

ORIGINAL ARTICLE

Early MRI versus conventional management in the detection of occult scaphoid fractures: what does it really cost? A rural pilot study

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Abstract

Introduction: To compare the cost-effectiveness and patient impact between acute magnetic resonance imaging (MRI) management and conventional management in the diagnosis of occult scaphoid fractures in a rural setting. **Methods:** Consecutive patients presenting to a rural emergency department (ED) with a suspected scaphoid fracture were randomly assigned to either conventional management (6) or acute MRI management (10) (3 patients were excluded from the study analysis). All healthcare costs were compared between the two management groups and potential impacts on the patients' pain, mobility and lifestyle were also measured. **Results:** There were no significant differences between the two groups at baseline. There was one (10%) scaphoid fracture in the MRI group and none in the conventional group ($P = 0.42$). A larger proportion of other fractures were diagnosed in the MRI group (20% (2) vs. 16.7% (1), $P = 0.87$), as well as less clinic attendances (1 (0–2.25) vs. 4 (2.25–5)) and diagnostic services (1 (1–1.25) vs. 2 (1–3)). Median management costs were \$485.05 (AUD) (MRI) and \$486.90 (AUD) (conventional). The MRI group had better pain and satisfaction scores as well as less time of immobilisation, treatment and time off work. **Conclusion:** MRI dramatically reduces the amount of unnecessary immobilisation, time of treatment and healthcare usage in a rural setting. The two protocols are suggested to be equivalent financially. When potential societal costs, the amount of unnecessary immobilisation, low prevalence of true fractures and patient satisfaction are considered, acute MRI should be the management technique of choice. Further studies are still required to assess the best method for managing bone bruise within the scaphoid.

Introduction

The scaphoid is the most frequently fractured carpal bone and accounts for a significant portion of presentations in the emergency department (ED).^{1,2} Hand and wrist injuries are the most common work-related injury type and an important problem in the Australian workforce.³ This is especially the case in rural EDs, as upper limb injuries are the most frequent agricultural worker injuries, accounting for 37% of injuries.⁴

The most frequent mechanism of injury for a scaphoid fracture is a fall on the outstretched hand (FOOSH).⁵ The classic hallmark sign of anatomic snuffbox tenderness on examination is a highly sensitive (90%) clinical examination for a scaphoid fracture, however it is non-specific with a specificity of 40%.^{6,7} A clinically important proportion of scaphoid fractures are not demonstrated on a radiograph immediately after injury. Several authors have suggested that fractures of the scaphoid are occult in about 16% of cases on initial radiographs.^{8–11}

The tenuous blood supply to the scaphoid can cause severe potential complications and it has been suggested that these complications occur in 5–12% of all cases.^{9,12,13} There is a clear need for a fast and reliable clinical and diagnostic protocol, in order to start appropriate treatment as soon as possible, to avoid these adverse outcomes. Therefore, a cautious approach is preferred.¹³ It is standard practice for patients to be immobilised in a plaster cast for 10–14 days, followed by repeated clinical examination and repeat radiographs.^{1,7,13–15} Patients may undergo serial radiographs and clinical review at intervals over several weeks until a definitive diagnosis is made.^{5,8,9,12} It has been argued that the prevalence of true fractures is low, with 3 out of 4 patients needlessly immobilised.^{10,12,16} Patients may be unable to work or perform their daily activities, with resultant loss of earnings. Unnecessary hospital attendance, diagnostic tests and plaster casting may result in costs to the patient, the hospital and society.^{1,5,8,15}

MRI does not use ionising radiation, so is considered a safer examination. MRI has been proven to be both sensitive and specific for the detection of occult scaphoid fractures, with a suggested sensitivity and specificity of almost 100%.^{1,9,12,13,17–19} Performing an MRI when the patient first presents with a wrist injury has traditionally been considered impractical, due to its lack of availability particularly in rural areas, and large cost.^{1,9,12} However, many studies have suggested that MRI may actually be a more cost-effective imaging method, allowing an earlier definitive diagnosis and the reduction in patients being overtreated.^{11,16,20,21} The use of MRI in rural areas has increased dramatically in recent times with its greater access, and can now be included in the acute imaging pathway when managing suspected scaphoid fractures.⁷

This study focused on introducing MRI into the acute diagnostic pathway for suspected scaphoid fracture management in a rural Australian setting. The aim of the study was to compare the cost-effectiveness and patient impact between acute MRI management and conventional management in the diagnosis of occult scaphoid fractures in a rural setting.

It was hypothesised that acute MRI management would improve patient outcomes and minimise costs to the community and the Australian healthcare system.

Methods

Patients presented to the ED with a clinical suspicion of a scaphoid fracture, but negative initial radiographs were randomly assigned to conventional management or acute MRI management. Blinding was not possible due to the large differences in nature of the experimental condition. The study was performed at an inner regional medium-sized community hospital with 24,347 emergency presentations

in the 2013/2014 year.²² Data were collected between March and August 2014. Ethical approval was obtained from the Charles Sturt University Human Research Ethics Committee (Protocol Number 2013/201) and South West Healthcare Warrnambool Ethics Committee.

Inclusion criteria were an appropriate mechanism for a scaphoid fracture, specific scaphoid tenderness (determined by snuff box clinical examination), a negative initial radiograph and a patient age greater than 15 years. Exclusion criteria were as follows: any contraindication to MRI, previous wrist surgery and patients who could not consent for themselves.

Once informed consent was obtained, patients were randomised into two management groups. One group received conventional management and the other an acute MRI scan. Random allocation was predetermined by computer generation and placed into sequentially numbered envelopes.

Patients in the conventional group were placed in a removable scaphoid cast and given a fracture clinic referral with one of two orthopaedic specialists in 10–14 days after the initial presentation to the ED. No advice from the study team was given to the orthopaedic specialists to change their treatment for patients in any way.

Patients in the MRI group were also placed in a removable scaphoid cast and given an MRI appointment in 1–3 days. Wrist MRI was performed on a 1.5T whole body unit (Magnetom Essenza, Siemens Medical Systems, Erlangen, Germany). The following imaging sequences were used: Proton Density (PD)-Turbo Spin Echo (TSE)-Axial (AX), PD-TSE-AX-Fat Saturation (FS), T1-spin echo (SE)-Coronal (COR), PD-TSE-COR-FS, PD-TSE-Sagittal (SAG), PD-TSE-SAG-FS. The presence of a scaphoid fracture was determined to be high signal intensity on FS images suggesting oedema and/or low signal intensity on T1 or PD images suggesting a linear fracture line. In this study 'bone bruise' was treated as a fracture, following the theory that bone bruising represents marrow oedema and hence blood flow disruption. The scan was reported on the same day by one of the two radiologists and an emergency consultant with advice telephoned the patient. Patients with non-significant injuries such as effusion and muscle oedema required no specific treatment. They were instructed to follow-up with a general practitioner (GP) if there was any ongoing pain or symptoms. Those with significant injuries were advised to retain the cast and attend a fracture clinic appointment with an orthopaedic specialist.

Upon recruitment, patients filled out a questionnaire that included baseline demographic data, as well as a validated Patient Rated Wrist Evaluation (PRWE) form to assess pain and function scores.²³ All participants were contacted by telephone at 6 weeks time for follow-up and

the PRWE form repeated. Information on time off work, school, service satisfaction, immobilisation and treatment time was obtained. Healthcare usage such as diagnostic services, specialist attendances and allied health services were also obtained. The initial ED visit and radiographs were not included, as all subjects received these services prior to study entry. The cost of healthcare services was derived from the Medicare Benefits Schedule 2014 and measured in Australian dollars (AUD). Information from electronic medical records and the Picture Archiving and Communication System (PACS) were accessed and reviewed.

Owing to the small sample size and non-normality of the data, non-parametric analysis was performed. Categorical variables were expressed as frequencies (%) and continuous variables as median with interquartile range (IQR). Differences between the two groups were assessed, using the Pearson chi-squared method for categorical data and for continuous data, the Mann-Whitney *U* Test. Cost analysis was performed by directly comparing the cost of management between the two groups. Statistical analysis was performed using SPSS software (IBM SPSS Statistics for Windows, Version 20.0.; IBM Corp., Armonk, NY).

Results

Participants

Twenty-four patients who were being treated for suspected scaphoid fractures during the time period of

the study were assessed for eligibility in the ED. Here 19 patients were recruited and entered into the study, 11 in the MRI group and 8 in the conventional group. There were 16 patients used for the main analysis, 10 in the MRI group and 6 in the conventional group (2 were excluded due to missing attendance at the follow-up appointment and 1 was non-contactable over the telephone follow-up interview) (Fig. 1). As seen in Table 1, the groups were similar at baseline.

The MRI group had one scaphoid fracture (10%) and the conventional group none ($P = 0.42$) (6.25% of the total study population). Two patients in the MRI group had other fractures (20%), with one in the conventional group (16.7%) ($P = 0.87$). Only 10% (1) of patients in the MRI group had a completely normal diagnosis. The majority of the conventional group (83.3% (5)) ($P = 0.003$) had a normal diagnosis. The MRI group was diagnosed with more injuries outside the scaphoid, including muscle oedema ($P = 0.24$), bone oedema ($P = 0.24$) and effusion ($P = 0.24$) (Table 2).

Patient impact

Healthcare resource

Follow-up data was obtained by a questionnaire at 42 days. The impact on work was greater in the conventional group, with a median time off of 7 days. There were 0 days off reported in the MRI group. This difference was not significant ($P = 0.437$) (Table 3).

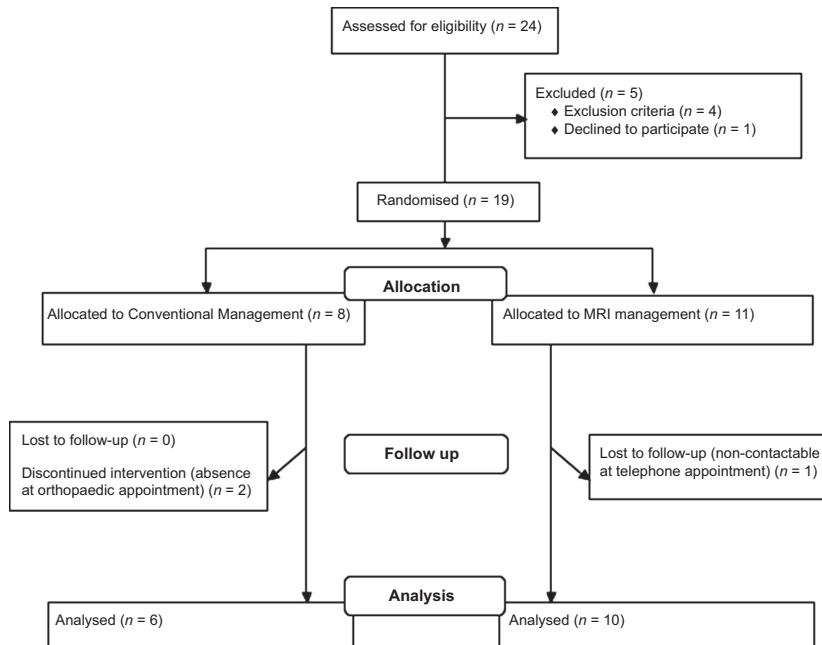


Figure 1. Trial profile (CONSORT flow diagram).

Table 1. Baseline characteristics of all patients (unless specified values are numbers [*n*]).

	Conventional <i>N</i> (%)	MRI <i>N</i> (%)	<i>P</i> -value
Number	10	6	
Age (median-IQR)	20.5 (17–25) ¹	18.5 (17–33) ¹	0.87 ²
Male (%)	7 (70)	3 (50)	0.42
Occupation			
Student (%)	2 (20)	3 (50)	0.21
Manual (%)	5 (50)	3 (50)	1
Non-manual (%)	3 (30)	0	0.14
Retired/unemployed/ non-worker	0	0	0
Dominant hand (%)	7 (70)	3 (50)	0.42

χ^2 test unless otherwise stated.

¹Median and IQR.

²Mann–Whitney test.

Table 2. Radiology findings depicted as percentages.

Diagnosis (%)	Conventional <i>N</i> (%)	MRI <i>N</i> (%)	<i>P</i> -value
Scaphoid fracture (6.25)	0	1 (10)	0.42
Other fracture (18.75)	1 (16.7)	2 (20)	0.869
Muscle oedema (12.5)	0	2 (20)	0.24
Ligament disruption (0)	0	0	
Effusion (12.5)	0	2 (20)	0.24
Normal (37.5)	5 (83.3)	1 (10)	0.003 ¹
Bone oedema (12.5)	0	2 (20)	0.24

χ^2 test unless otherwise stated.

¹*P*-value of statistical significance.

Pain and function scores were significantly lower in the MRI group at 42 days with a median score of 8.5 (0–17.88) compared with 26 (17.25–37.25) for the conventional group ($P = 0.019$). However, these were also lower at day 1 in the MRI group with a median of 76 (71–86) compared with 89.25 (86.86–93.5) (Fig. 2).

Table 3. Patient impact findings.

Patient impact	Conventional group ²	MRI group ²	<i>P</i> -value ³
Days off work	7 (0–43.5)	0 (0–14.25)	0.437
Days off school	0 (0–1.25)	0 (0–0.25)	0.474
Days of immobilisation	29.5 (17.25–37.25)	2.5 (1–18.38)	0.026 ¹
Days of treatment	31 (14–58.25)	3 (1.75–17.13)	0.022 ¹
Satisfaction score (1–10 scale)	8 (7.5–10)	9.5 (7.8–10)	0.526
Days of unnecessary immobilisation (subjects without fracture only)	21 (14–60.5)	1 (1–3)	0.004 ¹
Days of unnecessary treatment (subjects without fracture only)	21 (14–62)	2 (1–4)	0.004 ¹

¹*P*-value of statistical significance.

²Median and IQR.

³Mann–Whitney test.

The MRI group had a significantly less duration of immobilisation, with a median of 2.5 days (1–18.38) compared with 29.5 (17.25–37.25) ($P = 0.026$). The subsequent treatment time was also significantly less for the MRI group, 3 days (1.75–17.13) compared with 31 days (14–58.25) for the conventional group ($P = 0.022$). The MRI group also had higher satisfaction scores throughout the study period, 9.5 (7.75–10) (10-point scale) compared with 8 (7.5–10) ($P = 0.526$) (Table 3).

When only patients diagnosed as having no fracture were included in the analysis, the MRI group had a median of 1 day (1–3) of unnecessary immobilisation compared with 21 days (14–60.5) of immobilisation for the conventional management group. These results were significant ($P = 0.004$). The treatment time in patients without a fracture was also significantly less in the MRI group (2 days (1–4)), compared with the conventional group (21 days (14–62)) ($P = 0.004$) (Table 3).

Costs and healthcare usage

There were slightly higher costs associated with the conventional group with a median cost per person of \$486.90 (AUD) (149.51–724.63), compared with \$485.05 (AUD) (448–550.23) for the MRI group ($P = 0.74$). The median units of services used were 6 (3.25–8) in the conventional group, compared to 2 (1–3.5) in the MRI group ($P = 0.05$) (Table 4).

Discussion

Patient outcomes

This study demonstrated that in a rural hospital, the early use of MRI in patients with suspected scaphoid fractures facilitates an earlier diagnosis and management in cases

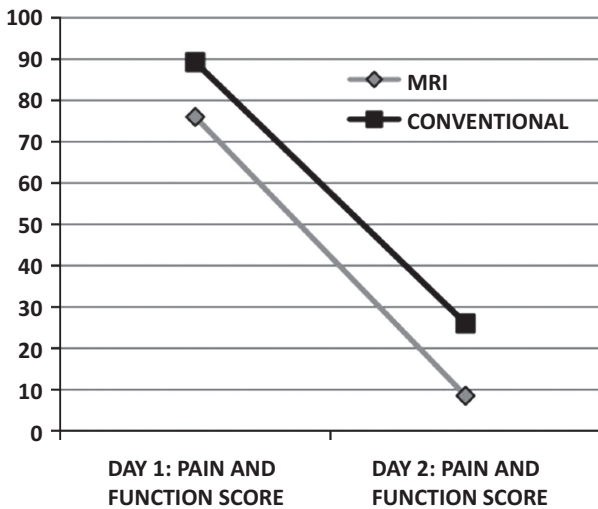


Figure 2. Diagrammatic representation of median pain and function scores (scale where 0 = no effect and 100 = total effect).

where pathology was diagnosed or the resumption of normal daily routines if normal. This markedly reduced patient inconvenience. There was only one confirmed scaphoid fracture in the total study population (demonstrated in the MRI group) and a total of 4

fractures, suggesting 75% of patients in this study were needlessly immobilised. These results mirror other studies, which suggest that the prevalence of true fractures is low.^{8,10} MRI also detected other injuries outside of the scaphoid that may go undetected using conventional management techniques. Significant findings in favour of reduced days of immobilisation in the MRI group, also allowed for less time off work or school (not significant). Pain and function scores at 42 days in MRI patients were much lower compared to the conventional group as well as higher satisfaction scores (not significant). This is most likely attributable to a quicker definitive diagnosis, shorter immobilisation time and earlier return to work. Patients were advised to see their GP if they had ongoing pain after the MRI to guide management and facilitate reassessment, however this did not occur. This suggests that there were no missed injuries in the MRI group and supports the idea that MRI-guided cast removal and management is safe.

Costs and healthcare usage

Early use of MRI was also slightly cheaper for the healthcare system. The greatest cost savings occurred when patients do not have a fracture, which is usually the case,

Table 4. Breakdown of healthcare usage and costs (Australian Dollars (AUD), \$).

	Cost (AUD)	Visits (N)	Total cost (AUD)	Cost (AUD)	Visits (N)	Total cost (AUD)	P-value ³
Healthcare services							
Emergency department	37.05	10	370.5	37.05	9	333.45	
General practitioner	37.05	1	37.05	37.05	2	74.1	
Specialist (initial)	72.75	2	145.5	72.75	5	363.75	
Specialist (subsequent)	36.55	1	36.55	36.55	4	146.2	
Hand therapy	62.25	0	0	62.25	1	62.25	
Median healthcare services per person ²		1 (0–2.25) ²			4 (2.25–5) ²		0.04 ¹
Median expenditure per person ²			37.05 (0–92.11) ²			183.40 (109.76–227.13) ²	0.06
Diagnostic services							
Radiographs	39.75	3	119.25	39.75	9	357.75	
MRI	448	10	4480	448	3	1344	
CT	220	0	0	220	0	0	
Median diagnostic services ¹		1 (1–1.25) ²			2 (1–3) ²		0.08
Median expenditure per person ²			448 (448–457.93) ²			303.50 (39.75–497.69) ²	0.68
Total visits/expenditure		27	5188.85		33	2681.49	
Mean cost per person			518.885			446.915	
Median visits ²		2 (1–3.5) ²			6 (3.25–8)		0.05 ¹
Median cost per person ²			485.05 (448–550.23) ²			486.9 (149.51–724.63) ²	0.74

¹P-value of statistical significance.

²Median and IQR.

³Mann–Whitney test unless otherwise stated.

given the low prevalence of true scaphoid fractures. This management technique resulted in a lower amount of healthcare usage in the MRI group. Despite this, a slightly lower non-significant median cost of management per patient when compared to the conventional group was suggested. The increased time off work in the conventional group, suggest that the impact on earnings would further add to the cost-effectiveness of MRI if loss of earnings were considered in the cost analysis.

Other studies

Our findings were similar to other previous studies performed abroad. Dorsay *et al.* demonstrated that in a cohort of 344 patients, 75% did not have a scaphoid fracture and underwent needless casting. They also reported comparable costs between management options.¹¹ Khalid *et al.* studied a cohort of 611 cases and suggested MRI to be a feasible method for acute diagnosis, reducing patient immobilisation time.¹² However, both of these studies evaluated consecutive cases in a retrospective manner. Hansen *et al.* compared 52 patients receiving either acute MRI or conventional management. They demonstrated that introducing early MRI decreased immobilisation time from 20 to 4 days, as well as decreasing the time off work from 27 to 11 days and concluded MRI to be cost-effective.⁵ However, this study used a non-randomised design and the two populations were slightly different which could potentially flaw the results. Patel *et al.* randomised 84 patients into MRI and control groups and diagnosed scaphoid fractures in 17% of the study population. They also demonstrated lower pain scores in the MRI group and less mean clinic appointments than the conventionally managed group and suggested MRI to be cost-effective.¹

In 2013, Ganeshalingham *et al.* performed research in a regional Australian setting. They suggested the potential cost saving of \$2453.50 (AUD) per patient receiving early MRI, when taking into account the cost of MRI versus X-ray and the loss of work time. They also demonstrated a change in management 76% of the time. However, this research was performed on 110 patients in a retrospective manner.²⁴ In 2005, Brooks *et al.* produced the first significant randomised controlled trial to date in a metropolitan Australian setting. They randomised 28 patients and reported a small non-significant cost-benefit in patients who were conventionally managed, compared with those who received acute MRI imaging. They did not demonstrate a reduction in days off work or difference in pain and function scores between the two management groups.¹⁶ This is in stark contrast to the findings of this study and much of the other research performed.^{16,21}

Limitations, generalisability and future recommendations

The main limitation of this study is the small sample size, however a pilot study has not previously been performed in this setting. Scaphoid fractures are a relatively common presentation to the Warrnambool ED, however there were very rigorous entry requirements to ensure only patients with a very high suspicion were included in the study. There was also a large amount of patients excluded in the final analysis due to missing attendance at the follow-up appointments. Blinding was not possible which may result in measurement biases such as expectation (investigators) and attention (patient) bias.

The management of a bone bruise of the scaphoid is controversial, with some studies allowing no treatment for such an injury and other studies providing immobilisation.²³ This study considered bone bruise to be a reduction in T1 signal with an increase in signal on fat suppressed sequences, but with no definite fracture line. This may have lead to unnecessary immobilisation in the MRI group and hence there is potential for further cost savings in centres where bone bruise is not treated. Further studies are still required on the best method for managing bone bruise within the scaphoid.

These findings may be generalised to rural hospitals that currently have good access to MRI or may be acquiring MRI in the near future. The 'early' MRI time of 1–3 days was selected, to ensure that this time could be readily transferable across national boundaries. However, this may not be achievable in some centres and should be considered when interpreting this study's findings. Although the study was performed in a rural Australia setting, also reported is the findings in healthcare usage units. This enables interpretation of this study's findings in other international settings. The cost analysis was performed to determine the cost to the entire healthcare system, however perhaps further breakdown of these costs in terms of the government sectors and funding may be warranted. Earning losses were not included in the cost analysis, which may further increase the cost-effectiveness of early MRI management.

Conclusion

This study found that in a rural hospital, the implementation of early MRI of patients with a suspected scaphoid fracture markedly reduced patient inconvenience, when compared with conventional management. Seventy-five percent of patients in the study population were needlessly immobilised. The use of MRI to facilitate an early diagnosis resulted in less visits to healthcare specialists and was suggested to be slightly

cheaper for the healthcare system. With this considered, early MRI should be the management technique of choice and should supersede conventional management, if the local availability of an MRI scanning resources is flexible. Further studies are still required on the best method for managing bone bruise within the scaphoid. This small-scale pilot study shows promising results for a full analysis to be approved by a healthcare facility in a rural setting, without the concerns of financial strain.

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Conflict of Interest

The authors declare no conflict of interest.

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