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Anatomical relationship of palmar carpal bone landmarks used in locating the lunate and capitate during palpation: A cadaveric investigation

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ABSTRACT

Study Design: Descriptive in situ cadaveric study.
Introduction: Performing accurately directed examination and treatment to the wrist requires clinicians to orient to carpal bone structures.
Purpose of the Study: To examine the anatomical relationships that exist within the wrist–hand complex and identify the accuracy of surface anatomy mapping strategies for localizing anatomical landmarks using a palmar approach.
Methods: Twenty-three embalmed cadavers were dissected using standardized procedures. Metal markers were placed in the most prominent palmar landmark of key carpal structures. Relationships between the most prominent palpation landmarks and the carpal bones of interest were visualized using fluoroscopy.
Results: The most successful methods of palmar capitate localization included the midpoint of a line from trapezium tubercle to pisiform; the midpoint of a line from scaphoid tubercle to hamate hook; or the intersection (cross) of these 2 diagonal lines, with successful capitate identification 100% (23/23) of the time. The most successful method for locating the lunate included the midpoint of a line from the radial styloid process to the ulnar styloid process, which identified the lunate in 100% (23/23) of cases.
Discussion: The results of this cadaveric anatomical relationship study support the use of the midpoint of a line from pisiform to trapezium tubercle, the midpoint of a line from scaphoid tubercle to hamate hook, or a combination (cross) of these lines to locate the capitate from a palmar approach. In addition, the anatomical relationships examined in this study support the use of the midpoint of a line from the radial styloid process to ulnar styloid process to locate the lunate from a palmar approach. Knowledge of these anatomical relationships may improve the clinician's confidence in locating the capitate and lunate during intercarpal examination, special testing, and treatment.
Conclusion: Results of this study provide information of the anatomical relationships of the carpal bones from a palmar approach, giving clinicians a foundation for proper orientation to the carpal bones during clinical examination and intervention. Further research is needed to evaluate the reliability and accuracy of these methods for surface palpation on live patients.

Introduction

The ability of a clinician to perform a precise clinical examination is important for determining the diagnosis of wrist pathology.[1-3] A correct and thoroughly performed assessment that corresponds with a detailed patient history can lead to an accurate hypothesis regarding patient diagnosis.[1,3] Additionally, information obtained from an accurate clinical examination may lessen the need for plain radiographic images, magnetic resonance imaging, or computed

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tomography, potentially reducing medical costs associated with unnecessary imaging.[4] However, in order to improve the confidence and accuracy of a diagnosis, it is suggested that imaging study findings must be in agreement with symptom reproduction during physical examination tests and direct palpation.[2]

Inspection and palpation are 2 essential skills involved in the clinical examination process, and both require extensive surface anatomy knowledge and skills.[1] Many manual examination and treatment techniques rely on an underlying knowledge of anatomical relationships. This knowledge becomes paramount to a well-performed clinical examination and an accurately localized intervention. The clinical examination requires clinicians to incorporate manual skills to reproduce the patient's symptom and manually assess joint mobility using precise joint mobility testing.[3] Moreover, a clinician's ability to locate carpal bones from a dorsal and palmar approach to the wrist–hand complex is necessary to augment accurate treatment localization.

Of the 8 carpal bones, key anatomical landmarks including the scaphoid tubercle, hamate hook, pisiform, and trapezium tubercle are readily palpable on the palmar surface of the wrist/hand complex.[5] However, direct palpation of the capitate and lunate from a palmar approach is difficult in part due to the arch of the distal carpal row, creating a deep concave palmar surface.[1,6] Palpation of the capitate and lunate is further complicated due to the overlying flexor retinaculum and finger flexor tendons. Despite this difficulty in palpating the capitate and lunate, in selected cases, it is necessary for the clinician to accurately locate these bones when delivering appropriately directed joint mobility testing and treatment.[3,7] Clinical examination tests for carpal-related instability such as (Reagan's) Ballottement test[8] require the clinician to stabilize or move the lunate using pressure from both the palmar and dorsal surfaces, whereas the Dorsal Capitate Displacement Apprehension Test requires pressure be applied to the capitate from the palmar surface only.[9]

Palpation methods have been suggested for locating the capitate on the dorsum of the wrist complex.[1,5] However, in spite of the importance for locating the capitate and lunate, no investigators to date have described anatomical relationships or accurate palpation mapping strategies used to localize the capitate or lunate using a palmar approach to the wrist complex. The purpose of this study was to examine the anatomical relationships that exist within the cadaveric wrist–hand complex and identify the accuracy of surface anatomy mapping strategies for localizing key anatomical landmarks using a palmar approach. Knowledge of these anatomical relationships provides clinicians with the foundation to orient to the carpal bones on the palmar wrist surface during clinical examination and intervention.

Methods

Twenty-five (13 male and 12 female) supine lying, embalmed human cadavers were used for this study. All cadaveric specimens used for this study were obtained from the Texas Tech University Health Sciences Center's Willed Body Program and data collection took place within the gross anatomy laboratory. Cadaveric specimens were handled according to the university policy and the State of Texas regulations defined by the State Anatomical Board of Texas. Through a standardized dissection process, palmar soft tissues covering the carpal bones were removed. Since the pisiform is a sesamoid bone that lies within the flexor carpi ulnaris tendon, this tissue was not dissected to allow the pisiform to remain stable and undisrupted. All palmar and dorsal carpal ligaments were left intact to respect the integrity of the radiocarpal and intercarpal articulations.

For the purpose of technique consistency, a single researcher placed a metal marker in the most prominent portion of the scaphoid tubercle, trapezium tubercle, hook of the hamate, and pisiform. Furthermore, attempts were made to place a marker in the center of capitate and lunate to assist in the appraisal of the surface anatomical maps being investigated. The metal marker placement allowed the investigator to establish spatial relationships observed on fluoroscopic imaging.

Fluoroscopy was used to capture an image of each wrist/hand complex that provided carpal bone visualization. During imaging, the upper extremity of the cadaveric specimen was positioned in 90° of glenohumeral joint abduction, with the elbow complex extended, and forearm supinated, along with the wrist and metacarpals in a neutral position (0° of palmar flexion, dorsal extension, radial deviation, and ulnar deviation).

The radiographic images were imported into a commercially available photo editing software program, where digital lines were constructed between specific markers on the resulting digital images of the radiographs. This digital process allowed for evaluation of the structural anatomical relationships across the wrist–hand complex.

Anatomical relationship investigation

Anatomical relationships among the carpal bones were evaluated using 5 methods (1–5) to localize the capitate (Figs. 1 and 2) using a palmar approach to the wrist/hand complex and 3 methods (A, B, and C) to localize the lunate (Figs. 3 and 4) from a palmar approach to the wrist/hand complex. All methods examined capitate and lunate locations in relation to 1 line coursing between 2 carpal bones, with the exception of method 5 (or "cross-method"), which used the intersection of 2 lines to locate the capitate bone (Table 1), and lunate method C, which used the radial and ulnar styloid processes. The frequency and location of correct carpal bone identification were noted, and percentages were calculated for each carpal bone identification method using the respective helper's lines.

Results

Initially, 25 cadavers were identified for dissection and inclusion. Fluoroscopic evaluation revealed disrupted carpal integrity of 2 of the 25 cadaveric subjects leading to disqualification of these 2 cadaveric specimens from the study. Subsequently, data collection and analysis was completed on a total of 23 cadavers (12 males, 11 females, 12 of the right upper extremity, and 11 of the left) with an average age of 75 years (range: 55–96 years).

Capitate location

All methods for locating the capitate can be seen in Figure 1 and Figure 2. Results with accuracy in locating the capitate can be seen in Table 2.

Method 1 (scaphoid tubercle to pisiform) located the proximal portion of the capitate in 100% of cadavers.

Method 2 (trapezium tubercle to hamate hook) located the distal portion of the capitate on 87% of cadavers, the joint line between the capitate and the base of the third metacarpal on 9%, and the base of the third metacarpal 4% of the time.

Method 3 (trapezium tubercle to pisiform) located the approximate center of the capitate on 100% of cadavers, with a point just distal to the center of the capitate located 78% of the time and a point just proximal to the center located 22% of the time.

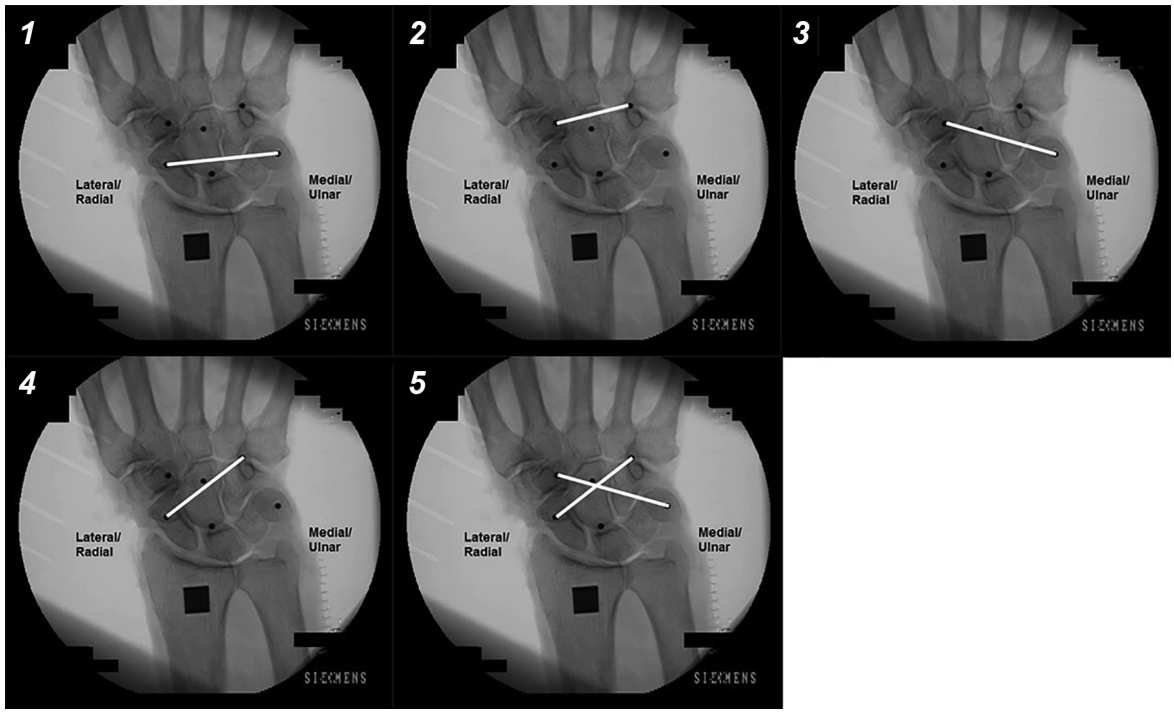

Fig. 1. Identification methods (1-5) for localizing the capitate. (**1**) Pisiform to scaphoid tubercle, (**2**) hamate hook to trapezium tubercle, (**3**) pisiform to trapezium tubercle, (**4**) scaphoid tubercle to hamate hook, (**5**) cross of pisiform to trapezium tubercle and scaphoid tubercle to hamate hook.

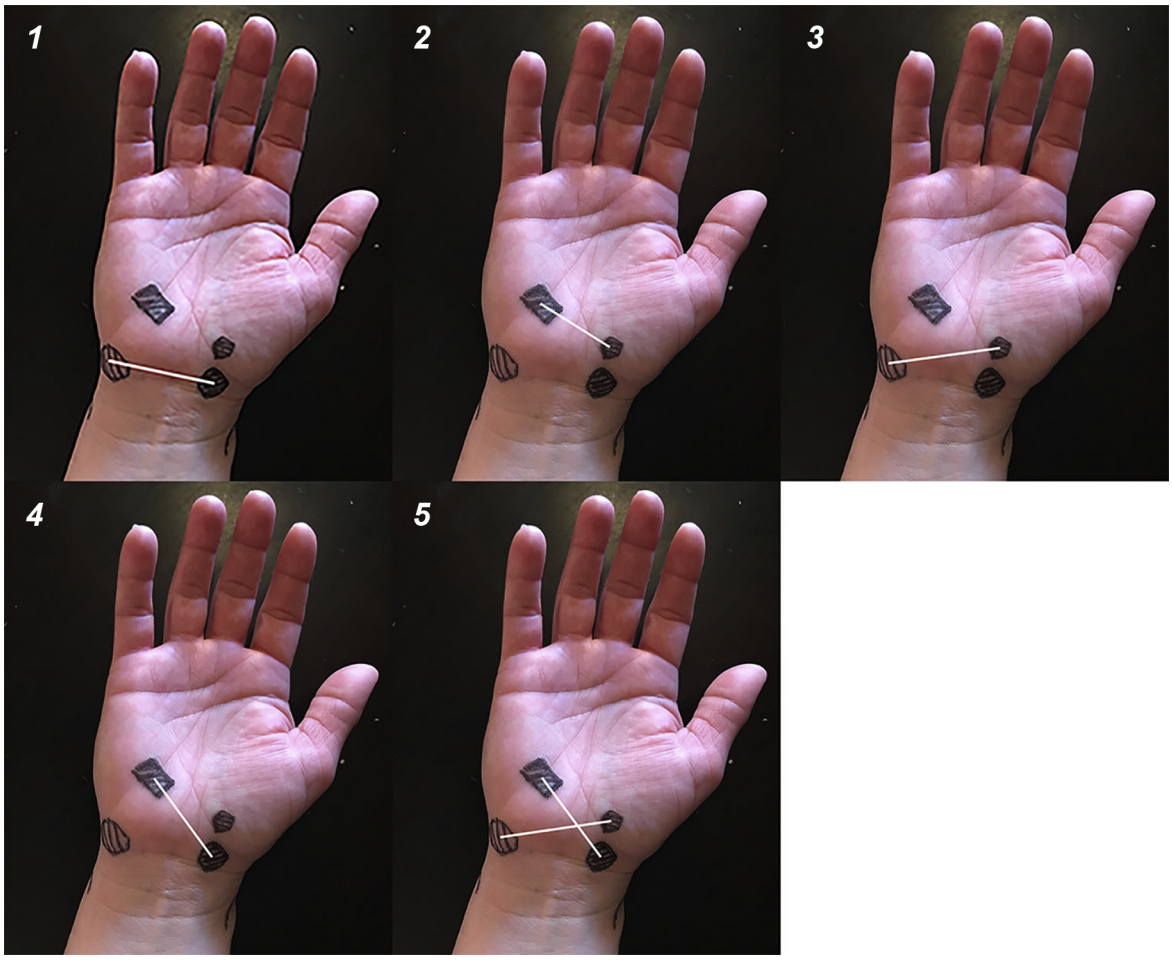

Fig. 2. Identification methods (1-5) for localizing the capitate on a live hand. (**1**) Scaphoid tubercle to pisiform, (**2**) trapezium tubercle to hamate hook, (**3**) trapezium tubercle to pisiform, (**4**) scaphoid tubercle to hamate hook, (**5**) cross of scaphoid to hamatehook and trapezium tubercle to pisiform.

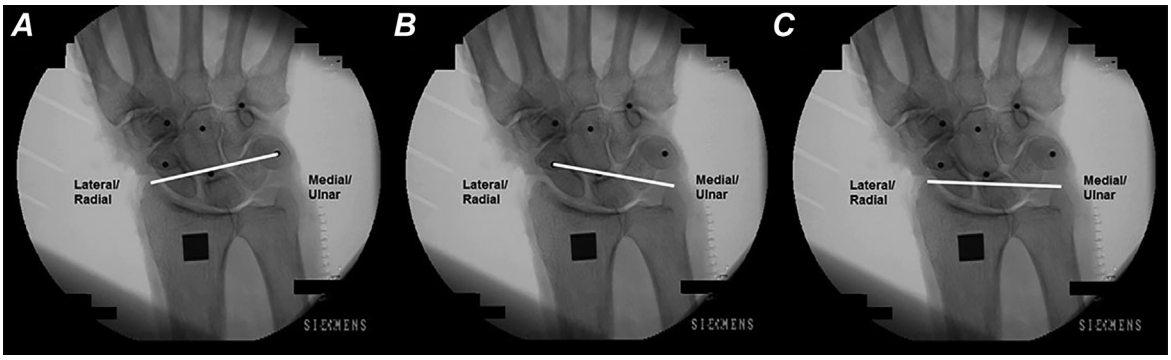

Fig. 3. Identification methods (**A-C**) for localizing the lunate. (**A**) Radial styloid process to pisiform, (**B**) scaphoid tubercle to ulnar styloid process, (**C**) radial styloid process to ulnar styloid process.

Method 4 (scaphoid tubercle to hamate hook) located the approximate center of the capitate on 100% of cadavers, with a point just distal to the center of the capitate located 83% of the time and a point just proximal to the center located 17% of the time.

Method 5 (cross-method: scaphoid to hamate hook and trapezium tubercle to pisiform) located the approximate center of the capitate on 100% of subjects, with a point distal to the center of the capitate located 60% of the time, a point proximal to the center located 26% of the time, a point just ulnar to the center located 9% of the time, and a point just radial to the center of the capitate located 4% of the time.

Lunate location

All methods for locating the lunate can be seen in Figures 3 and 4. Results with accuracy in locating the lunate can be seen in Table 2.

Method A (radial styloid process to pisiform) located the distal portion of lunate 17% of the time. Another 17% of the time, this method located the joint line between the lunate and capitate, and 65% of the time it located the proximal portion of the capitate.

Method B (scaphoid tubercle to ulnar styloid process) located the lunate 96% of the time, locating a point near the center 61% of the time and a point near the distal or ulnar borders of the lunate 35% of the time. The other 4% of the time, this method located the proximal capitate.

Method C (radial styloid process to ulnar styloid process) located a point just distal to the center of the lunate 100% of the time.

Discussion

This is the first study to assess the anatomical relationships associated with capitate and lunate locations on the palmar surface of the wrist–hand complex. This study identified several viable and valuable methods for locating the capitate and lunate using a palmar approach to the wrist/hand complex. The results from the present study provide information regarding the anatomical relationships and surface anatomy, which may be used to aid clinicians in locating the capitate and lunate during the clinical examination and treatment processes. Additionally, these methods may help professional students more easily learn the anatomic relationships of these carpal bones and aid in skill acquisition of carpal bone mobility testing and treatment.

Although all 5 investigated methods identified (coursed over) at least a portion of the capitate with relative consistency, some methods resulted in more consistent localization than others. Method 1 (pisiform to scaphoid tubercle) resulted in identification of the proximal capitate, whereas method 2 (hamate hook to trapezium tubercle) resulted in identification of the distal capitate in most cases and a space just proximal to the capitate in a small portion of the cases. In contrast, the 2 diagonal methods (method 3:

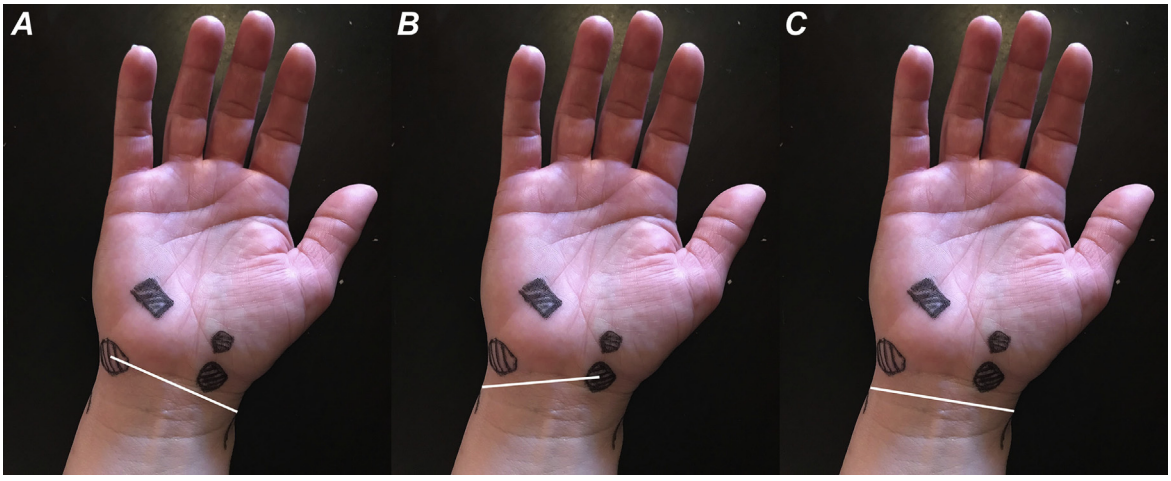

Fig. 4. Identification methods (**A-C**) for localizing the lunate on a live hand. (**A**) Radial styloid process to pisiform, (**B**) scaphoid tubercle to ulnar styloid process, (**C**) radial styloid process to ulnar styloid process.

Table 1
Carpal bone location methods

Identified bone	Method	Reference bones	
Capitate			
	1	Scaphoid tubercle	Pisiform
	2	Trapezium tubercle	Hook of hamate
	3	Trapezium tubercle	Pisiform
	4	Scaphoid tubercle	Hook of hamate
	5 (cross method)	Scaphoid tubercle AND	Hook of hamate
		Trapezium tubercle	Pisiform
Lunate			
	A	Radial styloid process	Pisiform
	B	Scaphoid tubercle	Ulnar styloid process
	C	Radial styloid process	Ulnar styloid process

pisiform to trapezium tubercle and Method 4: scaphoid tubercle to hamate hook) and method 5 (cross of pisiform to trapezium tubercle and scaphoid tubercle to hamate hook) located the approximate center of the capitate in all cases. Considering the consistency with which the 2 diagonal methods identified the capitate, it is recommended that clinicians utilize the midpoint of one or the cross of both diagonal methods (pisiform to trapezium tubercle and/or scaphoid tubercle to hamate hook) to accurately and efficiently locate the capitate. The cross method may be beneficial in that the intersection of the lines may indicate the relative center of the capitate.

Regarding the investigated methods to localize the lunate using a palmar approach to the wrist/hand complex, method A (pisiform to radial styloid process) resulted in correct identification of the distal lunate in a small portion of the cases, versus the proximal capitate in the majority of cases, and the joint space in a small portion of the cases. Method B (scaphoid tubercle to Ulnar Styloid Process) successfully identified the lunate in nearly all cases but did identify the proximal capitate in a small portion of cases. Method C (radial styloid process to ulnar styloid process) successfully identified a point just distal to the center of the lunate in all cases. Variations in styloid process length, forearm position (supination vs. pronation), and wrist position (radial vs ulnar deviation) may influence the exact location on the lunate. Although it might be suspected that some anatomical variation existed within the 25 wrists that were assessed in this study, Method C consistently identified the lunate in all cases despite any potential anatomical variations. Based on the current results, it is recommended that clinicians not use method A (pisiform to radial styloid process) for identifying the lunate as incorporation of this method will likely result in clinicians more frequently identifying the capitate than the lunate. In contrast, clinicians can use method B or method C with relative confidence that the lunate will be correctly identified.

Comparison of these carpal location methods with other methods is not currently possible, as no other methods for locating the capitate and lunate using a palmar approach were identified in the literature. Additionally, no studies assessing these specific palpation methods were identified during a literature search. Although Reddy and Compson[1] provided a thorough description of palpation techniques for the carpal structures, localization of the capitate and lunate from the palmar side were not described.

Although the present study assessed the anatomical relationships with the forearm in a supinated position and the wrist in a neutral position (no flexion/extension or radial/ulnar deviation), it is recognized that variations in clinical testing are inevitable. As a result, the accuracy of these proposed methods may vary slightly depending on the testing position. However, it is unlikely that forearm position or wrist radial/ulnar deviation will drastically change the ability of these methods to locate each respective bone. This is even more likely to be the case when identifying the capitate, as wrist and forearm position changes are much less likely to result in drastic position changes of the lunate in relation to its neighboring carpal bones.

This study has limitations. All subjects were of older age and may not accurately represent the population for which these techniques would be frequently used in a clinical setting. Additionally, markers were placed in the most prominent portion of the bones and not always in the center. However, this more closely mimics clinical practice, as these are portions of the bones that clinicians will most likely palpate. As the present study was performed on embalmed cadavers, it is recommended that further research evaluate the reliability and accuracy of these methods for surface palpation with live patients.

Conclusion

The results of this cadaveric anatomical relationship study support the use of the line from pisiform to trapezium tubercle, the line from scaphoid tubercle to hamate hook, or a combination (cross) of these lines to locate the capitate using a palmar approach to the wrist/hand complex. These 3 methods successfully identified the capitate in 100% of assessed wrists. Additionally, results of this study indicate that the lunate is best located using a line from the radial styloid process to the ulnar styloid process, which successfully identified the lunate in 100% of the assessed wrists. The use of these techniques may improve the clinician's confidence in locating the capitate and lunate during precise intercarpal joint play/laxity testing, special test performance, and treatment delivery.

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Table 2
Carpal bone location accuracy by method

Bone	Method	Located along a line between	Proximal	Near center	Distal	Missed
Capitate						
	1	Scaphoid tubercle to pisiform	23/23 (100%)	0/23 (0%)	0/23 (0%)	0/23 (0%)
	2	Trapezium tubercle to hamate hook	0/23 (0%)	0/23 (0%)	20/23 (87%)	3/23 (13%)
	3	Trapezium tubercle to pisiform	0/23 (0%)	23/23 (100%)	0/23 (0%)	0/23 (0%)
	4	Scaphoid tubercle to hamate hook	0/23 (0%)	23/23 (100%)	0/23 (0%)	0/23 (0%)
	5	Cross method	0/23 (0%)	23/23 (100%)	0/23 (0%)	0/23 (0%)
Lunate						
	A	Radial styloid process to pisiform	0/23 (0%)	0/23 (0%)	4/23 (17%)	19/23 (83%)
	B	Scaphoid to ulnar styloid process	0/23 (0%)	14/23 (61%)	8/23 (35%)	1/23 (4%)
	C	Radial to ulnar styloid processes	0/23 (0%)	23/23 (100%)	0/23 (0%)	0/23 (0%)

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1. Carpal location was established
   a. with MRI imaging
   b. using traditional AP x-rays
   c. palmarly
   d. dorsally
2. The capitate was correctly located _____ % of the time
   a. 100
   b. 95
   c. 80
   d. 75
3. The midpoint of a line from the radial styloid to the ulnar styloid is directly over the
   a. scaphoid
   b. capitate
   c. Lister's tubercle
   d. lunate
4. Skin creases and lines
   a. are the preferred landmarks in locating the proximal pole of the scaphoid
   b. are better used dorsally than palmarly in locating carpal bones
   c. were not used to locate bones
   d. were shown to be superior in locating bones than using "other boney landmarks"
5. The horizontal lines described were based upon accurate palpation of boney landmarks
   a. false
   b. true

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