An Original Study

Physical Examination and Radiographic Interpretation of Carpal Anatomy in Orthopedic Residents and Emergency Medicine Physicians

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Abstract

The purpose of this study was to evaluate carpal anatomy proficiency in orthopedic residents as well as emergency medicine physicians.

Orthopedic surgery residents and emergency medicine physicians were tested on their understanding of normal carpal anatomy using a Wrist Anatomy Assessment (WAA) score, which consists of both palpation of carpal bony landmarks and radiographic interpretation of the carpal bones. There were 89 participants in this study. Cohorts of orthopedic residents (n = 20), emergency medicine residents (n = 21), emergency medicine attending physicians (n = 26), and 4th-year medical students (22) were used. Group size was based on 100% orthopedic resident involvement.

Total WAA scores (score of 17 = 100% correct) ranged from 2 to 16, with a mean of 8.6. Carpal palpation and radiographic interpretation means were both significantly better in the orthopedic resident cohort (total WAA score, 13.8), compared with either of the emergency medicine groups (resident total WAA score, 7.5; attending total WAA score, 7.2).

Orthopedic residents have a better understanding of the clinical and radiographic anatomy of the carpal bones than emergency medicine residents and attending physicians. Future research to test educational interventions to improve carpal anatomy education is warranted.

When a patient presents to the emergency department with wrist pain after a trauma such as a fall on an outstretched hand, he or she will be assessed by medical professionals with varying degrees of expertise, from emergency medicine (EM) residents, to EM attending physicians, to orthopedic resident consultants. A limited understanding of normal carpal anatomy can lead to an inaccurate diagnosis and potentially an inappropriate treatment plan for patients who have sustained a wrist injury such as a carpal fracture or pericarpal dislocation. Correctly diagnosing carpal injuries may sometimes be challenging in the acute trauma setting and requires a solid understanding of carpal bone anatomy. The initial physical exam in the emergency department directs the subsequent course of treatment, and therefore, marks a critical moment in a patient's care. Knowledge of carpal anatomy, which is second nature to the trained hand surgeon, may or may not have been mastered during medical school by EM physicians. How good are we in the United States at medical student musculoskeletal education, let alone the narrow topic of carpal anatomy? Can we do better? One study conducted by Day and colleagues[1] at Harvard Medical School indicated that medical students do not feel adequately prepared in the area of the musculosk-

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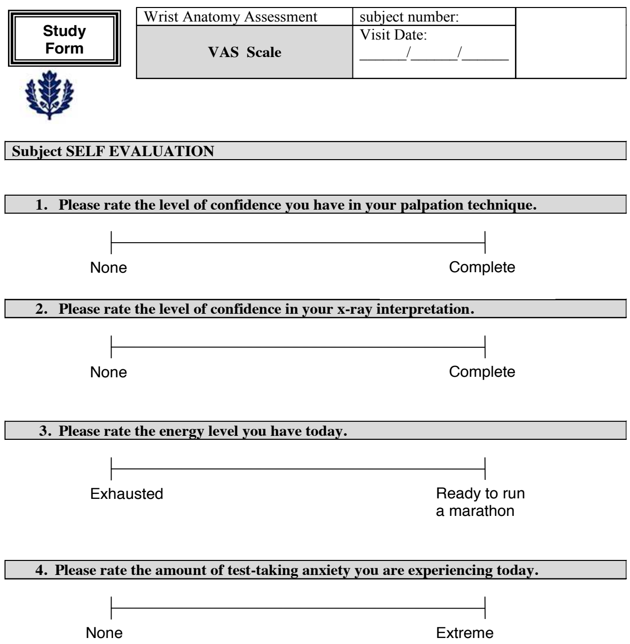


Study Form

Wrist Anatomy Assessment — VAS Scale — subject number: — Visit Date: ____/____/____

Subject SELF EVALUATION

1. Please rate the level of confidence you have in your palpation technique.

None — Complete

2. Please rate the level of confidence in your x-ray interpretation.

None — Complete

3. Please rate the energy level you have today.

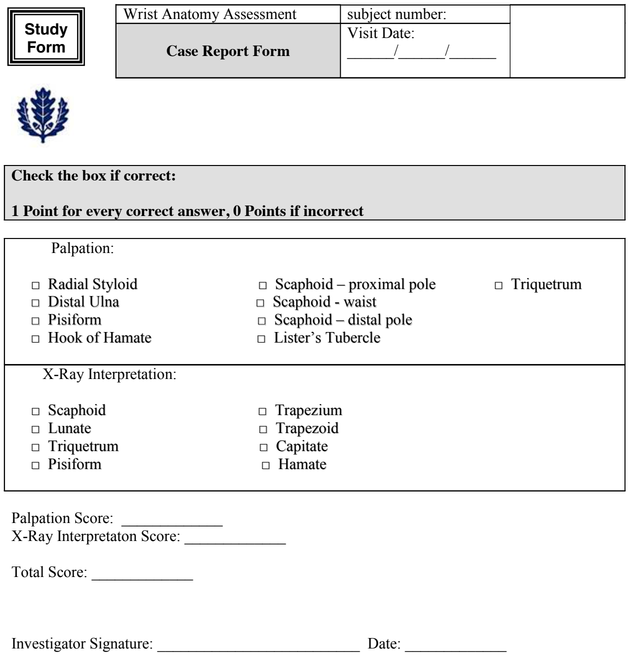
Exhausted — Ready to run a marathon

4. Please rate the amount of test-taking anxiety you are experiencing today.

None — Extreme

Figure 1. Visual analog scale questionnaire.

Figure 2. Standardized posterior-anterior wrist radiograph.



Study Form

Wrist Anatomy Assessment	subject number:
Case Report Form	Visit Date: _____/_____/_____

Check the box if correct:

1 Point for every correct answer, 0 Points if incorrect

Palpation:

- □ Radial Styloid
- □ Distal Ulna
- □ Pisiform
- □ Hook of Hamate
- □ Scaphoid – proximal pole
- □ Scaphoid - waist
- □ Scaphoid – distal pole
- □ Lister's Tubercle
- □ Triquetrum

X-Ray Interpretation:

- □ Scaphoid
- □ Lunate
- □ Triquetrum
- □ Pisiform
- □ Trapezium
- □ Trapezoid
- □ Capitate
- □ Hamate

Palpation Score: ____________
X-Ray Interpretaton Score: ____________

Total Score: ____________

Investigator Signature: ________________________ Date: ____________

Figure 3. Case report form.

eletal system. In a follow-up to this study, Day and his group[2] designed an educational intervention to address this very problem. Some investigators proposed changing teaching styles from a lecture to a more interactive format in order to improve the retention of orthopedic lessons.[3] Studies in both the US and the United Kingdom have designed and implemented new musculoskeletal curricula for undergraduate medical students; both of which have shown improved outcomes.[4,5]

Recently, 3 studies published in the UK examining the proficiency of carpal examination skills in both orthopedic and emergency clinicians.[6-8] A 2009 British study, also led by Roche and colleagues,[9] conducted a similar investigation of foot and ankle assessment in these 2 groups of physicians. These studies expressed concern over inadequate knowledge of anatomic landmarks and palpation technique. However, to our knowledge, there has yet to be a similar investigation comparing US emergency medicine and orthopedic residents' carpal assessment abilities.

The purpose of this study was to evaluate carpal anatomy proficiency in orthopedic residents and EM physicians. Our null hypothesis was that there would be no difference in Wrist Anatomy Assessment (WAA) scores and palpation of bony landmarks in the wrist and radiographic carpal bone identification between orthopedic residents, EM residents, and EM attending physicians.

Materials and Methods

This project received approval from the University of Connecticut Health Center (UCHC) Institutional Review Board, #10-052-3. The principal investigator (CMR), an orthopedic hand surgeon, approached the EM heads of 2 area hospitals that support the UCHC residency program to collaborate on this project. Lists of potential residents and attending physicians were compiled through this agreement. As this is an original pilot of the WAA, a power analysis could not be performed. The goal a priori was to obtain data on all of the orthopedic residents in the University's program. Therefore, the orthopedic resident group became the limiting cohort of participants, which numbered 21 minus this study's co-author (RO) for a final group size of 20. The other cohorts (EM residents and EM attending physicians) were randomly selected on a convenience basis in order to have approximately equal numbers to the orthopedic resident group. An equal cohort of 4th-year medical students was also tested. Each participant was given a number to ensure that each person only took part once in the study. Their identity was then removed from the data at the time of analysis and reporting.

Through personal communication with Roche's group in the UK, we employed a study design for testing carpal anatomy proficiency based upon the methodology he employed in both his own study of carpal anatomy proficiency,[8] as well as his study on foot and ankle anatomy expertise.[9] The carpal bone palpation portion of Roche's study design was, in turn, very similar to that put forth by Jayasekera's group in 2005.[7] Data was collected from orthopedic residents of all postgraduate year (PGY) levels (1-5), EM residents (PGY 1-3), and EM attending physicians. A cohort of 4th-year medical students was also included. Prior to data collection, the examiners were trained to properly identify the carpal landmarks and interpret the wrist radiographs by the senior author (CMR). Testing was conducted to ensure inter-rater reliability, wherein multiple tests were

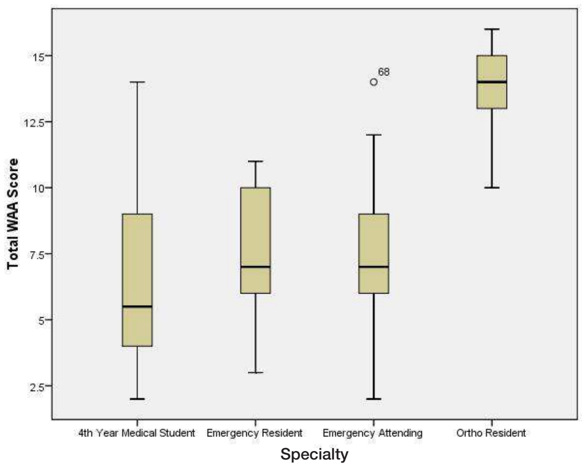


Figure 4. Boxplots of total Wrist Anatomy Assessment score by participant groups. The central dark band represents the median and the box extends from the 25th to 75th percentile of scores. The whiskers extend to the largest and smallest observed values within 1.5 box lengths.

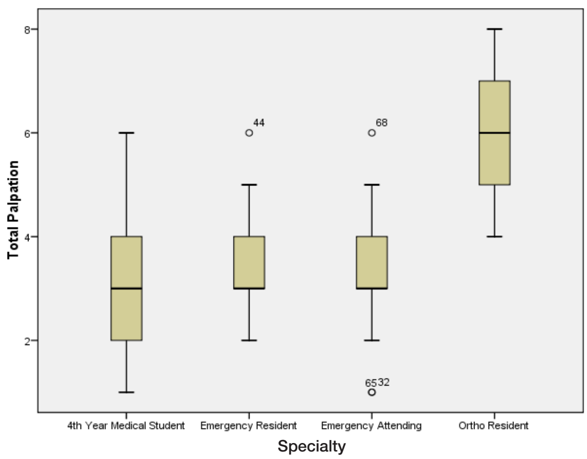


Figure 5. Boxplots of palpation scores by participant groups.

administered by the senior author to the 2 examiners. In this series of tests, the senior author played the role of a study participant and as such, he would palpate the bony landmarks in each of the examiners' wrists according to the testing protocol described below. With his understanding of carpal anatomy, he was able to determine the examiners' accuracy in having the bony landmarks palpated on their own wrists. Multiple series of tests, occurring over the course of several weeks were conducted until the examiners consistently demonstrated 100% accuracy in the series of known correct and incorrect simulated exams conducted by the senior author.

Orthopedic residents were all enrolled at weekly didactic sessions over a period of 1 month. EM residents and attending physicians, as well as the 4th-year medical students, were randomly recruited on a convenience basis. Invited participants were presented with an Institutional

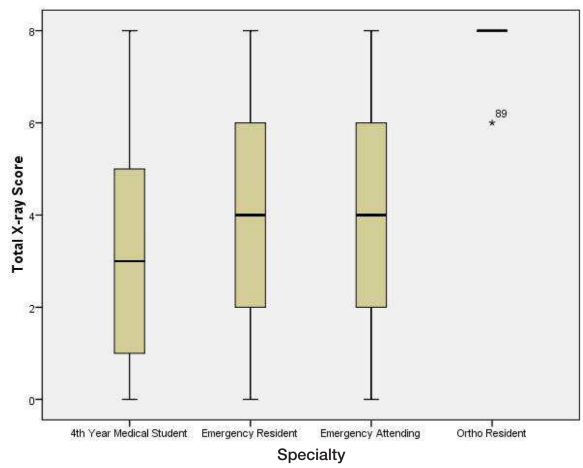


Figure 6. Boxplots of x-ray interpretation scores by participant groups.

Review Board (IRB)-approved explanation and purpose of this project. Participants were first asked to fill out a demographics form and a visual analog scale (VAS) (Figure 1), which was a secondary outcome measure in this study. These measures assessed the participant's level of confidence in his or her palpation technique and radiographic interpretation, his or her level of energy at the time of testing, and the test-taking anxiety that he or she experienced at the time of evaluation.

Each participant was tested by 1 of the examiners. The first component of the WAA evaluation was the palpation of bony landmarks of the wrist. The examiner would present their right hand in a "neutral" position of elbow flexion of 90º degrees and forearm medial rotation of 90º (ie, as if shaking hands) to the study participant. The participant was then instructed that they were free to bend or turn the examiner's arm and wrist to palpate the requested bony landmark in whatever manner they felt was most convenient. After the participant finalized their answer, the examiner's arm and wrist were returned to neutral position before the identification of the next bony landmark was requested. Each participant was asked to palpate 9 bony landmarks on the examiners' wrist. The landmarks testing sequence was carried out in the following order for each participant: radial styloid, distal ulna, pisiform, hook of hamate, proximal pole of the scaphoid, scaphoid waist, distal pole of the scaphoid, Lister's tubercle, and the triquetrum. Most of these structures, by virtue of their anatomic location, could only be palpated and correctly identified by 1 approach. However, it was considered acceptable for the distal ulna to be identified by both dorsal and volar palpation. Also, the scaphoid waist was correctly identified if palpated either medial or lateral to the extensor pollicis longus tendon. In the second part of the WAA evaluation, each participant was asked to identify all 8 of the carpal bones on a standardized posterior-anterior radiograph of a normal adult (Figure 2).

Table 1. Carpal Palpation: Correct Responses Across Specialties (N = 89)

Landmark	% Correct
Distal ulna	96.6
Radial styloid	89.9
Scaphoid waist	49.4
Pisiform	42.7
Scaphoid distal pole	32.6
Listers tubercle	20.2
Triquetrium	16.9
Hook of hamate	15.7
Scaphoid proximal pole	7.9

Table 2. Carpal Radiograph Correct Responses Across Specialties (N = 89)

Landmark	% Correct
Scaphoid	91.0
Pisiform	77.5
Lunate	75.3
Triquetrum	58.4
Capitate	53.9
Hamate	51.7
Trapezium	39.3
Trapezoid	38.2

Scores for these 2 portions of the WAA were added together on the Case Report Form (Figure 3) to establish the total WAA score. Each bony landmark correctly palpated or carpal bone correctly identified on the x-ray awarded the participant 1 point out of a total 17 points. If the participant was incorrect, he or she was awarded no points. These data for the WAA scores, along with the secondary outcome measurements of the VAS, which were converted to a 0-100 score, were then analyzed using an SPSS, version 17.0, database (SPSS Inc., Chicago, Illinois).

Descriptive statistics, including means, standard deviation, skewness, and frequency, were calculated on demographic variables and continuous measures (ie, numbers of cases and VAS). Grouped comparison analysis (Palpation/X-Ray, Ortho/EM) used an independent t-test. Statistical significance was set a priori as a $P<.05$ or a confidence level set at 95%, with select items later tested at a 99% confidence interval (CI).

Results

Data were collected on 89 participants and comprised 20 orthopedic residents, 21 EM residents, and 26 EM attending physicians. In addition, our cohort of 4th-year medical students consisted of 22 participants who will serve as a baseline for future carpal anatomy educational research.

The WAA consisted of 2 subdomains: palpation of bony landmarks and radiographic identification of the carpal bones. Table 1 lists the bony landmarks palpated and the percentage correctly identified by the entire sample across specialties in descending order. The 2 wrist landmarks that were most commonly correctly identified by participants were the distal ulna (96.6%) and the radial styloid (89.9%). Correctly identifying the carpal bones on palpation had much greater variability and ranged from 7.9% correct (proximal pole of the scaphoid) to 49.4% (the scaphoid waist). Table 2 lists the second part of the WAA evaluation with the percentage of carpal bones correctly identified on x-ray across specialties in descending order. Participants had the least difficulty identifying the scaphoid (91% correct) and the most difficulty in identifying the trapezoid (38.2% correct).

Total WAA scores (score of 17 = 100% correct) ranged from 2-16, with a mean of 8.6. The mean WAA for the orthopedic resident cohort was 13.8, which was significantly greater ($P<.01$) than the mean WAAs for the EM residents (7.5) and the EM attending physicians (7.2). When subdivided into postgraduate training years, the orthopedic residents showed consistent WAA scores with statistical improvement in the chief year. WAA scores (SD) in PGY years 1 to 5 were 13.20 (1.30), 13.25 (2.50), 14.00 (1.41), 13.33 (1.12) and 15.25 (0.50), respectively. Nearly all of the incorrect responses from the orthopedic resident cohort were from the palpation of bony landmarks as opposed to the x-ray interpretation segment of the exam. The 4th-year medical students' mean WAA score was 6.5. The boxplot shown in Figure 4 illustrates the distribution of the total WAA scores between our participant groups. The central dark band represents the median WAA score and the shaded box includes the 25th to 75th percentile of the scores. The whiskers extend to the largest and smallest observed values within 1.5 box lengths. When looking at the total WAA scores of 89 participants, there is only 1 individual who lay outside these whiskers and that is subject 68, an EM attending physician who we later learned had previously authored a chapter on the wrist for a textbook. Figure 5 illustrates the palpation scores (part 1 of the WAA) and Figure 6 similarly illustrates the x-ray interpretation scores (part 2 of the WAA). Orthopedic resident scores were statistically higher ($P<.01$) than the other groups (palpation mean score, 5.9; SD, 1.37; x-ray interpretation mean score, 7.9; SD, 0.45) using a t-test analysis set first at a 95% CI and again when run a second time due to the small sample size at a 99% CI. There were no statistical differences in the palpation or radiograph identification scores among EM residents (palpation mean score, 3.24; SD, 0.99; x-ray interpretation mean score, 4.29; SD, 2.31) or EM attending physicians (palpation mean score, 3.12; SD, 1.11; x-ray interpretation mean score, 4.12; SD, 2.37) when using independent sample t-test at a 95% CI. Fourth-year medical students scores (palpation score mean, 2.95; SD, 1.17; x-ray interpretation mean score, 3.5; SD, 2.77) will serve as a baseline for future educational intervention studies.

Additional Findings

We examined a few secondary outcome measures in an effort to determine the effect, if any, of the participants' level of confidence in their performance and their self-reported state of well-being. Four VAS were utilized (Figure 1). Self-reported confidence in palpation technique ranged from 0-89 (SD) with a mean of 50.5 (23.9). VAS self-confidence in radiograph identification ranged from 0-100 (SD) with a mean of 57.4 (24.5). VAS level of energy ranged from 0-100 (SD) with mean of 54.8 (25.7). VAS test-taking anxiety ranged from 0-93 (SD) with a mean of 18.8 (22.1). Those who reported a higher confidence in palpation scored higher on that subscore ($r = 0.32$, $P<.01$), while those who reported confidence in x-ray identification scored higher on both palpation ($r = 0.45$, $P<.01$) and radiograph identification ($r = 0.51$, $P<.01$) scores. Orthopedic residents reported higher confidence overall in both their palpation skills ($r = 0.27$, $P<.05$), as well as their radiographic identification performance ($r = 0.49$, $P<.01$). Neither self-reported level of energy nor test-taking anxiety appeared to be a predictor for one's WAA score.

Discussion

Our study identified a clear difference between orthopedic residents and EM—both resident and attending—physicians with respect to their proficiency in palpating anatomical landmarks of the wrist and identifying the carpal bones on an x-ray. Therefore, the null hypothesis was rejected. Figure 4 illustrates that the total WAA scores for orthopedic residents at our university was significantly higher than that of both the EM residents and attending physicians, who scored similarly to one another. This finding suggests that orthopedic resident consultation by an EM physician in certain cases of carpal trauma is quite appropriate. Additionally, given that the orthopedic resident cohort showed consistent WAA scores over all training years, with a statically significant increase in the average WAA scores in the chief year, we conclude that orthopedic residents in all levels of their training could contribute to an emergency department consult of this nature.

Our findings of carpal palpation showed similar trends to the work of Jayasekera and colleagues[7] and Roche and colleagues[8] who each compared physical examination of the carpal bones by UK orthopedic surgeons to that of accident and emergency clinicians. In their 2 studies, as in this study, the scaphoid waist was the most correctly identified carpal bone by palpation. The proximal pole of the scaphoid, the hook of hamate, and the triquetrum were less commonly identified in both our study and the UK studies. Not surprisingly, our data and Roche's both revealed that the radial styloid and distal ulna were the 2 most easily palpated bones in the wrist; and also that orthopedic clinicians were more proficient at radiographic interpretation of carpal anatomy than emergency physicians.[8]

Throughout our testing, both examiners received many comments, especially from EM physicians, stating that our testing methods were too "specific" with respect to what we were asking. For example, many EM attending physicians commented that they knew to check the "snuffbox" for a scaphoid fracture when they examined a wrist, but objected to further topographical delineations within the scaphoid bone.

A limitation of this study was that 2 different examiners, and therefore 2 different wrists, were being used to test the study participants. Although the examiners' wrists were roughly similar in dimension and soft tissue caliber, it is clear that they were not identical. Since these 2 wrists were used to test the study population, it is possible that the data may have been skewed by this discrepancy. However, given the similarity of the examiner's wrists and their validation as examiners, we believe that the data was minimally affected by this discordance. Another weakness of this study is that we did not distinguish between participants who admitted to not knowing an answer and those who incorrectly guessed an answer with bravado. In other words, if a participant did not know what they were palpating, or looking at on x-ray and told us so ("I have no idea"), this was given a zero on that component of the WAA score, no different from the participant who confidently stated the wrong answer. In clinical practice, an EM physician who doesn't know how to interpret a certain wrist x-ray, but calls for an orthopedic resident consultation to assist, is likely to arrive at the correct diagnosis more frequently than the EM doctor who mistakenly believes him or herself to be correct and does not seek an orthopedic consult. The latter type of EM physician is more likely to miss diagnoses, such as perilunate dislocations and subtle scaphoid fractures, than his more conservative counterpart.

The finding that orthopedic surgery residents possess superior carpal anatomy knowledge to EM physicians does not necessarily point towards a deficiency in EM residency training, as these physicians of course are responsible for a vast array of health problems and organ systems, compared with the orthopedic resident's much more focused expertise. Naturally, the diagnosis of less common carpal injuries represents a smaller proportion of their clinical training. To better understand the natural history of musculoskeletal knowledge as one progresses from medical school to an orthopedic surgery or EM residency, we have included medical students in our study to serve as baseline of wrist palpation and carpal bone identification proficiency. However, further research is warranted to understand how our university, and perhaps the US at large, can most effectively enhance education of carpal anatomy, in a way that students and clinicians can actually retain the information they learn so that they can put it to good use in their careers in the future.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.