A complete interactive guide to using musculoskeletal ultrasonography in pediatric rheumatology patients

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Musculoskeletal Ultrasonography is increasingly being recognized as an important adjunct to the clinical exam in pediatric rheumatology. Whilst the educational resources to support the use of pediatric ultrasound are increasing, there is still a need to provide a practical tool that can easily be incorporated into daily clinical practice.

We are very proud to provide the Ped-MUS e-book, that covers all relevant aspects of pediatric musculoskeletal ultrasonography in rheumatology practice. The key sections include: technical aspects; specific scanning instructions including anatomy and pathology; practical aspects of scoring and report generation. The e-book is designed to be used as a flexible tool and the user can navigate directly to the area of interest.

International efforts on standardization of pediatric musculoskeletal ultrasonography have progressed significantly in recent years and many areas are still in evolution. The content of this e-book has been modelled on existing knowledge and expert opinion but will undoubtedly evolve further in future years. We encourage any type of feedback that can help to make this resource more useful to clinical practice.

We hope that you will enjoy using ultrasonography as part of your pediatric rheumatology practice as much as we do.

The steering committee of Ped-MUS:

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Why use ultrasonography in pediatric rheumatology?

- Many anatomic regions are complex\(^1\)
- JIA patients are often young\(^2\)
- History and physical exam can be challenging\(^2-3\)
- Direct combination of history, exam and imaging provide an enhanced assessment

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Ultrasonography reveals many pathologies - for example in a swollen wrist or finger.

DIP, distal interphalangeal joints; PIP, proximal interphalangeal joint.

Rooney ME et al. J Rheumatol 2009;36:1725-1729; Roth J, personal images
**Additional benefits**

- Well tolerated, no sedation
- Multiple joint assessment
- No radiation/gadolinium
- Ability to do ultrasonography-guided injections
- Supports interaction with patient and parent
- Visual illustration of abstract concepts for patients

How does “Ultrasound” work?

- Ultrasound is safe, painless and produces pictures of the inside of the body

- Ultrasound imaging uses transmission and reflection of high frequency longitudinal mechanical waves (ultra sonic waves)

- Image information is provided by energy of waves reflected from surfaces between different tissues

- The reflected echoing waves are analyzed and displayed by a computer, which creates a real-time picture of tissues, structures and organs on the display
Acoustic Impedance

- Reflection at the interface of two tissues depends on the difference in the acoustic impedance of the tissues and the angle of insonation of the sound beam.

- Reflection of sound increases with the increase in difference in acoustic impedance.

- Typical reflection at soft tissue interfaces:
  - 99.9% soft tissue air
  - ≈ 40% muscle and bone
  - < 1% soft tissue to soft tissue
B-Mode

- The bright dots on the monitor represent the reflected echoes.
- The intensity of the brightness indicates the energy of the reflected soundwaves on a real-time B-Mode image.
- B-Mode stands for Brightness-Modulation.

Doppler-Mode

- Doppler detects the Frequency shift between the emitted and reflected soundwave when the reflection originates from a moving object.
- Color is then assigned to these moving objects, e.g. red blood cells.
- Two Doppler techniques are commonly used: Power and Color Doppler.
- A color image displaying blood flow overlays a real time B-mode image.
How do I choose the right ultrasound equipment for my pediatric MSUS?

• Before buying or using specific ultrasound equipment consider the
  » image resolution and quality
  » equipment size
  » transducer types
  » Doppler option

• Unfortunately image resolution and quality are related to the cost

• Verify your own equipment requirements (size and portability, minimum quality, cost and budget)

• Compare different devices and manufacturers before buying

• Test the equipment on various patients as well as large and small joints (B-Mode and Doppler-Mode)

• For education, research and more complex indications you will need a larger and higher-end system

• For everyday clinical practice you may prefer a smaller and portable device

Kane et al. Rheumatology 2004;43:823–828
How do I choose the right ultrasound equipment for my pediatric MSUS?

Equipment size

Consider the required mobility of your machine and the space available for your ultrasound device. Some larger high-resolution systems may produce audible sound from the ventilator and heat up the room but offer excellent imaging results.
How do I choose the right ultrasound equipment for my pediatric MSUS?

**Image resolution**

For testing the image resolution of a system you can compare the visual discrimination between the median nerve and the flexor tendons in the longitudinal volar scan of the wrist!
How do I choose the right ultrasound equipment for my pediatric MSUS?

**Colour/Power-Doppler option**

Power or Colour Doppler capabilities are a minimum quality standard for pediatric MSUS to detect increased blood flow as an important sign of inflammation in your region of interest. You can test the sensitivity of the colour Doppler-Mode or Power-Doppler-Mode by demonstrating a few smaller physiological vessels for example in your own finger pulp. The rule of thumb is that there should be Doppler flow detectable in at least 50% of the area of the finger pulp.

This will depend on optimal Doppler settings though.
How do I choose the right ultrasound equipment for my pediatric MSUS?

Transducer Types

A multi-frequency linear transducer covering medium and higher frequencies is required.

Overall frequency range is 4 to 24 Mhz.

Many devices produce excellent images in the 12-18 MHz range.

For deeper structures lower frequencies in the 6-10 Mhz range are necessary.

Smaller footprint, high-frequency transducers are excellent for detailed visualization of small structures and guided injections.

A curvilinear probe may have a broader field of view but often a lower frequency (good penetration but less resolution).

Depending on budget may consider several transducers but priority is on one excellent linear multi-frequency transducer.
General recommendations for the pediatric MSUS assessment

- Be close to your patient and the machine
- Hold your transducer in one hand and guide your machine with the other hand
- Verify your settings before the examination
- Warm up your gel for smaller children
- Share the view on the monitor with your patient and the parents
General recommendations

- Linear transducers are generally more suitable for musculoskeletal ultrasound
- Use enough gel to keep contact between the transducer and the patient’s skin without exerting too much pressure
- Hold and guide the probe with your hand resting on the patient

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Hockey Stick
Linear
Hand Position
Positioning of Patient

Shown here are ultrasound images of the hip joint capsule in longitudinal view during external (left) and internal rotation (right).

TIPS /

- Take care of the position, i.e. flexion, extension or rotation of the joint that is being examined
- The sonographic configuration of the capsule or the synovial recess may vary with different positions of the joints (e.g. anterior hip recess during rotation of the legs, wrist recesses during flexion/extension)
- Echoic (white)
- Hyperechoic (white/grey)
- Isoechoic (grey)
- Hypoechoic (grey/dark grey)
- Anechoic (black)
• Homogeneous
• Inhomogeneous
Frequency

- Should be set higher (up to 22 MHZ) for smaller joints or more superficial areas.
- Should be set lower (up to 5 or 6 MHZ) for deeper joint regions (e.g., hip) or patients with a high body mass index.
- Rule of thumb: set frequency as high as possible and as low as necessary.

**High frequency image (18 MHZ) of needle in the tibalis posterior tendon sheath**

Lower Frequency = Better Penetration

Higher Frequency = Better Resolution
Depth

The depth should be adjusted until area of interest is centred, seen completely but is not too large or too small.

- **Increased depth** (structures below the tendon are visible)
- **Decreased depth** (tendon is centred on the image).
Focus

Should be positioned at the level of the area of interest (more focus points than one are possible)
Gain

- Adjusts the amplification of echoes on the monitor
- Compensates for attenuation
- Will increase brightness of the entire image
- Gain should only be adjusted after image has been optimized through probe and patient positioning as well as adjustment of frequency, focus & depth
Doppler box

- Has to cover the region of interest
- Close to the surface (to recognize artifacts of vessels overlying the region of interest)
- Not too large (to optimize PRF and Doppler frequency)
Doppler PRF

- The pulse repetition frequency (PRF) is set in order to allow time for the most distant echoes to return before sending the next pulse.

- For the very slow velocity blood flow in small vessels of the synovium the PRF has to be set low enough (e.g. 0.6-0.8 KHz) to detect vascularization.

- When the Doppler shift frequency exceeds half of the PRF, the “Aliasing” artifact occurs (overlap from the first pulse with returning echoes from the second pulse).

PRF 0.6 kHz (wrist)  
PRF 2.6 kHz (wrist)
Doppler wall filter

- The Doppler wall filter helps to filter out low frequency signals that may cause artifacts on your images for example from movement of the vessel wall.

- If the wall filter is set too high, the normal vascularization of low velocity flow vessels may not be detected.
Tissue characteristics

**Bone (B)**
Hyperechoic with posterior acoustic shadowing

**Cartilage (C)**
Hyaline cartilage is hypoechoic or anechoic

**Connective tissue (CT) and Fat (F)**
Hypoechoic to hyperechoic and slightly irregular

Examples of different tissue characteristics (suprapatellar knee scan)
Tissue characteristics

**Tendons (T)**
Tendons have a fibrillar pattern. The fine hyperechoic bands represent the tendon fascicles and run parallel to the transducer.

**Nerves (N)**
More hypoechoic areas and less fibrillar compared with tendons. Fascicular pattern.

**Median nerve and flexor tendons (longitudinal)**

**Median nerve and flexor tendon (transverse)**
Tissue characteristics

**Muscle (M)**
Usually hypoechoic depending on the transducer orientation. Fine intramuscular hyperechoic lines (epimysium and perimysium). Thicker hyperechoic lines (septae)

**Joint capsule**
Hyperechoic structure which may be seen over bones, cartilage, and other intra-articular tissue

Anterior hip joint capsule and iliopsoas muscle (longitudinal)
B mode - **anisotropy**

**Anisotropy**
Decreased echogenicity of soft-tissue structures when the ultrasound beam is not directed perpendicular to the examined structure. A majority of the insonating sound beam is reflected in a direction away from the transducer.

**Anisotropy is frequent in tendons & ligaments**

Taljanovic M et al. Semin Musculoskelet Radiol 2014;18:3–11
Posterior acoustic shadowing

- Occurs when the ultrasound echoes are reflected, absorbed, or refracted
- Shadowing appears as an anechoic area that extends from the involved interface (e.g. bone, calcifications, some foreign bodies, or gas)
- Refractile shadowing may occur at the edges of some structures (e.g. tendons)
B mode - **increased through transmission** (posterior enhancement)

- Occurs when the attenuation of the ultrasound beam is lower in an imaged structure (e.g. fluid-filled cyst) compared to the adjacent tissue.

- Results in a hyperechoic appearance of soft tissues below the targeted (e.g. fluid-filled) structure.

*TIP* / Together with compressibility/displaceability, the increased through transmission or posterior enhancement can help in the characterization of a structure as fluid filled.
B mode - reverberations

During the ultrasound examination of two highly reflective surfaces, the echo beam may be repeatedly reflected back and forth between the two structures ("reverberates"). The ultrasound transducer interprets the sound waves returning as deeper structures since it took longer for the wave to return to the transducer. Reverberation may also occur between the transducer itself and a very reflective structure.

Needle (wrist joint)

Reverberation
A series of linear reflective echoes occur below the examined structure with equal distances to each other
Doppler blooming

- Caused by Doppler gain setting!
- Decreasing the Doppler gain minimizes the blooming artifact!
- Vessels appear larger due to color outside of the vessel.
Doppler movement artifact

- Caused by movement of the patient or the probe
- Often occurs in younger children
- Appears as short flashes of confluent color

Vascularization in the wrist (calm patient)

Vascularization in the wrist plus movement artifact
Mirror artifact

- Reflection of Doppler signals from the highly reflective bone surface may result in a false mirror image of a vessel inside the bone
- More frequently seen with larger vessels
- Can be seen in B-mode with mirroring of the B-mode image as well

Doppler mirroring of the radial artery (arrow)
Minimum quality standards for the ultrasound machine

- A linear broadband transducer with a frequency of 5 to a minimum of 13 MHz (or higher)

- Optional: Convex transducer with a frequency of 4-8 Mhz (for imaging obese patients or examining deep structures)

- Optional: hockey stick transducer

- Harmonic imaging

- Spatial compound imaging

- Doppler options

The immature skeleton

- Bones forming joints are important reference structures in ultrasonography.
- Depending on age and skeletal maturity, a variable portion of short bones and the epiphysis in long bones consist of hyaline cartilage.
- The secondary ossification center in the epiphysis can have an irregular shape and will increase with age and maturation.

The healthy joint – key characteristics on ultrasonography

- Clearly identify the cartilage surface and note the growth plate interrupting the cortical bone\textsuperscript{1,2}
- The joint capsule delineates the outer limit of the joint but not necessarily the synovial recess\textsuperscript{1}
- Fat/connective tissue can be found intra-articularly but is extrasynovial\textsuperscript{3}
- Hyperechoic dots on B mode within cartilage represent vascular channels, i.e. blood vessels within cartilage\textsuperscript{1,2}

The healthy joint – key characteristics on ultrasonography

- Doppler signals within the intra-articular fat, cartilage, and growth plate can be physiologic\textsuperscript{2,3}

Normative data for synovial recesses in B mode

- Normative data on B mode for various joints have been published\textsuperscript{1-4}

- A variable amount of distension of the synovial recess may be present in normal joints\textsuperscript{1-4}

- The comparison with normative data should serve as guidance, but not absolute cut-off, for pathology

\textbf{TIPS}:

- Synovial distensions in some locations might persist even with resolution of synovitis
- Longitudinal evaluation of findings can be more informative than single assessments
- The combined assessment with B mode and Doppler may be more reliable in diagnosing synovitis

Assessment of cartilage

- Ossification centers can be irregular and this will affect the ability to measure cartilage thickness reliably.
- Cartilage thickness will change with age and sex but also with maturity.
- In JIA maturation of cartilage can be advanced in synovitic joints affecting the thickness of cartilage.
- The cartilage surface (presence of the cartilage interface sign) might be an important indicator of healthy cartilage.

Assessment of Cartilage

Advanced Ossification with Synovitis

Bilateral suprapatellar longitudinal scan of a 3 year old JIA patient with psoriatic arthritis and involvement of the left knee. US of the left knee shows synovial hypertrophy (SH) in the suprapatellar recess and accelerated ossification (arrows) of the left patella in comparison to the right and healthy side.
• Synovitis on ultrasonography in children can be seen on B mode and Doppler

• It will appear as hypoechoic or anechoic on B mode; fluid is displaceable and synovial hypertrophy non-displaceable

• Abnormal Doppler signals need to be within an area of synovial hypertrophy

• Physiologic Doppler signals can be present in any area of the joint

The enthesis

- The enthesis and its associated structures are often called an enthesis organ.
- It includes the tendon with the insertion into bone through fibrocartilage (enthesis), the fat pad, and the bursa.

Adapted from Weiss PF et al. Curr Rheumatol Rep 2016;18:75
Maturation of the normal enthesis

- Initially the tendon inserts into cartilage
- With increasing age a layer of fibrocartilage forms between the tendon and the hyaline cartilage
- Within the hyaline cartilage ossification centers appear
- With advancing age and maturation ossification will complete leaving only a thin layer of fibrocartilage


Illustration designed, based on an illustration by Carlo Martinoli, Genoa, Italy
Maturation of the normal enthesis

Insertion of the Achilles tendon in the posterior calcaneus

Doppler in the normal enthesis

- Physiologic Doppler signals can be found in the fat pad, within the tendon, along the tendon, close to the enthesis, and within the cartilage
- Some entheses might be more prone to the detection of physiologic Doppler signals
- The presence of physiologic Doppler signals also varies with age

Pathology of enthesitis

Definition of enthesopathy (mechanical lesions and spondylarthropathies, no pediatric definition exists):

Abnormally hypoechoic (loss of normal fibrillar architecture) and/or thickened tendon or ligament at its bony attachment (may occasionally contain hyperechoic foci consistent with calcification), seen in 2 perpendicular planes that may exhibit Doppler signal and/or bony changes including enthesophytes, erosions, or irregularity.

- Interpret Doppler signals cautiously taking into account the presence of B-mode abnormalities
- The distinction between mechanical lesions and enthesitis has to be done based on the clinical background
- Some entheses are more prone to mechanical lesions

Apophysitis

- During growth, forces on entheses at bony protuberances (apophyses) increase.

- As a result, inflammatory changes of the entheses may occur including thickening, hypo- and anechogenicity, bursal distension, but also fragmentation of the ossification center.

- This condition is called apophysitis and may manifest at the tibial tuberosity (Osgood–Schlatter disease), posterior calcaneus (Sever’s disease), distal patella (Sinding-Larsen–Johansson syndrome), and other locations.

- The clinical (symptoms) and imaging correlation varies.

- Presence of several ossification centers is physiologic at the posterior calcaneus, proximal 5th metatarsal, and other locations.

- Apophysitis is an important differential diagnosis of enthesitis as part of spondyloarthropathy.

Tendon and tendon sheath

The normal tendon has a hyperechoic (relative to subdermal fat) fibrillar pattern (i.e. hyperechoic parallel lines in longitudinal planes and hyperechoic dots in transverse planes) with a thin hypoechoic (relative to tendon fibers) halo in transverse or thin hypoechoic lines above and below the tendon in longitudinal views.

- Do not mistake anisotropy for tendonitis or tenosynovitis
- Verify the presence of anisotropy by angling the probe

Tenosynovitis

Tenosynovitis presents as hypoechoic or anechoic thickened tissue with or without fluid within the tendon sheath, which is seen in 2 perpendicular planes and which may exhibit Doppler signal.

Ultrasound images showing parapatellar views

Transverse view, Doppler

Peroneus tendons

Paratenonitis

- Many tendons do not have a tendon sheath but a paratenon instead.

- The paratenon is an elastic sleeve surrounding the tendon that consists of type 1 and 3 collagen and also synovial cells in a single layer.

- Paratenonitis presents as hypoechoic or anechoic thickened tissue with or without fluid around the tendon, which is seen in 2 perpendicular planes and which may exhibit Doppler signal.

Paratenonitis is well described as a characteristic feature of psoriatic arthritis but can also be seen in rheumatoid arthritis. No data on findings in children exist currently but images above are taken from a 14 year old girl with JIA.

Erosions

• Erosions are an interruption of the cortical bone surface seen in two perpendicular planes.

• In children they tend to be in a more epiphyseal location than in adults.

• Do not mistake the growth plate or openings for feeding vessels for erosions.

• Many epiphyses contain several ossification centers; do not mistake the gaps between them as erosions.
How to scan in practice - **exact positioning of the probe**

The exact positioning of the probe through angulation, rotation, and heel-toeing is necessary to obtain a clear depiction of the relevant structures.

This is particularly important in order to see a clear outline of the cartilage in the immature bone and be able to distinguish it from joint effusions.

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How to scan in practice - **gull wing sign**

The cartilage of two adjacent bones in a younger child with incomplete ossification will show a shape reminiscent of the wings of a bird (gull wing).

This concave shape is the opposite of what one would see in the case of an effusion, where it would be convex.
How to scan in practice - tornado sign

In the absence of synovial fluid a white reflection can be seen descending into the joint space between the cartilage of the immature bone – this is called the tornado sign.
How to scan in practice - move the joint to clarify findings

In this example, while bending the wrist slightly, the shape of the incompletely ossified bones remains the same, suggesting that the black areas are cartilage and not effusions.

- It can be difficult to differentiate structures well especially in younger children with a significant cartilage component.
- Movement of the joint will allow better understanding of findings.
- Cartilage will retain its shape during movement whereas fluid will change shape.
Introduction to the guide-to-scanning regions

- In this section specific ultrasound scans are shown for each anatomic area commonly assessed with musculoskeletal ultrasonography.

- As there is not yet an international consensus on standard ultrasound scans for all anatomic areas in children, the selected scans were chosen based on existing literature and experience but may differ in some details from other recommendations. They nevertheless allow a comprehensive assessment of each of the joints.

- For each anatomic area, the following is portrayed in this chapter:
  1. The rate of ossification is initially described, as some knowledge of this is essential to properly interpret ultrasound images in children.
     - Please note that the ossification rates are approximate as females will typically be 6-12 months ahead of males.
     - The rates reported in the literature also sometimes vary by region and by ethnic group.
  2. Subsequently the probe position is shown as a photograph and a schematic image together with the anatomic structures that will be visible. These schematic illustrations have been inspired by the work of Carlo Martinoli, Genoa, and the illustrations for the knee have been designed based on illustrations by Carlo Martinoli.
  3. This is followed by a page with ultrasound images of the respective scan at 4 different ages in order to illustrate changes, especially with regards to ossification across the age spectrum.
4. The final page for each scan shows examples of pathology, usually both on B-mode and Doppler but in some cases only B-mode or Doppler is shown

» Only examples of the most common pathologies are shown as a comprehensive depiction of pathology for each region would exceed the format of this e-book

• The anatomic images have been simplified for easier understanding

• Probe positions for the various scans were developed based on:
  
  
  
  » Windschall D e al, Arthritis Care Res (Hoboken). 2017 Aug 4
  
  
  » Collado et al Rheumatology 2013;52:1477148
  
  
  

• Ultrasound images and photographs of healthy volunteers were taken for this guide after written consent was given. Ultrasound images of pathology were used according to the laws of the country of origin.
Shoulder Ossification

**HUMERAL HEAD**

The three secondary ossification centers join in the 5th year and metaphysis closes 18-20th year. Junction of ossification centers may be incomplete especially when still younger.

**OSSIFICATION CENTERS OF THE CLAVICLE APPEAR:**

**OSSIFICATION CENTERS OF THE SCAPULA APPEAR:**
Shoulder Ossification

Humeral Head

Ossification centers of the Clavicle appear:
- Lateral end: 5 weeks in utero
- Medial end: 15 years

Ossification centers of the scapula appear:
- Acromion: 14th year
- Lat clavicle: intrauterine
- Glenoid: 10 years
- Inferior glenoid: 14 years
- Head: 1st year
- Greater tuberosity: 1st year
- Lesser tuberosity: 2nd year
- Coracoid: 2nd year
- Glenoid: 10 years
Shoulder Ossification

Humeral Head

Ossification centers of the clavicle appear:

Ossification centers of the scapula appear:

Body: 8 weeks in utero
Coracoid process (two centers): 12-18 months
Glenoid: 10-11 years
Inferior angle: 14-20 years (puberty)
Acromion (three centers): 14-20 years (puberty)
Medial border: 14-20 years (puberty)
Scanning the shoulder - glenohumeral posterior

TIP: Examine the dorsal shoulder joint dynamically with 90° flexion of the elbow joint and external rotation of the shoulder.
Scanning the shoulder - glenohumeral posterior

TIP / Examine the dorsal shoulder joint dynamically with 90° flexion of the elbow joint and external rotation of the shoulder
Scanning the shoulder - glenohumeral posterior

**TIP** / Examine the dorsal shoulder joint dynamically with 90° flexion of the elbow joint and external rotation of the shoulder.
Scanning the shoulder - glenohumeral axillary

TIP / The axillary scan is very easy and may help to detect effusion in the shoulder joint
Scanning the shoulder - glenohumeral axillary

TIP / The axillary scan is very easy and may help to detect effusion in the shoulder joint.
Scanning the shoulder - glenohumeral axillary

**TIP** / Move the transducer along the entire length of the biceps tendon
Scanning the shoulder - biceps tendon

TIP / In younger children the hyperechoic biceps tendon runs on top of thick hypo- or an-echoic cartilage
Scanning the shoulder - biceps tendon

TIP / In younger children the hyperechoic biceps tendon runs on top of thick hypo- or an-echoic cartilage
Scanning the shoulder - **biceps tendon**

**TIP** / Move the transducer along the entire length of the biceps tendon

Do not mistake the normal circumflex artery for pathologic Doppler

Do not mistake anisotropy of the biceps tendon as pathology
Scanning the shoulder - acromioclavicular joint

TIP / Palpating the clavicle and acromion helps to position the probe easily
Scanning the shoulder - acromioclavicular joint

**TIP** / Palpating the clavicle and acromion helps to position the probe easily.
Scanning the shoulder - acromioclavicular joint

- Healthy
- Pathology

- Effusion, Doppler signal and irregular bone
Scanning the shoulder - sternoclavicular joint

TIP / Use enough gel to keep your probe in contact with the sternoclavicular joint
Scanning the shoulder - **sternoclavicular joint**

**TIP** / Use enough gel to keep your probe in contact with the sternoclavicular joint
Scanning the shoulder - sternoclavicular joint

- Effusion and increased Doppler signals suggestive of synovitis

Windschall D, Trauzeddel R. Arthritis und Rheuma 2012;32:35–41
Elbow Ossification

center capitulum appears 1st year centers capitulum and trochlea join 14th year epiphyses fuse 16 to 18th year

center radial head appears 4th year epiphysis fuses 18th year

center lateral epicondyle appears 12th year

center medial epicondyle appears 5th year

center trochlea appears 11th year

center olecranon appears 11th year epiphysis unites 16th year

Humerus

Radius

Ulna
Scanning the elbow - anterior 1

TIP / The brachioradialis muscle runs straight across the humeroradial joint
Scanning the elbow - anterior 1

**TIP** / The brachioradialis muscle runs straight across the humeroradial joint
Scanning the elbow - anterior 1

Effusion and synovitis

TIP / Moving the arm helps to identify an effusion in the radial fossa
A small degree of synovial recess distension can often be found in the area of the radial, coronoid or olecranon fossa
Scanning the elbow - anterior 2
Scanning the elbow - anterior 2

Healthy

Pathology

3 years

7 years

10 years

15 years

Humerus

Radius

Ulna

SHOULDER

WRIST

FINGER

HIP

KNEE

ANKLE/FOOT
Scanning the elbow - anterior 2

Effusion and synovitis

TIP / Smaller effusions will be located in the area of the fossa only, larger effusions as shown on the right (Doppler) image will extend distally across the joint line.
Scanning the elbow - posterior

**TIP** / The dorsal elbow joint has to be examined in 90° flexion
Scanning the elbow - posterior

TIP / The dorsal elbow joint has to be examined in 90° flexion
Scanning the elbow - posterior

**TIP** / The elbow joint has to be examined in 90° flexion from dorsal

- **Effusion and fluid, synovial proliferation and increased Doppler suggestive of synovitis**

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**Healthy**

**Pathology**
Scanning the elbow - *medial enthesis*

*TIP* / In order to scan the common flexor tendon it may be helpful to bring the forearm in supination with mild flexion at the elbow.
Scanning the elbow - medial enthesis

TIP / In order to scan the common flexor tendon it may be helpful to bring the forearm in supination with mild flexion at the elbow.
Scanning the elbow - medial enthesis

**B-mode pathology**

**Doppler pathology**

**aUCL**, anterior bundle of the ulnar collateral ligament

Inhomogeneous echotexture of the tendon and enthesis with Doppler suggestive of enthesopathy
Scanning the elbow - lateral enthesis

TIP / The lateral enthesis can be scanned in supination or pronation of the forearm
Scanning the elbow - lateral enthesis

TIP / The lateral enthesis can be scanned in supination or pronation of the forearm.
Scanning the elbow - lateral enthesis

Healthy Pathology

Enthesitis with hypervascularization

Common extensor tendon and muscles
Humerus RCL AL Radius
**Wrist and hand ossification**

Carpal Bones age in years when ossification centers appear (counterclockwise direction starting with capitate)

- **Distal end of radius appears 2nd year of life**
- **Distal ulna 8th year**
- **Epiphyses unite 20th year**

Secondary ossification centers metacarpals and epiphyses fingers appear 2nd to 3rd year of life. Epiphyses unite 18th year.
Scanning the wrist - radio ulnar joint
Scanning the wrist - radio ulnar joint

Healthy

Pathology

3 years

7 years

10 years

15 years

SHOULDER

ELBOW

WRIST

FINGER

HIP

ANKLE/FOOT
Scanning the wrist - radio ulnar joint

Healthy

Pathology

Extensor tenosynovitis and radioulnar synovitis
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in midline

- Physiologic synovial recesses
- MC, metacarpal

**TIPS**
- Os lunatum and os capitatum are very useful as anatomic landmarks
- Assess during mild flexion and extension
Scanning the wrist - radio-carpal/mid-carpal/carpometacarpal in midline

- Os lunatum and os capitatum are very useful as anatomic landmarks
- Assess during mild flexion and extension
Scanning the wrist - **radiocarpal/midcarpal/carpometacarpal in midline**

- **Effusion and synovitis in the radiocarpal, midcarpal and carpometacarpal joint**
- **Effusion and synovitis in the radiocarpal, midcarpal and carpometacarpal joint with hypervascularization**
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in ulnar

- **Physiologic synovial recesses**
- MC, metacarpal

_TIP_/ Slide from midline to the ulnar side and use os triquetrum and os hamatum as anatomic landmarks
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in ulnar

TIP / Slide from midline to the ulnar side and use os triquetrum and os hamatum as anatomic landmarks.
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in ulnar

Healthy

Synovitis around Triquetrum
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in radial

- Physiologic synovial recesses
- MC, metacarpal

**TIP** / Slide from midline to the radial side and use os scaphoideum and os trapezoideum as anatomic landmarks.
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in radial

TIP / Slide from midline to the radial side and use os scaphoideum and os trapezoideum as anatomic landmarks.
Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in radial

**Healthy**

**PATHOLOGY**

- **Ganglion cyst on B-mode**

  Typical: posterior enhancement communication with joint but extrasynovial location (tissue deep to it and superficial to bone)

- **Synovitis on Doppler**

  Synovial proliferation with significantly increased Doppler signals
Scanning the wrist - palmar long midline

**TIP** / The median nerve runs parallel on top of the flexor tendons
Scanning the wrist - palmar long midline

- **Healthy**
- **Pathology**

Images showing the wrist at different ages:
- **3 years**
- **7 years**
- **10 years**
- **15 years**

**Anatomical structures:**
- Radius
- Lunate
- Capitate
- Median nerve
- Flexor tendons
Scanning the wrist - palmar long midline

Healthy

Pathology

Compressed median nerve

Flexor tendons
Scanning the wrist - extensor tendons

1-6 = Extensor tendon compartments

- Lister's tubercle

TIP / If you see hypoechoic or anechoic areas in the region of the tendons verify for anisotropy or the distal extension of the muscle.
Scanning the wrist - extensor tendons

TIP / If you see hypoechoic or anechoic areas in the region of the tendons verify for anisotropy or the distal extension of the muscle.
Scanning the wrist - extensor tendons

**Healthy**

**Pathology**

**TIP** / If you see anechoic or hypoechoic areas in the region of the tendons consider anisotropy or the distal extension of a muscle before making a diagnosis of tenosynovitis.

**Healthy**

**Doppler pathology**

**Extensor tenosynovitis**

**Extensor tenosynovitis**
Scanning the wrist - flexor tendons

**TIP** / Avoid anisotropy of the flexor tendons
Scanning the wrist - flexor tendons

**TIP** / Avoid anisotropy of the flexor tendons
Scanning the wrist - flexor tendons

Healthy

Flexor Tenosynovitis
**Finger ossification**

- **Carpal Bones age in years when ossification centers appear (counter-clockwise direction starting with capitate):**
  - 9
  - 2
  - 1
  - 7
  - 6
  - 3
  - 4
  - 5

- **Secondary ossification centers metacarpals and epiphyses fingers appear**:
  - 2nd to 3rd year of life
  - Epiphyses unite 18th year

- **Distal end of radius appears**: 2nd year of life
- **Distal ulna**: 8th year epiphyses unite 20th year
Scanning the finger - dorsal long metacarpophalangeal joints

TIP / Smaller hockey-stick probes are very useful for the small finger joints
Scanning the finger - **dorsal long metacarpophalangeal joints**

**TIP** / Smaller hockey-stick probes are very useful for the small finger joints.
Scanning the finger - *dorsal long metacarpophalangeal joints*

- **HEALTHY**
- **PATHOLOGY**

**TIPS** / **EFFUSION**
- The synovial distension tends to extend proximally.
- Due to the compression of the extensor tendon synovial distension is often more visible medial and lateral to the extensor tendon and can also be nicely demonstrated on a transverse view.
- In the Doppler image shown here there is very minimal distension of the synovial recess but clear intrasynovial Doppler signals.
Scanning the finger - dorsal long proximal interphalangeal joints
Scanning the finger - dorsal long proximal interphalangeal joints

TIP / In addition to the joint visualize the insertion of the extensor tendon
Scanning the finger - dorsal long proximal interphalangeal joints

**Healthy**

- Extensor tendon
- Proximal phalanx
- Middle phalanx

**B-mode pathology**

- Effusion and synovitis

**Doppler pathology**

- Irregular bone with a pathological vessel and synovitis

**TIP** / Erosions have to be confirmed in two perpendicular planes
Scanning the finger - dorsal long distal interphalangeal joints
Scanning the finger - dorsal long distal interphalangeal joints

**Healthy**

3 years

7 years

10 years

15 years

**Pathology**

TIP / Smaller hockey-stick probes are very useful for the small finger joints
Scanning the finger - dorsal long distal interphalangeal joints

Healthy

Pathology

Effusion and synovial hypertrophy

TIP / Smaller hockey-stick probes are very useful for the small finger joints
Scanning the finger - *palmar long metacarpophalangeal joints*

**TIP** / Examine dynamically with finger flexion
Scanning the finger - palmar long metacarpophalangeal joints

**TIP** / Examine dynamically with finger flexion
Scanning the finger - **palmar long metacarpophalangeal joints**

**Healthy**

**Pathology**

- Flexor tenosynovitis
Scanning the finger - palmar long proximal interphalangeal joints

TIP / A small amount of fluid in the volar joint recess may be seen as a physiological finding
Scanning the finger - palmar long proximal interphalangeal joints

TIP / A small amount of fluid in the volar joint recess may be seen as a physiological finding.
Scanning the finger - palmar long proximal interphalangeal joints

- **Healthy**

- **Pathology**
  - B-mode pathology: Flexor synovitis and tenosynovitis
  - Doppler pathology: Flexor tenosynovitis

**TIP** / Flexor tenosynovitis may occur in all subgroups of JIA.
Scanning the finger - palmar long distal interphalangeal joints

A small amount of fluid in the volar joint recess may be seen as a physiological finding.
Scanning the finger - palmar long distal interphalangeal joints

**Healthy**

**Pathology**

3 years

7 years

10 years

15 years
Scanning the finger - palmar long distal interphalangeal joints

**Healthy**

**Pathology**

- Synovial distension and increased Doppler signals

**Tips**
If pathology is identified on a longitudinal scan, it will need to be confirmed on the transverse scan.
Scanning the finger - palmar long distal interphalangeal joints

**HEALTHY**

**PATHOLOGY**

**B-mode pathology**

**Doppler pathology**

- Synovial distension and increased Doppler signals in transverse view

TIP / If pathology is identified on a longitudinal scan, it will need to be confirmed on the transverse scan
Scanning the finger - collateral ligament

- Sagittal band
- Collateral ligament
- Superficial & deep
- Proximal phalanx
- Middle phalanx
Scanning the finger - collateral ligament

HEALTHY
PATHOLOGY

3 years 7 years
10 years 15 years
Scanning the finger - collateral ligament

- **Sagittal band**
- **Collateral ligament**
- **Proximal phalanx**
- **Middle phalanx**

**Healthy**

**Pathology**

- **Enthesitis with hypervascularization**
Femur ossification

- Center appears 1st year
- Center appears 4th year
- Center appears 13th year

All secondary ossification centers fuse with shaft 18th to 20th year.
Scanning the hip - anterior long

TIP / In older children use lower frequencies to clearly visualize all structures of the anterior recess
Scanning the hip - anterior long

**TIP** / In older children use lower frequencies to clearly visualize all structures of the anterior recess. Pay attention to the patient’s position. The sonographic configuration of the capsule varies with leg position and should be in external rotation.

**Healthy**

**Pathology**

**4 years**

**7 years**

**10 years**

**15 years**
Scanning the hip - anterior long

TIP / Recognize the cartilage interface sign between the cartilage and effusion

Effusion and synovial hypervascularization
Scanning the hip - greater trochanter transverse

TIP / The transverse scan helps to identify the different muscles/tendons
Scanning the hip - greater trochanter transverse

TIP / The transverse scan helps to identify the different muscles and muscle tendons. Avoid anisotropy
Scanning the hip - greater trochanter longitudinal
Scanning the hip - greater trochanter longitudinal

**TIP** / Consider trochanteric enthesitis or bursitis in the case of pain in this region
Scanning the hip - greater trochanter longitudinal

**TIP** / Consider trochanteric enthesitis or bursitis in the case of pain in this region.
Knee ossification

- One or several ossification centers appear 2-6th year and complete 14th year.

- Ossification centers appear just before birth and unite with shaft 18th to 20th year.

- Ossification center appear 5th year birth and unite with shaft 18th to 20th year.
Scanning the knee - suprapatellar long

**TIP** / Bend and flex the knee 3 times before doing the scan in a 30° flexion position

All knee illustrations were designed based on illustrations by Carlo Martinoli, Genoa.
Scanning the knee - suprapatellar long

TIP / Physiological fluid may be visible in the suprapatellar recess
Scanning the knee - suprapatellar long

**Healthy**

**B-mode pathology**

Effusion

**Doppler pathology**

Effusion and increased Doppler signals

**TIP** / Dynamic examination helps to detect smaller amounts of fluid
Scanning the knee - parapatellar medial

- Patella
- Medial retinaculum
- Medial parapatellar recesses
Scanning the knee - parapatellar medial

TIP / A small amount of fluid is often detected in healthy children
Scanning the knee - parapatellar medial

**TIP** / The parapatellar medial scan is very helpful to detect synovial hypertrophy and much more sensitive to detect hypervascularization in the knee on Doppler than the suprapatellar scan.
Scanning the knee - parapatellar lateral
Scanning the knee - parapatellar lateral

**HEALTHY**

**PATHOLOGY**

**TIP** / A small amount of fluid is often detected in healthy children
Scanning the knee - parapatellar lateral

- **Healthy**
  - Lateral parapatellar recess
  - Patella

- **Pathology**
  - Effusion
  - Synovial proliferation with increased Doppler signals
Scanning the knee - infrapatellar long

TIP / Dynamic examination is helpful to detect bursitis and enthesitis
Scanning the knee - infrapatellar long

TIP / Dynamic examination is helpful to detect bursitis and enthesitis
Scanning the knee - infrapatellar long

Bursitis infrapatellaris profunda can be found in children with JIA.
Scanning the knee - transverse posterior

TIP / Check the whole intercondylar region dynamically

Illustration designed based on illustration by Carlo Martinoli, Genoa
Scanning the knee - transverse posterior

**TIP** / Check the whole intercondylar region dynamically
Scanning the knee - transverse posterior

**TIP** / The echostructure and dimension of popliteal cysts can be variable.
Ankle and foot ossification I

- Tibia
- Diaphysis
- Intrauterine ossification
- Secondary ossification center epiphysis appears 2nd year and unites 20th year
Ankle and foot ossification II

- Talus: Intrauterine ossification
  - Occasional secondary ossification center posterior talus
  - Appears 6th to 10th year, unites around 16th year

- Calcaneus: Intrauterine ossification
  - Appears 3rd to 6th year and unites with primary ossification center 17th to 20th year
  - Lateral cuneiform 1st year, medial cuneiform 3rd year, intermediate cuneiform 4th year

- Navicular: Appears 6th to 10th year, unites around 16th year

- Cuboid: 9th month intrauterine ossification, navicular 4th year
Scanning the ankle - tibiotalar long

Joint capsule

Intraarticular fat

Tibia

Talus

Navicular
Scanning the ankle - tibiotalar long

- The capsule is usually well visible and defines the intraarticular space.
- This does not equal the intrasynovial space.
Scanning the ankle - tibiotalar long

Healthy

Tibiotalar synovitis

PATHOLOGY

TIP / In younger children with effusion the “cartilage sign”, a hyperechoic band between cartilage and effusion, helps to distinguish between hypoechoic cartilage and effusion
Scanning the ankle - midfoot long

**TIP** / Move the probe medially and laterally to cover the entire midfoot area
Scanning the ankle - midfoot long

**TIP** / Move the probe medially and laterally to cover the entire midfoot area
Scanning the ankle - midfoot long

**TIP** / Move the midfoot to detect small amounts of effusion
Scanning the ankle - anterior tendons in transverse
Scanning the ankle - anterior tendons in transverse

TIP / The myotendinous junction especially for the extensor hallucis longus can be quite distal and should not be confused with tenosynovitis
Scanning the ankle - anterior tendons in transverse

Healthy

Pathology

Extensor tenosynovitis
Scanning the ankle - subtalar medial

TIP / Use the prominent sustentaculum tali as anatomic landmark
**Scanning the ankle - subtalar medial**

**TIP** / Use the prominent sustentaculum tali as anatomic landmark

**Healthy vs. Pathology**

- **4 years**
- **7 years**
- **10 years**
- **15 years**

**Anatomical Structures**
- Tibia
- Talus
- Tibialis posterior
- Flexor digitorum
- Flexor hallucis
- Sustentaculum tali
- Calcaneus

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**Guide to scanning regions**

- **SHOULDER**
- **ELBOW**
- **WRIST**
- **FINGER**
- **HIP**
- **KNEE**
- **ANKLE/FOOT**
Scanning the ankle - subtalar medial

**TIP** / Effusions from the subtalar joint will extend proximally and can merge with distensions of the recess from the tibiotalar joint.
Scanning the ankle - subtalar lateral

TIP / Position the probe at a 90 degrees angle to the sole of the foot and then slide it posterior in this position to explore the entire extent of the sinus tarsi and the posterior subtalar joint.
Scanning the ankle - **subtalar lateral**

![Image of ankle and subtalar joint](image)

**Healthy**

**Pathology**

- **3 years**
- **7 years**
- **10 years**
- **15 years**

**痨les**

- Talus
- Calcaneus

**Pathology:**

- Talus sinus tarsi
- Peroneus tendons

**Integration into clinical flow**

- SHOULDER
- ELBOW
- WRIST
- FINGER
- HIP
- KNEE
- ANKLE/FOOT
Scanning the ankle - subtalar lateral

TIP / Dynamic examination helps to detect smaller effusions
Scanning the ankle - posterior superficial

TIP / Younger children may show physiological bony irregularities of the calcaneal bone
Scanning the ankle - posterior superficial

**TIP** / Younger children may show physiological bony irregularities of the calcaneal bone
Scanning the ankle - posterior superficial

TIP / The patient should move the ankle joint during the examination

Retrocalcaneal bursitis
Scanning the ankle - posterior deep

TIP / Younger children may show physiological bony irregularities of the calcaneal bone
Scanning the ankle - posterior deep

TIP / Reduce frequency to visualize the posterior tibiotalar joint and the posterior subtalar joint.
Scanning the ankle - posterior deep

Effusion and synovial proliferation

TIP / Synovitis of the posterior tibiotalar joint or subtalar joint may lead to effusion in this area
Scanning the ankle - tendons medial

1 = Tibialis posterior tendon
2 = Flexor digitorum tendon
3 = Tibialis posterior nerve
4 = Flexor hallucis longus tendon

TIP / Use the neurovascular channel as anatomic landmark
Scanning the ankle - **tendons medial**

**TIP** / Use the neurovascular channel as anatomic landmark

**HEALTHY**

**PATHOLOGY**

- **3 years**
- **7 years**
- **10 years**
- **15 years**

**ANKLE/FOOT**

- **Tibia**
- **Talus**
- **Calcaneus**
- **Artery**
- **Veins**

1. Tibialis posterior tendon
2. Flexor digitorum tendon
3. Tibialis posterior nerve
4. Flexor hallucis longus tendon
Scanning the ankle - tendons medial

Healthy

Pathology

Tenosynovitis of the tibialis posterior tendon

B-mode pathology

Doppler pathology

1 = Tibialis posterior tendon
2 = Flexor digitorum tendon
3 = Tibialis posterior nerve
4 = Flexor hallucis longus tendon
Scanning the ankle - **tendons lateral**

**TIP** / The peroneus brevis tendon runs closer to the bone
Scanning the ankle - tendons lateral

**TIP** / The peroneus brevis tendon runs closer to the bone
Scanning the ankle - tendon lateral

- Healthy
- Pathology

- B-mode pathology
- Doppler pathology

- Tenosynovitis of the peroneus tendon compartment
- Peroneus tendons

- Peroneus longus
- Peroneus brevis
- Fibula
- Peroneal tubercle
- Peroneus longus
- Peroneus brevis
- Peroneus brevis
- Peroneus brevis
- Peroneus longus

Guides:
- SHOULDER
- ELBOW
- WRIST
- FINGER
- HIP
- KNEE
- ANKLE/FOOT
Scanning the ankle - plantar fascia

TIP / Note that the main bundle of the plantar fascia inserts a bit medially on the calcaneus and the probe needs to be positioned accordingly.
Scanning the ankle - plantar fascia

**TIP** / Note that the main bundle of the plantar fascia inserts a bit medially on the calcaneus and the probe needs to be positioned accordingly.
**Scanning the ankle - plantar fascia**

**HEALTHY**

**PATHOLOGY**

**Calcaneus**

**Plantar fascia**

**TIP** / Some patients may demonstrate bone irregularities at the insertion of the plantar fascia in case of fasciitis. Use low frequencies to see all structures. Doppler might be very difficult to detect.
Scanning the toes - MTP

Metatarsal

Phalanx
Scanning the toes - MTP

TIP /There may be a small amount of physiological fluid in the dorsal recess of MTP 1 and 2 especially.
Scanning the toes - MTP

Synovial fluid, proliferation and increased Doppler signals
Scanning the toes - IP

Phalanx

Phalanx
Scanning the toes - IP

Healthy

Pathology

3 years

7 years

10 years

15 years

Scanning the toes - IP

Healthy

Pathology

3 years

7 years

10 years

15 years
Scanning the toes - IP

- **Healthy**
- **Pathology**

- Synovial fluid, proliferation and increased doppler signals
Equipment and settings

- The equipment (i.e. US machines, frequency of the probe) should be indicated in the report since it might influence the result of MSUS examination.\(^1\)

- Optimize image settings for B-mode (by adjusting frequency, depth, and focus) and Doppler ultrasound (the optimum frequency must be found in practice and not in theory; use low PRF and the lowest possible filters; set Doppler gain by turning it up until random noise is encountered and then lowering it until the noise disappears; place the focus where highest sensitivity is required).\(^2\)

- The choice between color and power doppler depends on the equipment.\(^2\)

- Transducer pressure may influence the flow; visible gel between the transducer and skin will ensure light pressure.\(^2\)

**TIP** / Use a generous amount of gel. Cortical margins have to appear bright, sharp, and hyperechoic. Correct the size of the Doppler box, which has to contain the relevant joint structures and extend to the top of the image.

The report is an integral part of the MSUS examination and its implementation in a homogenous form can assist in the correct interpretation of the findings.

**MSUS Report**

Wrist swelling lasting 2 months. Suspected tenosynovitis

Wrist joint recesses and tendons

Machine X
High-frequency linear array probe (10 to 18 MHz)

Distension of the dorsal recess of the radiocarpal joint due to the presence of synovial effusion (score 3) and synovial hypertrophy (score 2) with signs of vascularization on PD (score 3). Normal aspect of the extensor and flexor tendons of the wrist

Conclusions: Synovitis of the radiocarpal joint

Include representative images of the pathological findings.

The report is an integral part of the MSUS examination and its implementation in a homogenous form can assist in the correct interpretation of the findings.

**MSUS Report**

Mario Rossi  
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

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Conclusions: Synovitis of the radiocarpal joint

Signature

Include representative images of the pathological findings.

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**MSUS Report**

Patient’s full name and age

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Conclusions: Synovitis of the radiocarpal joint

Pathological condition should be described according to internationally accepted terminology (e.g. synovitis, tenosynovitis, etc.)

Scoring systems are essential to quantify pathological findings and to evaluate the efficacy of therapeutic interventions.

Synovitis may be assessed using any of the following:

1. Qualitative approach (based on the description of changes in synovial hypertrophy, joint effusion, and Doppler signals)

2. Quantitative approach (measurements, pixel count, etc.)

3. Semiquantitative scores (4-point grade: 0: absent, 1: mild, 2: medium, and 3: severe)

Tibiotalar joint in a patient with JIA and ankle involvement. US images have been collected before (A) and after (B) treatment.
Grading

- A semiquantitative scoring system to assess synovitis in the wrist/hand joints is suitable for use in clinical practice and has been extensively validated in RA\textsuperscript{1-3}

- Validation of MSUS grading in JIA is ongoing

- Since both large and small joints are affected in JIA, a “one size fits all” approach is not feasible

Longitudinal scan of the II interphalangeal distal joint of an 11-year-old JIA patient

Longitudinal anterior suprapatellar scan of the knee of a 2-year-old JIA patient

Grading

Dorsal longitudinal scan of the wrist

B-mode US of the intercarpal joint showing different grades of severity of synovitis:

0: absent, 1: mild, 2: moderate, and 3: severe synovitis

TIP / Score assignment should be based on a comprehensive evaluation of the whole joint recess aiming to establish the precise extent of the pathological findings
Grading

Dorsal longitudinal scan of the wrist

Power Doppler US of the intercarpal joint showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe synovitis.

Doppler signals should be graded considering only the area of synovial hypertrophy and not the entire synovial recess.

TIPS

- A sound knowledge of physiological joint vascularization is necessary to avoid misinterpretation of normal physiological vascularization as inflammation.
- Feeding vessels can traverse the synovial recess but can be easily recognized by their direct trajectory into the bone/cartilage.
### Grading

<table>
<thead>
<tr>
<th>B mode</th>
<th>Power Doppler US</th>
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<tbody>
<tr>
<td><img src="image1" alt="Image" /></td>
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Longitudinal anterior scan of the ankle. B mode and power Doppler US of the tibiotalar joint showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe synovitis.
Grading

B mode

Power Doppler US

Posterior subtalar joint from lateral focusing on posterior subtalar joint synovitis extending into the sinus tarsi. B mode and power Doppler US of the subtalar joint showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe synovitis
Grading

B mode

Longitudinal anterior suprapatellar scan of the knee in B mode showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe

Power Doppler US

Transverse lateral parapatellar scan of the knee in power Doppler showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe

Ting TV et al. Arthritis Care Res (Hoboken) 2018 (Epub); doi: 10.1002/acr.23746
Grading

• US plays an important role in detecting hip involvement which is considered a poor prognostic factor

• Joint involvement appears as a hypo-anechoic collection causing changes of the normal concave orientation of the capsule (1) to a straight (2) or convex orientation

• The maximum distance between the anterior surface of the femoral neck and the anterior limit of the capsule (NCD-A) allows detection and quantification of hip joint effusion

• NCD-A is mainly correlated to the child’s height. In younger children the mean NCD-A increases from 2.5 mm to 5 mm. In older children the mean NCD-A is 5.5 mm and should not exceed 7 mm

• A difference of more than 2 mm between the two hips is an important additional criterion for the sonographic diagnosis of hip joint effusion

Grading

Ankle flexor tendons

- MSUS allows accurate detection of tenosynovitis
- The most common US components of tendon involvement are hypoechogenic or anechoic synovial sheath widening or thickening, hypoechogenic or anechoic tendon sheath effusion, tendon thickness and peritendinous ± intratendinous PD or CD Doppler signal
- Since definition and scores are not available, tendon abnormalities should be reported using a binary (absence=0/absence=1) score

Flexor digitorum tendons

Ting TV et al. Arthritis Care Res (Hoboken) 2018 (Epub); doi: 10.1002/acr.23746
Grading

• In children ossification is incomplete and the subcondral bony profile may appear wavy, irregular, and fragmented, making the interpretation of bone erosion a real challenge (1)

• Physiologically the cartilage thickness decreases with growth (2A, 2B), making it difficult to determine whether the reduction in cartilage thickness is part of age-related changes or an expression of erosive disease

• Age- and gender-related normal US measurements of cartilage thickness in small and large joints are available. However, evaluating cartilage damage by using the quantitative measurement of cartilage thickness is not very practical in routine clinical settings

• Until US definitions of bone and cartilage damage are validated in a pediatric setting, the diagnostic accuracy of MSUS to detect joint damage remains questionable

Spannow AH et al. J Rheumatol 2010;37:2595–2601
Standard Set of Joints

- US seems a promising tool for evaluating and monitoring inflammatory lesions in JIA but needs greater standardization in scanning methodology and scoring systems.

- The minimum number and the optimal set of joints to be scanned for US monitoring in JIA are yet to be established.

- Of note, a reduced US 10-joint count, including bilateral knee, ankle, wrist, elbow, and the second MCP joints, was found to be feasible, reliable, and able to reflect overall inflammatory activity in the same way as the 44-joint US comprehensive evaluation.

- The evolution of pathological findings should influence patient management rather than the results of a single US examination.

Collado P et al. Rheumatology 2013;52:1477-1784
Evidence Based use of Ultrasonography in clinical practice

- In many areas of pediatric MSK ultrasonography the evidence base is not fully established yet\(^1\)

- This does not preclude clinical use provided the technique is applied well\(^1\)

- Taking into account the pediatric principles of differentiating normal findings from pathology will ensure correct diagnosis\(^2-3\)

Ultrasonography can add important information at all stages of the patient journey and may be valuable in a treat-to-target approach

- Diagnosis and differential diagnosis
- Monitoring of disease activity
- Determination of remission status

Ultrasonography detects subclinical inflammation

- Approximately 30% of clinically inactive joints show active synovitis on ultrasound.
- Careful evaluation is necessary to avoid misinterpretation of physiologic findings.
- The time since remission may be important as ultrasound findings might persist initially but decrease over time.
- Ultrasonography should not replace the clinical exam and should be integrated into the overall assessment.

Baseline ultrasound can be a predictor of flare in JIA in remission:

- Ultrasound was abnormal in 23% of patients in a recent prospective trial at baseline.
- Ultrasound abnormalities were associated with an odds ratio of flare of 3.8.
- The combination B mode and power Doppler had a higher predictive value of relapse (65%, 13/20) than B mode alone (33%, 6/18).

Implementation into clinic flow – do I have the time?

• Time constraints will become less with practice
• Find a good time to practice initially
• Practice regularly
• The real time availability of important information will ultimately save time
• A targeted vs complete exam can help to be time efficient especially in follow up
Imaging and treat to target

- There is compelling evidence for a treat-to-target approach with the goal of achieving inactive disease

- Imaging may help to define the target
