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## NMR findings in patients after wrist trauma with a negative plain radiographs

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### Summary

**Background:**

The purpose was to assess the prevalence and location of the injuries of the carpal bones and soft tissue of the wrist on NMR in patients with negative radiographs.

**Material/Methods:**

A total of 89 patients (9–81 years) were consecutively examined after wrist trauma. Radiographs were performed in four projections: AP, PA, oblique and lateral. In 63 cases of negative radiographs and persistent clinical problem, simplified NMR (T1, T2, STIR; in coronal plane) was conducted with a 1.5 Tesla magnet. Results were evaluated by two independent observers. A positive X-ray result was stated when at least one observer suggested bone fracture. The MR images were viewed for detection of possible bone fracture, bone edema and soft tissue injuries. Cohen's kappa coefficient was calculated to assess the quality of chosen criteria by means of agreement between both observers and both methods.

**Results:**

As many as 26 X-ray studies were classified as positive. Substantial agreement between independent observers was found ( $\kappa=0.63$ ). In 17 cases out of 63 with two negative wrist radiogram, the NMR result was positive (19%). The most frequently fractured or injured bone was scaphoid (10 cases) and distal radius (5 cases). Fair agreement was found between X-ray and NMR studies ( $\kappa=0.37$ ) due to different diagnostic information received in both methods.

**Conclusions:**

Simplified NMR imaging of the wrist proved to be strongly efficient in the detection of pathological changes in injured wrists.

**Key words:**

wrist trauma imaging • wrist MRI • wrist X-ray • occult scaphoid fracture

**PDF file:**

<http://www.polradiol.com/fulltxt.php?ICID=882964>

### Background

Wrist region is a frequent site of injury regardless of patient's age.

Occult fractures of carpal bones, scaphoid bone in particular, pose a serious clinical problem. Fractures invisible in conventional radiographs are not properly treated, leading to serious complications such as posttraumatic necrosis, nonunion, instability or sympathetic dystrophy. There has been a long search for an optimal diagnostic pathway in patients after wrist injury that would take into consideration the costs of imaging [1] (mainly NMR) on one hand and the economic burden of patient's several-week-long absence from work due to complications arising from undiagnosed fracture on the other.

Authors of this work analyze their own findings on detection of occult posttraumatic lesions in the carpal region, propose a simplified NMR examination protocol and evaluate the results presented by researchers from other centers.

### Material and Methods

#### Material

Retrospective analysis included 89 patients: 62 women aged 9–81 years (mean 35.8 years) and 27 men aged 10–81 years (mean 27.2 years).

All patients were referred from the Emergency Medical Department to the Radiology Department for conventional



**Figure 1A.** A 19-year-old woman, negative standard radiograph, AP position. Picture performed 24 hours after trauma.



**Figure 1B.** A 19-year-old woman, negative standard radiograph, oblique position. Picture performed 24 hours after trauma.

hand X-rays because of wrist injury. All patients sustained an injury to the hand within 24 hours before admission and presented with signs of scaphoid fracture, including soft tissue edema and pain in the area of anatomical snuffbox, in clinical examination. NMR examination was performed in patients with persisting wrist pain and without any findings on X-ray.

**Methods**

*Radiographic studies*

In all cases the time from injury to the first X-ray did not exceed 24 hours. Digital X-rays of the wrist encompassed



**Figure 1C.** A 19-year-old woman, NMR examination performed one month after trauma. STIR-sequence, coronal plane: bone marrow edema within the site of trauma.



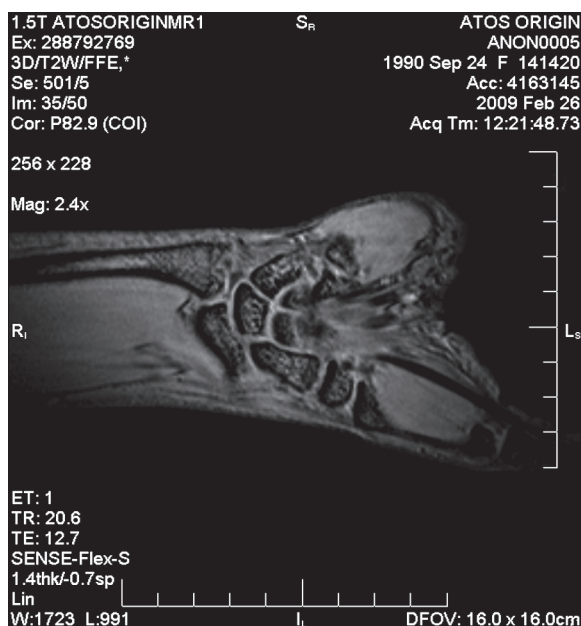
**Figure 1D.** A 19-year-old woman, NMR examination performed one month after trauma. T1-weighted image, coronal plane: fracture within the scaphoid waist.

distal epiphyses of the forearm bones and were conducted in the following projections:

1. Anteroposterior with oblique ulnar deviation
2. Posteroanterior with oblique ulnar deviation
3. Lateral
4. Axial posteroanterior

*NMR examination*

Time from X-ray to NMR examination was 1-194 days (mean 52 days).



**Figure 1E.** A 19-year-old woman, NMR examination performed one month after trauma. 3D/T2W/FFE\*-sequence, coronal plane: fracture within the scaphoid waist.

Studies were performed using an Achiva 1.5T scanner by Philips.

Surface coil was used. Hand was fully extended in a prone position.

A simplified study protocol included the following sequences:

1. T1W SE parameters:

TR: 381 TE: 20.0 slice 3mm gap=0.3 matrix 256×205; number of scans: 12

Time: 2 min.

2. T1W 3D FFE

TR: 25.0 TE: 4.6 slice 2 mm gap=1.0 matrix 208×208; number of scans 50

Time: 4 min. 23 sec.

3. STIR

TR: 1200.00 TE: 15.0 slice 3 mm gap=0.3 matrix 256×204; number of scans 24

Time: 2 min. 32 sec.

4. T2W/FFE

TR: 500.0 TE: 14.9 slice 3 mm gap=0.3 matrix 256×228; number of scans 12

Time: 2 min. 56 sec.

5. 3D/T2W/FFE

TR: 20.7 TE: 12.9 slice 1.4 mm gap=0.7 matrix 256×228; number of scans 50

Time: 3 min. 18 sec.

Each study protocol consisted of 3 sequences. Total time of the study, depending on applied sequences, ranged from 8 to 10 min.

Analysis of radiological image.

We looked for interruptions in the cortical layer or bone dislocation in the carpal region indicating ligament

damage. In the absence of the above signs, examination was considered negative for fractures.

#### NMR image analysis

We assessed images for the presence of bone marrow edema, continuity and signal from bone trabeculae, width of interosseous spaces, presence of free fluid, continuity and signal from radial and ulnar ligaments as well as width of space between distal parts of radius and ulna.

Occult fracture was diagnosed when the fracture line was visible in NMR image but not in an X-ray picture (Figure 1A–E).

The term “bone contusion” referred to cases where high signal was obtained from the bone marrow (edema) in T2W sequences, but without a visible fracture line in T2W and STIR sequences (Figure 2A–D).

Acquired images were evaluated independently by two radiology specialists experienced in the diagnostics of the musculoskeletal system.

Cohen’s kappa test was applied in order to assess the agreement between findings made by two researchers and two imaging methods.

## Results

Radiograms of 26 patients were considered positive for fracture and treatment was implemented. There was a good agreement between independent investigators (kappa=0.63). The remaining 63 patients with negative radiograms and persisting pain were examined using a simplified NMR protocol. NMR examination was positive in 17 cases among 63 subjects with negative radiograms, including 12 people (19%) with visible fractures. We noted fair agreement between the two applied methods (kappa=0.37), probably due to their various degrees of informativeness. Scaphoid bone (6 cases) was the most frequent site of fracture, followed by epiphysis of the radius (4 cases). There was also 1 case of capitate and trapezoid bone fracture.

Bone marrow edema was detected in:

Scaphoid bone – 7 cases,

Capitate bone – 1 case,

Lunate bone – 2 cases.

In two patients we diagnosed scapholunate ligament disruption and damage to the triangular fibrocartilage complex (TFCC) in one subject (Figure 3A–D).

## Discussion

Posttraumatic changes in carpal structures pose a serious radiological challenge. X-ray pictures have been used for a long time for detecting damage to bone structures. In most symptomatic patients additional projections are used apart from the standard two projections: axial and oblique (15 or 45 degrees) with ulnar deviation. Aside from the lack of possibility to assess ligament structures as well as possible bone edema, a great deal of the injured are not diagnosed



**Figure 2A.** A 12-year-old boy, negative standard radiograph, slightly oblique projection, performed on the day of admission to hospital.



**Figure 2B.** A 12-year-old boy, negative standard radiograph, PA position, performed on the day of admission to hospital.

with fractures. It happens despite performing repeated radiograms, usually two weeks following trauma. Some authors question the benefits of control examinations after 2 weeks [1] and indicate an NMR study [2]. A percentage of patients with carpal bone fractures invisible on X-ray pictures ranges, depending on the source, from over a dozen [3,4]: 11% in a study by Low et al. [2] to 37% according to Pierre-Jerome et al. [5]. Moreover, in about 30% of clinically symptomatic patients injuries involve only soft tissues and spongy bone. As there are great disparities in the reports on the subject regarding the percentages of radiologically occult injuries, we conducted a retrospective



**Figure 2C.** A 12-year-old boy, NMR examination performed 6 weeks after trauma. T1W sequence, coronal plane, posttraumatic bone marrow edema, attenuated signal detected within scaphoid and capitate bones.



**Figure 2D.** A 12-year-old boy, NMR examination performed 6 weeks after trauma. STIR sequence, coronal plane, posttraumatic bone marrow edema. High signal within scaphoid and capitate bones.

analysis of X-ray and NMR images in patients with clinical symptoms and normal radiograms. We assessed the frequency of occurrence and location of posttraumatic lesions in wrist bones and soft tissues. Methodology of radiological examination involved four projections which, compared to a standard diagnostic pathway, should have increased sensitivity. In the analyzed time, which was relatively short, we found 63 people fulfilling these criteria. NMR imaging is usually poorly accessible, time-consuming and



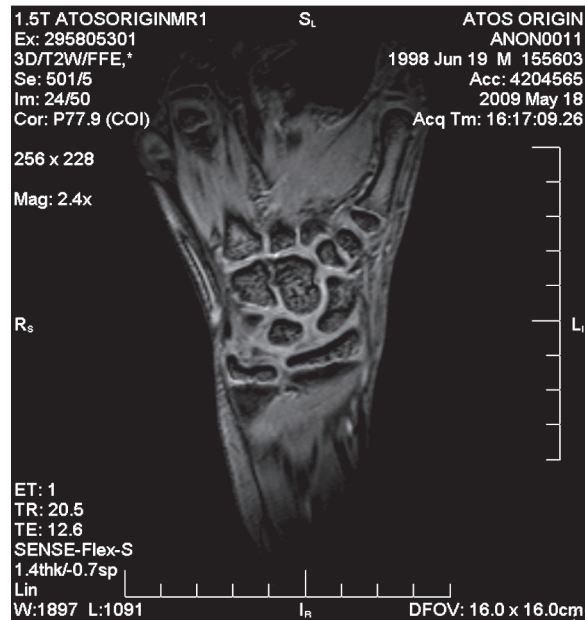
**Figure 3A.** A 12-year-old boy, negative posttraumatic standard radiograph, PA position.



**Figure 3C.** A 12-year-old boy, NMR examination performed one month after trauma. STIR sequence, coronal plane: bone marrow edema within the distal pole of the scaphoid.



**Figure 3B.** A 12-year-old boy, NMR examination performed one month after trauma. T1W sequence, coronal plane, fracture within scaphoid waist.



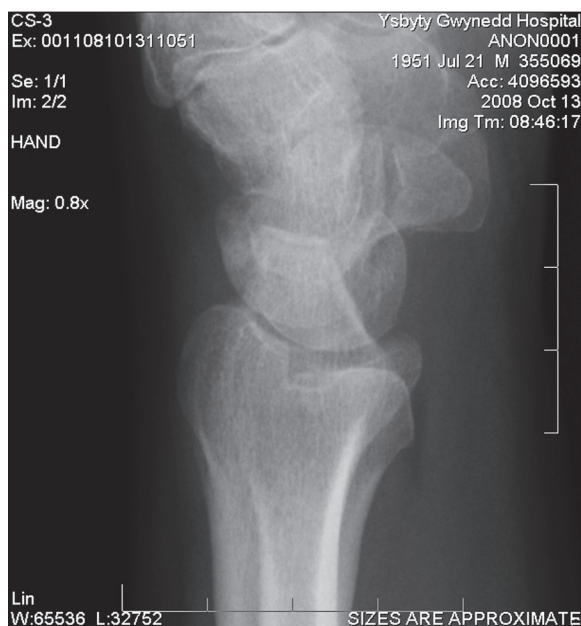
**Figure 3D.** A 12-year-old boy, NMR examination performed one month after trauma. 3D/T2W/FFE\* sequence, coronal plane: fracture line within the scaphoid waist.

costly. Often, this is a consequence of a high number of performed acquisition sequences (up to over a dozen), including sequences after intravenous and intraarticular injection of contrast. In our center, a simplified NMR protocol was used in symptomatic patients with wrist trauma and included three NMR sequences (T1, T2 and STIR) acquired in a coronal plane. The entire study lasted several minutes and did not require application of contrast medium. Despite significant time period between trauma and NMR examination, the analysis included only the lesions that could have resulted from the injury (fractures, bone marrow edema or soft tissue damage).

Images were re-evaluated by two experienced radiologists, which was supposed to increase the probability of correct interpretation. In some studies authors compared findings acquired by investigators with various qualifications. Low et al. [2] compared the results of analysis of radiograms performed by trauma specialists and radiologists and noted great disparities between their evaluations. It indicated that investigator's experience greatly influenced the end results. In our study, analysis of images acquired on the day of trauma by two independent radiology specialists allowed for detection of fractures in 26 out of 89 studied



**Figure 4A.** A 57-year-old man after wrist trauma, negative standard radiograph, PA position.



**Figure 4B.** A 57-year-old man after wrist trauma, negative standard radiograph, lateral view.

subjects. Intraobserver agreement measured by kappa coefficient was 0.63 (good agreement). In his study, Low [2] acquired the highest agreement (53%) between a radiology specialist and a hand surgeon. In most facilities the first radiogram assessment is not performed by radiologists or hand surgeons. Persisting pain is an indication for a specialist consultation, often long-awaited while immobilized [6]. Second radiogram is characterized by low sensitivity even when evaluated by proper specialists. In one of his works Low et al. [2] detected only 1/3 of occult scaphoid fractures (compared to NMR results) on the second X-ray. Performing NMR of the wrist right away seems to be a good solution to the problem. Most often simple algorithms

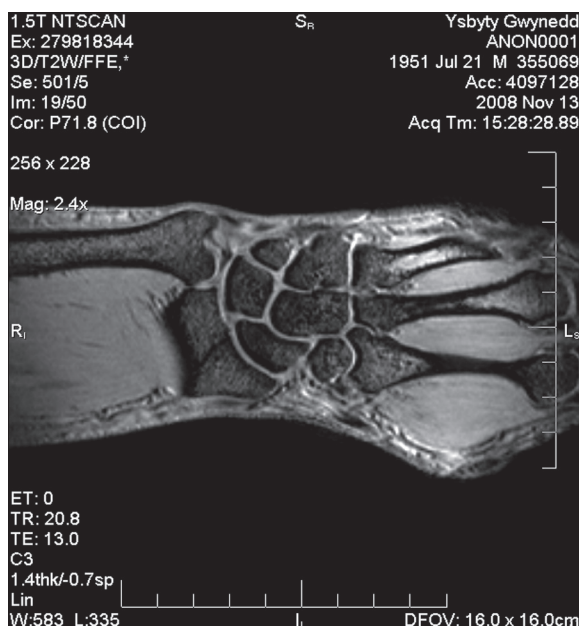


**Figure 4C.** A 57-year-old man after wrist trauma, NMR examination performed one month after trauma. T1W sequence, coronal plane, fracture within the distal aspect of the radius.



**Figure 4D.** A 57-year-old man after wrist trauma, NMR examination performed one month after trauma. STIR sequence, coronal plane: fracture within the distal aspect of the radius.

are used comprising of two to four sequences with a total acquisition time of 10 to 20 minutes. We recommend using three sequences in coronal plane. A similar protocol (T1, T2 and STIR in coronal plane) was used by Gabler et al. [6]. Pierre-Jerome et al. [5] described three algorithms consisting of 4 sequences each (a significant difference involves the lack of STIR sequence and replacing it with fat saturation sequence – FatSat). On the other hand, Low et al. [2] used only two sequences – T1 and STIR in coronal plane, while Spence et al. [7] used five sequences with additional



**Figure 4E.** A 57-year-old man after wrist trauma, NMR examination performed one month after trauma. 3D/T2W/FFE\*sequence, coronal plane: fracture within the distal aspect of the radius.

T1 sequence in sagittal and T2 in transverse planes. In justified cases patients are referred for more detailed NMR studies, including NMR arthrography. In this study we compared the agreement between X-ray and NMR studies and acquired a kappa coefficient of only 0.37 (poor agreement) indicating that both studies carry different informative values with regard to posttraumatic carpal lesions. Among 63 patients with persisting symptoms and negative X-rays (both investigators) we acquired positive NMR results for 17 (27%) patients, including 12 (19%) subjects

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diagnosed with carpal bone fractures. In similar studies Pierre-Jerome [5] detected occult (radiologically silent) lesions in as many as 62.4% of patients, including fractures in 37% of cases. Our findings revealed significantly lower number of an occult traumatic changes within the wrist bones. Possibly, those differences arise from various management algorithms in cited studies. Pierre-Jerome [5] did not specify whether radiograms had been evaluated by experienced radiologists or Emergency Department staff (report was published in *Emergency Radiology*).

In 12 patients, fractures visualized in NMR involved scaphoid bone in 50% and the radius in 33% (Figure 4A–E).

Similarly, isolated spongy bone edema without fracture mainly involved the scaphoid. This is consistent with the reports by other researchers.

Two patients were diagnosed with scapholunate ligament disruption.

A small number of subjects does not allow for drawing in-depth conclusions.

## Conclusions

In summary, persisting wrist pain following trauma should be an indication for extended NMR diagnostics despite the lack of radiological signs. Most posttraumatic changes are visible in NMR. Moreover, a more detailed description of these lesions is possible, which determines proper management. Lack of suitable treatment may lead to serious complications: delayed bone union, pseudoarthrosis formation, posttraumatic necrosis. Increasing availability of NMR equipment and a short, cheap study protocol give trauma patients a chance to avoid serious complications resulting from missed injuries.