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Preoperative nerve imaging using computed tomography in patients with heterotopic ossification of the elbow

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Hypothesis: This study evaluated the usefulness of computed tomography (CT) imaging for preoperative planning of heterotopic ossification (HO) excision, specifically the spatial relationship between HO and radial and median nerves. Our hypotheses were that CT imaging of the elbow can be used (1) to trace the paths of the radial and median nerves, (2) to distinguish the nerves from the heterotopic bone, and (3) to precisely measure distances from the respective nerve to the most clinically relevant HO.
Materials and methods: Patients who had HO removed from the elbow were reviewed retrospectively. On the basis of preoperative CT scans, 22 were identified as likely having HO along the pathway of the radial or median nerve. These cases were independently evaluated by 4 observers, who answered these questions: (1) Can the location of the nerve be adequately seen on sequential images to permit tracing of its path for surgical planning? (2) Can the nerve be distinguished from the HO accurately enough to permit measurement of its distance from the bone? Each observer also measured the shortest distance between nerves and the HO.
Results: Overall utility of the CT images for visualizing the nerves was high. The radial nerve was more readily distinguished from the HO (21 of 22 cases) than the median nerve (17 of 22 cases). The distance measured from HO was less for the radial nerve (3 mm) than for the median nerve (9 mm).
Conclusion: This study demonstrates the usefulness of CT imaging to determine the paths of the radial and median nerves and their spatial relationship to HO at the elbow.
Level of evidence: Basic Science Study, Anatomy, Imaging.

Keywords: Heterotopic ossification; computed tomography; nerve imaging; elbow; preoperative planning

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Heterotopic ossification (HO) around the elbow is often associated with significant loss of motion and is typically an indication for surgery.[7,10] However, surgical excision of such HO can be complex and associated with risk of nerve injury.[1,2,9] Advances in arthroscopic options for restoring elbow motion have raised the possibility of performing HO removal by minimally invasive techniques.[2] However, HO that is extensive or close to a major nerve could increase the risk of nerve injury. The senior author's practice consists of removing posteromedial HO (adjacent to the ulnar nerve) through a limited open posteromedial incision used to release the ulnar nerve routinely. He has used computed tomography (CT) to determine whether the radial or median nerve will be at increased risk during the removal of heterotopic bone arthroscopically.[2]

CT is routinely performed for the evaluation and preoperative planning of patients undergoing excision of HO around the elbow. Because CT can be used to image soft tissues as well as bone, it would be ideal if the nerves around the elbow could be visualized and their spatial relationships to the HO determined for preoperative decision-making and planning. To our knowledge, although use of CT for identifying nerves during preoperative planning has been part of individual surgeons' preoperative practice,[2,12] no studies have been reported on details of this approach or its reliability.

The purpose of this study was to evaluate the usefulness of CT imaging for preoperative planning of HO excision, specifically the spatial relationship between the HO and the radial and median nerves. Our hypotheses were that CT imaging of the elbow can be used (1) to trace the paths of the radial and median nerves, (2) to distinguish the nerves from the heterotopic bone, and (3) to precisely measure distances from the respective nerve to the most clinically relevant HO.

Materials and methods

After Institutional Review Board approval was obtained, 188 patients who underwent their first surgery for HO removal from the elbow by the senior author (S.O.D.) between 2003 and 2013 were identified. Patient inclusion criteria consisted of preoperative CT images containing the distal humeral diaphysis to the proximal radial shaft, 3-dimensional (3D) reconstructions available, and radiologically detectable anterior elbow HO likely blocking motion or in the general vicinity of the radial or median nerve. In addition, the CT scan had to be able to be performed with the arm overhead. This criterion was chosen because a pilot study revealed that CT imaging with the arm at the side did not provide adequate resolution to follow nerves and to distinguish them from the surrounding soft tissues or bone.

Four observers—an expert elbow surgeon, 2 practicing orthopedists, and an orthopedic surgery resident—reviewed CT scans using a systematic method described later. There were some advances in the CT imaging during the years, but in general, CT scans were performed with 16- or 64-slice multidetector CT scanners employing 140- to 160-mm fields of view, pitch 1.0, and 0.4-mm slice thickness acquisition. Images were reconstructed in the axial plane (1-mm slice thickness) and in the coronal and sagittal planes (2-mm slice thickness each), using both bone and soft tissue kernels. The 3D volume rendered color models were constructed in all patients. For the purpose of this study, CT scans were examined with a standard picture archiving communication system (QREADS version 5.4.0.2, Mayo Clinic ©Copyright 2013).

In a pilot study, the techniques used by the senior author for many years while looking at CT imaging of nerves were taught to the other observers. These techniques are as follows: before looking at the nerves themselves, the observer should dynamically rotate the 3D surface renderings of the elbow in the transverse and sagittal planes multiple times to register a 3D image of the HO in relation to the bone landmarks. Based on familiarity with the anatomic location of the radial and median nerves,[11,13] the observer then scrolls through the CT axial and sagittal images manually, or views them in cine mode, to create a visual impression of the paths of the nerves before taking measurements (Fig. 1). In some cases, a nerve could not be identified in 1 or more consecutive slices. In such cases, a potential space outlined by the perineural fat tissue was usually seen. Because this hypodense material has a larger volume than the nerve itself, it is useful for defining the pathway. In those situations, we used the scrolling feature of the imaging software to visualize the nerve as a continuous structure as one would do for animation using a series of illustrations in a flip book. By interpolating between proximal and distal or lateral and medial cuts in which the nerve was visualized, one could infer the location of the nerve in those images in which it was not discretely identifiable.

To define the usability and to establish reliability of the proposed preoperative planning method, 2 questions were posed to each of the 4 observers independently and blindly: (1) Can the location of the nerve be adequately seen on sequential images to permit tracing of its path for surgical planning (yes/no)? (2) Can the nerve be distinguished from the HO accurately enough to permit measurement of its distance from the bone (yes/no)? The observers were allowed to use axial cuts or sagittal reconstructions to make their determinations. For each of these questions, consensus was defined as agreement among 3 or 4 of the observers, including the expert. If 2 or more observers disagreed, the final response was recorded as unsure.

In addition to answering the 2 qualitative questions, each observer also measured the shortest distance between the HO and radial and median nerves, respectively (Figs. 1 and 2) to determine if these measurements could be made and done so reliably. Each observer selected his own image on which to take these measurements. However, if the measured distances varied by more than 2 standard deviations for any given nerve in any particular patient (once the data had been analyzed), the nonexpert observers met together and repeated their measurements in the presence of the other observers to determine what caused the disparity. If the disparity was due to selection of different pieces of HO, they discussed and came to an agreement as to which piece was the most relevant clinically, and then they independently remeasured them. This typically occurred in cases containing a very small piece of HO (possibly clinically insignificant) close to the nerve as well as a large area of HO farther away from the nerve.

Measurements were rounded off to the nearest millimeter and reported ± standard error to the nearest 0.1 mm, after all computations and statistical analyses had been performed with JMP Statistical Software (SAS Institute, Inc., Cary, NC, USA). Statistical analyses were performed by t tests for parametric data and the Fisher exact test for categorical data.