

## Amsterdam MRI assessment of the Physis

## Protocol

The Amsterdam MRI assessment of the Physis protocol has been developed for uniform assessment of the periphyseal area of the distal radius and ulna on MRI on four coronal sequences:

- Turbo spin-echo (TSE) proton-density (PD) weighted series;
- PD TSE series with fat suppression ((S)pectral Attenuated Inversion Recovery, SPAIR);
- T2-weighted 2-point Dixon series;
- Three-dimensional (3D) water-selective cartilage scan (WATSc) series.

The protocol consists of three components: A) Epiphysis, B) Physis, and C) Metaphysis. In total 12 items can be scored in the radius, and 5 items in the ulna. All items, their grading options and the sequences that are recommended for optimal assessment are discussed below, with example images.

### A. Epiphysis

#### Extent of bone marrow oedema

**Description:** Presence of ill-defined area of increased signal intensity on water-sensitive sequences. Extent of bone marrow oedema is determined in the entire volume of the epiphysis, i.e. over all slices displaying the epiphysis. This item is graded only in the radius.

**Best visibility:** T2 Dixon, PD TSE SPAIR

GRADE	0	1	2
	No oedema	<50% of epiphyseal volume	>50% of epiphyseal volume

#### Location of bone marrow oedema

**Description:** Location of bone marrow oedema in relation to the physis, either in an epiphyseal area connected to the physis, or with a clear area of epiphyseal bone not affected by oedema between the physis and the area of bone marrow oedema. This item is graded only in the radius.


**Best visibility:** T2 Dixon, PD TSE SPAIR

GRADE	0	1	2
	No oedema	Oedema adjacent to physis	Oedema not adjacent to physis

#### Signal intensity of bone marrow oedema

**Description:** Signal intensity of epiphyseal bone marrow oedema. This item is graded only in the radius.

**Best visibility:** T2 Dixon, PD TSE SPAIR

GRADE	0	1	2	3	4	5
	No oedema					Maximal signal intensity

### Visibility of bone marrow oedema on 3D WATSc

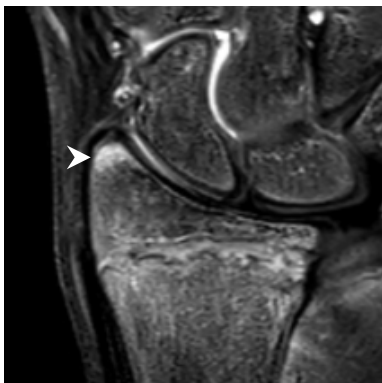
**Description:** Visibility of bone marrow oedema on 3D WATSc. This item is graded only in the radius.

**Best visibility:** 3D WATSc

<b>GRADE</b>	<b>0</b>	<b>1</b>	<b>2</b>
	No oedema	Oedema not visible	Oedema visible

### Examples

#### T2 Dixon



Focal area (marked by white arrowhead) of epiphyseal bone marrow oedema of less than 50% of the epiphyseal volume, not adjacent to the physis, with Grade 4 signal intensity.

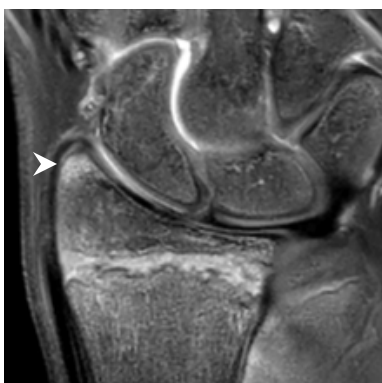


Area (marked by white arrowhead) of epiphyseal bone marrow oedema of more than 50% of the epiphyseal volume, adjacent to the physis, with Grade 3 signal intensity.



Area (marked by white arrowhead) of epiphyseal bone marrow oedema of more than 50% of the epiphyseal volume, adjacent to the physis, with Grade 2 signal intensity.

#### PD TSE SPAIR



Focal area (marked by white arrowhead) of epiphyseal bone marrow oedema of less than 50% of the epiphyseal volume, not adjacent to the physis, with Grade 4 signal intensity.



Area (marked by white arrowhead) of epiphyseal bone marrow oedema of more than 50% of the epiphyseal volume, adjacent to the physis, with Grade 3 signal intensity.



Area (marked by white arrowhead) of epiphyseal bone marrow oedema of more than 50% of the epiphyseal volume, adjacent to the physis, with Grade 2 signal intensity.

## B. Physis

### Thickness

**Description:** Thickness of the physis compared to what would be expected at the maturity stage of the patient. This item is graded only in the radius.

**Best visibility:** 3D WATSc, T2 Dixon, PD TSE

GRADE	0	1
	Normal	Increased

### Thickness compared to proximal physis of first metacarpal (MC1)

**Description:** Thickness of the physis in relation to the proximal physis of the first metacarpal bone (MC1), which should be included in the field of view. This item is graded only in the radius.

**Best visibility:** 3D WATSc, T2 Dixon, PD TSE

GRADE	0	1	2	3
	Not increased	2 x thicker than MC1	3 x thicker than MC1	4 x thicker than MC1

### Examples

#### 3D WATSc



Distal radial physis that is increased in thickness (white arrowheads), and 4 times thicker than proximal physis of MC1 (marked with white asterisk).



Unilateral widening of the distal radial physis (marked with white arrowhead), that is 3 times thicker than the proximal physis of MC1 (marked with white asterisk).



Unilateral widening of the distal radial physis (marked with white arrowhead), that is 2 times thicker than the proximal physis of MC1 (marked with white asterisk).

**PD**



Distal radial physis that is increased in thickness (white arrowheads), and 4 times thicker than proximal physis of MC1 (marked with white asterisk).



Unilateral widening of the distal radial physis (marked with white arrowhead), that is 3 times thicker than the proximal physis of MC1 (marked with white asterisk).

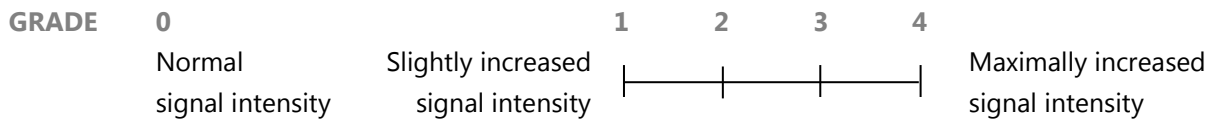


Unilateral widening of the distal radial physis (marked with white arrowhead), that is 2 times thicker than the proximal physis of MC1 (marked with white asterisk).

**Signal intensity of physis**

**Description:** Subjectively graded signal intensity of the physeal cartilage. This item is graded only in the radius.

**Best visibility:** 3D WATSc, T2 Dixon, PD TSE



**Examples**

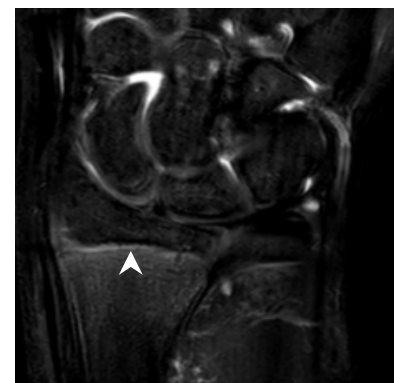
**T2 Dixon**



Increased (Grade 4) signal intensity of the distal radial and ulnar physes, marked with white arrowheads.



Increased (Grade 3) signal intensity of the distal radial and ulnar physes, marked with white arrowheads.



Increased (Grade 2) signal intensity of the distal radial physis, marked with white arrowhead.

## PD TSE



Increased (Grade 4) signal intensity of the distal radial and ulnar physes, marked with black arrowheads.



Increased (Grade 3) signal intensity of the distal radial and ulnar physes, marked with black arrowheads.



Increased (Grade 2) signal intensity of the distal radial physis, marked with black arrowhead.

## C. Metaphysis

### Physeal border on metaphyseal side

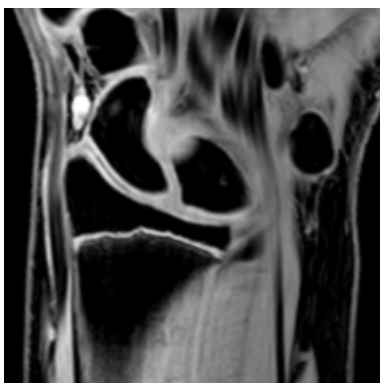
**Description:** Appearance and regularity of the physis on the metaphyseal side of the physis. This item can be graded in the radius and the ulna.

**Best visibility:** 3D WATSc

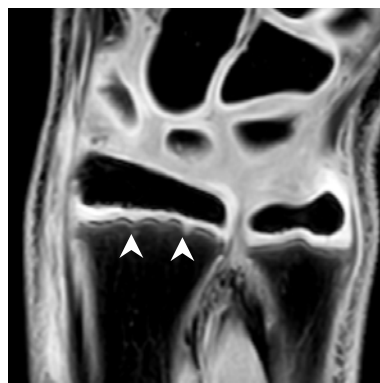
GRADE	0	1	2
	Undulating	Slightly irregular	Distinctly irregular

### Examples

#### 3D WATSc



Undulating shape of metaphyseal border of the radial physis.



Slightly irregular border of the metaphyseal side of the radial physis (marked by white arrowheads).



Distinctly irregular border of the metaphyseal side of the radial physis (marked by white arrowheads).

### Metaphyseal intrusions

**Description:** Presence of high signal intrusions into the distal metaphysis originating from (or directly below) the physis. This item can be graded in the radius and the ulna.

**Best visibility:** 3D WATSc

<b>GRADE</b>	<b>0</b>	<b>1</b>
	Absent	Present

### Connection of metaphyseal intrusions with physis

**Description:** Presence of a connection between the metaphyseal intrusion and the physis. This item can be graded in the radius and the ulna.

**Best visibility:** 3D WATSc

<b>GRADE</b>	<b>0</b>	<b>1</b>	<b>2</b>
	No intrusions	Connected with physis	Not connected with physis

### Depth of metaphyseal intrusions

**Description:** Extent of the metaphyseal intrusion into the distal metaphysis. This item can be graded in the radius and the ulna.

**Best visibility:** 3D WATSc

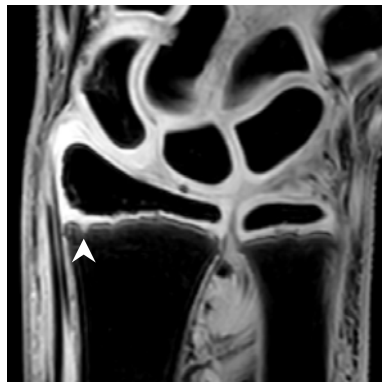
<b>GRADE</b>	<b>0</b>	<b>1</b>	<b>2</b>
	No intrusions	Intrusions <2 mm	Intrusions >2 mm

### Examples

#### 3D WATSc



High signal intrusions of less than 2 mm into the radial metaphysis and not connected to the physis (white arrowhead).



High signal intrusions of less than 2 mm into the radial metaphysis and with connection to the physis (white arrowhead).

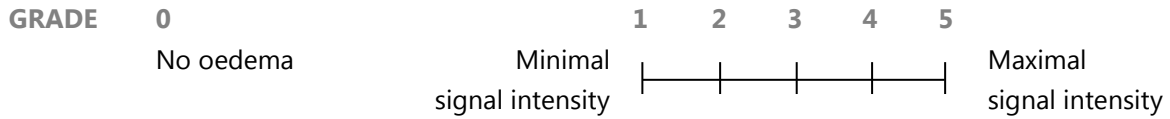


High signal intrusion of more than 2 mm into the radial metaphysis and with connection to the physis (white arrowhead).

**Metaphyseal bone marrow oedema**

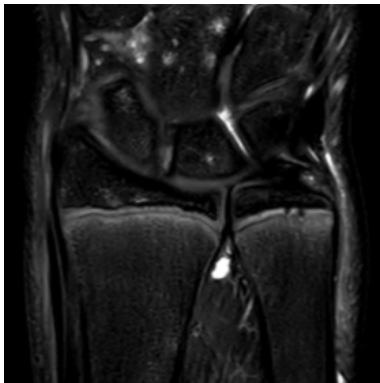
**Description:** Signal intensity of metaphyseal bone marrow oedema. This item can be graded in the radius and the ulna.

**Best visibility:** T2 Dixon, PD TSE, PD TSE SPAIR, 3D WATSc



**Examples**

**T2 Dixon**



Diffuse area of metaphyseal bone marrow oedema with Grade 1 signal intensity in the radius and the ulna.



Diffuse area of metaphyseal bone marrow oedema with Grade 3 signal intensity in the radius and the ulna.



Diffuse area of metaphyseal bone marrow oedema with Grade 4 signal intensity in the radius.

**PD TSE SPAIR**



Diffuse area of metaphyseal bone marrow oedema with Grade 1 signal intensity in the radius and the ulna.



Diffuse area of metaphyseal bone marrow oedema with Grade 3 signal intensity in the radius and the ulna.



Diffuse area of metaphyseal bone marrow oedema with Grade 4 signal intensity in the radius.