

Short MRI Protocol for Excluding Traumatic Lesions of the Scaphoid Bone in Children

AIKATERINI KANAVAKI¹, CHRISTOPHE DRAENERT³, DIMITRI CERONI² and SYLVIANE HANQUINET¹

Departments of ¹Pediatric Radiology, and ²Pediatric Orthopedics,
Geneva University Children's Hospital, Geneva, Switzerland;

³Department of Internal Medicine, Cantonal Hospital of Fribourg, Fribourg, Switzerland

Abstract. *Background/Aim: Management of scaphoid trauma includes imaging with repeated X-rays whose interpretation is difficult and often ambivalent. The aim of the study was to propose a fast magnetic resonance imaging (MRI) protocol permitting exclusion of traumatic lesions of the scaphoid bone in children, which would avoid unnecessary immobilization and irradiation in negative cases. Patients and Methods: Two pediatric radiologists retrospectively reviewed the X-rays and MRIs of 45 children with clinical suspicion of scaphoid trauma. X-Rays and MRI sequences [short tau inversion recovery (STIR), T1] were scored as: 0 (negative) or 1 (equivocal or positive). X-ray results were compared to those of MRI and interobserver reliability was measured for both methods. Results: MRI was shown to be more reliable than X-ray in excluding pediatric traumatic scaphoid lesions. X-Ray results differed significantly between the two readers ($p=0.0001$), and the interobserver reliability was low ($\kappa=0.529$). For MRI interpretation, there was no significant difference between the two readers' assessments. The interobserver reliability was high ($\kappa=0.9544$) and only in one case was there discordance. Absence of scaphoid trauma was confirmed on MRI in 18 out of 45 patients. For these patients, immobilization was reconsidered and no follow-up X-ray was performed. Conclusion: Early MRI is useful in the management of pediatric scaphoid trauma. A short MRI protocol consisting of a STIR and a T1 sequence is sufficient for differentiating positive from negative cases and gives a good negative predictive value for exclusion of a traumatic scaphoid lesion.*

Correspondence to: Aikaterini Kanavaki, Magnisias 163, Dionysos, 14576, Athens, Greece. Mobile: +30 6974319350, e-mail: katerinakan@yahoo.gr

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The scaphoid is the most commonly fractured carpal bone in children (1). Scaphoid fractures in skeletally immature patients may be easily missed, especially when the fracture is associated with a more evident distal forearm injury. Many cases of scaphoid fractures remain undiagnosed after the initial injury because early symptoms can be minimal, and identification of the fracture on an initial radiograph can be tremendously difficult in skeletally immature patients, where carpal bones are partially ossified (1). As in adult patients, early recognition and prompt diagnosis of scaphoid fractures is necessary to achieve satisfactory outcome.

Recent literature has shown the beneficial role of magnetic resonance imaging (MRI) in diagnosis of these fractures in adults (2-9) but very little has been reported for the use of MRI in clinically suspected traumatic scaphoid lesions in children (10-12). MRI would be useful in diagnosis of scaphoid fractures in children, leading to a reduction not only of missed fractures and complications, but also of unnecessary immobilization and excessive irradiation in the absence of such fractures.

In this retrospective study, we reviewed the cases of 45 children admitted to our hospital with clinical suspicion of scaphoid trauma and compared the X-ray and MRI results in order to evaluate the value of MRI in excluding traumatic scaphoid lesions in a pediatric population. We present our experience from the introduction of fast MRI in the management of pediatric scaphoid trauma.

Patients and Methods

Patients. After approval by the Institutional Review Board (CER 08-224) we retrospectively reviewed the medical files of 45 children who presented to the Emergency Department of our tertiary hospital between January 1, 2009 and December 31, 2012 with a clinical suspicion of scaphoid trauma and benefited from an early MRI. Pain in the anatomic snuffbox or on the scaphoid after palpation were considered as clinical criteria suggestive of traumatic scaphoid lesion.

Table I. X-Ray and magnetic resonance imaging (MRI) results for the two readers.

Method	Fracture	Reader A, N (%)	Reader B, N (%)	Difference in distributions	Kappa value
X-Ray	Absent	17 (38)	26 (58)	$p=0.0001$	0.53
	Equivocal/present	28 (62)	19 (42)		
MRI	Absent	22 (49)	21 (47)	$p>0.5$	0.95
	Equivocal/present	23 (51)	24 (53)		

Data sets. X-Rays were performed on the day of admission (between days 0-3 after the trauma) and included posteroanterior (PA) and lateral views of the wrist, as well as special scaphoid views. MRI was performed between days 3 and 10 after the trauma. All MRIs were performed on a 1.5 T machine (Avanto, Siemens Healthcare GmbH, Erlangen, Germany). No sedation was applied nor was there use of contrast media. Our imaging protocol included a coronal T1 [repetition time/echo time, (TR/TE): 582/12, flip angle 50°, 2.5 mm slices, field of view (FOV): 120×112 mm, acquisition time 04:57 min] and a coronal short tau inversion recovery (STIR) [TR/TE 4000/25, inversion time (TI): 160 ms, flip angle 150°, 2.5 mm slices, FOV 120×120 mm, acquisition time 04:02 min] sequence. The patient was placed in a prone position with the arm extended and the FOV was limited to the wrist (covering the area from the distal radius and ulna to the metacarpal heads). A knee coil (8 channels coil) was used for image acquisition.

Image analysis. All initial X-rays and MRIs were anonymized, coded, transferred to and stored on a dedicated computer station in a random order. Two experienced pediatric radiologists (S.H. and A.K.) retrospectively and independently reviewed the examinations. The readers were blinded to all clinical and radiological data except patient age and clinical suspicion of scaphoid trauma. At the time of analysis of the X-rays, the readers were blinded to the results of the MRI and *vice versa*.

X-Rays were scored from 0 to 1 depending on the presence or absence of a traumatic scaphoid lesion (0: negative, 1: equivocal or positive).

In the same way, MRI examinations were also scored from 0 to 1 (0: negative, 1: positive). In the absence of bone marrow edema, fracture line or joint fluid, the examination was considered as negative.

The presence of any other bone traumatic lesion was also noted.

Patient treatment. All patients were initially treated by wrist immobilization (under the elbow cast) until the MRI study. Patients found to be positive for scaphoid trauma were treated with wrist immobilization (cast) and had a clinical and X-ray follow-up at 3 and 6 weeks and 3 months after the trauma. In cases where the MRI was negative, immobilization was reconsidered and patients were treated symptomatically; no additional X-rays were performed. Clinical follow-up revealed no complication in these cases.

Statistical analysis. In order to compare the results (presence or absence of a traumatic scaphoid lesion) of the two readers, Fisher's exact Chi-square test was used. The significance level was set at 0.05.

The agreement between the two readers was assessed by Cohen's kappa and the confidence intervals given. The value of kappa was

interpreted on the Landis and Koch scale (0.0-0.2: slight agreement; 0.21-0.40: fair agreement; 0.41-0.60: moderate agreement; 0.61-0.80: substantial agreement; 0.81-1.00: almost perfect agreement).

The statistical analysis was performed with tools freely available at <http://faculty.vassar.edu/lowry/kappa.html>. In the further statistical evaluation, when there was a difference between observers, the result of a reached consensus was used.

Results

Forty-five children were included in our study that had a clinical suspicion of a scaphoid lesion after a substantial trauma. These patients were investigated according to our hospital's management protocol, not only with an X-ray but also with an early MRI (between days 3 and 10 after the trauma).

Our group consisted of 22 boys and 23 girls, aged between 8 and 16 years (mean=12.7 years, standard deviation=2.0 years).

The interpretation of X-rays differed significantly between the two readers ($p=0.0001$): a fracture was present on X-ray in 28 cases for reader 1, whereas in only 19 cases for reader 2. The interobserver reliability was low ($\kappa=0.53$, fair agreement).

In contrast, for MRI analysis, the interobserver reliability was very high ($\kappa=0.95$). There was only one case with a discordant analysis, which was resolved by consensus between the two readers (Table I).

Out of the 45 children with clinical suspicion of scaphoid fracture, 18 had a normal MRI and were released from treatment and X-ray follow-up. Twenty-three (51%) had a traumatic scaphoid lesion on MRI (Figure 1). In four patients, the MRI was negative for scaphoid fracture but positive for another hand or wrist fracture (*e.g.* capitate, trapezium, distal radius) not seen on the X-ray, whereas one patient with scaphoid fracture also had another fracture of carpal bone (capitate, trapezium).

Discussion

Scaphoid fractures correspond to about 3% of all hand and wrist fractures in children (1, 10, 13, 14). In the pediatric population, these fractures occur more frequently between the ages of 12 and 15 years (1) and are rare in those under 6 years of age, with only one case report in literature of such a fracture in a 4-year-old patient (15). Our patients were aged between 8 and 16 years (mean age of 12.7 years). This age



Figure 1. Imaging for a 12-year-old boy with a clinical suspicion of scaphoid fracture. Anteroposterior (a), and lateral (b) views of the wrist and dedicated scaphoid views (c, d). The fracture was not evident on plain X-ray. Soft-tissue signs were not conclusive for scaphoid fracture. The magnetic resonance imaging shows scaphoid fracture (white arrow), evident on coronal T1 (e) and coronal short tau inversion recovery (f) sequences.

predilection may be associated with the ossification of this bone. According to studies on the development of carpal bones, the ossification center of the scaphoid appears at 5-6 years and is always present at 7.5 years. Ossification advances from the center to the periphery and is complete at about 13 years in girls and 15 years in boys (16). The relatively low frequency of this fracture in children is probably due to the peripheral cartilage protecting the ossification center (1, 17).

Clinical examination typically reveals pain in the anatomic snuff-box, but examining an injured child can sometimes be difficult (17) and clinical diagnosis of scaphoid fractures in children remains a challenge.

In common practice, X-ray remains the initial imaging technique in case of a clinical suspected scaphoid fracture (13). Scaphoid fractures are, however, difficult to see on plain radiographs, with different studies showing that such fractures were missed in both initial and delayed X-rays, independently of the degree of the observers' experience (18, 19).

Especially in children, the sensitivity of X-rays in the diagnosis of scaphoid fracture varied to a great extent in different studies (between 21 and 97%), showing that this modality is not reliable for excluding a fracture (13). Other studies (also including the adult population) show that 25-65% of scaphoid fractures were missed in plain radiography (1). This may be due to the difficulties in interpretation of plain X-rays, especially in skeletally immature patients, where a fracture line is not always obvious. On the other hand, normal lines of scaphoid bone in plain X-rays can be mistakenly taken to be fractures, leading to a false-positive diagnosis of scaphoid fracture (18).

As for radiographic soft-tissue signs that could aid in the detection of occult scaphoid fracture, the obliteration or displacement of the scaphoid fat stripe (a small triangular or linear collection of fat between the radial collateral ligament and the tendon sheath of the *abductor pollicis longus* and the *extensor pollicis brevis*) and dorsal swelling of the wrist, when present, should be considered with cautiousness, but their absence cannot rule out a scaphoid fracture (20-22). Especially for skeletally immature patients, the scaphoid fat stripe sign is unreliable because it may be absent below the age of 11-12 years (10, 20).

In our study, X-ray was found to be highly unreliable for the diagnosis of traumatic scaphoid lesions in children. There was a very low interobserver reliability for X-ray interpretation. Our results do not support reliance on X-ray imaging in the clinical management of scaphoid trauma in children.

The beneficial role of MRI in the investigation of suspected scaphoid fractures has been already reported in literature, mostly in adults, but also in children (1-8, 10, 11). Pediatric studies are few and relatively old (>10 years) (11), reporting small series. An interesting point is that the percentage of scaphoid fractures confirmed on MRI is greater in pediatric studies [58% in the study of Johnson *et*

Table II. Scanning parameters of the proposed short magnetic resonance imaging protocol.

	Coronal STIR	Coronal T1
Field of view, mm	120	120
Matrix	256×205	448×269
Voxel, mm	0.6×0.5×2.5	0.4×0.3×2.5
Thickness, mm	2.5	2.5
Slices, n	15	18
Type of sequence	IR	SE
TE, ms	25	12
TR, ms	4000	582
TI	160	
Flip angle	150°	50°
Duration, min	4	5

TE: echo time, TR: repetition time, TI: inversion time, IR: inversion recovery, SE: spin echo.

al. (11) and 51% in the present study] compared to studies concerning adults, where 9% (9) to 19% (3,9) of clinically suspected fractures were confirmed on MRI.

Out of the 45 children in our study with clinical suspicion of wrist trauma, almost half of them (18 children) had no abnormality on MRI. These children were treated symptomatically and were further released from follow-up. No additional X-rays were performed, resulting in a reduction of irradiation administered. With the early release of immobilization, these patients returned earlier to their regular activities. No complications were found in these patients.

Patients with positive clinical examination and positive MRI were conventionally treated by immobilization (cast) and had regular radiographic and clinical follow-up.

In the four cases where MRI was negative for a scaphoid fracture but positive for another, the treatment was appropriately adjusted and MRI thus permitted a better management of these patients.

It is interesting to mention that we have had no problem in interpreting MRIs as positive or negative for osseous traumatic lesions. In cases considered normal, the marrow signal was homogeneous on STIR and T1 and there was no joint fluid. Our experience has not shown high prevalence of non-specific heterogeneous marrow signal of the wrist bone as reported in the article by Muller *et al.* in a normal population (23).

Concerning the different MRI protocols referred to in literature, studies on adults propose coronal STIR and T1 sequences as the most appropriate for making a diagnosis of a traumatic scaphoid lesion. In their study on a pediatric population, quite similar to ours, Johnson *et al.* propose sagittal STIR and coronal T1 and T2 sequences (11). Our imaging protocol included a coronal STIR and T1 sequence. We chose the coronal plane for imaging as we believe that it is the best plane for providing a whole view of the carpal and

wrist bones. Fractures other than those of the scaphoid can also be easily detected in this plane.

We therefore propose this short MRI protocol consisting of a coronal STIR (4 min) and a coronal T1 (5 min) sequence to investigate clinically suspected traumatic scaphoid lesions. The total duration of MRI acquisition in this case would be approximately 9 minutes. Young patients, reluctant to remain still for a long time in the MRI machine, easily accept this short MRI protocol (Table II).

Our study showed that MRI has a good negative predictive value enabling exclusion of a traumatic wrist injury. It is also a cost-effective method for management of traumatic scaphoid lesions in children; if the MRI is negative, immobilization should be reconsidered, permitting an earlier return to normal school and sport activities of young patients. Unnecessary irradiation due to follow-up X-rays and unnecessary costs related to clinical and radiological follow-up are also reduced in such cases.

Our study has some limitations; it was a retrospective study including a small number of patients of our institution; further investigations with a higher number of patients, preferably prospective studies, are needed to validate our findings. Secondly, we considered the MRI to be the gold standard for excluding traumatic scaphoid lesions. This is an *a priori* decision that cannot be tested, empirically based on our data.

Conclusion

X-Ray is unreliable in diagnosis of scaphoid traumatic lesions in children. Early MRI in clinically suspected pediatric scaphoid fractures helps to rule out scaphoid traumatic lesions, leading to reduction of unnecessary irradiation and immobilization. A short MRI protocol consisting of a coronal STIR and a coronal T1 sequences is sufficient to detect normal cases.

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