Review article

Scaphoid fractures: A higher order analysis of clinical tests and application of clinical reasoning strategies

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Abstract

Introduction: The purpose of this study was to identify clinical tests for scaphoid fractures and, using a higher order analysis, to determine their diagnostic accuracy.

Methods: A literature review of the databases CINAHL, Embase, Medline and PUBMED from 1980 to September 30, 2011 was conducted to obtain applicable literature on clinical tests used in identifying scaphoid fractures. Methodological quality was determined using the criteria for validity suggested by Sackett et al (2000). Using a random effects model, pooled positive likelihood ratios (PPLR) were established for any test evaluated in at least 3 published studies. Moderator analyses provided insight into heterogeneity of results.

Results: Higher order analysis indicated that the scaphoid compression test, anatomical snuffbox tenderness and scaphoid tubercle tenderness demonstrated statistically significant ability to identify scaphoid fractures with PPLR of 2.37 (1.27–4.41), 1.52 (1.12–2.06) and 1.67 (1.33–2.09) respectively. Descriptive factors (gender and mechanism of injury) were also identified but did not demonstrate significant diagnostic ability. Pooled data revealed the existence of heterogeneity for the three clinical tests and descriptive factors, which could not be easily explained.

Conclusion: Three clinical tests with statistically significant diagnostic validity were identified. In isolation, the clinical significance of each is questionable. Further studies with description of sample characteristics, blinded assessments, and agreement on a reference standard are recommended.

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1. Introduction

The scaphoid is the most commonly fractured carpal bone (Hunter, 2005; Geissler et al., 2012) but these fractures are difficult to diagnose, whether by diagnostic imaging or clinical examination. Faced with this uncertainty, a conservative approach to treatment, through immobilization, is often taken. The risks of an improperly treated scaphoid fracture include non-union, degeneration and avascular necrosis in non-immobilized fractures. Patients are often immobilized for 10–14 days pending follow-up imaging. Immobilization itself however is not free of risks or side effects, which can include muscle atrophy, disuse, and osteopenia (Geissler et al., 2012). Of note, Pillai and Jain (2005) found that as many as 80% of immobilized patients do not have an actual scaphoid fracture. When clinical tests for fracture diagnoses have been scrutinized, most have been found to have low diagnostic validity in independent samples (e.g. Tai et al., 2005). The inaccuracy in the diagnosis of scaphoid fractures remains problematic as supported by Shetty et al. (2011) who found that as many as 76% of patients who were ultimately free of fractures were immobilized for 31 days on average.

Currently there is no agreement on a gold standard for diagnostic studies to detect a scaphoid fracture (Buijze et al., 2011a, 2011b, 2011c; Duckworth et al., 2011). Magnetic Resonance Imaging (MRI) has been proposed as a tool for early detection (Patel et al., 2012), but this has yet to achieve universal agreement (Mallee et al., 2011). A systematic review and meta-analysis by Yin et al. (2010) has called for more research to compare the diagnostic performance of computed tomography (CT) to MRI and bone scintigraphy. Due to the high cost, questionable diagnostic accuracy as well as radiation exposure of current medical imaging approaches, sound clinical screening tests can play an important role in early diagnosis. A quick, accurate and inexpensive clinical screening protocol could be useful for determining the need for diagnostic imaging and may reduce unnecessary immobilization,
and facilitate implementation of appropriate care (Parvizi et al., 1998; Rhemrev et al., 2010). This approach has been successfully implemented for other areas such as the ankle (Stiell et al., 1994) and the cervical spine (Stiell et al., 2001).

A prudent intermediate step between exploratory and confirmatory research is to synthesize the data currently available from exploratory research with which to inform the creation of evidence-based clinical prediction rules. Currently, no comprehensive higher order analysis of the literature has been done to assess the diagnostic accuracy of proposed clinical examination techniques for scaphoid fractures. Therefore, the purpose of this paper was to conduct a structured, systematic search of the available literature on clinical tests for scaphoid fractures in adults, and to use a statistical pooling technique to determine the diagnostic accuracy of tests that have been evaluated in at least three independent cohorts.

2. Methods

2.1. Search strategy

The search strategy developed to find and retrieve relevant literature was formulated by a group of experienced clinical physiotherapists and researchers. Databases searched were: CINAHL, Embase, Medline and PUBMED. Search terms used were: scaphoid AND fracture AND [sensitivity OR specificity OR likelihood OR accuracy] OR validity OR diagnos* OR discriminat*. Furthermore, our search was limited to full text articles performed on humans, in English and no earlier than 1980.

A secondary hand search was also carried out using reference lists from the papers identified in the database search, but that did not appear in our original search criteria. It was apparent that no universally-accepted gold standard diagnostic procedure was available at the time of our search. Therefore, acceptance of studies was based on the use of comparison to an adequate standard, defined as a diagnostic test that was supported in the literature and represented a common method of practice (i.e. MRI, CT, scintigraphy, repeat x-ray). Where we were unsure of the clinical aspects of a reference standard, consultation with a local hand surgeon was used to clarify (K. Faber, MD, oral communication, June 2012). We also required that studies incorporated evidence of diagnostic accuracy, including those noted above in our search criteria or that provided enough data to derive such information manually. Exclusion criteria included: studies with participants outside the age range of 18–80, studies with the use of scaphoid fractures outside the acute stage of healing (>3 weeks), and the use of diagnostic test standards uncommon in the literature. We did not include books, manuals, or single case based research.

2.2. Quality scoring

A scoring system found in previous literature was used in assessment of methodological quality for diagnostic tests (Sackett et al., 2000; Walton and Sadi, 2008). Each paper was scored by two reviewers according to the inclusion criteria described below. Where disagreement in ratings occurred, the two raters met to discuss and obtain consensus. Where consensus could not be reached, a third (senior) author was consulted. All discrepancies were solved through this process. This scoring system assessed the quality of articles based on criteria with regards to risk of bias in diagnostic studies drawn from Sackett et al. (2000). The indicators of quality were as follows:

Criterion 1: Was there an independent, blind comparison with a reference (‘gold’) standard of diagnosis?

Criterion 2: Was the diagnostic test evaluated in an appropriate spectrum of patients (like those in whom it would be used in practice)?

Criterion 3: Was the reference standard applied regardless of the diagnostic test result?

Criterion 4: Was the test (or cluster of tests) validated in a second, independent group of patients?

Using these criteria, papers that score positive on at least 3 of the 4 criteria were considered of high quality. Those scoring 2 were moderate quality, and those scoring 0 or 1 were low quality. These scores were retained as potential moderator variables in the statistical pooling procedure.

2.3. Data extraction and analysis

In an effort to obtain all relevant literature, a method of acquisition suggested by Coronado et al. (2012) was used. Two researchers independently extracted relevant data to be included and compared findings to ensure consistency. If information was incomplete, an attempt was made to contact the study’s primary author for clarification. If no response was obtained after 2 attempts at contact, the study was excluded from this review. Once data were retrieved, a database was developed and then analyzed using the Meta-Disc v1.4 software (Zamora et al., 2006). The statistic chosen to aggregate findings was the positive likelihood ratio (PLR), a ratio of sensitivity to 1-specificity that provides the magnitude of change in probability that a condition exists given a positive result. This was chosen due to its relatively simple adaptation to clinical use. Given the high likelihood of heterogeneity within the client populations, a random-effects model was used for statistical pooling (Borenstein et al., 2012).

2.4. Moderator analysis

Where significant heterogeneity was found across pooled effect sizes, a moderator analysis was undertaken to identify the cause of the heterogeneity. A moderator can be considered a stratification variable. Comparison within and across levels of the variable can be used to identify moderators, similar to an Analysis of Variance approach. A Q statistic with associate p value can be calculated to determine deviation from homogeneity, and the I² statistic indicates overall degree of heterogeneity (Higgins et al., 2003). A coding scheme was developed which included the following: paper quality (high vs. low based on median split), geographic region, type of diagnostic reference standard used, sampling frame (emergency room or GP office), and length of interval from injury to initial assessment (<1 week vs. 1–3 weeks).

2.5. Publication bias

Smaller studies with positive outcomes may exhibit exaggerated effect sizes, while studies with negative results are less likely to get published, the so-called ‘file drawer effect’ (Warden et al., 2008). In both cases, the calculated effect size may be subject to a systematic publication bias that inflates its magnitude. In an effort to account for this, a fail-safe N statistic was calculated and used to determine if the outcomes appeared to be influenced by this bias (Rothstein et al., 2005). This statistic calculates the minimum number of studies with a negative result that would be required in the analysis to nullify a significant effect. We used a common rule of thumb, in assuming that any predictor with a fail-safe N statistic greater than 5 times the number of primary sources included in the analysis was robust to publication bias (Rosenthal, 1979).
3. Results

Fig. 1 displays the search strategy and results. The primary search yielded 384 relevant articles. Application of inclusion criteria to the titles reduced the pool of literature to 54 articles. Further review of abstracts reduced the number of articles to 14. A manual search of the reference lists of the selected articles yielded an additional article meeting the same criteria. Thus a total of 15 articles were identified and underwent a full review (Table 1). All met our inclusion criteria, but two from the same author group (Stenvoorde et al., 2006a,b) did not provide data adequate for pooling. Despite attempts to contact the authors we were unable to obtain the data and therefore the final pool of primary sources was 13, following a total of 1812 subjects. Four clinical tests ("clamp" sign, scaphoid compression test, anatomical snuffbox (ASB) tenderness test, and scaphoid tubercle tenderness test), eight clinical assessment techniques (thumb movements, resisted supination, wrist flexion, wrist extension, grip strength, assessment of ulnar deviation, and assessment of swelling in the snuffbox) and seven descriptive factors (male, female, simple fall, fall from height, unknown mechanism of injury, other mechanism of injury and sport injury) were described and evaluated for their diagnostic accuracy amongst the remaining pool of 13 papers.

Three clinical tests and three demographic factors had been evaluated in at least 3 independent cohorts. The three tests were the scaphoid compression test (Waeckerle, 1987; Chen, 1989; Esberger, 1994; Waizenegger et al., 1994; Grover, 1996; Parvizi et al., 1998; Unay et al., 2009), ASB tenderness test (Waeckerle, 1987; Freeland, 1989; Waizenegger et al., 1994; Grover, 1996; Parvizi et al., 1998), and scaphoid tubercle tenderness test (Freeland, 1989; Grover, 1996; Parvizi et al., 1998). The three descriptive factors were male gender, female gender and simple fall as the mechanism of injury. Figs. 2 and 3 illustrate the forest plots for each of the three clinical tests and three demographic factors.

All three clinical tests had positive predictive likelihood ratio (PPLR) values, which were low but statistically significant (Fig. 2a–c). Based on its PPLR, the scaphoid compression test (PPLR 2.37, 95% CI 1.27–4.47) demonstrated a higher diagnostic ability to identify a scaphoid fracture than the ASB tenderness test (PPLR 1.52, 95% CI 1.12–2.06) and scaphoid tubercle tenderness test (PPLR 1.67, 95% CI 1.33–2.09).

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**Table 1**

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Significant heterogeneity was present for all 3 clinical tests. In the case of the pooled data from both the scaphoid compression test and the tubercle tenderness test no clear moderator variable could be identified. However, in the case of the pooled data from the ASB tenderness test, the study by Waeckerle (1987) appeared to be an outlier. Removal of that data point resolved the heterogeneity with the remaining cohorts providing PPLR of 1.35, 95% CI 1.21–1.51 (Fig. 4). The reason for the discrepancy between this and the other four papers was unclear.

None of the three descriptive factors revealed a PPLR that was statistically greater than parity (1.0) nor were they clinically significant. Male gender (compared to females) had a PPLR of 1.26 with a lower limit of the 95% CI right at 1.00, suggesting near statistical significance but little clinical significance. Moderate
heterogeneity existed within each of the effect sizes, but an appropriate moderator variable could not be found (Fig. 3). The fail-safe N statistic was 69, 87 and 33 for ASB Tenderness Test, the Scaphoid Compression Test, and the scaphoid tubercle tenderness test, respectively. These values suggest the findings for the three clinical tests are robust to publication bias.

4. Discussion

We have described the results of a systematic review and statistical pooling procedure to determine which clinical tests might be used with confidence in the identification of a scaphoid fracture. The systematic review identified a number of clinical tests and clinical factors that have been evaluated for their usefulness in diagnosing scaphoid fractures, with 6 factors appropriate for statistical pooling based on our a priori decision to only pool the results of tests that have been evaluated in at least 3 independent cohorts. By requiring a minimum of 3 primary sources, the effect of a single disparate finding could be more meaningfully identified and explored, which would not have been possible with only 2 sources. The scaphoid compression test had the highest PPLR (2.37) of the tests analyzed. Clinically, this represents a marginal increase in diagnostic ability compared to the ASB tenderness test and the scaphoid tubercle test. (McGee, 2002) Although results revealed that the three tests demonstrated statistical significance, they also indicated that each test was of questionable clinical usefulness when used in isolation for discriminating between the presence and absence of a scaphoid fracture. Analysis of the pooled data for the three clinical tests indicated significant heterogeneity raising questions as to the accuracy of the pooled estimates across all conditions.

The pooled data for the descriptive factors did not demonstrate statistical significance with poor diagnostic accuracy and a moderate degree of heterogeneity. When such heterogeneity exists among effect sizes, one may speculate the possibility that outcomes of tests may be context specific, the nature of which we have been unable to determine. The lack of robust results implies that caution needs to be used when interpreting the results of the included studies and this higher order analysis overall. It is important that in order for a test to be recommended for clinical use, the primary evidence source should be internally valid (Sackett et al., 2000). Four criteria were used to determine internal validity of individual studies. None of the studies reviewed satisfied all of the four criteria. Some of the studies met three of the four criteria but many satisfied only two. Out of the 13 studies analyzed, not one satisfied the fourth criteria: that the test or cluster of tests be validated in a second, independent group of patients. Independent analysis would have increased confidence in the findings of the original studies and improved external validity.

A choice was made to use only those tests and factors, which had been evaluated in at least three independent samples. Statistical pooling of data from only two studies would not have been as meaningful and could have potentially led to misleading results, especially where heterogeneity exists. There were some tests and factors that were not included in the pooling and analysis due to the inability to obtain original data despite multiple attempts. Readers should be aware that with a relatively small pool of primary literature, the addition of one or two sources could lead to differences in the calculated effects. The fail-safe N provides some protection against nullifying the calculated effects with the addition of one extra paper, but fail-safe N is only calculable for significant findings. For those that have been reported to be non-significant in this paper, additional sources may have resulted in significant effects. However, this concern is tempered somewhat by the generally low clinical significance of the tests, which would not be expected to change with the addition of one or two sources. This lack of information eliminated the pooling of data for the “clamp” sign and assessments of resisted supination, ulnar deviation and swelling in the ASB. Future authors are encouraged to provide adequate data for statistical pooling, including frequencies of positive and negative findings across the diagnostic classifications.

There is currently little to no consensus of a reference “gold” standard for identifying scaphoid fractures (Duckworth et al., 2011). The reference standards used in the primary sources included any or all of x-ray, CT scan, MRI, bone scintigraphy, and clinical signs, often with tests repeated after 1–2 weeks. Currently, the most common standard reported in our pool of literature is evidence of fracture on radiographs two weeks after the injury. This lack of consistency may have explained some of the heterogeneity in our results, although our moderator analysis did not support this. While only those primary sources, which used adequate clinical tests, have been included, the results of our, and any subsequent review should be interpreted with caution in light of the lack of standardized testing protocols.

Arguably the most important limitation to consider is the consistent heterogeneity amongst effect sizes, which was difficult to explain. The simple interpretation is that the diagnostic accuracy of the tests and factors identified here may be context-dependent, but due either to limited reporting or a variable we have not considered, the important contextual factors are unclear. Another potential limitation is that data may exist that were not included in this pooled analysis. This is true in at least one case in which we were unable to contact the author group. It is likely that other examples of data exist that are either unpublished, or not published in the databases searched. While we are confident that we have identified the most prominent data in the area, the possibility of missed or unpublished data speaks to the value of ongoing updates of reviews and higher order analyses at regular (e.g. 5-year) intervals. In the future, consideration of various strategies may help to improve the identification of scaphoid fractures. The results of our approach would suggest that none of the tests or factors evaluated

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Fig. 4. ASB tenderness with removal of outliers.
provide strong diagnostic accuracy in isolation. However, it is possible that groups of tests may be more useful, a hypothesis that we are unable to test with the data as presented but that has found some support by Parvizi et al. (1998) and Rhemrev et al. (2010). Appendix A provides a clinical example of the utilization of the diagnostic tests previously discussed to help in the identification and management of scaphoid fractures. Clinical prediction rules have proven useful to improve clinical decision making with respect to use of diagnostic imaging in ankle and neck problems, and may be similarly useful in scaphoid fractures. Better uniformity might minimize the effect of clinical diversity and potentially the heterogeneity among studies (Higgins et al., 2003). Consistent use of blinding amongst researchers and establishment of consistency within the literature pertaining to operational definitions of clinical tests and outcomes could further improve the estimate of diagnostic accuracy (Higgins et al., 2003).

5. Conclusion

A total of 13 articles underwent a full review. Of the clinical tests, assessment techniques and descriptive factors identified, three clinical tests (ASB tenderness test, scaphoid compression test, scaphoid tubercle tenderness test) and three descriptive factors (male gender, female gender and simple fall) were appropriate for statistical pooling. Despite the statistical significance of the pooled results for the clinical tests, the PLR values revealed generally poor diagnostic accuracy with moderate to high heterogeneity between studies. The values for the three demographic factors were not statistically significant. Further studies with description of sample characteristics, blinded assessments, and agreement on a reference standard are recommended. The results of this analysis would suggest that clinicians are not currently able to reliably identify scaphoid fractures through conservative clinical tests.

Statement of ethics

No formal review was required for the development of this article. Because all literature utilized in the development of this article had previously received documentation of approval from their respective ethics boards and the higher order analysis performed represents a summation of existing literature, no further obligations were required from local ethics review.

Conflict of interest

The authors declare that there is no conflict of interest regarding material reported, financial or otherwise, in formulation of this manuscript.

Appendix A

Case example

Jared is a 27-year-old triathlete. He was training early one morning on his road bike, when he hit some gravel and fell off his bike. He recalls taking most of the impact through his left hand as he reached out to break his fall. He reported that his left wrist began to swell immediately, and he was unable to grip the left handlebar for the rest of his training session. He later presented to his primary care physiotherapist for assessment of his wrist and hand.

Subjectively, he reports a reluctance to move either the thumb or wrist since getting off his bike and pain at the base of his left thumb, both at rest and with movement. Jared describes his pain as dull and constant in nature encompassing the radial aspect of his hand and wrist at rest (P1). Active movements as well as gripping actions result in a sharp pain in the same area (P2).

At this point in the assessment, there are several differential diagnoses:

- Contusion to the thenar eminence
- Scaphoid fracture — 70–79% of hand/carpal # (Dennis et al., 2011)
- Triquetrum fracture — 14% of hand/carpal # (Dennis et al., 2011)
- Distal radius fracture (Colles fracture) — 44% of wrist/forearm (Dennis et al., 2011)
- Radial collateral ligament sprain
- Extensor pollicis brevis/abductor pollicis longus strain
- Scapho-lunate dissociation

Due to the traumatic nature of the mechanism of injury (fall), a fracture may be suspected. A distal radius fracture (Colles fracture) may be considered; however, such an injury is more common in pre-adolescent and older populations. A fall onto an extended wrist and pain in the specific area described may lead one to suspect a scaphoid fracture. At this point in the assessment and based on clinical experience and knowledge of her patient population, the therapist estimates the probability that Jared has a true scaphoid fracture is 20% (Pillai and Jain, 2005).

A physical examination is performed. Due to the mechanism of injury, in the absence (or presence) of a fracture, ligamentous sprain and/or muscular strain are still probable. Assessment of active and passive movements of his thumb and wrist are painful and limited and offer little in the way of differentiation due to the presence of an acute inflammatory state. Palpation of the flexors and extensor muscles of the forearm does not reproduce his pain. Further palpation of the thenar eminence reveals tenderness but does not reproduce his primary pain. Isometric testing of the muscles of the forearm, wrist and hand reveals moderate strength and does not provoke his specific pain. At this point, contractile structures are less likely to be the source of symptoms. While some of the differential diagnoses are now less likely, others remain, and the current probability that Jared has sustained a scaphoid fracture is 40%, or 1:1.5 odds. To aid in differentiation and increase the likelihood of the primary diagnosis, a careful selection of special tests is warranted.

Given the results of this higher order analysis, tests considered in assessment include the scaphoid tubercle tenderness test, anatomical snuffbox tenderness test and scaphoid compression test. A choice is made to perform the scaphoid compression test. Based on the higher order analysis results, reproduction of Jared’s pain with this test may increase the probability of the existence of a scaphoid fracture. When performing the scaphoid compression test, Jared winces in pain and reports reproduction of his primary pain. To determine post-test odds one multiplies the pre-test odds by the PPLR to obtain the post-test probability. In Jared’s case, the pre-test odds were 1:1.5. The post-test odds now become (1 × 2.37):1.5, or 2.37:1.5. Convert this into a probability by dividing 2.37/(2.37/C15) to get a post-test probability of 61.2%, a small but potentially meaningful shift in the likelihood that a scaphoid fracture exists. At this point however, the therapist is still uncomfortably close to chance (50%) with a 38.8% chance of being wrong, meaning that it would be unreasonable to declare a definitive diagnosis. The clinician then must make the decision to continue with clinical testing, refer for diagnostic imaging, or treat the condition using her current knowledge. Knowing the risks of being wrong (unnecessary immobilization) increasing confidence in the diagnosis seems a reasonable way forward.

The physiotherapist may now use the post-test odds calculated above as the pre-test odds for additional testing. Using odds of...
2.37:15, a positive test on the scaphoid tubercle tenderness test (PPLR 1.67) leads to post-test odds of (2.37 × 1.67) or 4.04:1, the probability of scaphoid fracture is now 72%. The clinician can then continue to move forward with clinical tests, refer for additional diagnostic procedures, or proceed with appropriate treatment. For ease of use in practice, a nomogram can also be used to determine post-test odds from PLR and pre-test odds (Fig. 5). A straight line (index line) is drawn from the pre-test probability to the PLR, and through the right column. Where the index line crosses on the right is where the post-test probability is approximated. This is a practical tool that can be used to obtain results quickly, aid clinicians in interpretation of clinical tests and use evidence-based research to strengthen the clinical reasoning process.

References


