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Anatomical study of ultrasound vs landmark guidance for needle placement in the obliquus capitis inferior

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Needling of obliquus capitis inferior (OCI) muscle could be an important intervention for individuals with upper cervical pain; however, precision is important due to its sensitive location. The aim was to assess the accuracy, safety and performance of needling OCI using palpation versus ultrasound-guidance in a cadaveric model. A cross-sectional anatomical study was conducted. Five therapists each performed a series of 20 needle insertion tasks (n = 100) on 10 anatomical samples. Distance from the needle tip to the target, if the OCI muscle belly was reached (accuracy), surrounding sensitive structures targeted (safety), time needed, number of needles passes, and the length of the needle remaining outside the skin were assessed. The ultrasound-guided procedure was associated with significantly greater accuracy and safety ($p < 0.001$). The ultrasound-guided procedure achieved 100% accuracy of reaching the OCI compared to 40% with the palpation-guided procedure, with a shorter distance from the needle tip to the target. In the palpation-guided procedure, potentially sensitive structures were pierced in 38% of cases compared to only 4% with the ultrasound-guided approach. However, the palpation-guided procedure required less time and fewer passes. Our findings suggest that ultrasound-guided procedure showed greater accuracy and safety than palpation-guided procedures for properly targeted the OCI muscle belly.

Keywords Obliquus capitis inferior, Ultrasound, Palpation, Needling, Cadaver, Physiotherapy

The suboccipital musculature consists of four muscles: rectus capitis posterior minor, rectus capitis posterior major, obliquus capitis superior and obliquus capitis inferior. The upper cervical musculature has up to 200 muscle spindles per gram, unlike other body areas such as the thenar eminence, which has 16 spindles per gram[1]. The presence of a high density of muscle spindles suggests that the upper cervical region plays a crucial role in proprioception and the maintenance of muscle tone[2,3]. Thus, the suboccipital musculature has been shown to undergo morphological changes in different pain conditions, such as whiplash-associated neck pain[4], tension-type headache[5], cervicogenic headache[6] or temporomandibular pain[6]. Furthermore, clinical trials have demonstrated that manual treatment of the suboccipital muscles provides symptom improvement in various head and neck pain conditions[7,8].

Dry needling, a procedure in which a solid filament needle is introduced into the muscle, is advocated as a therapeutic tool effective for the management of musculoskeletal chronic pain associated with trigger points[9]. In fact, trigger points in the suboccipital muscles refer pain to the head and are highly frequent in individuals with headaches[10]. A recent network meta-analysis found that the combination of dry needling with manual therapy was the highest-ranked intervention to reduce headache, at least in the short term[10]. Accordingly, dry needling of the suboccipital musculature is clinically applied to treat patients with head and neck pain. However,

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Fig. 1. Application of the needling procedure on the obliquus capitis inferior (OCI) muscle. (**A**) Palpation-guided needle procedure without handpiece, (**B**) Ultrasound-guided needle procedure without handpiece, (**C**) Palpation-guided needling procedure with handpiece, (**D**) Ultrasound-guided needling procedure with handpiece.

	Mean (SD)
Experience with invasive techniques (years)	10.3 ± 2.3
Experience with ultrasound (years)	9.0 ± 3.5
Total needle procedures (n)	100
Palpation-guided/ultrasound-guided (n)	50/50
With/without handpiece (n)	50/50
Distance to the target (mm)	5.72 (10.0)
Target contact (yes/no)	70/30
Time required (seconds)	32.9 (1.0)
Passes (total number)	1.7 (1.1)
Needle length outside (mm)	13.1 (4.2)

Table 1. Clinical characteristics (mean ± standard deviation) of the therapists and overall data on interventions. *n* number, *mm* millimetres.

it is important to note that introducing a needle into the upper cervical region is not without risk[10]. Currently, only one study has described the potential safety of the needling approach to the obliquus capitis inferior (OCI) muscle[9]. This study performed the technique on five anatomical samples and ten individuals to test the accuracy of the procedure[9]. However, it did not assess which part of the OCI muscle was targeted (muscle belly or any of its insertions). Additionally, accurate needle positioning is crucial for interventional procedures performed by various healthcare professionals[11]. Incorrect needle placement significantly reduces intervention effectiveness and increases the risk of adverse events[11]. Historically, needling procedures have relied on anatomical landmarks or palpation for guidance; however, ultrasound imaging has improved the performance and accuracy of these techniques[12]. To the best of the authors' knowledge, no previous study has investigated the differences between performing a needling approach targeting the OCI muscle with and without ultrasound guidance, determining the central part of the muscle belly as the primary target. Additionally, no study provides data on distances to potentially surrounding sensitive structures.

The aim was to assess performance accuracy, safety, and effectiveness of needling OCI using palpation versus ultrasound guidance in a cadaveric model. Additionally, as a secondary objective, the differences between using or not using the handpiece (handheld device, Fig. 1C,D) during the procedure on a cadaveric model were analyzed.

Results

Five experienced therapists in needling interventions participated. Clinical characteristics of the therapist are detailed in Table 1.

The comparison of measurements between palpation-guided and ultrasound-guided procedures is summarized in Table 2.

The ultrasound-guided showed 100% accuracy in reaching the OCI muscle belly compared to the palpation-guided procedure (40%), with a shorter distance from the tip of the needle to the target (mean: 0.45 ± 1.5 mm vs. 11.8 ± 12.1 mm, $P < 0.001$). During the palpation-guided procedure, sensitive structures (spinal cord, greater occipital nerve or third occipital nerve) were pierced in 38% of the cases, compared to 4% with the ultrasound-guided procedure ($P < 0.001$). The palpation-guided procedure took less time (mean: 21.0 ± 7.5 vs. 43.3 ± 29.7 s), used fewer passes (mean: 1.3 ± 0.6 vs. 2.1 ± 1.3 in total), and required a greater needle length outside the skin (mean: 15.0 ± 3.1 vs. 11.25 ± 4.3 mm) than the ultrasound-guided procedure (all, $P < 0.001$, Table 2).

	Palpation-guided	Ultrasound-guided	*p*
Structure where the tip of the needle was placed			
Obliquus capitis inferior muscle	20 (40%)	50 (100%)	< 0.001
Splenius capitis	5 (10%)	0 (0%)	
Semispinalis	12 (24%)	0 (0%)	
Rectus capitis superior major	2 (4%)	0 (0%)	
Great occipital nerve	5 (10%)	0 (0%)	
Spinal cord	6 (12%)	0 (0%)	
Success/failure (n)	20/30	50/0	< 0.001
Distance to the center of the OCI muscle belly (mm)	11.8 ± 12.1	0.45 ± 1.5	< 0.001
Time required (s)	21.0 ± 7.5	43.3 ± 29.7	< 0.001
Passes (total number)	1.3 ± 0.6	2.1 ± 1.3	< 0.001
Unwanted sensitive structures during needling			
None	31 (62%)	48 (96%)	< 0.001
Great occipital nerve (C2 nerve)	11 (22%)	2 (4%)	
Spinal cord	5 (10%)	0 (0%)	
Third occipital nerve	3 (6%)	0 (0%)	
Needle length outside (mm)	15.0 ± 3.1	11.25 ± 4.3	< 0.001

Table 2. Comparison of the measurements (mean ± standard deviation) between palpation-guided (n = 50) and ultrasound-guided (n = 50) procedures. *n* number, *mm* millimetres.

	Without handpiece	With handpiece	*p*
Structure where the tip of the needle was placed			
Obliquus capitis inferior muscle	10 (40%)	10 (40%)	0.530
Splenius capitis	4 (16%)	1 (4%)	
Semispinalis	6 (24%)	6 (24%)	
Rectus capitis superior major	1 (4%)	1 (4%)	
Great occipital nerve	2 (8%)	3 (12%)	
Spinal Cord	2 (8%)	4 (16%)	
Success/failure (n)	10/15	10/15	–
Distance to the center of the OCI muscle belly (mm)	12.6 ± 12.3	11.1 ± 12.1	0.661
Time required (s)	21.4 ± 7.5	20.6 ± 7.7	0.683
Passes (total number)	1.3 ± 0.6	1.3 ± 0.55	1.000
Unwanted sensitive structures during needling			
None	17 (68%)	14 (56%)	0.366
Great occipital nerve (C2 nerve)	4 (16%)	7 (28%)	
Spinal Cord	2 (8%)	3 (12%)	
Third occipital nerve	2 (8%)	1 (4%)	
Needle length outside (mm)	16.0 ± 3.2	14.1 ± 2.8	0.024

Table 3. Comparison of the measurements (mean ± standard deviation) between palpation-guided procedure with (n = 25) and without (n = 25) handpiece. *n* number, *mm* millimetres.

Table 3 shows the differences between using the handpiece and not using it during the palpation-guided technique. The only significant difference (P = 0.024) was that performing the needling procedure without the handpiece resulted in more of the needle remaining outside the skin (mean: 16.0 ± 3.2 mm) than when using the handpiece (mean: 14.1 ± 2.8 mm). No other significant differences were identified (Table 3).

Differences between using or not using the handpiece during the ultrasound-guided procedure are shown in Table 4. The use of the handpiece required more time (mean: 55.5 ± 34.7 vs. 31.1 ± 15.3 s, P = 0.001) and more passes (mean: 2.6 ± 1.6 vs. 1.6 ± 0.8, P = 0.011) than when not used. No other significant differences were observed (Table 4).

Discussion

This study aimed to compare ultrasound-guided versus palpation-guided needling procedures targeting the OCI muscle belly and to assess the differences between using or not using a handpiece in a cadaveric model. The results showed that the ultrasound-guided procedure significantly increased precision, reaching a success rate of 100%, compared to the 40% accuracy rate of the palpation-guided procedure. Additionally, during the

	Without handpiece	With handpiece	*p*
Structure where the tip of the needle was placed			
Obliquus capitis inferior muscle	25 (100%)	25 (100%)	–
Splenius capitis	0 (0%)	0 (0%)	
Semispinalis	0 (0%)	0 (0%)	
Rectus capitis superior major	0 (0%)	0 (0%)	
Great occipital nerve	0 (0%)	0 (0%)	
Spinal cord	0 (0%)	0 (0%)	
Success/failure (n)	25/0	25/0	–
Distance to the center of the OCI muscle belly (mm)	0.15 ± 0.7	0.75 ± 1.95	0.151
Time required (s)	31.15 ± 15.3	55.45 ± 34.8	0.001
Passes (total number)	1.6 ± 0.8	2.6 ± 1.6	0.011
Unwanted sensitive structures during needling			
None	25 (100%)	23 (93%)	0.149
Great occipital nerve (C2 nerve)	0 (0%)	2 (8%)	
Spinal Cord	0 (0%)	0 (0%)	
Third occipital nerve	0 (0%)	0 (0%)	
Needle length outside (mm)	11.55 ± 4.25	10.95 ± 4.4	0.520

Table 4. Comparison of the measurements (mean ± standard deviation) between ultrasound-guided procedure with (n = 25) and without (n = 25) handpiece. *n* number, *mm* millimetres.

palpation-guided procedure, sensitive surrounding structures were targeted in 60% of cases, with the spinal cord being reached in 12% of cases.

In our study, the palpation-guided procedure resulted in a greater distance from the middle of OCI (mean: 11.8; SD: 12.1 mm) compared to the ultrasound-guided procedure (0.45, SD 1.5 mm). Previous studies using ultrasound guidance have achieved accuracies ranging from 1.5 to 3.27 mm using different phantoms (synthetic or anatomical models)[13–15]. Further, similar studies on other regions, such as the knee[16] and elbow[17], also observed improved accuracy, safety, and performance with ultrasound-guided procedures. However, this is the first study providing data on the OCI muscle.

The safety of needling therapies is crucial for daily clinical practice. In our study, when the technique was performed with ultrasound guidance, no sensitive structures were punctured in 96% of cases. However, when performed through palpation, sensitive structures other than the OCI were reached in 60% of cases, including the spinal cord in 12%. Other studies on regional anesthesia have also demonstrated higher safety when the procedure is ultrasound-guided[18]. Miyamoto et al. described a case report in which an acupuncture needle applied to the upper cervical spine was inserted into the foramen magnum, reaching the spinal cord[10]. Although this is unlikely to occur in clinical practice, we reached the spinal cord in 12% of needle insertions. Accordingly, to achieve greater accuracy and safety, ultrasound-guided procedures should be applied when targeting the OCI, although this procedure requires more time (mean: 43.3 s, SD: 29.7) than palpation-guided needling (mean: 21.0 s, SD: 7.5). These results are similar to those reported in previous studies performed in other regions[16,17]. These findings may be related to the fact that ultrasound guidance provides visual feedback on needle positioning, enabling therapists to make more accurate adjustments and refine the technique until the proper targeted point is reached, making the process more time-consuming. Nevertheless, ultrasound offers real-time visual assistance for guiding needling interventions in a cost-effective, radiation-free, non-invasive, and portable manner. Its use could be particularly crucial in anatomical areas with significant risks that require more precise needle placement. Finally, we also observed that the use of the handpiece required more time and a greater number of passes compared to the needle procedure alone. Other studies in the regions of the patellar tendon[16] and ulnar nerve[17] have shown similar results with the use of the handpiece, a procedure typically used in interventions such as percutaneous electrolysis. If the clinician does not have enough time to perform the ultrasound-guided technique and can only rely on palpation guidance, it would be beneficial for them to undergo prior ultrasound-guided training. This would help them understand the depth, needle angulation, and distance to sensitive structures required to reach the target muscle. In this way, the risks associated with the palpation-guided technique could be minimized.

Our study has some limitations that should be considered when interpreting the results. First, we always started with palpation-guided techniques, since performing the ultrasound-guided technique first could have introduced a learning effect. The visual feedback provided by ultrasound has been demonstrated to be a crucial factor in the learning process[19]. Second, our investigation was conducted using a human cadaveric model, making it impossible to assess surrounding vascular structures due to the lack of pulse, patient movement, and variations in tissue texture. Third, the sample size was relatively small (10 cadaveric models, 100 needle insertions). A larger sample size might provide more generalizable data across a wider range of anatomical variations. Future studies involving live patients would be valuable to confirm these findings while considering the mentioned limitations. Additionally, further research should analyze the accuracy of these procedures when applied to other regions and tissues.

Conclusion

The ultrasound-guided procedure applied to the OCI muscle demonstrated greater accuracy and higher safety than the palpation-guided procedure. In the palpation-guided technique, sensitive structures such as the occipital nerve or the spinal cord were accidentally punctured. However, the ultrasound-guided procedure required significantly more time. Additionally, the use of a handpiece increased both the procedure duration and the number of passes required compared to needling alone. Further studies are needed to confirm these results in an in vivo sample and to analyze their clinical implications.

Methods

A cross-sectional anatomical study was conducted. Five physical therapists with more than 10 years of experience in needling interventions (Table 1) performed a series of 20 needle insertion task each (n = 100), 10 palpation-guided (n = 50) and 10 ultrasound-guided (n = 50) on ten cryopreserved specimens. The study obtained approval from the Local Ethics Committee of the Universitat Internacional de Catalunya (CBAS-2021*09). This study conforms to all STROBE guidelines and reports the required information accordingly (see Supplementary Checklist) and complies with the Declaration of Helsinki. All participants in this study signed a written consent to donate their bodies for research.

A cadaveric model was used to simulate a realistic human anatomical situation. Ten frozen anatomical samples were stored under refrigerated conditions (− 20 °C) and thawed to ambient temperature 36 h before the study to ensure normal tissue characteristics. The cadaveric model was positioned prone, similar to a standard clinical situation, with optimized ergonomics, including appropriate handling of the transducer and needle. Before beginning the protocol, participants received a 10-min standardized instructional and practical session to understand the study's purpose and familiarize themselves with the procedure[9].

Therapists ere instructed to place the tip of the needle in the belly of the OCI muscle of the cadaveric model, performing as many insertions as necessary until they were satisfied with the procedure.

The needling procedure was conducted using both palpation-guided (anatomical landmarks) and ultrasound-guided techniques. A total of 100 punctures were performed by the five therapists. Each participant completed 20 needle tasks (10 palpation-guided and 10 ultrasound-guided) with a short washout period between each procedure and a 5-min rest break after every 10 attempts to prevent fatigue. To avoid pre-visualization bias, participants first performed the 10 palpation-guided insertions before proceeding with the 10 ultrasound-guided insertions.

The palpation-guided procedure used the same landmarks as described by Fernández-de-las-Peñas et al.[9], specifically the spinous process of C2 and the transverse process of C1. With the cadavers in a prone position, the needle was inserted perpendicularly to the skin at a point midway between the spinous process of C2 and the transverse process of C1, targeting the approximate middle of the OCI muscle's anatomical projection (Fig. 1A). The needle formed an angle of approximately 45° with both landmarks and was advanced from posterior to anterior at a slight inferior angle of 10° to the skin until reaching the lamina of the C2 vertebra.

The ultrasound-guided procedure was performed using a LOGIQ eR8 (General Electric Healthcare) ultrasound scanner with a 4–12 MHz linear transducer. Ultrasonographic imaging was pre-calibrated and optimized for frequency, depth, gain, and focus by an external researcher in a standardized manner, allowing participants to focus on the approach. The probe was held with the non-dominant hand, while the dominant hand performed the needling procedure (Fig. 1B). To identify the OCI muscle belly, the spinous process of C2 was located using a transverse section. The lateral end of the transducer was then adjusted toward the transverse process of C1, generating an oblique view that provided a longitudinal image of the OCI muscle (Fig. 2A). The needle was introduced "in-plane," and its entire path was visualized in real-time until reaching the target. The medullary canal and the greater occipital nerve were always visualized in the ultrasound image (Fig. 2B).

Both techniques were performed using a filiform solid needle, with five palpation-guided and five ultrasound-guided attempts per participant. Additionally, the procedures were repeated with an acupuncture needle inserted into a handpiece, following a randomized assignment using a computerized list (five palpation-guided attempts, Fig. 1C, and five ultrasound-guided attempts, Fig. 1D). All insertions were performed under fixed conditions using a needle size of 40 × 0.32 mm.

Following each needle placement, an independent researcher with more than ten years of experience in ultrasound assessment recorded the following measurements from the ultrasound images[9]: (1) the distance from the needle tip to the target (in millimeters); (2) whether the OCI muscle belly was reached or not (accuracy); (3) any contact with sensitive structures (spinal cord, other muscle or nerve); (4) time needed for the procedure (seconds); (5) total number of needle passes (each instance of advancing the needle after changing direction was counted as one pass); and, (6) length of the needle remaining outside the body (in millimeters). An attempt was considered successful if the needle tip reached the OCI muscle belly without puncturing any surrounding sensitive structures (Fig. 2C,D). To prevent learning bias, no feedback was provided regarding needle placement at the end of each attempt[20], as previous research has demonstrated that receiving feedback improves practitioners' performance[21].

Data were analyzed with IBM SPSS statistics 22.0 software. Descriptive data were expressed as total number, percentage, mean and standard deviation (SD). The normal distribution of the variables was analysed using the Kolmogorov–Smirnov test. Comparative analyses of the quantitative measurements between palpation-guided and ultrasound-guided procedures and between use of not of the handpiece were performed using independent student t-tests or Mann–Whitney U test. The chi-square (χ^2) test was used to assess the differences in nominal variables. The significance level was set at 0.05.

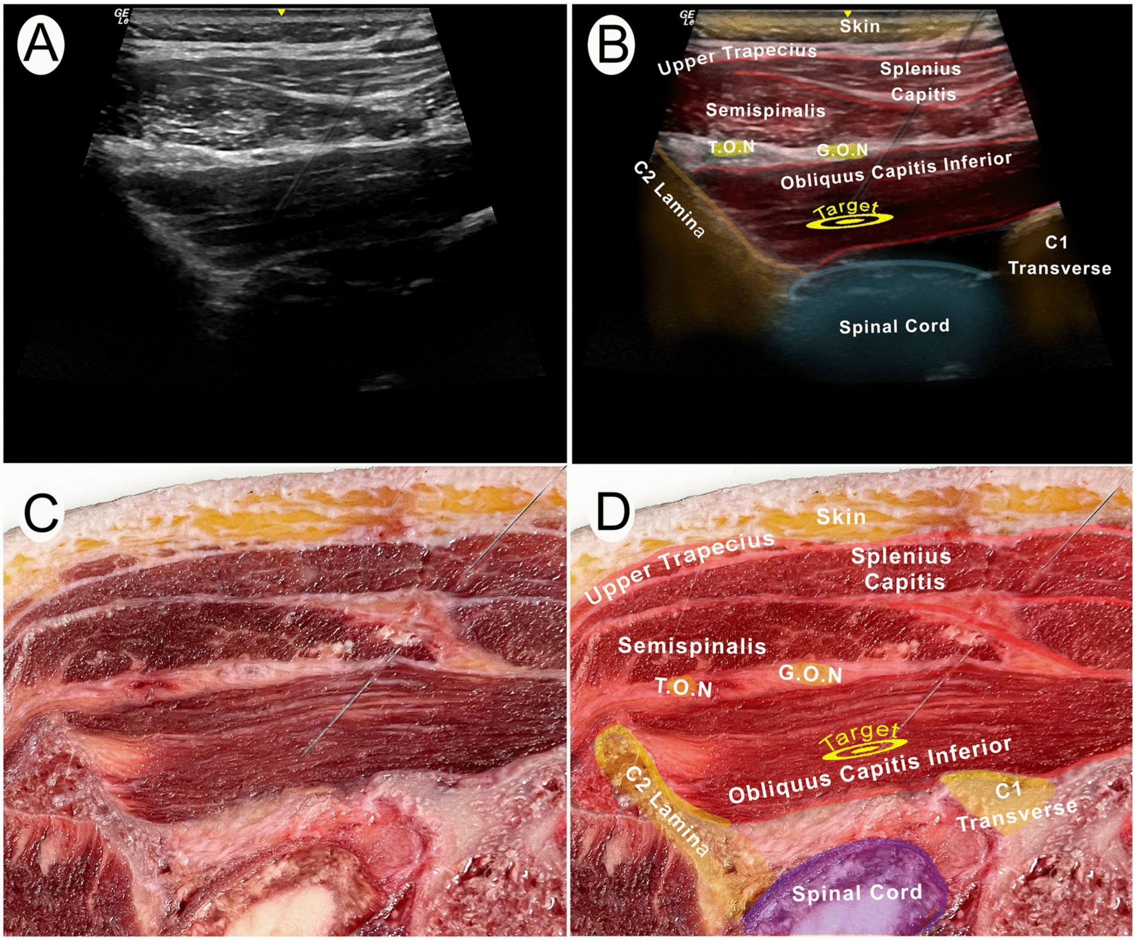

Fig. 2. Needling intervention of the obliquus capitis inferior (OCI) muscle with surrounding structures. (**A**) Ultrasound image for the needling procedure, (**B**) Ultrasound identification of the structures for measurements, (**C**) Cross-sectional image of the obliquus capitis inferior (OCI) muscle in a cadaver with the needle reaching the targeted zone, (**D**) Cadaveric identification of the structures with the tip of the needle in the targeted point. *T.O.N* Third Occipital Nerve, *G.O.N* Great Occipital Nerve.

Data availability

Data from the present study are available upon request from the corresponding author.

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Author contributions
J.R.S.: Conceived and designed the methodology of the study, performed experimentation and data collection, interpreted the results, drafted the manuscript, edited and critically revised the manuscript. C.F.D.P.: Conceived and designed the methodology of the study, performed experimentation and data collection, prepared tables and figures, interpreted the results, drafted the manuscript and prepared tables and figures, edited and critically revised the manuscript. S.B.A.: Technical support for all the specific data collection aspects, performed experimentation and data collection. C.L.D.C.: Performed experimentation and data collection, interpreted the results, drafted the manuscript and prepared tables and figures, edited and critically revised the manuscript. J.L.A.B.: Technical support for all the specific data collection aspects, performed experimentation and data collection, edited and critically revised the manuscript. A.P.B.: Technical support for all the specific data collection aspects, performed experimentation and data collection, edited and critically revised the manuscript. I.A.C.: Technical support for all the specific data collection aspects, performed experimentation and data collection, edited and critically revised the manuscript. M.M.U.: Interpreted the results, drafted the manuscript and prepared tables and figures, edited and critically revised the manuscript. All the authors approved the final version.

Declarations

Competing interests
The authors declare no competing interests.

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