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The utility of cross-sectional imaging in the management of suspected scaphoid fractures

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Abstract

Introduction: Scaphoid fractures are the commonest carpal bone fracture. If untreated they pose significant risk to patients, thus if a scaphoid fracture is suspected, patients are managed with immobilisation. Although scaphoid fractures may be difficult to diagnose on plain radiography, sometimes for months after injury, ongoing radiographic surveillance is preferred due to its low upfront cost. Patients in immobilising casts for long periods experience significant personal and social ramifications such as difficulty working and self-caring. This study examines whether cross-sectional imaging by computed tomography (CT) or magnetic resonance imaging (MRI) is quicker than serial X-ray surveillance at allowing a scaphoid fracture to be either excluded or confirmed. **Methods:** A retrospective record review was performed of the 1709 patients who presented to Royal North Shore Hospital in 2015 with wrist injuries, finding 104 patients clinically suspicious for a fractured scaphoid. **Results:** All patients were examined by X-ray during their initial hospital presentation, providing 33.7% of final diagnoses in 0.6 $\pm$ 1.7 days. However, if initial X-ray proved inconclusive, subsequent serial X-ray surveillance made a final diagnosis after a mean of 24.1 $\pm$ 17.2 days, with some being immobilised for up to 67 days before diagnosis. Cross-sectional imaging significantly reduced diagnosis time to 9.8 $\pm$ 5.8 days ($P = 0.0016$), with a maximum immobilisation time of 24 days. **Conclusion:** Cross-sectional imaging allows for faster scaphoid fracture diagnosis than X-ray. We propose a protocol for scaphoid fracture diagnosis wherein patients undergo two episodes of X-ray separated by 7 days, followed by a single MRI if clinical suspicion remains, minimising unnecessary immobilisation.

Introduction

Scaphoid fractures are the commonest carpal bone fractures, representing 2–6% of all fractures.[1,2] They are commonly misdiagnosed and may be difficult to appreciate on plain radiography, especially if non-displaced. While subtle scaphoid fractures tend to become more visible on plain film after 1–2 weeks,[3] they may remain radiographically occult for over 6 weeks.[4]

Despite X-ray being the preferred primary investigation, a large patient cohort review found that up to 16% of scaphoid fractures were missed on initial X-ray.[3] Due to the distal-to-proximal blood flow, a missed waist scaphoid fracture may disrupt blood flow to the proximal bone, causing long term morbidity by avascular necrosis, resulting in early-onset osteoarthritis of the wrist, chronic pain and loss of function.[4] Hence, based upon clinical signs alone (such as anatomical snuffbox tenderness), clinicians immobilise patients with a scaphoid cast until radiological confirmation becomes available, resulting in loss of function and time off work, particularly if injury is to the dominant hand.

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Immobilisation will have been unnecessary if scaphoid fracture is subsequently excluded.[5,6]

Cross-sectional imaging (CSI) techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) avoid delayed diagnosis of non-displaced and radiographically occult scaphoid fractures,[2] but due to the higher cost of cross-sectional imaging compared to plain X-ray (CT: AU$220.00, MRI: AU$448.00, X-ray: AU $34.75–$93.75[7]), most emergency departments (EDs) and outpatient clinics, even after multiple visits, use ongoing radiographic surveillance despite evidence to suggest that MRI is the gold-standard diagnostic technique for scaphoid fracture.[2,3,5]

The aim of this study is to investigate the time before a final diagnosis can be made, either confirming or ruling out a scaphoid fracture, if only X-ray is used, or if X-ray is used in conjunction with either CT or MRI. Furthermore, we aim to suggest an algorithm to optimise patient care while still economically using healthcare resources.

Methods

With the approval of the Northern Sydney Local Health District Human Research Ethics Committee, a retrospective record review was performed of the electronic medical records (EMR) of all 1709 patients presenting to the ED at Royal North Shore Hospital (RNSH), a major tertiary referral hospital in Sydney, Australia, who were examined for a wrist injury from 01 January to 31 December 2015. The patients were found via a search of the radiology information systems for patients whose ED presentation included a history, physical examination and series of plain X-rays of the wrist, comprising 4 views, including a posterior-anterior (PA), an oblique PA, a lateral and a single specific scaphoid-angled view. Each patient's EMR documents were searched according to their EMR identification numbers to find all patients over the age of 5 years with a confirmed or suspected scaphoid fracture for inclusion in the cohort. The 12 patients excluded from the cohort never received a final diagnosis or did not return to RNSH for their final diagnosis. Patient imaging includes X-ray, CT and MRI. In none of the 1709 cases evaluated from the RNSH ED was a nuclear medicine scan used. The imaging modalities each patient underwent were chosen on a case-by-case basis by clinicians in ED and in hand and wrist outpatient clinics, in conjunction with patient wishes, and were not based on any standard algorithm. Anyone who presented to the RNSH ED with a scaphoid fracture which was missed upon initial presentation, then represented to another hospital with ongoing symptoms was not able to be captured by our search and could not be included in this study.

The demographic data collected from the EMR was: date of birth, sex, date of injury, provisional diagnosis and date, initial imaging technique and date, any subsequent imaging and dates thereof and further management of patient care. These data were collected by reviewing patient discharge summaries, imaging reports and ED or fracture clinic patient progress notes. The imaging to diagnosis time interval (in days) (subsequently referred to as the IDI) between the initial image and the final diagnosis was found for each patient. A final diagnosis was defined as the point at which clinical and imaging evidence coincided to provide a definitive account of the patient's condition.

All statistical analysis was performed on GraphPad Prism 7.00. The IDI is presented as mean $\pm$ standard deviation and since the dataset is not normally distributed, the Mann–Whitney *U*-test examines significant differences between IDIs. A Kaplan–Meier plot with a log-rank test compares the IDI for cases in which only X-ray was used, with those in which X-ray was used in combination with another imaging modality (CT or MRI). In this study, a *P*-value of less than 0.05 holds statistical significance.

Any cost analyses were performed based on the Medicare Benefits Schedule (MBS) operating from 03 April 2016.[7]

Results

In this study, the 1709 patients presenting to RNSH ED with wrist injuries were initially surveyed. Cohort demographic data are presented in Figure 1.

Of these, only 104 patients (6.1% of the total cases examined) were included in this study, and until a definitive diagnosis was made, these patients were presumed to have scaphoid waist fractures and were managed with an immobilising cast. The mean age of the included patients was 31.4 $\pm$ 23.3 years, with 57 (54.8%) being male and 47 (45.2%) being female. Of the included suspected scaphoid fractures, 52 (50.0%) were found to have a definite scaphoid fracture, evident on some imaging modality, and 52 (50.0%) cases initially diagnosed as scaphoid fractures based on clinical evidence were found to have no scaphoid fracture upon subsequent assessment (Fig. 1). Of the 52 definite scaphoid fractures diagnosed, 54.2% were of the waist and 45.2% were of the distal pole or tubercle.

We found that X-ray was the first line of imaging for all 104 (100%) of patients presenting to ED with a wrist injury. CSI was less common, with only 4 (3.8%) of patients receiving a CT and 31 (29.8%) receiving an MRI.

Using exactly one-four-projection X-ray series alone, a definitive diagnosis of scaphoid fracture could be made in

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35 (33.7%) of the patients (Fig. 2), and 30 (57.7%) of the 52 definite scaphoid fractures were discovered. However, further imaging was required to reach a final diagnosis in the remainder of the cohort. Those who required exactly one X-ray and no CSI to reach their final diagnosis had a mean IDI of 0.6 ± 1.7 days (Fig. 3A).

In 42 (40.4%) of the patients, exactly two imaging episodes were required to make a diagnosis (Fig. 2), and 13 (25%) of the definite scaphoid fractures were discovered (4 by X-ray, 3 by CT and 6 by MRI). Patients who received two episodes of imaging had a mean IDI of 10.5 ± 9.6 days (Fig. 2), however, if both images were X-rays, the IDI was 14.6 ± 11.8 days, significantly higher than if patients received an X-ray and a CT (4.5 ± 2.5; $P = 0.0054$) or an X-ray and an MRI (6.7 ± 4.1; $P = 0.0043$) (Fig. 3A).

In 22 (21.2%) of the patients, exactly three imaging episodes were required to reach a final diagnosis (Fig. 2)

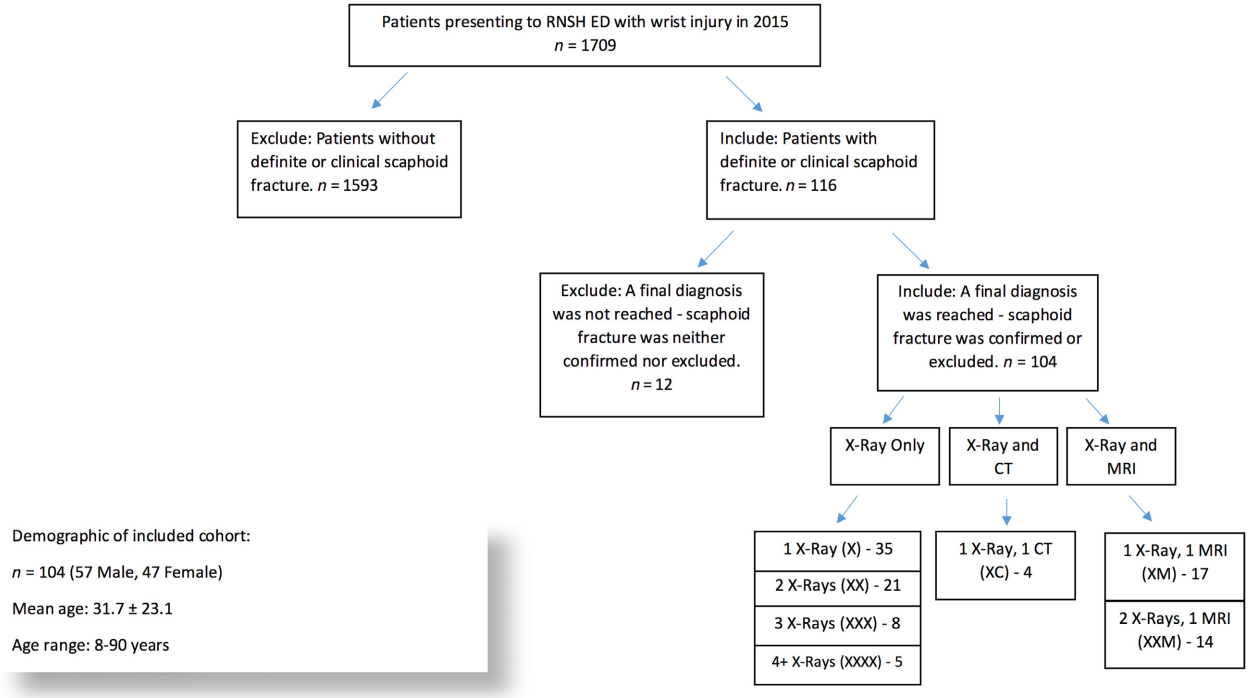

Figure 1. Inclusion criteria for the study. The 104 patients included in the cohort were then sorted into X-ray (X, XX, XXX, XXXX), X-ray with CT (XC) and X-ray with MRI (XM, XXM) based on all episodes of imaging prior to final diagnosis. RNSH, Royal North Shore Hospital; ED, emergency department.

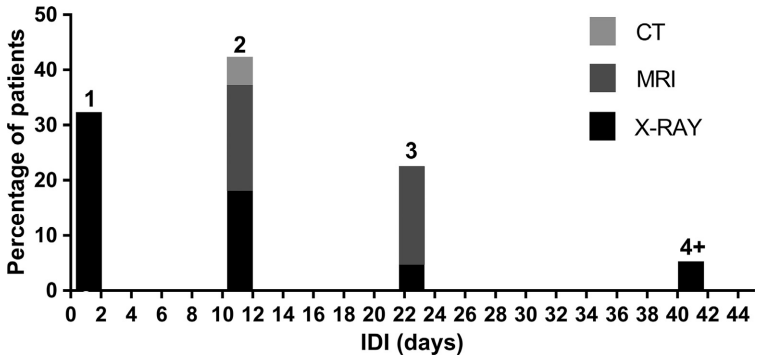

Figure 2. The distribution of patients by the number of images of any sort they underwent – represented by the number above each column, imaging sequence – indicated by shading as per key, and injury to diagnosis interval (IDI) associated with each number of images – on the *x*-axis.

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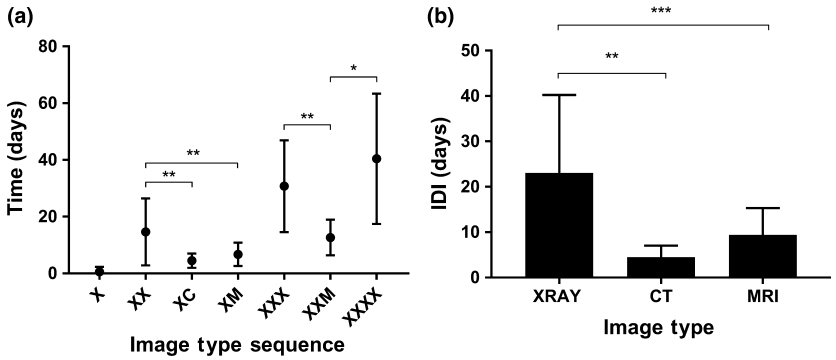

Figure 3. (a) The chronological sequence of images taken to reach the final diagnosis, and the IDI for each. X = exactly 1 X-ray, XX = exactly 2 X-rays, XXX = exactly 3 X-rays, XXXX = 4 or more X-rays, XC = exactly one X-ray and CT, XM = exactly one X-ray and MRI, XXM = exactly 2 X-rays and one MRI). XC and XM are associated with a significantly shorter and less variable IDI than XX ($P = 0.0054$ and 0.0043 respectively) and XXM is associated with a significantly shorter and less variable IDI than XXX and XXXX ($P = 0.0076$ and 0.00277 respectively). (b) The mean IDI of each imaging modality after 'X' group is removed. X-ray alone is associated with a longer IDI than CT ($P = 0.0011$) and MRI ($P = 0.0002$). (*$P < 0.05$; **$P < 0.01$; ***$P < 0.005$).

and 7 (13.4%) of the definite scaphoid fractures (2 by X-ray and 5 by MRI). The mean IDI with three imaging episodes was 20.6 ± 13.3 days in an immobilising scaphoid cast (Fig. 2), however, if all three images were X-rays, the IDI was 30.8 ± 16.1, significantly higher than when a patient received two X-rays and an MRI (12.6 ± 6.3; $P < 0.0001$) (Fig. 3A). In our cohort, no patient received a CT scan following 2 X-rays.

In five (4.7%) cases, four or more imaging episodes were required to reach a final diagnosis, and each time, all images were X-rays (Fig. 2), and 3 (5.8%) of all definitive scaphoid fractures were so demonstrated. The mean IDI was 40.4 ± 23.0 days of immobilisation (Fig. 2), significantly more than all other possible sequences of images (Fig. 3A, and B).

If CSI was utilised following an ambiguous initial X-ray, the standard deviation was lower than if plain radiographic surveillance was continued (Fig. 3B). Moreover, CT and MRI both significantly reduce IDI if they are used at some point in patient management of clinically suspected scaphoid fracture ($P = 0.0011$ and $P = 0.00002$ respectively) (Fig. 3B).

The IDI was compared for patients who only received X-rays and patients who received CSI after their initial X-ray, using a log-rank test of a Kaplan–Meier survival plot (Fig. 4). Patients whose final diagnosis was made based on the first X-ray have been removed to show the significant decrease in IDI conferred by performing CSI (IDI = 9.8 ± 5.8) instead of ongoing radiographic surveillance (IDI = 24.1 ± 17.2), if there is clinical suspicion for a scaphoid fracture following a negative initial X-ray ($P = 0.0016$). Furthermore, the significance of MRI decreasing IDI compared to ongoing X-ray ($P = 0.0002$) is stronger than that of CT ($P = 0.011$), potentially due to the paucity of CT data in the cohort.

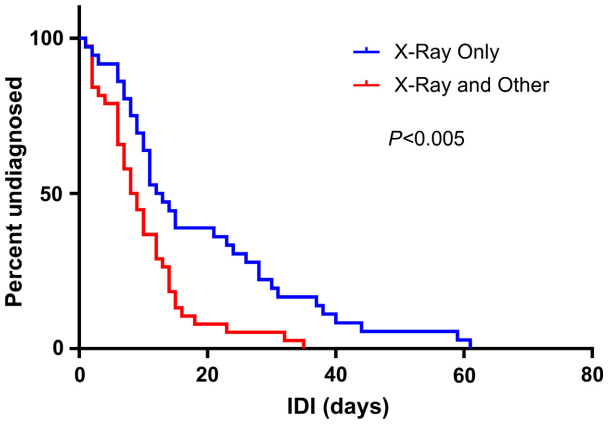

Figure 4. IDI if the initial X-ray did not yield a final diagnosis. Using an imaging modality other than X-ray significantly reduces the IDI.

Discussion

In this retrospective study, patients with clinically suspected scaphoid fractures with normal initial wrist radiographs were found to have a final diagnosis reached most efficiently if an imaging modality other than X-ray was used. In 33.7% of patients a final diagnosis was quickly reached based on the initial radiograph, but the remaining patients required follow-up imaging and had to wait on average 16.8 ± 14.5 days to reach their final diagnosis: 24.1 ± 17.2 days if X-ray alone was used and 9.8 ± 5.8 if CSI was employed. Those who only require one X-ray to reach a final diagnosis will not be subject to

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unnecessary immobilisation, and therefore their management is already optimal, thus may be excluded from analysis (Figs. 3B and 4).

The prevalence of X-ray is not commensurate with its efficacy: whilst 100% of patients receive at least one X-ray, only 66.3% of wrist injuries were diagnosed using X-ray alone. But, in every instance where a patient is given a CT or MRI, it may be used to immediately provide the patient's final diagnosis, suggesting that these tests are more powerful definitive diagnostic tools than X-ray. However, performing an X-ray does not guarantee reaching a final diagnosis. Several prospective studies have found that a protocol incorporating rapid MRI have a significantly lower IDI than a repeat X-ray protocol.[8–10]

The high standard deviation of X-ray IDI (SD = 16.5 days) suggests more variability than for MRI (SD = 5.9 days) or CT (SD = 2.5 days) (Fig. 3B). Moreover, there was the potential for a lengthy IDI, with some patients being in a cast for up to 67 days before a final diagnosis was reached using X-ray alone. Such long IDIs were seldom seen if CT or MRI were used, with the maximum IDI for CT being 7 days, and MRI being 24 days.

False-positive clinically suspected scaphoid fractures lead to unnecessary immobilisation in up to 75% of patients.[11,12] Patients with fractures of the distal scaphoid (including the tubercle) also undergo unnecessary immobilisation. In our study, 45.8% of scaphoid fractures were of the distal scaphoid. This injury is less significant, never leading to avascular necrosis, and requiring treatment largely for comfort.[13] However, one patient presented with a fracture of both the scaphoid waist and tubercle, highlighting the importance of CSI to detect all injuries. Clinical symptoms of distal scaphoid fractures are similar to those of waist fractures, thus all suspected scaphoid fractures are managed as waist fractures. Patients given the final diagnosis of distal scaphoid fracture did not require immobilisation, thus were unnecessarily immobilised for 15.2 ± 18.5 days if the fracture was missed on initial X-ray. Hence, 74.0% of patients in our cohort with either distal scaphoid fracture or no scaphoid fracture were unnecessarily immobilised for a mean of 11.5 ± 12.4 days.

Several studies found that while X-ray had a 60–70% scaphoid fracture sensitivity, MRI/CT images consistently had a sensitivity of over 95%.[13–15] A recent prospective study found that when clinically suspected scaphoid fracture patients were imaged, MRI detected 54% more scaphoid fractures than X-ray.[16] Moreover, X-ray sensitivity has been found to decrease from 60% in the initial to 30% in repeat X-rays, validating the claim that serial X-ray surveillance is an inefficient technique.[17] This technique of serial surveillance was first suggested as a primary approach to scaphoid fracture diagnosis in 1949, and since has been repeatedly called into question.[18] One study concludes that signal changes on MRIs of uninjured patients may mimic scaphoid fractures, leading to false-positive diagnoses.[15] However, in our study only 32.3% of patients who underwent MRIs were given the final diagnosis of scaphoid fracture, and in none of these instances did the consultant's final clinical examination reject this diagnosis.

The increased time, and perceived and actual costs associated with CSI compared to X-ray have been factors in X-ray being maintained as standard practice in management of clinically suspected scaphoid fractures. Despite the high inter-observer reliability of CT, MRI is the preferred imaging modality due to its reduced radiation risk, and higher sensitivity to non-displaced fractures.[3] The American College of Radiologists recommended MRI as the best second-line investigation, however, since then the number of MRIs performed in scaphoid fracture diagnosis has not significantly increased[2] despite MRI changing the management of clinically suspected scaphoid fracture cases in 92% of cases.[12] Additionally, it is reported that in approximately 10% of cases scaphoid fractures are concomitant with other fractures of the hand or wrist, fractures which are often radiographically occult, such as capitate[12,16] and lunate fractures.[19,20] Frequently, the signs and symptoms of clinically suspected scaphoid fractures are due to other bony or soft tissue injuries,[2,11,21] as in 50.0% of our cohort. Unlike X-ray, CSI may confirm or eliminate scaphoid fracture and reveal other soft tissue or cartilage injuries which may require a change in management. MRI is usually chosen due to high negative predictive value of no bone oedema excluding a fracture. But despite its radiation risk, CT may be used preferentially in some cases since MRI is difficult to obtain urgently, and CT demonstrates complex bony anatomy with better detail. The increased time of booking and performing an MRI compared to X-ray is a factor in favour of performing X-ray or CT, however, it has been found that a limited wrist MRI takes 5–10 min, comparable to an X-ray scaphoid sequence,[17] and does not require cast removal.[11]

Cost analysis based on the MBS reveals that X-ray surveillance is cheaper than CSI, with respect to imaging cost and follow-up clinic presentations.[7] However, the true cost to the patient and the healthcare system likely outweighs these small differences in imaging cost. Despite an X-ray being cheaper than a CT or MRI,[10] multiple studies have found that there is either no significant difference in cost[8,22] or that serial radiographic surveillance is less cost effective than CT or MRI,[10,14,23] and that MRI is overall more cost-effective than CT due

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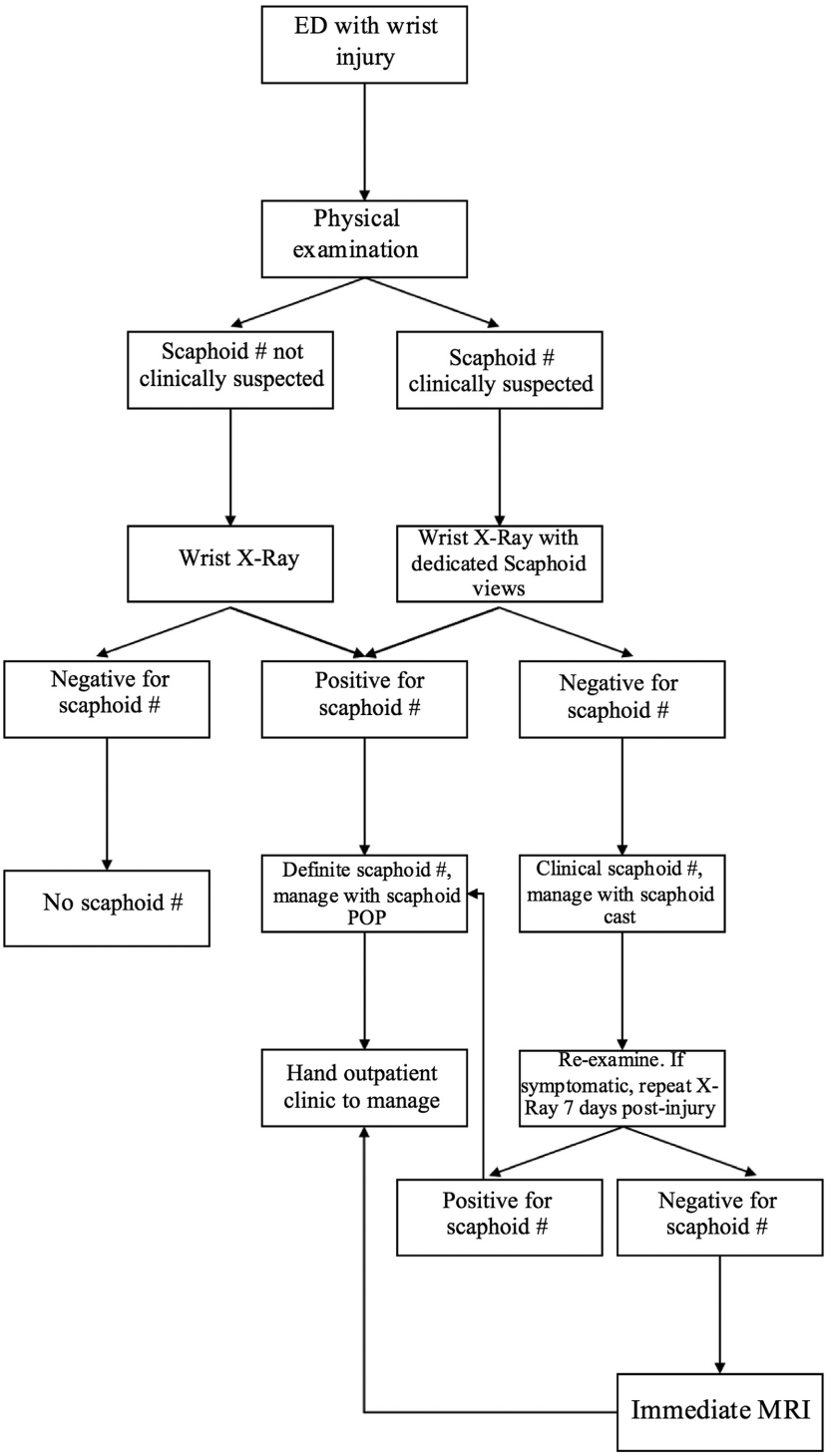

Figure 5. Proposed algorithm for scaphoid fracture management. POP, plaster of paris; #, fracture.

to its higher sensitivity.[23] Patient productivity is a major issue with prolonged unnecessary immobilisation of clinically suspected scaphoid fractures, since immobilising scaphoid casts make working difficult, forcing patients to take leave from work and lose wages. Days off work were significantly reduced for clinically suspected scaphoid

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fractures if an MRI was performed quickly after injury,[8,22] and patients with average or above average incomes were found to be willing to pay the higher upfront cost for faster diagnosis.[10] To save on cost even further, a cheaper low field-strength MRI has been found to have statistically similar rates of detecting carpal fractures as higher field-strength MRI[16] and is as cost-effective as performing two X-rays.[11] We propose an algorithm for suspected scaphoid fracture management following wrist trauma (Fig. 5): If the initial X-ray is negative, but there is clinical suspicion of a fracture, the patient should remain in an immobilising cast for 7–14 days, with the exact period depending on circumstances and preferences. Following re-examination in the hand and wrist clinic, the patient is still symptomatic, a second X-ray should be performed, since our study found that X-rays are the cheapest imaging modality, and most scaphoid fractures are detected by the first 2 X-rays. If the second X-ray is negative, an immediate MRI should be the next imaging study, limiting IDI to approximately 2 weeks, since patients most impacted by immobilisation are willing to pay for more expensive care in return for a shorter IDI. We aim to test this algorithm in a future prospective study, however the authors believe that the issue of standardising scaphoid fracture diagnosis requires urgent attention, and this algorithm minimises healthcare expenditure by maximising the chance of a plain-film diagnosis, whilst limiting unnecessary patient inconvenience.

The primary limitation of our study was its retrospectivity: patients could not be monitored following their final diagnosis. Hence, any incorrect final diagnoses (missed scaphoid fractures or unnecessary immobilisation) were not included. Moreover, the retrospectivity of the study prevents determination of the optimum interval between the first and second X-ray episodes, therefore our proposed 7–14 days figure should serve as a guideline until a prospective study is performed. Additionally, since no protocol was prospectively established to compare MRI and CT, it is difficult for us to make first-hand comment on their relative merits. An important complication with untreated scaphoid fracture is avascular necrosis, but due to the nature of our study it was impossible to ascertain how many patients in our cohort developed this condition.

Through retrospective review, statistical analysis of IDI and a review of the literature, our study clearly states that CSI should be used preferentially in clinically suspected scaphoid fracture diagnosis over repeat plain radiographic surveillance. Moreover, since MRI has numerous benefits over CT, it should be regarded as the gold standard for diagnosing radiographically occult scaphoid fractures.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. Hannemann PF, Brouwers L, van der Zee D, et al. Multiplanar reconstruction computed tomography for diagnosis of scaphoid waist fracture union: A prospective cohort analysis of accuracy and precision. *Skeletal Radiol* 2013; **42**: 1377–82.
2. Tibrewal S, Jayakumar P, Vaidya S, Ang SC. Role of MRI in the diagnosis and management of patients with clinical scaphoid fracture. *Int Orthop* 2012; **36**: 107–10.
3. Smith M, Bain GI, Turner PC, Watts AC. Review of imaging of scaphoid fractures. *Aust N Z J Surg* 2010; **80**: 82–90.
4. Lenoir H, Coulet B, Lazerges C, Mares O, Croutzet P, Chammas M. Idiopathic avascular necrosis of the scaphoid: 10 new cases and a review of the literature. Indications for Preiser's disease. *J Orthop Traumatol* 2012; **98**: 390–7.
5. Bethel J. Scaphoid fracture: Diagnosis and management. *Emerg Nurse* 2009; **17**: 24–9.
6. Steinmann SP, Adams JE. Scaphoid fractures and nonunions: Diagnosis and treatment. *J Orthop Sci* 2006; **11**: 424–31.
7. Australian Government Department of Health. Medicare Benefits Schedule Book Category. 2, 2015 [cited 2017 February 4]. Available from: http://www.health.gov.au/internet/mbsonline/publishing.nsf/Content/45CBF3F97BA64FBDCA257FD5000E6666/$File/201607-Cat2.pdf.
8. Bergh TH, Steen K, Lindau T, et al. Costs analysis and comparison of usefulness of acute MRI and 2 weeks of cast immobilisation for clinically suspected scaphoid fractures. *Acta Orthop* 2015; **86**: 303–9.
9. Raby N. Magnetic resonance imaging of suspected scaphoid fractures using a low field dedicated extremity MR system. *Clin Radiol* 2001; **56**: 316–20.
10. Brooks S, Cicuttini FM, Lim S, Taylor D, Stuckey SL, Wluka AE. Cost effectiveness of adding magnetic resonance imaging to the usual management of suspected scaphoid fractures. *Br J Sprots Med* 2005; **39**: 75–9.
11. Dorsay TA, Major NM, Helms CA. Cost-effectiveness of immediate MR imaging versus traditional follow-up for revealing radiographically occult scaphoid fractures. *AJR Am J Roentgenol* 2001; **177**: 1257–63.
12. Brydie A, Raby N. Early MRI in the management of clinical scaphoid fracture. *Br J Radiol* 2003; **76**: 296–300.

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13. Platon A, Poletti PA, Van Aaken J, et al. Occult fractures of the scaphoid: The role of ultrasonography in the emergency department. *Skeletal Radiol* 2011; **40**: 869–75.
14. Yin ZG, Zhang JB, Gong KT. Cost-effectiveness of diagnostic strategies for suspected scaphoid fractures. *J Orthop Trauma* 2015; **29**: e245–52.
15. De Zwart AD, Beeres FJ, Ring D, et al. MRI as a reference standard for suspected scaphoid fractures. *Br J Radiol* 2012; **85**: 1098–101.
16. Jorgsholm P, Thomsen N, Besjakov J, Abrahamsson S, Bjorkman A. MRI shows a high incidence of carpal fractures in children with posttraumatic radial-sided wrist tenderness. *Acta Orthop* 2016; **87**: 533–7.
17. Khalid M, Jummani ZR, Kanagaraj K, Hussain A, Robinson D, Walker R. Role of MRI in the diagnosis of clinically suspected scaphoid fracture: Analysis of 611 consecutive cases and literature review. *Emerg Med J* 2010; **27**: 266–9.
18. Dias JJ, Thompson J, Barton NJ, Gregg PJ. Suspected scaphoid fractures. The value of radiographs. *J Bone Joint Surg Br* 1990; **72**: 98–101.
19. Balci A, Basara I, Cekdemir EY, et al. Wrist fractures: Sensitivity of radiography, prevalence, and patterns in MDCT. *Emerg Radiol* 2015; **22**: 251–6.
20. Kaewlai R, Avery LL, Asrani AV, Abujudeh HH, Sacknoff R, Novelline RA. Multidetector CT of carpal injuries: Anatomy, fractures, and fracture-dislocations. *Radiographics* 2008; **28**: 1771–84.
21. Pillai A, Jain M. Management of clinical fractures of the scaphoid: Results of an audit and literature review. *Eur J Emerg Med* 2005; **12**: 47–51.
22. Kelson T, Davidson R, Baker T. Early MRI versus conventional management in the detection of occult scaphoid fractures: What does it really cost? A rural pilot study. *J Med Radiat Sci* 2016; **63**: 9–16.
23. Karl JW, Swart E, Strauch RJ. Diagnosis of occult scaphoid fractures: A cost-effectiveness analysis. *J Bone Joint Surg Am* 2015; **97**: 1860–8.

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