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Inter-rater reliability of MRI superior articular process angle measurement for use in the modified approach to cervical transforaminal epidural steroid injections

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A B S T R A C T

Background: Upper extremity radicular pain is commonly treated with a cervical transforaminal epidural steroid injection (CTFESI). Recently, a new technique, the modified approach CTFESI, has been developed with a theoretical safety advantage to avoid the neurovascular structures. This approach requires an angle measurement of the superior articular process (SAP) on MRI. The inter-rater reliability of this angle measurement among practicing physicians is yet to be investigated.
Objective: The purpose of this study was to determine the inter-rater reliability of SAP angle measurements on MRI.
Methods: Three raters independently measured the SAP angle on 50 cervical MRIs. A two-way, mixed effects, absolute agreement, single rater statistical model was used to determine the intraclass correlation coefficient (ICC) between all three raters, as well as between each pair of raters.
Results: Inter-rater reliability among all raters showed good reliability with an ICC = 0.837709 (95% CI 0.75–0.9, $p < 0.001$). Similarly, good inter-rater reliability was found between each of the pairs of raters.
Conclusion: This study demonstrates good inter-rater reliability of MRI SAP angle measurement among clinicians for use in the modified CTFESI approach.

1. Introduction

Cervical transforaminal epidural steroid injections (CTFESI) are a common treatment for use in individuals with upper extremity radicular pain [1]. The procedure entails placing corticosteroid along the affected nerve root and into the epidural space with the use of image guidance. The conventional fluoroscopic injection technique requires an oblique view of the target foramen, in which the "foramen is maximally wide transversely, and the anterior wall of the superior articular process projects onto the silhouette of the lamina [2]." The fluoroscopic angle of this oblique view is based upon maximizing the appearance of the foraminal dimensions [3].

Recently, however, a modified CTFESI injection technique has been described which theoretically decreases the risk of needle puncture of the neurovascular structures [4–6]. The technique has been described in prior publications [4,5]; it uses a preset fluoroscopic oblique angle based upon the specific angle of the superior articular process (SAP) ventral surface of the patient's target foramen [4]. The angle of the SAP is measured on an axial MRI slice prior to the procedure. From the patient's positional true fluoroscopic A-P on the procedural table, the C-arm is rotated ipsilaterally to the predetermined oblique angle from the MRI measurement. The needle is advanced in this specific oblique angle so that the needle trajectory is tangential to the ventral surface of the SAP. An AP view is then used to determine needle depth [4] (Figs. 1–3).

In order to evaluate the new modified approach, two prior studies have been performed [4,5]. An independent analysis of contrast flow patterns of the modified CTFESI approach compared to the conventional technique demonstrated superior contrast flow with the modified technique in obtaining intraforaminal and epidural flow pattens [4]. A safety and tolerability study of the modified approach was then performed showing excellent tolerance for the procedure in a non-sedated population with no serious adverse events [5]. As the modified approach requires an angular measurement of the SAP on MRI, the reliability of the angle measurement technique needs to be determined. The present study aims to examine the inter-rater reliability of the MRI angle measurement.

2. Methods

Formal IRB exemption was obtained from an independent IRB (Stirling IRB ID#: 8633-DLevi). A retrospective review of the authors' (DL and SH) practice was conducted to include all CTFESI's performed between October 2018 to January 2021 (n = 973). From this list, generated from

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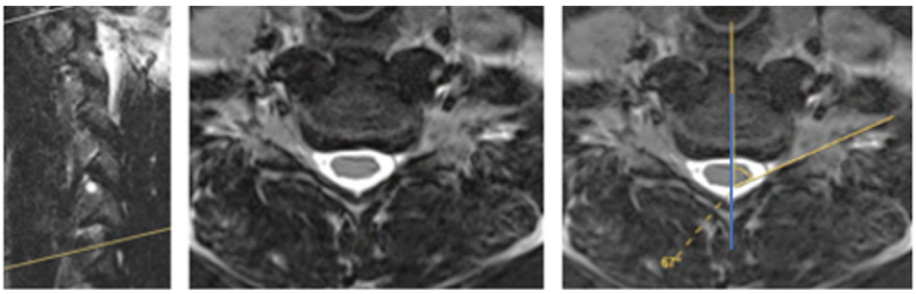

Fig. 1. Sagittal and axial T2 MRI. In preparation for a left C6/7 TFESI, the axial slice was selected at the inferior portion of the foramen. The ventral surface of the SAP angle is measured in relation to the sagittal line through the spinous process and mid portion of the disc or vertebral body. In this case, the SAP angle measured 67°.

Fig. 2. Modified approach fluoroscopic set up. The patient is positioned in an oblique manner, ipsilateral side up. The C-arm is rotated, based upon the patient's position, to obtain a true AP fluoroscopic image (2A). The C-arm is then rotated ipsilaterally the number of degrees determined from the MRI SAP angle measurement (as determined in Fig. 1), to obtain the specific fluoroscopic oblique angle used for modified approach (2B). In this case the patient's positional AP angle was 30° and the MRI angle measurement was 67°. Therefore, the C-arm was rotated from 30°, ipsilaterally, past zero, to 37° degrees (67°–30° = 37°).

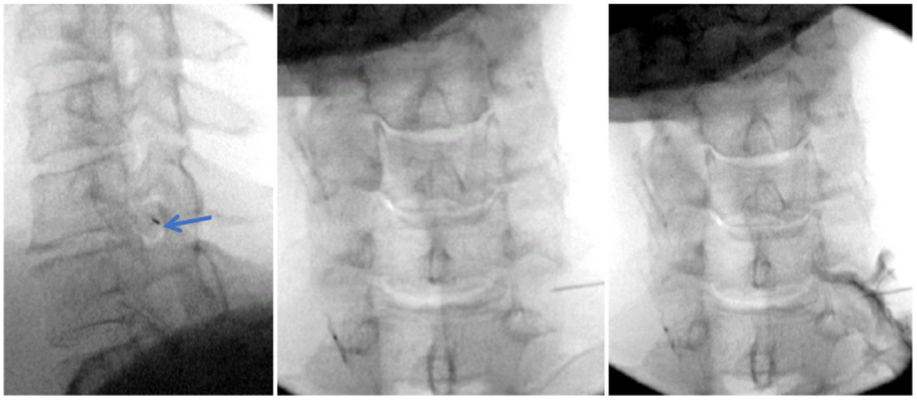

Fig. 3. Needle placement: The needle was inserted at the oblique angle approach determined in Fig. 2. The needle tip directed along the ventral surface of the SAP in the oblique view (blue arrow). When the needle reached the lateral portion of the articular pillar, the needle was advanced further medially into the foramen using the AP view to determine depth. Live contrast administration (with digital subtraction) was performed in the AP view. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

the electronic medical record, cervical MRIs were examined chronologically with respect to procedure date. Two of the authors (DL, SH), experienced with the modified approach, performed an initial screening examination of the MRI, focusing on the same level and side as was performed in the procedure. As the specific MRI axial cut used during the procedure was not documented, the recorded angle in the procedure note was neither utilized to determine the inter-rater nor the intra-rater reliability in this study. MRIs of poor image quality were excluded. In addition, a minority of SAP morphology is irregular or curvilinear, in which case, the approach trajectory and angle measurement may be based more upon a designated safe trajectory rather than a specific SAP angle measurement. Such MRIs were excluded as well.

If the MRI was deemed acceptable during the initial screening, the examiner navigated to the MRI slice—typically on T2 axial series but occasionally gradient echo axial series—that would best facilitate measurement of the SAP angle. The axial slice selected was within the lower half of the SAP, consistent with the modified approach needle placement. The series and axial slice numbers for this image were recorded for each rater to confirm. Three of the investigators performed the measurement independently. Two (DL and SH) were very experienced, fellowship trained, and developers of the modified approach. The third investigator (RC) performing the angle measurements was an interventional spine fellow (rater #3) with only limited experience with the approach. Each rater independently inspected the MRI image and measured the SAP angle using angle measurement software within the MRI digital viewing platform. Each angle measurement was then recorded by an independent investigator. This process was repeated until 50 MRIs were examined and measured by all three raters.

2.1. *Measurement protocol (Fig. 4)*

Using the MRI software line tool, a sagittal line was drawn bisecting the spinous process and the sagittal midline of the anterior portion of the disc or vertebral body. A line was then drawn along the ventral surface of the SAP intersecting the sagittal line. The angle was then determined using the angle measurement software tool.

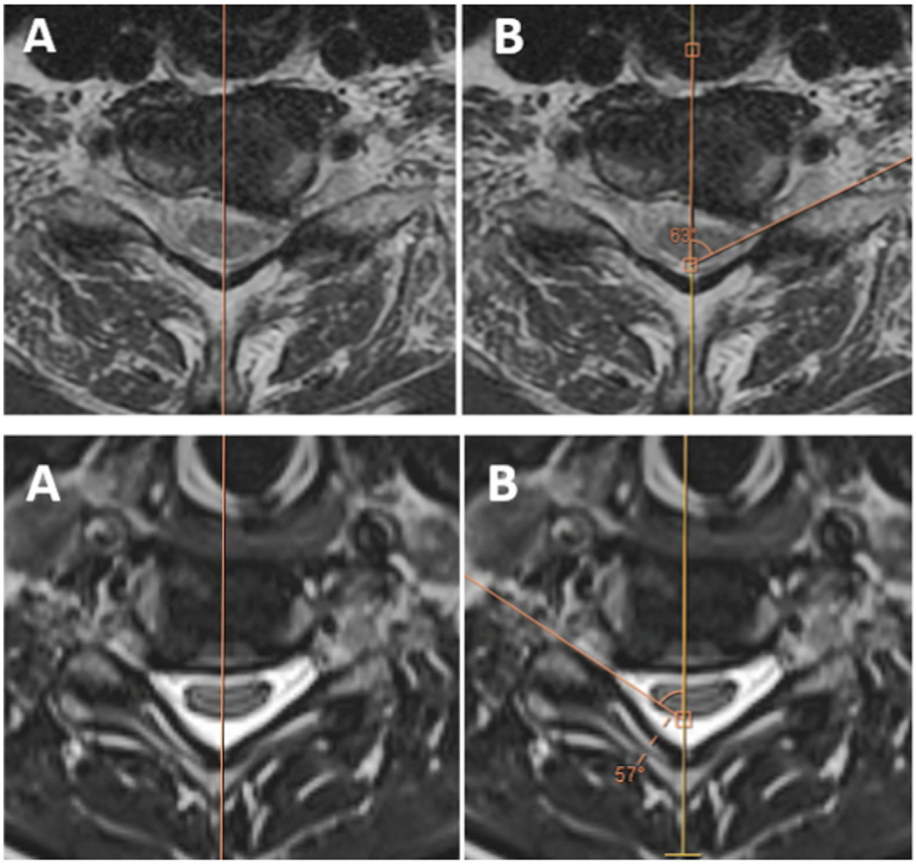

Fig. 4. Angle measurement protocol: Axial T2 MRI images at C6/7 for a planned left C6/7 (top) and C5/6 for a planned right C5/6 TFESI (bottom). (A) A sagittal line was drawn using the MRI program software to bisect the disc and spinous process (or midpoint of the lamina). (B) The angle measuring software was used to determine the angle between the sagittal line and the ventral surface of the superior articular process.

2.2. Inter-rater reliability statistical analysis

A two-way, mixed effects, absolute agreement, single rater statistical model was used to determine the intraclass correlation coefficient (ICC) between all three raters, as well as between each individual pair of raters. Intraclass correlation coefficient was performed using Pingouin Python statistical package. ICC values less than 0.5 indicate poor reliability; values between 0.50 and 0.75 indicate moderate reliability; values between 0.75 and 0.90 indicate good reliability; and values greater than 0.90 indicate excellent reliability [7].

Categorical analysis was also performed. The percentage of angle measurements within 5° amongst the raters was also determined. A range of 5° of variability was chosen by the authors as 5° is very unlikely to represent a significantly different needle trajectory.

3. Results

Fifty MRIs were included in the study after evaluation of 83 total MRIs. Although the exact reason for exclusion was not recorded, approximately half of the 33 excluded MRIs were omitted for lower image quality (about 20% of total). The remaining exclusions (also about 20% of the total) were due to a mildly irregular or curvilinear SAP ventral surface, in which the measurements would have inherent variability.

The SAP angles of the included 50 MRIs were measured by all three raters. One data point, however, was excluded as rater #3 inadvertently measured the angle on the incorrect side for one subject. For that subject, only the data points from raters #1 and #2 were included in the analysis.

Inter-rater reliability among all raters showed good reliability with an ICC = 0.84 (95% CI 0.75–0.9, $p < 0.001$). Inter-rater reliability between individual raters showed good reliability between raters 1 and 2 with an ICC = 0.82 (95% CI 0.7–0.9, $p < 0.001$); good reliability between raters 1 and 3 with an ICC = 0.84 (95% CI 0.73–0.91, $p < 0.001$); and good reliability between raters 2 and 3 with an ICC = 0.86 (95% CI 0.76–0.92, $p < 0.001$) (Table 1).

In addition, the percentage of measurements within 5° amongst the raters was also determined. The frequency of agreement within 5° for raters 1 and 2 was 76% (95% CI 63–86); for raters 1 and 3 was 82% (95% CI 69–90); and for raters 2 and 3 was 88% (95% CI 76–94). Agreement within 5° among all 3 raters was 65% (95% CI 51–77).

4. Discussion

The modified approach to CTFESI requires the physician to measure the SAP angle of the target foramen. This angle measurement is used to pre-set the fluoroscope for a needle trajectory that has a potential safety advantage over the conventional approach. Although flow pattern, safety, and tolerability of the modified approach have been previously evaluated [4,5], the angle measurement, which is an important feature of the approach, has not been assessed prior to this study. Our findings demonstrate, overall, good inter-rater reliability of the SAP angle

Table 1
Inter-rater reliability of Raters #1, #2, and #3 angle measurements. ICC, intraclass correlation coefficient; CI, confidence interval.

Raters	ICC	95% CI	P value	Interrater Reliability Interpretation
All raters	0.84	[0.73, 0.91]	<0.001	Good
1,2	0.82	[0.7, 0.9]	<0.001	Good
1,3	0.84	[0.73, 0.91	<0.001	Good
2,3	0.86	[0.76, 0.92]	<0.001	Good

measurements on MRI by ICC.

The percent of agreement of angle measurement within 5° was far from perfect. The agreement was as high as 88% between 1 pair of raters, but only 65% among all 3 raters. Within 5° was subjectively considered to be excellent agreement by the authors and likely to represent the same needle trajectory. Although the ICC analysis demonstrates good inter-rater reliability, our findings clearly indicate that there is some variability when measuring the SAP angle for the modified CTFESI technique. The implications of the variability must be considered in the context of the procedure itself. Although the angle measurement may differ slightly, the physician determines a safe needle trajectory based upon the MRI. The small variability in the trajectory chosen and angle measurement is unlikely to negatively affect the performance and potential safety advantage of the modified approach.

Karm et al. reviewed 312 MRIs and measured the SAP ventral surface angle in a similar method to the current study [6]. They found that the incidence of penetrating the vertebral artery, common carotid artery and internal jugular vein was significantly decreased using a trajectory tangential to the SAP ventral surface compared to a trajectory used with the conventional approach CTFESI. Karm and colleagues suggest that using a specific angle of 70° would provide for safer access to the foramen. The authors of the current study would caution against such a practice. There is great variability in the angulation of different SAP's even within the same level [6]. Using an angle that is too obtuse would result in the needle being initially placed against the posterior aspect of the articular pillar. Subsequent needle advancement would deflect the needle anteriorly into the foramen with subsequent increased risk to the vertebral artery and spinal nerve. Using a trajectory angle too acute may also result in a needle trajectory far too anteriorly in the path of the vertebral artery or spinal nerve. The authors of the current study, therefore, recommend an individualized SAP angle measurement for each procedure, rather than promoting a generic angle to be used for all procedures.

The inter-rater reliability between the experienced physicians (raters #1 and #2) and more novice fellow physician (rater #3) was essentially equivalent. A good inter-rater reliability was seen across all pairings of raters. Learning to use the MRI software is relatively simple as is the placement of the angle lines. The authors feel that the measurement technique is simple to learn and can easily be performed by practicing proceduralists. Although not specifically measured in this study, the time required to measure the SAP angle is typically one to 2 min.

There are several limitations to this study. MRI measurements were performed using the built-in accompanying software. There is considerable variability in the ease of use of the line drawing and angle measurement features, and this could affect the inter-rater reliability. In addition, when off-line viewing discs are used, measurement software may not be available. In such cases, one would have to rely on “by hand” angle measurement which has the potential for large variability. A second limitation is that intra-rater reliability was not assessed. The authors assumed there would be greater inter-rater reliability than intra-rater reliability, but that may not be the case. A further limitation of this study is that lower quality MRIs were excluded; in this case, about 16 of the 83 MRIs were excluded due to lower image quality. The authors recognize that a poor-quality image could certainly worsen the angle measurement reliability. MRIs with an irregular or curvilinear SAP ventral surface were also excluded from the study. In these instances, a safe trajectory angle can still easily be determined directly from the MRI image but will inherently have greater variability [4].

5. Conclusion

This study demonstrates good inter-rater reliability of SAP angle measurements among experienced and more novice physicians for the use in performance of the modified approach CTFESI. This study contributes to the growing body of research in support of the modified technique.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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