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ORIGINAL ARTICLE

Use of Ultrasound in Needle Placement in Intercostal Muscles: A Method for Increased Accuracy in Cadavers

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Abstract

Objective: To validate the use of ultrasound technology for the positioning and leveling of intercostal needle placement.

Design: Double-blinded experimental study.

Setting: An anatomy laboratory.

Participants: Two board-certified physical medicine and rehabilitation physicians, 2 first-year medical students, 1 anatomist, and 8 cadavers.

Interventions: Four unfixed cadavers were used for unguided needle placement, and 3 unfixed and 1 partially fixed cadavers were used for ultrasound-guided needle placement. Ultrasound-guided needle placement was then confirmed with computed tomography and blind dissection.

Main Outcome Measure: The accuracy of needle placement.

Results: The unguided study showed needle placement in an intercostal muscle 89% of the time, but in only 15.4% of the time was the correct level sampled. In the 96 needle placements completed, the unguided needle placements had an accuracy of 8.3%, while ultrasound-guided needle placements had an accuracy of 93% (χ^2 with $P<.005$).

Conclusions: Ultrasound guidance dramatically increases needle placement accuracy for intercostal nerve blocks and intercostal muscle sampling for electromyography.

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Ultrasound waves were discovered in the late 1700s, but it was not until the 1940s that they became of interest to the medical community. Since then, the use of ultrasound technology has expanded into nearly all subspecialties, from obstetrics to emergency medicine. Whether it is used for guided placement of central line catheters or intrauterine diagnostics, ultrasound technology has become an important, noninvasive, cost-efficient, and portable means of imaging.[1]

As in the use of line placement, ultrasound technology is being used by physicians other than radiologists for visualization during invasive therapeutic or diagnostic procedures such as intercostal nerve blocks (INBs). The thoracic wall poses certain challenges because of its unforgiving anatomy and the morbidity associated with complications.[2] Before the advent of modern-day imaging techniques, needles were placed using anatomic guidelines.[3] However, unguided anatomic placements are less than ideal as studies have demonstrated significant risks of pneumothorax, hemothorax, hemoptysis, hematoma, intravascular injection, and neuritis,[4] while a 2006 study[5] noted concerns about the accuracy of needle placement in identifying the correct thoracic level. Furthermore, when identifying bony landmarks are absent because of body habitus or when anatomy has been altered because of trauma or surgery, or in high-risk situations when patients are receiving anticoagulant therapy, guidance is key. Hence, current practices for procedures involving the thoracic wall are typically performed under fluoroscopic guidance for needle placement.

Fluoroscopic methods pose an added risk because they expose clinician and patient to ionizing radiation. Also, fluoroscopy lacks portability and is expensive. Because of the need for precision to access the target muscle or nerve in INBs, it is crucial that the clinician target the correct intercostal space without penetrating the thoracic cavity. Ultrasound is particularly well suited for

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thoracic procedures, especially in thin patients, as the pleura is clearly visible and inhalation can be monitored, thereby enabling the operator to determine the safest approach in real time.[6] Furthermore, with recent advances in technology leading to excellent image quality and decreases in price, portable ultrasonography has become a practical imaging modality that can be used in the office or laboratory setting.[7]

Ultrasound guidance provides other distinct advantages. Often in patients with intercostal neuralgia or thoracic radiculopathy, dysesthesias are present that can be exacerbated by palpation. Patients with intercostal neuralgia from prior surgery have anatomic landmarks that are not present or are deviated from the norm. Some patients have chest wall deformities or scoliosis. Some patients are obese. In all of these situations, using anatomic landmarks can be quite difficult. Direct visualization with ultrasound allows the operator to know exactly what level is being targeted and to see it happen in real time.[8]

This study aims to test the potential of ultrasound as a viable and radiation-free method of accurately imaging and targeting intercostal nerves.

Methods

Eight anatomic donor cadavers were used. The average age of the cadavers was 86 years (range, 73−94y). Cadavers that were overly obese or emaciated were not selected for the study. Four of the cadavers were embalmed with standard fixative methods for medical school preparation, 3 cadavers were unembalmed, and 1 was partially fixed using a decontaminating alcohol rinse. An approval by way of a research waiver was granted by the university institutional review board.

Needle insertions and ultrasound were performed by 2 board certified physical medicine and rehabilitation physicians with adequate experience at needle placement under fluoroscopy. A Mini Focus ultrasound machine[a] with a 5-MHz linear musculoskeletal transducer was used. All cadavers were in the prone position for placements and insertions, which were made near the posterior angle of the ribs ranging from T12 through T6. For unguided placements in the fixed specimens, ribs were palpated and counted in relation to bony landmarks including the inferior angle of the scapula, the seventh cervical spinous process, the inferior posterior aspect of the rib cage, and the last fixed rib (8th) and the ends of the free ribs. The palpator (inserting physician) inserted an 18-gauge cannula containing a bent 21-gauge florist wire perpendicular to the skin to enter the intercostal muscle. Once accomplished, the cannula was removed, leaving the bent florist wire in the muscle. The wire was identified with a sticker on which was a randomly assigned number, which was also placed on a dissector's list. After placement was completed, each wire was dissected out and anatomically verified by the anatomist.

In the guided placements using unfixed and lightly fixed cadavers, the ribs were not palpated before ultrasound visualization. To localize rib levels, the ultrasound transducer was oriented in the sagittal plane at the level of the lumbar spine just lateral to the transverse processes by the ultrasound operator. The transducer was moved cephalad until the most inferior rib was localized, at which point the operator would count ribs from this landmark. It was demonstrated that a 22-gauge and a 25-gauge needle could be successfully used to place the needle with this view, but the silicone product (PR 12 and PR 90 at a ratio of 1:1 containing calcium chloride [CaCl] at a concentration of .25g/mL) was too viscous to inject through the narrow needle. Therefore, an 18-gauge spinal needle was directed from the caudal midpoint of the ultrasound transducer via an in-plane technique. The transducer was positioned so that the inferior border of the rib shadow was visible on the ultrasound screen, thus allowing the needle to be visualized while it penetrated the soft tissue layers with an in-plane approach. The needle was advanced until the driver felt bone, then angled the tip caudally and continued to slightly advance to reach the nerve space. Once both the inserter and the ultrasound operator had confirmed the position of the needle along the angle of the rib, medial to the medial border of the intercostalis intimus muscle, the inserter injected colored silicone. The needle was then removed. All ultrasound data were captured via continuous video feed and screen captures taken during positioning and injection. The cadaver torsos were then subjected to a computed tomography (CT) scan (GE Lightspeed Volution 64-slice scanner[b]) at 1.25mm per slice for CT validation of placement (fig 1). The cadavers were then dissected and needle placements verified by an academic anatomist and medical students. Once all the silicone pellets were exposed, the level of injection was determined by exposing the ribs and spinous processes (fig 2). Photographs were taken using a Canon Rebel 3.5-megapixel camera.[c]

Accuracy was defined as a hit on the preindicated nerve. The colored silicone spread through the tissue as would an anesthetic agent,[9] coating the intercostal nerves in a blue color that could be clearly visualized during dissection, as it was not possible to identify each nerve precisely on ultrasound. In this double-blinded experimental study, the chi-square test was used to validate our data (χ^2 $P<.005$).

List of abbreviations:

CT computed tomography
INB intercostal nerve block

Results

Ninety-four placements were made in the specimens, 46 ultrasound guided and 48 unguided. Table 1 demonstrates the results obtained during unguided positioning of needles in intercostal muscles T6 to T11, while table 2 lists the results obtained with ultrasound guidance in targeting the intercostal nerves T6 to T11. For the unguided needle placement in the intercostal muscles, the total accuracy was 8.3%, while ultrasound-guided intercostal nerve placement was greater than 94%. For the unguided targets, the most frequent cause of misses was due to needle placement at the incorrect level, as shown in table 3. In the unguided needle placement study, an intercostal muscle needle placement was accomplished 89% of the time, but only 15.4% of these were at the correct level targeted, while the others were too far from the nerve or in the chest cavity. For the ultrasound-guided injections, 2 (5.3%) of 38 needle insertion targets were inaccurate. These specific silicone pellets could not be located in the tissues, speculatively because of the runny nature of the product used, and have been counted as misses. There was no evidence on dissection that any dangerous structure such as the pleural space was entered.

Discussion

This study aimed to scientifically examine the accuracy and practicability of an ultrasound-guided approach to target intercostal