


# Early MRI for Pediatric Wrist Injuries—Prospective Case Series of 150 Cases

Cynthia de Courcey, MBChB, BSc, FRCS<sup>1</sup>  Andrea Jester, MD, FRCS Plast<sup>1</sup> Sarbjit Kaur, PA<sup>1</sup>  
Tommy R. Lindau, MD, PhD<sup>2</sup> Kerstin Oestreich, MD, FRCS(Plast), MSc<sup>1</sup>

<sup>1</sup>Department of Plastic Surgery, Hand and Upper Limb Service, Birmingham Women and Children's Hospital, Birmingham, United Kingdom

<sup>2</sup>Pulvertaft Hand Centre, Derby, United Kingdom

**Address for correspondence** Kerstin Oestreich, MD, MSc, Department of Plastic Surgery, Hand and Upper Limb Service, Birmingham Women's and Children's NHS Foundation Trust, Steelhouse Lane, Birmingham B4 6NH, United Kingdom (e-mail: Kerstin.oestreich@nhs.net).

J Wrist Surg 2023;12:96–103.

## Abstract

**Background** Pediatric carpal injuries are a clinical challenge due to their non-specific clinical features and occult nature on plain radiography. We hypothesized that early magnetic resonance imaging (MRI) will allow prompt diagnosis and treatment stratification, and that distal pole fracture of the scaphoid requires a shorter duration of immobilization. This study aims to assess the injury pattern and clinical outcomes of under-16-year-olds treated with acute post-traumatic wrist injuries in accordance with the unit's protocol.

**Methods** All patients under the age of 16 years treated for suspected pediatric wrist injuries in our tertiary pediatric hand and upper limb service were included. Prospectively collected data included patient demographics, radiological findings, treatment and adherence to the unit's protocol.

**Results** There were 151 patients with a mean age of 12 years. The majority (72%) had occult bony injury with radiological evidence of fracture on MRI. The sensitivity and specificity of plain film radiography were 42.7% and 71.4%, respectively. Almost one in four patients benefitted from early MRI demonstrating no injuries, permitting early mobilization and discharge. The scaphoid was the most commonly injured carpal bone. Non-displaced fractures of the distal pole of the scaphoid in patients over 10 years old were treated with 4 weeks' immobilization with no adverse outcome.

**Conclusion** Standardized care in our unit has yielded good results with low complication rate and fewer hospital appointments. Our results support the routine early use of MRI and a shorter duration of immobilization in fracture of the distal pole of the scaphoid at 4 weeks.

**Level of Evidence** This is a level IV, case series study.

## Keywords

- carpus
- scaphoid
- fracture
- pediatric
- MRI

Carpal injuries in children present a clinical challenge due to their non-specific clinical features, partial ossification of the carpus, and often occult radiological findings on plain radiography. While blunt wrist trauma is common, carpal injuries in children are not. Timely interventions are important to avoid missed injuries and complications, such as non-

union or avascular necrosis from scaphoid fractures.<sup>1</sup> For children without bony or ligamentous injuries, it is beneficial to minimize unnecessary immobilization and multiple hospital attendances. Diagnosis and treatment should take into account the progressive ossification of the pediatric carpus and its inherent diagnostic challenge. There is a scarcity of

received

November 7, 2021

accepted

June 13, 2022

article published online

September 29, 2022

© 2022. Thieme. All rights reserved.  
Thieme Medical Publishers, Inc.,  
333 Seventh Avenue, 18th Floor,  
New York, NY 10001, USA

DOI <https://doi.org/10.1055/s-0042-1753508>.  
ISSN 2163-3916.

evidence-based guidance for the management of symptomatic wrist following acute trauma in the pediatric population.

In recognition of this, our pediatric hand and upper limb service in a tertiary Children's Hospital developed a management algorithm to standardize treatment. We hypothesized that early magnetic resonance imaging (MRI) will identify those with bony or ligamentous injuries, allowing prompt stratification between immobilization and early therapy.<sup>2,3</sup> For those with distal pole fracture of the scaphoid, we hypothesized that this cohort requires a shorter duration of immobilization than those with a waist or proximal pole fracture.<sup>4,5</sup>

The purpose of this study was to assess the injury pattern and clinical outcomes of the under-16-year-olds treated with suspected acute post-traumatic wrist injuries in accordance with the unit's algorithm. A secondary aim was to evaluate the patient care pathways and adherence to, and limitations of, the proposed algorithm.

## Methods

This is a prospective case series of children and adolescence under the age of 16 years treated in our institution for acute post-traumatic suspected carpal injuries over a period of 26 months. Chronic injuries or those with uncertain date of injury were excluded. All children were initially assessed by the local Pediatric Accident & Emergency Department (A&E), with plain film radiography, and were referred to the pediatric hand and upper limb trauma clinic with splintage, cast immobilization or advice for hand elevation as appropriate. We followed our unit's management protocol/algorithm (►Fig. 1). Patient care journeys were recorded prospectively, which include patient's symptoms, investigations, and treatment prescribed at each clinic attendance. Injury pattern, clinical outcome, and patient care pathway were assessed. Adherence to the algorithm was analyzed retrospectively and deviations were recorded. Descriptive analyses and statistics were conducted, with exclusion of cases lost to follow-up. Bone and soft tissue injury diagnoses were taken from formal radiological reports of plain film radiography and MRI scans, although treatment may be initiated acutely from clinician interpretations of imaging findings.

## Results

### Demographics

A total of 151 cases (95 boys) were treated during the study period over 26 months. Three cases were lost to follow-up and were excluded. The mean age was 12 years (range of 7–15 years). Twenty-two percent of the cases ( $n=33$ ) were 10 years or under. The majority (72%) had occult bony injury with radiological evidence on MRI. There was a strong male predominance in those with carpal bone injuries, which shifted to an almost equal gender distribution in those 10 years or under (►Table 1).

### Impact of Early MRI

MRI was performed in all but six cases (4%). This revealed bony and/or soft tissue injuries in the majority of patients

(74%), while the remaining quarter had no injuries identified on MRI permitting early mobilization, reassurance, and discharge (►Fig. 2).

Using MRI as the "gold standard," the sensitivity and specificity of plain film radiography in this study were 42.7 and 71.4%, respectively (►Table 1). Despite no obvious bony injury on initial plain radiography, 72% had evidence of occult bony injury on MRI, highlighting the value of early use of MRI (►Fig. 3). There was a single case where a fracture diagnosed on plain film was subsequently discounted based on unremarkable MRI findings.

The presence of pain, swelling, and reduced range of motion (ROM) was not reliably predictive of carpal injuries. Only 21 patients described all three features on initial assessment, of which 33% did not have bony or ligamentous injury on MRI.

### Distal Pole Scaphoid Fracture

The scaphoid was the most commonly involved carpal bone, with 90 fractures out of 108 patients with carpal bone injury on MRI (►Table 2). Distal pole fractures were more common than fracture of the waist, and there was one case of proximal pole fracture in an 11-year-old boy (►Table 1). All acute fractures were minimally displaced and managed in accordance with the unit's protocol/algorithm (►Fig. 1B) and achieved union without surgical fixation. Undisplaced fracture of the distal pole of the scaphoid in patients over 10 years old was treated with a shorter period of immobilization (4 weeks) with no adverse impact on outcome.

### Injury Pattern and Clinical Outcome

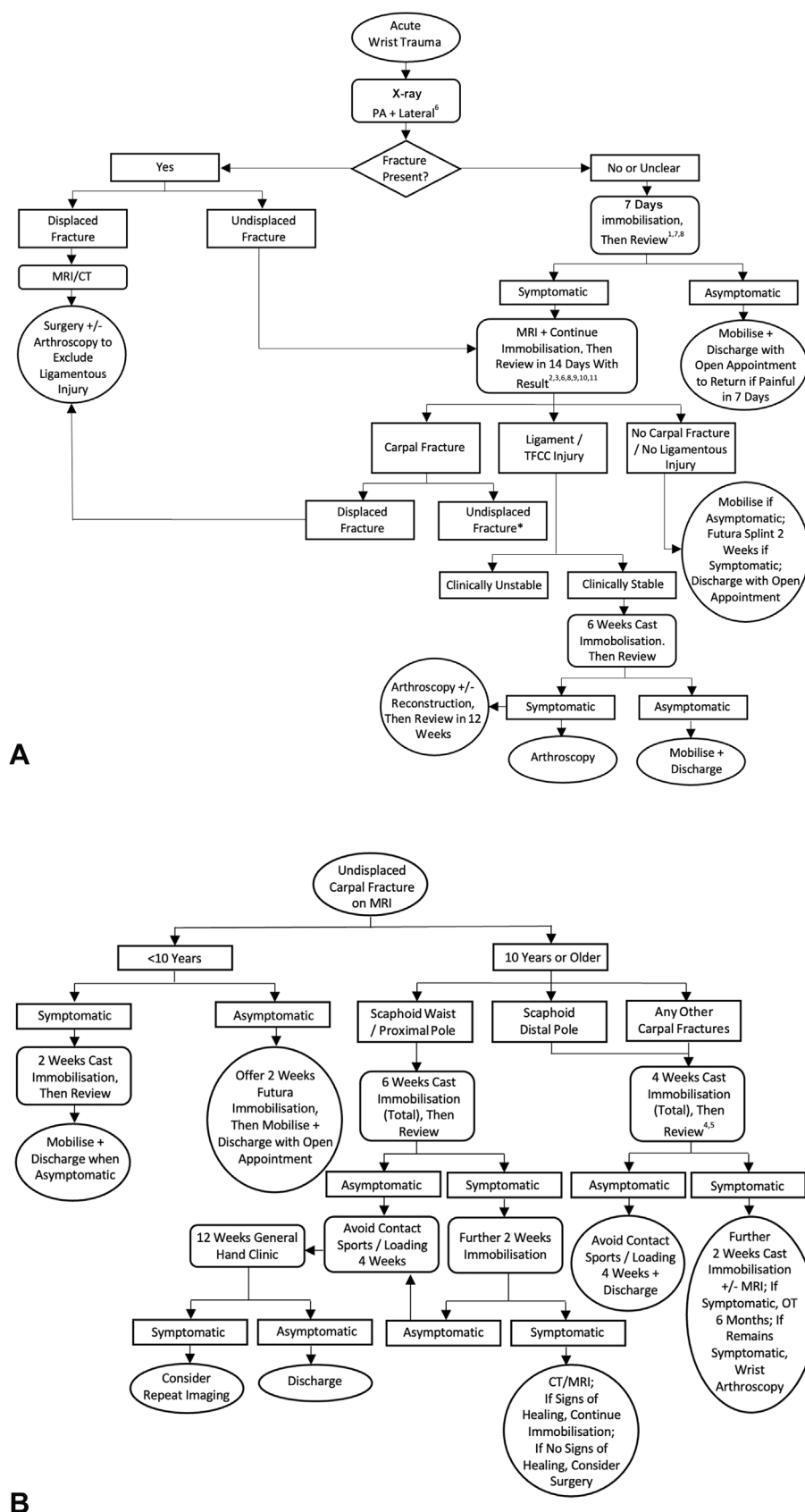
MRI revealed concomitant injury of more than one carpal bone in one-fifth of cases and this was consistent across the ages (►Table 1). Following the scaphoid, the next most commonly affected carpal bones were the capitate and trapezium (►Table 2).

The injury pattern of those requiring prolonged follow-up included fractures of the scaphoid waist, fractures of more than one carpal bone, and soft tissue injuries (►Fig. 4). Soft tissue injuries identified on MRI constituted a small number of cases (4%), which included two ganglions and one case each of scapho-trapezium-trapezoid ligament disruption, scapho-lunate ligament disruption, triangular-fibro-cartilage complex injury, and soft tissue edema only. A bone cyst in the triquetrum was identified as an incidental finding and was not included as bony injury from trauma.

The greater sensitivity of MRI also detected bone injuries of lesser severity described radiologically as "bone bruise," contusion or edema ( $n=19$ ). This often involved scaphoid fractures in combination with bone bruise of the carpus, and were managed as bony injury in accordance with the unit's protocol/algorithm (►Fig. 1A, B).

### Adherence and Limitations

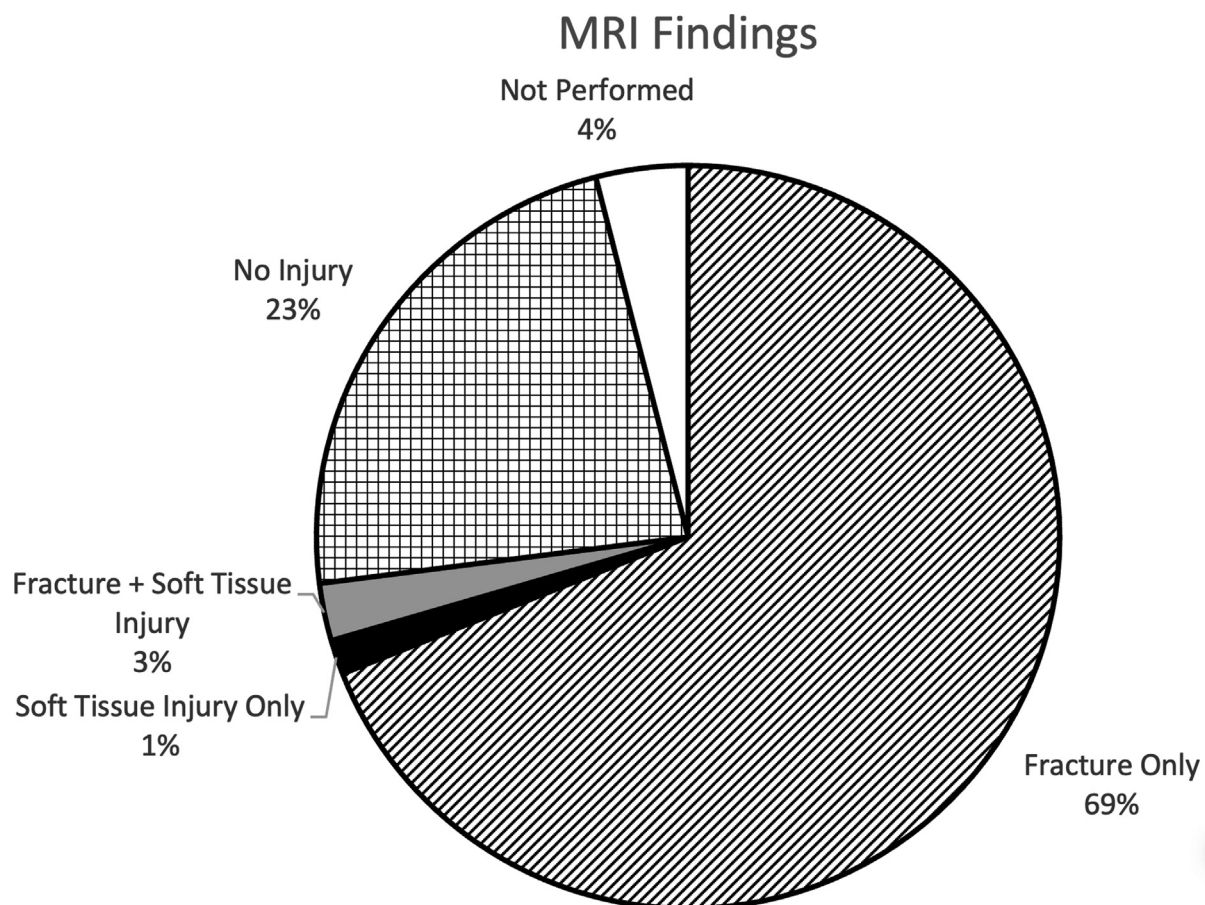
The core statistics of the cohort's treatment pathway is presented in ►Fig. 5. Prompt hand clinic referral following injury, early use of MRI and diagnoses and standardized management protocol allowed safe stratification of patients,

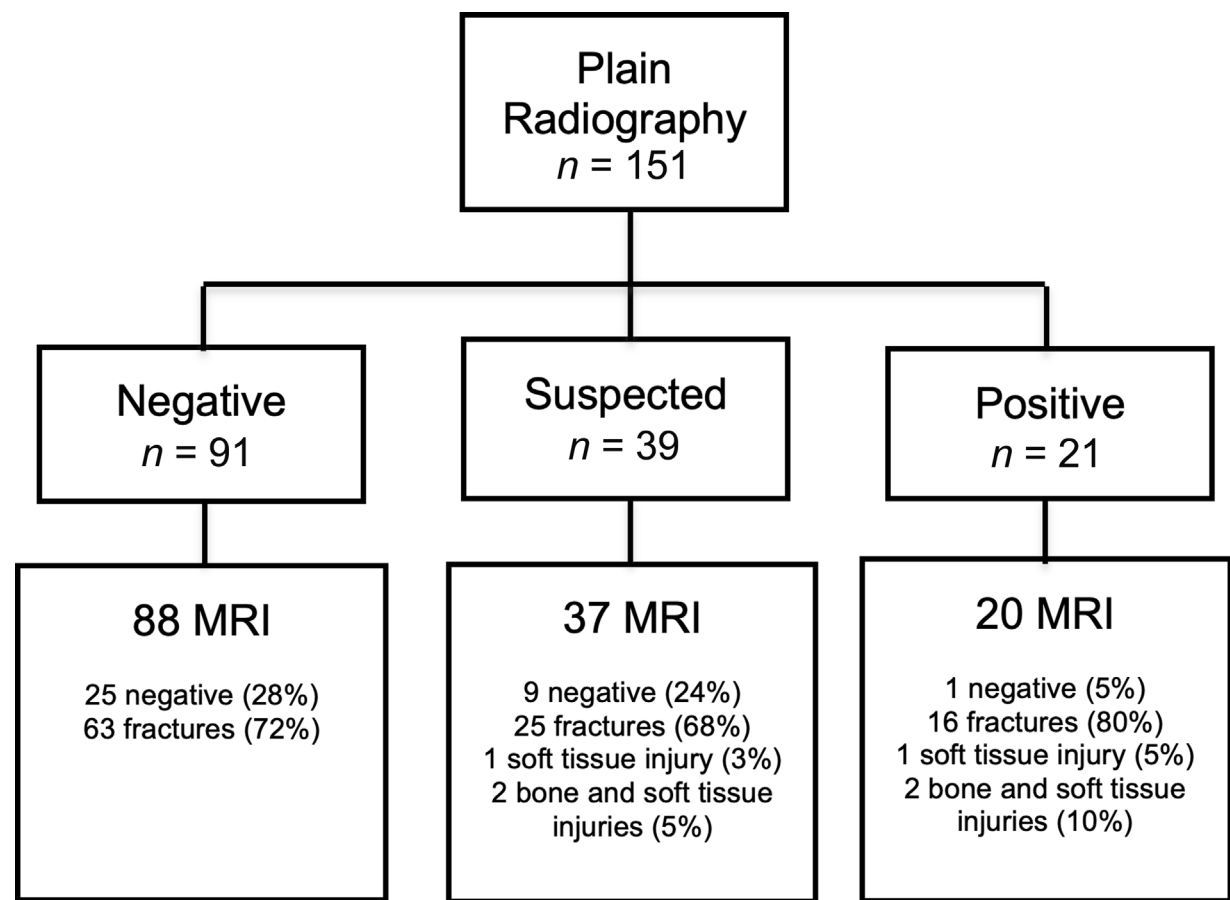


**Fig. 1** (A) Management algorithm for acute post-traumatic suspected carpal injuries (under 16 years).<sup>1-3,6-11</sup> (B) \*Management of symptomatic undisplaced carpal fractures confirmed on MRI. MRI, magnetic resonance imaging.

**Table 1** Demographics and radiological findings in accordance with age

		10 y or less	11–15 y	Total
<b>No. of cases</b>		<b>33</b>	<b>118</b>	<b>151</b>
Gender	Male	16	79	95
	Female	17	39	56
	M:F	1:1.1	2:1	1.7:1
MRI findings	Fracture only	28 (85%)	76 (65%)	104 (69%)
	Fracture + soft tissue injury	0 (0%)	4 (3.5%)	4 (2.5%)
	Soft tissue injury only	0 (0%)	2 (1.5%)	2 (1.5%)
	No injury	4 (12%)	31 (26%)	35 (23%)
	Not performed	1 (3%)	5 (4%)	6 (4%)
Plain film imaging "suspicious" = positive	Sensitivity	39.3%	43.9%	42.7%
	Specificity	100%	67.7%	71.4%
Scaphoid fractures	Number of cases (%)	25 (76%)	65 (55%)	90 (60%)
	Distal pole	17	33	50
	Waist	7	22	29
	Proximal pole	0	1	1
	Distal pole + waist	1	9	10
	Ratio (distal pole: waist)	2.4:1	1.5:1	1.7:1
>1 Fracture	Number of cases (%)	7 (21%)	24 (20%)	31 (21%)

**Fig. 2** MRI findings. MRI, magnetic resonance imaging.



**Fig. 3** Distribution of plain radiography and subsequent MRI findings. MRI, magnetic resonance imaging.

**Table 2** Fracture pattern in accordance with age

	10 y or less	11–15 y	Total
Scaphoid	25	65	90
Capitate	6	9	15
Trapezium	1	10	11
Distal radius	2	5	7
Triquetrum	2	5	7
Lunate	0	6	6
Metacarpal	0	5	5
Hamate	0	3	3
Trapezoid	1	2	3
Pisiform	1	2	3
Distal ulna	0	2	2

minimizing number of hospital visits and follow-up duration. Patients on average attended three hand clinic visits, excluding initial A&E assessment, with a mean follow-up of 5.5 weeks and an immobilization period of 5.1 weeks. Almost four out of five patients (79%) had three clinic visits or less.

Cast or splint immobilization applied from A&E (88% of cases) was included within the total immobilization period, limiting excess period of treatment. In patients with radiologically confirmed carpal fractures (►Fig. 6A–C), the mean

duration of treatment was 6.0 weeks, with three (3.2) clinic attendances, compared with 4.0 weeks and three (2.7) clinic attendances for those without bony or ligamentous injuries.

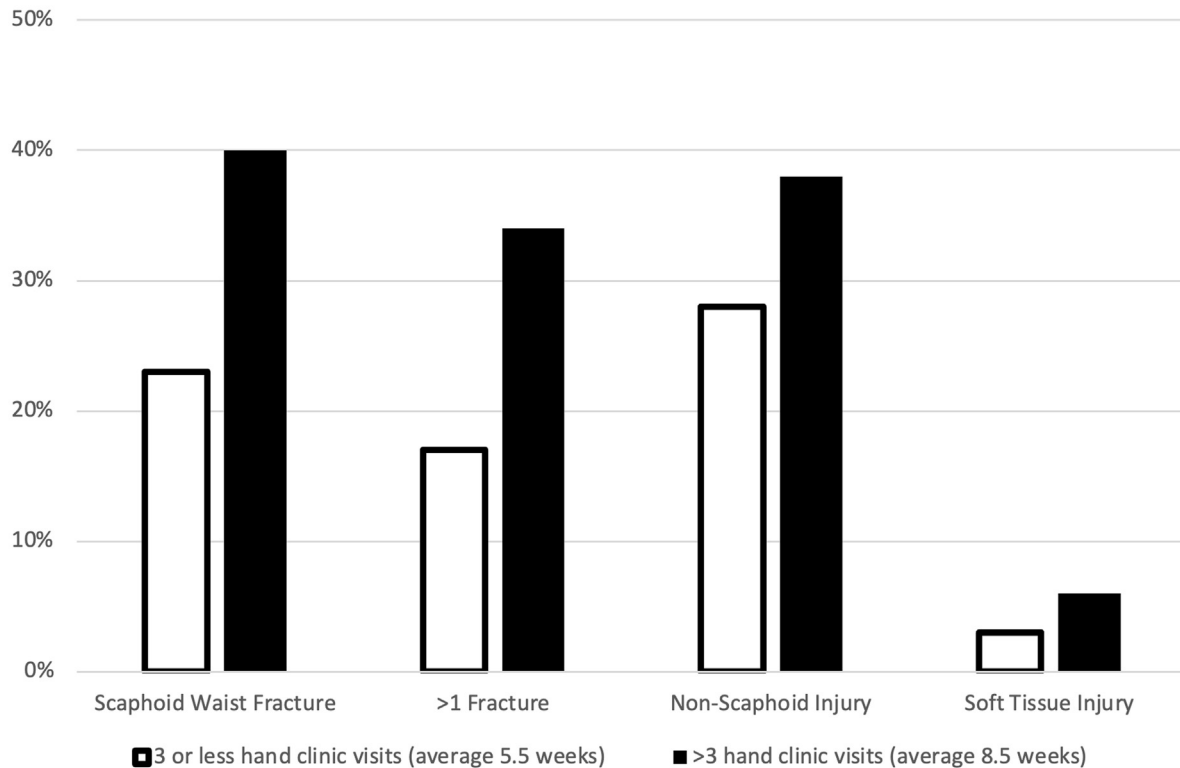
Variation from the management protocol/algorithm predominantly surrounds an extended follow-up timeframe following MRI from 1 to 2 weeks, accounting for 65% of cases. Compliance with the protocol/algorithm improved from 13 to 78% excluding this most common cause of variation. Other deviations from the algorithm included discharge without General Hand Clinic follow-up for scaphoid waist fractures, prolonged cast immobilization of distal pole fractures beyond the recommended 4 weeks and the use of removable splints, such as the Futura, instead of full cast immobilization.

**Discussion**

**Radiological Imaging**

In the 2015 Cochrane review, bone scans were found to have the highest sensitivity (100%), specificity (98%), and a positive predictive value of 85 to 93% at 72 hours.<sup>12</sup> Their drawbacks include the increased radiation exposure, diagnostic delay of at least 72 hours, and invasiveness.<sup>9</sup> In comparison, computed tomography (CT) carries a sensitivity of 85.2% and specificity of 99.5%, and MRI sensitivity of 97.7%, specificity of 99.8% and a negative predictive value of 100%.<sup>9</sup> Despite reduced sensitivity and added radiation exposure compared



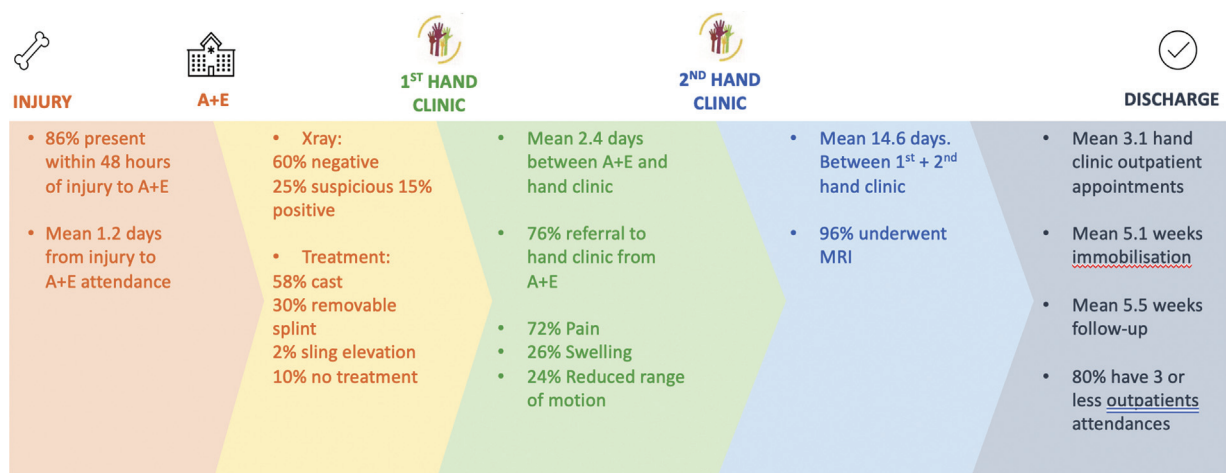


**Fig. 4** Injury patterns and out-patient follow-up requirements.

with MRI, CT may be more appropriate in cases necessitating detailed delineation of fracture fragments, and in some units, they are more readily available and economical.<sup>2</sup>

Multiple studies in the literature assessed the yield of varying imaging modality in suspected pediatric scaphoid and other carpal injuries. Interpretation of plain radiographs can be challenging due to incomplete ossification of carpal bones and physal lines.<sup>7</sup> Conventional approach based on repeated plain radiography and subsequent CT or MRI when symptomatic is likely to confer additional hospital attendances, diagnostic uncertainty and parent and child anxiety. In this study, 58% had an initial unremarkable X-ray and 25%

had a suspicious fracture on plain film as occult fractures later were identified on MRI scan. In a series of 56 patients, 75% of those with confirmed scaphoid fracture on MRI reported negative initial X-rays.<sup>9</sup> In another series, 74 fractures were identified in 64 patients in 90 MRIs performed for radially symptomatic wrists.<sup>2</sup> MRI was found to have greater interobserver reliability.<sup>2,3</sup> Due to the variable ossifications of carpal bones and the relative greater chondral components in younger patients and reduced radiation exposure, the use of MRI was deemed more suitable in our series than other imaging modalities such as CT. The availability of various imaging modalities and the turnover time for reporting vary



**Fig. 5** Treatment pathway core statistics.



**Fig. 6** (A–C). X-ray and MRI of scaphoid fracture: 14-year-old girl, left wrist, high velocity trauma. (A) X-ray PA view: no fracture reported (lunate cyst coincidental finding). (B) MRI (T2\_tse\_fs\_cor) and (C) (T1\_tirm\_sag): undisplaced fracture distal pole of scaphoid, marrow edema within the body of the scaphoid. Nonspecific marrow edema noted within the lunate, in addition to an incidental cyst. MRI, magnetic resonance imaging.

between institutions, especially in an emergency setting. In this study, based on a tertiary referral center, prior arrangement with the radiology department supported a policy of performing and reporting of MRI for carpal trauma within 7 to 10 days. We recommend working in partnership with the radiology department in designing a management algorithm that takes into consideration the local demographics, trauma caseload, and available resources. Where MRI availability is limited, it is reasonable to perform plain film radiography and immobilization for suspected carpal trauma, with early MRI at 2 weeks for those with persistent symptoms.

The diagnostic challenges posed by non-specific signs and symptoms and occult radiological findings of the injured wrist are well recognized. Volar tenderness, radial deviation pain, and pain with active ROM were identified as predictors of scaphoid fractures in those with negative initial radiographs.<sup>8</sup> However, examination of a painful wrist in a child or adolescent may be challenging, and the positive predictive value of clinical scaphoid tenderness in children aged 4 to 11 years is low.<sup>13</sup> In one study, 31 out of 104 (30%) patients with suspected scaphoid fracture and an initial unremarkable plain film had subsequent radiological confirmation of fracture on follow-up.<sup>8</sup> This figure was 63 out of 91 (72%) patients in our study.

### Scaphoid Fractures

Historically, scaphoid fractures in adolescence were thought to be more common in the distal pole, with a male preponderance, as reflected in our cohort.<sup>4,9</sup> This may be due to the distal to proximal direction of ossification pattern of the scaphoid.<sup>14</sup> It is worth noting that waist fractures were more common, resembling an adult fracture pattern.<sup>14,15</sup> Higher BMI and high-energy trauma, including sport injuries, were thought to be contributory factors and account for such adult-type injury patterns.<sup>14</sup> Distinction between fractures of the distal pole and that of the waist or proximal pole was incorporated into our unit's management algorithm based on literature findings of a quicker rate of healing in the former. Undisplaced fracture of the distal pole of the scaphoid, in the majority, heals without complications after 4 to 6 weeks of

cast immobilization.<sup>5</sup> In a review of 56 patients with scaphoid fractures, aged 13 years or under, all but one case united without complication.<sup>4</sup> An average of 4 weeks immobilization was required for distal pole fractures versus 4.9 weeks for waist fractures.<sup>4</sup>

### Concomitant Injuries

The high incidence of concomitant injuries was another key finding of this study. This finding is related to the high sensitivity of MRI and the standardized usage within our unit's algorithm. While associated injuries alongside pediatric scaphoid fractures are uncommon, recent studies suggest they are not rare.<sup>5</sup> Some reports present 15 and 21% incidence of associated injuries.<sup>2,14</sup> In our study, 27 out of 90 pediatric scaphoid fractures (30%) had associated injuries. The three most common carpal fractures, in descending order of frequency, were the scaphoid, capitate, and trapezium.

### 10 Years or Under

Pediatric scaphoid fractures are clustered within the 11 to 15-year group, and are rare in those under 9 years of age.<sup>9,16</sup> In this study, a greater female distribution was observed in those aged 11 years or younger. This contrasted with a strong male majority for the full cohort of under 16. More advanced skeletal maturity may account for this. The appearance of the scaphoid ossification nucleus (4–5 years vs. 5–6 years) and the completion of endochondral ossification (13 vs. 15 years) both occur at a younger age in females compared with males.<sup>9</sup>

### Management Algorithm

Our study demonstrated that the cohort of patients without bony or ligamentous injury received a shorter duration of immobilization and fewer hospital appointments. There were 34 cases that presented with a symptomatic wrist which were subsequently shown to have no abnormality on MRI. Of these patients, half remained symptomatic at their second visit, and the reassuring findings on MRI may have facilitated earlier return to mobilization and full recovery. MRI has a strong negative predictive value.<sup>3</sup>

## Limitations

There are inherent biases within a cohort observational study like ours, where our algorithm was set up based on the literature, but not proven prior to the study period. We admit that it is difficult to plan clinical trials due to the relative low incidence of pediatric carpal injuries. Hence, we focused on capturing patients with a symptomatic post-traumatic wrist via A&E referral to our regional pediatric hand and upper limb clinic. Some A&E departments within our catchment area have follow-up facilities, and it is reasonable to believe that a proportion of patients would have been managed solely in A&E.

There are further unknowns making our algorithm difficult to fully judge. The optimal imaging modality of the injured pediatric carpus is not known. The clinical relevance of occult carpal fractures identified on MRI, but not seen on CT is not determined. The advantages of limiting radiation exposure and greater sensitivity, compared with CT, may lead to additional immobilization in cases otherwise not detected on X-ray or CT. Therefore, the choice between MRI and CT in the management of the symptomatic pediatric wrist remains nuanced.

## Summary

Pediatric carpal injuries are uncommon, and clinical examination findings correlate poorly with radiological diagnoses. The use of a departmental management algorithm allowed for standardized care and in our unit, has shown good results with low complication rate and favorable fewer hospital appointments. Our results support routine use of MRI scan for the identification or exclusion of occult carpal injuries in the pediatric population. We also noted a shorter duration of immobilization in fracture of the distal pole of the scaphoid at 4 weeks.

### Note

The study was undertaken at the Birmingham Women and Children's Hospital, Birmingham, United Kingdom.

### Conflict of Interest

None declared.

## References

- 1 Bae DS, Gholson JJ, Zurakowski D, Waters PM. Functional outcomes after treatment of scaphoid fractures in children and adolescents. *J Pediatr Orthop* 2016;36(01):13–18
- 2 Jørgsholm P, Thomsen N, Besjakov J, Abrahamsson S, Björkman A. MRI shows a high incidence of carpal fractures in children with posttraumatic radial-sided wrist tenderness. *Acta Orthop* 2016; 87(05):533–537
- 3 Kanavaki A, Draenert C, Ceroni D, Hanquinet S. Short MRI protocol for excluding traumatic lesions of the scaphoid bone in children. *In Vivo* 2016;30(04):495–499
- 4 Ahmed I, Ashton F, Tay WK, Porter D. The pediatric fracture of the scaphoid in patients aged 13 years and under: an epidemiological study. *J Pediatr Orthop* 2014;34(02):150–154
- 5 Goddard N. Carpal fractures in children. *Clin Orthop Relat Res* 2005;(432):73–76
- 6 D'Arienzo M. Scaphoid fractures in children. *J Hand Surg [Br]* 2002;27(05):424–426
- 7 Pretell-Mazzini J, Carrigan RB. Simultaneous distal radial fractures and carpal bones injuries in children: a review article. *J Pediatr Orthop B* 2011;20(05):330–333
- 8 Evenski AJ, Adamczyk MJ, Steiner RP, Morscher MA, Riley PM. Clinically suspected scaphoid fractures in children. *J Pediatr Orthop* 2009;29(04):352–355
- 9 Grenier G, Samora JB. What's new in pediatric wrist fractures? *Oper Tech Orthop* 2019;29(01):55–66
- 10 Eckert K, Tröbs RB, Schweiger B, Liedgens P, Radeloff E, Ackermann O. Diagnostically approach to pediatric carpal fractures: a retrospective analysis. *Z Orthop Unfall* 2016;154(01):43–49
- 11 Wilson EB, Beattie TF, Wilkinson AG. Epidemiological review and proposed management of 'scaphoid' injury in children. *Eur J Emerg Med* 2011;18(01):57–61
- 12 Mallee WH, Wang J, Poolman RW, et al. Computed tomography versus magnetic resonance imaging versus bone scintigraphy for clinically suspected scaphoid fractures in patients with negative plain radiographs. *Cochrane Database Syst Rev* 2015;(06):CD010023
- 13 Porter J, Chan K, Porter R. The predictive value of clinical scaphoid tenderness for fractures in children. *Paediatr Child Health* 2015; 20(05):e92
- 14 Gholson JJ, Bae DS, Zurakowski D, Waters PM. Scaphoid fractures in children and adolescents: contemporary injury patterns and factors influencing time to union. *J Bone Joint Surg Am* 2011;93 (13):1210–1219
- 15 Garala K, Taub NA, Dias JJ. The epidemiology of fractures of the scaphoid: impact of age, gender, deprivation and seasonality. *Bone Joint J* 2016;98-B(05):654–659
- 16 Tataria R, Ting J, Jester A, Lindau TR, Oestreich K. Scaphoid fractures below the age of 10: case series and review of the literature. *J Wrist Surg* 2020;9(06):458–464