the muscle. Attachments were left at the lateral borders to facilitate reflection but not to allow removal of the muscle.
   b. Incisions were made starting where each wire passed through the splenius capitis and were extended medially to the border of the muscle. This allowed the wires to pass through the incision as the muscle was reflected laterally.
7. The semispinalis capitis muscle was then reflected laterally.
   a. Incisions were made at the superior nuchal line of the skull and at C7. The incisions did not completely detach the muscle. Attachments were left at the lateral borders to facilitate reflection but not to allow removal of the muscle.
   b. Incisions were made starting where each wire passed through the semispinalis capitis muscle. These continued medially to allow the wires to pass through the muscle as it was reflected laterally.

The location of the end of the hooked wire (or the location of the latex) was identified and scored as a ''hit'' or a ''miss,'' based upon its physical relationship to the targeted muscles. An injection was judged to be a ''hit'' if the latex adhered to a surface of the muscle or was contained within the muscle. A hooked wire was judged to be a ''hit'' if the wire was lodged within the muscle. The position of a ''miss,'' for both techniques, was recorded as superior, inferior, medial, lateral, posterior, and/or anterior relative to the targeted muscle.