Ped-MUS™

International intiative for
Pediatric musculoskeletal ultrasonography

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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.

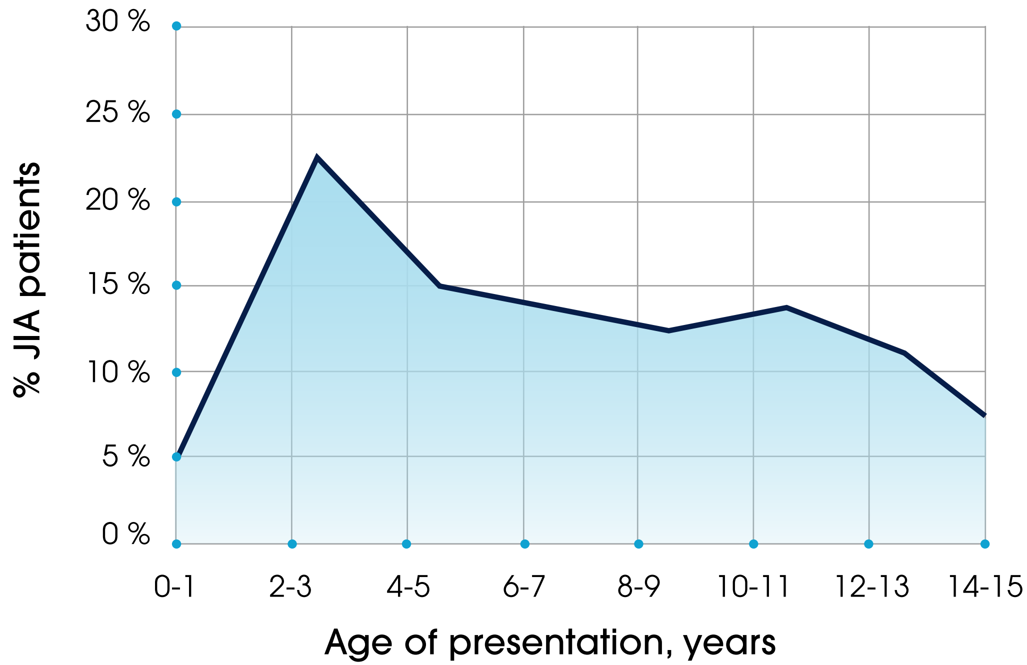
International efforts on standardization of pediatric musculoskeletal ultrasonography have progressed significantly in recent years and many areas are still in evolution. The content of this e-book has been modelled on existing knowledge and expert opinion but will undoubtedly evolve further in future 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:

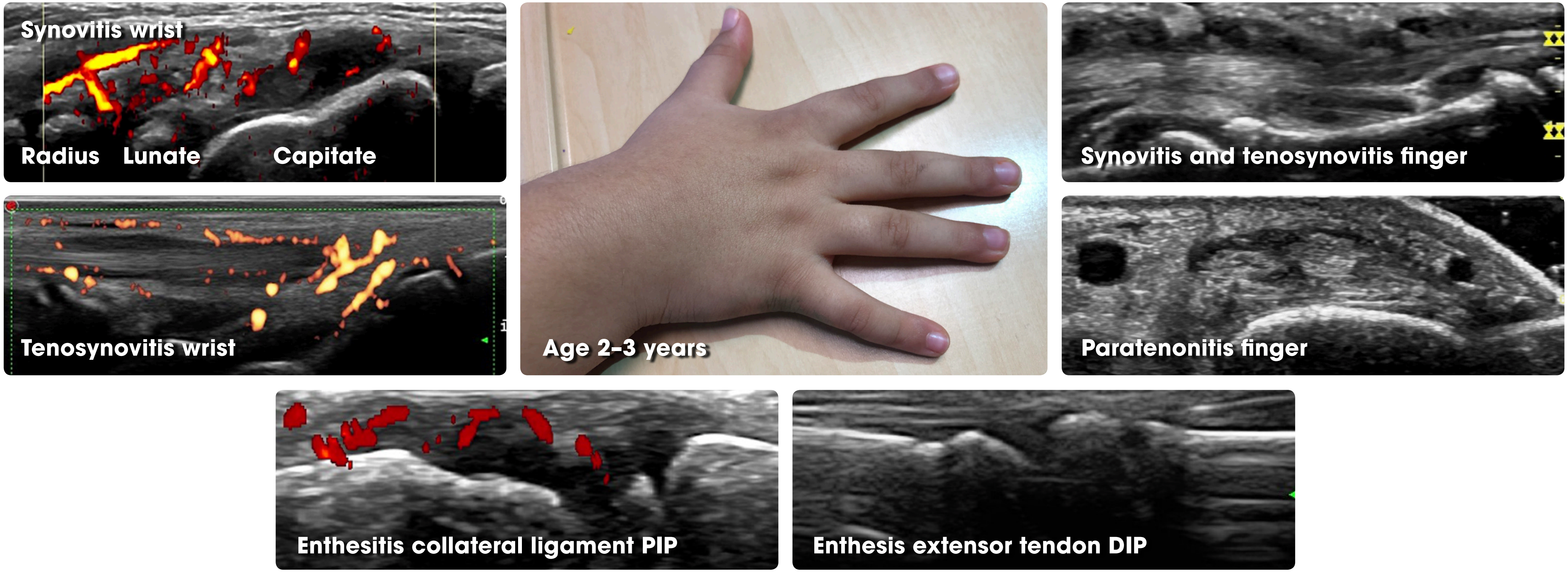
Why use ultrasonography in pediatric rheumatology?

- 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



1. Rooney ME et al. J Rheumatol 2009;36:1725–1729; 2. Ravelli A, Martini A. Lancet 2007;369:767–778;
3. Beukelman T. et al Pediatr Rheumatol Online J 2017;15:31

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

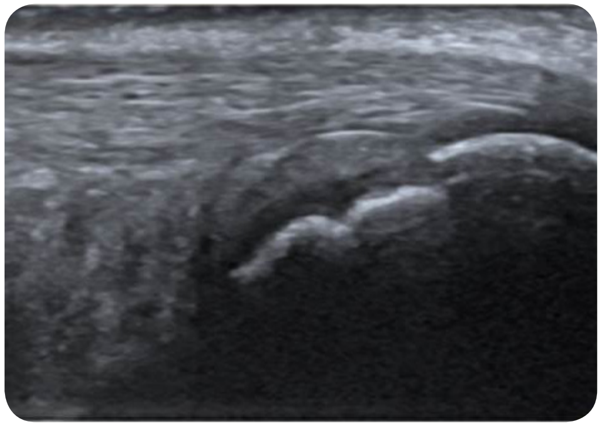
Additional benefits

- 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

Malattia C et al. Expert Rev Clin Immunol 2018;14:681–694; Roth J, personal image

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



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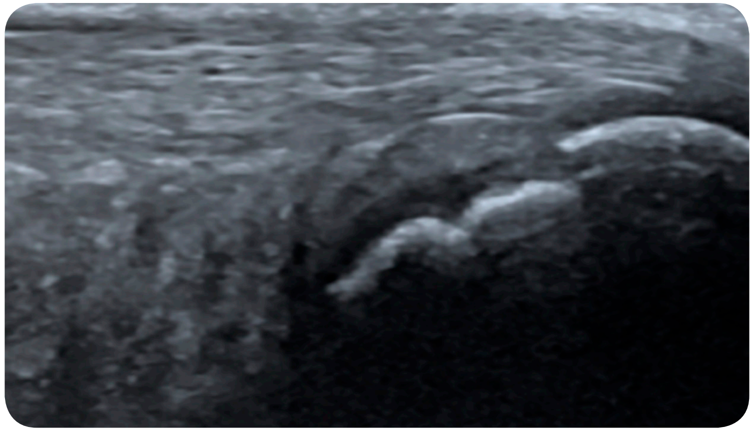
Acoustic Impedance

- 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

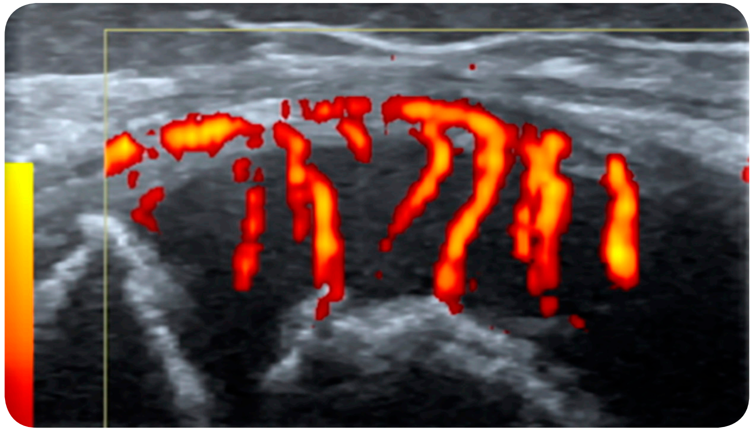
B-Mode

- 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

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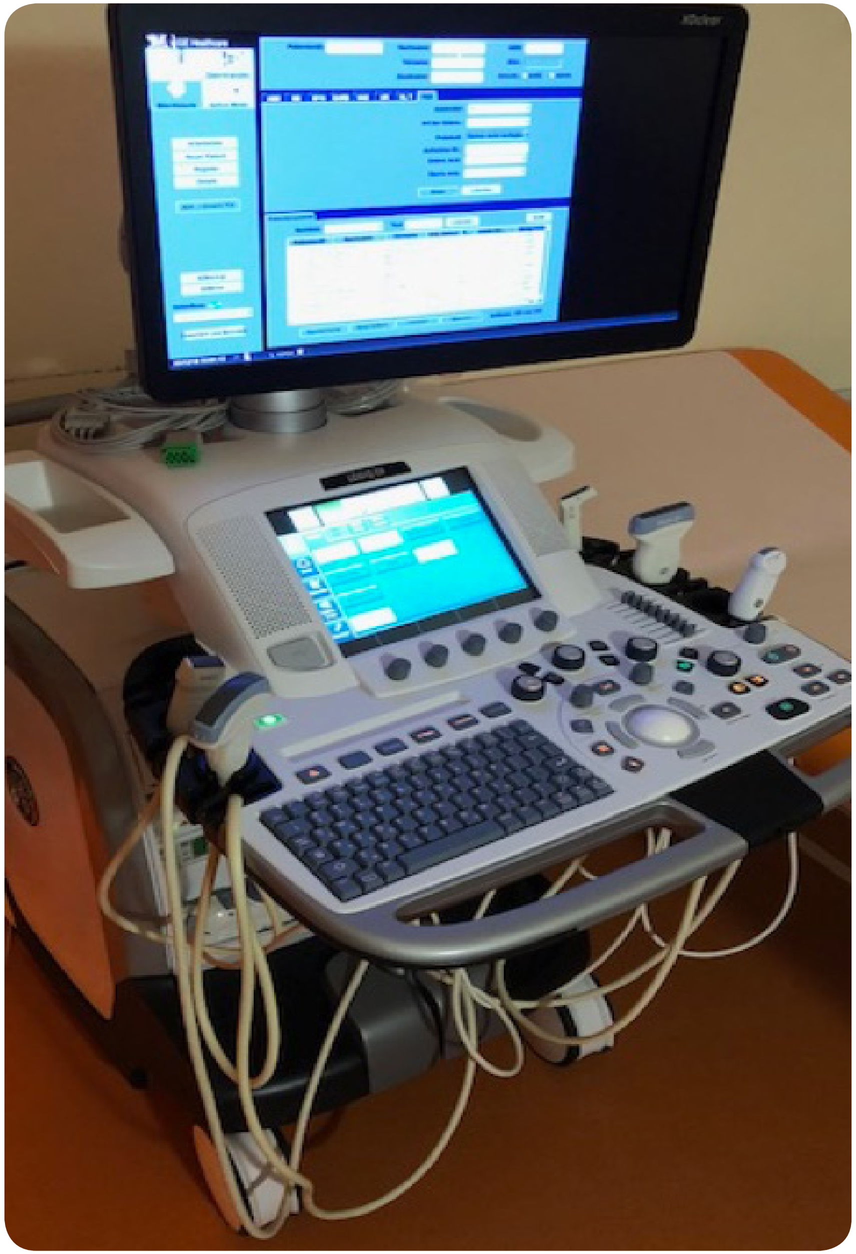
Kane et al. Rheumatology 2004;43:823–828

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 ?

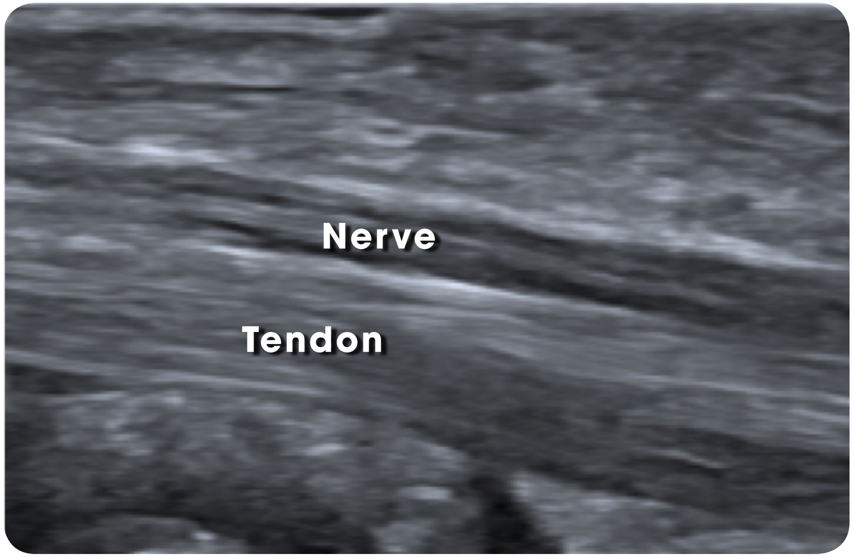


Image resolution

For testing the image resolution of a sytem you can compare the visual discrimination between the median nerve and the flexor tendons in the longitudinal volar scan of the wrist!

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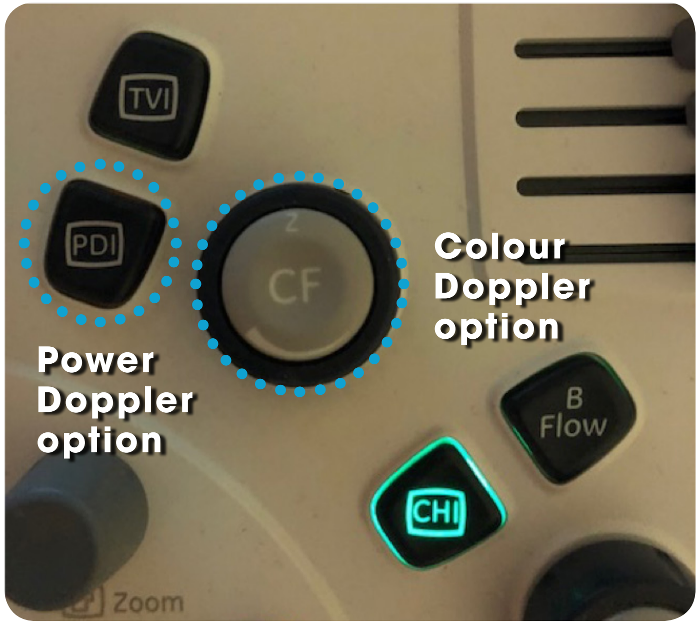
How do I choose the right ultrasound equipment for my pediatric MSUS ?

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.



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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.

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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

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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

Joint	Shoulder	Elbow	Wrist/ Finger	Hip	Knee	Ankle	Midfoot/ Toe
Frequency	5-12 MHZ	10-15 MHZ	10-20 MHZ	5-12 MHZ	8-15 MHZ	8-15 MHZ	10-20 MHZ
Probe	Linear	Linear	Linear/ Hockey	Linear (Curved)	Linear	Linear	Linear/ Hockey

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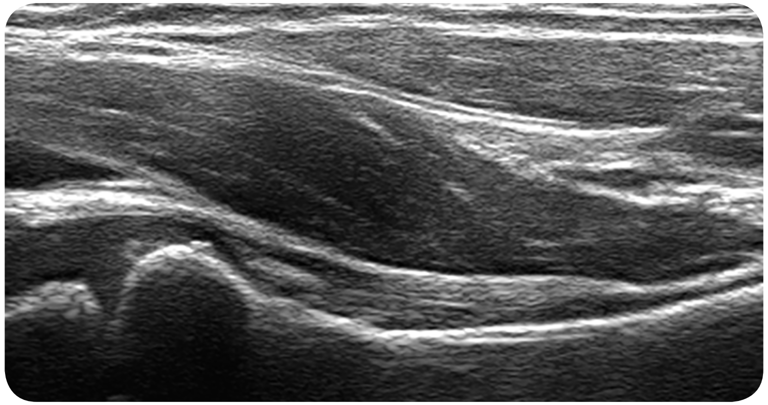
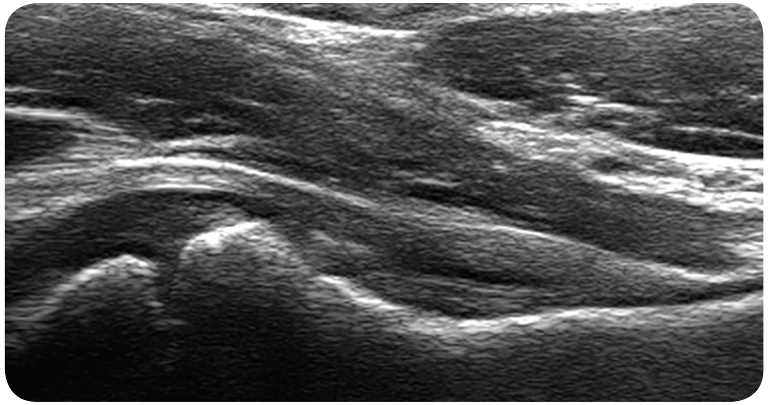
Positioning of Patient



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

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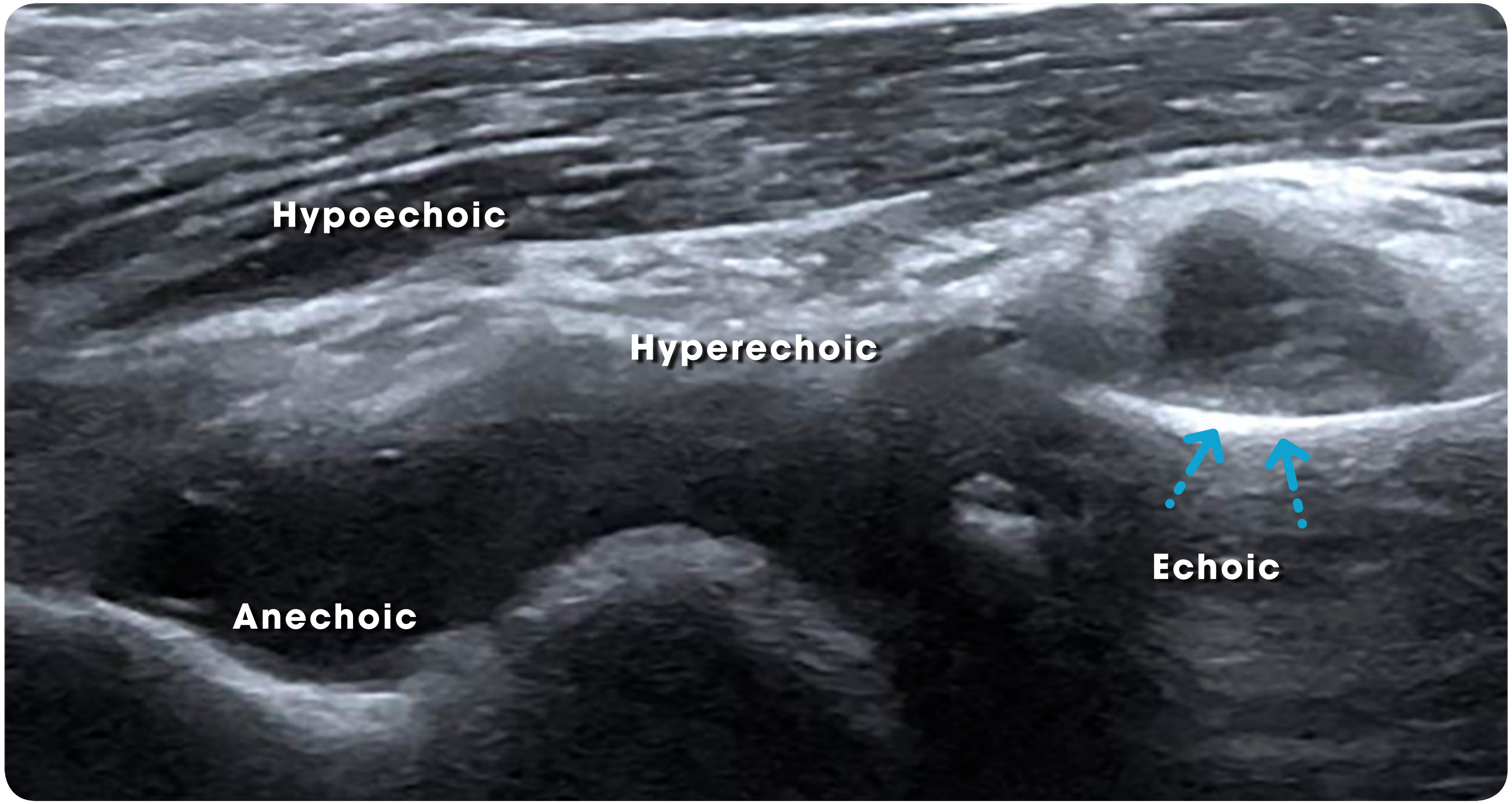
TIPS /

- 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)

ECHOGENICITY | ECHOSTRUCTURE



- Echoic (white)
- Hyperechoic (white/grey)
- Isoechoic (grey)
- Hypoechoic (grey/dark grey)
- Anechoic (black)

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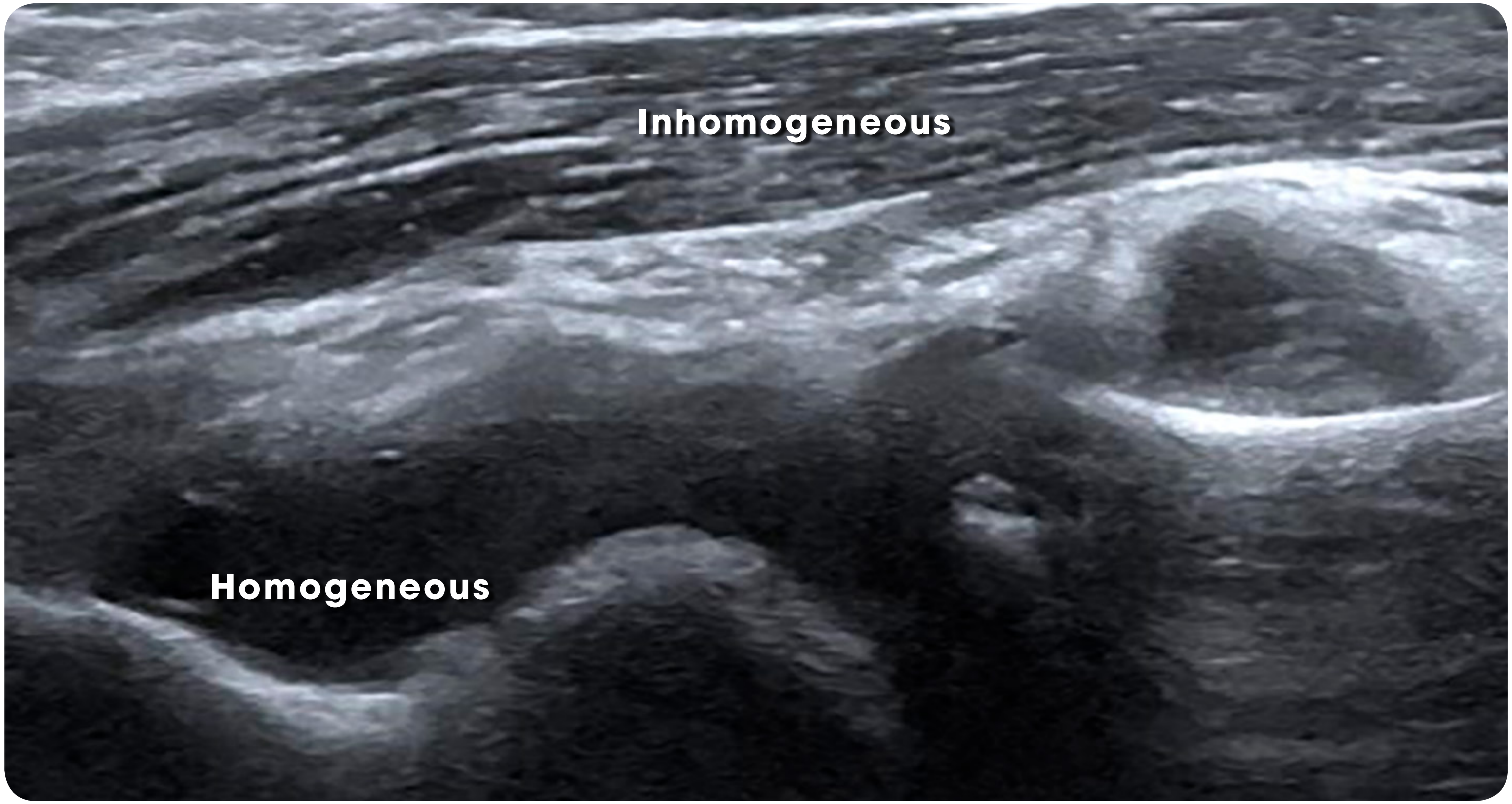
ECHOGENICITY ECHOSTRUCTURE



- Homogeneous
- Inhomogeneous

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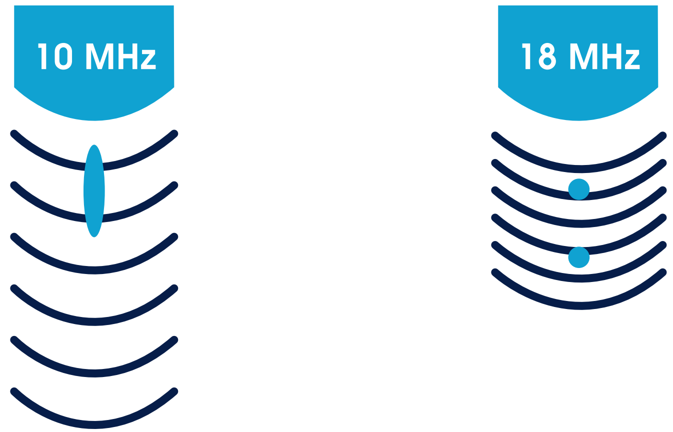
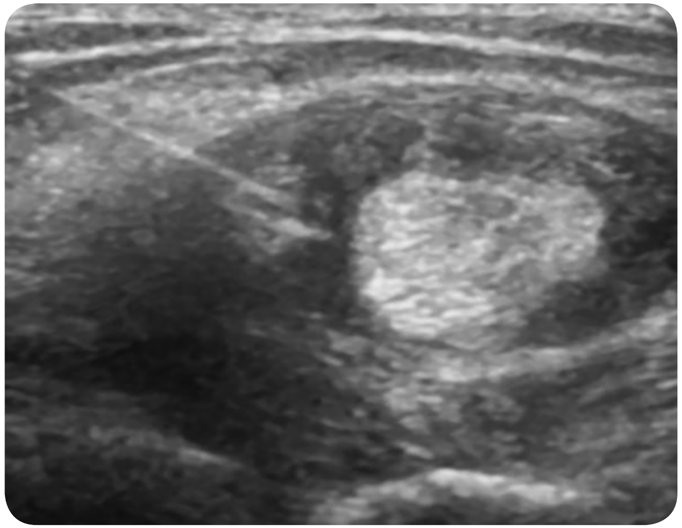
Frequency

- 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



LOWER FREQUENCY = BETTER PENETRATION

HIGHER FREQUENCY = BETTER RESOLUTION



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

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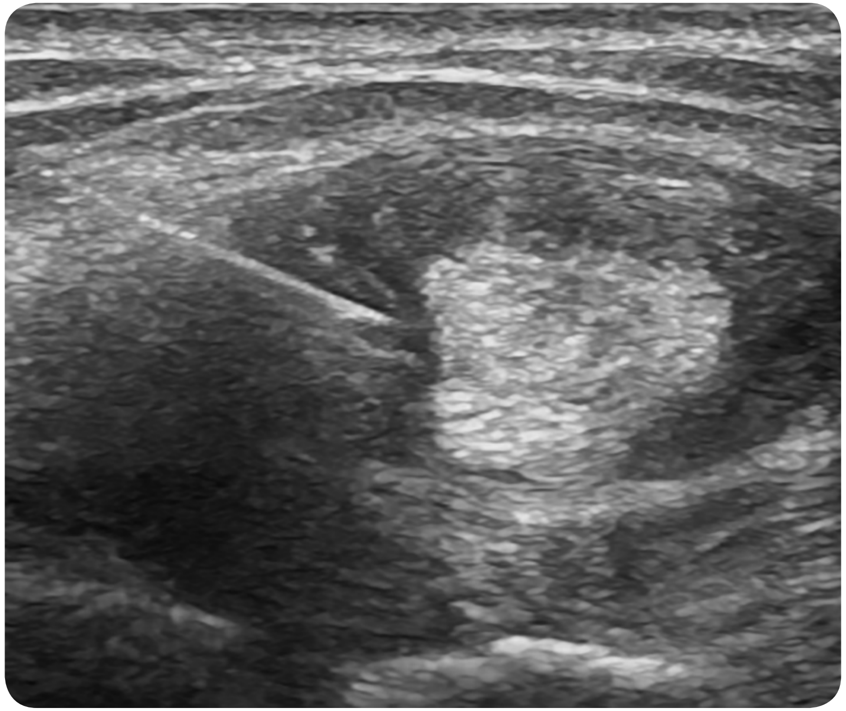
Depth

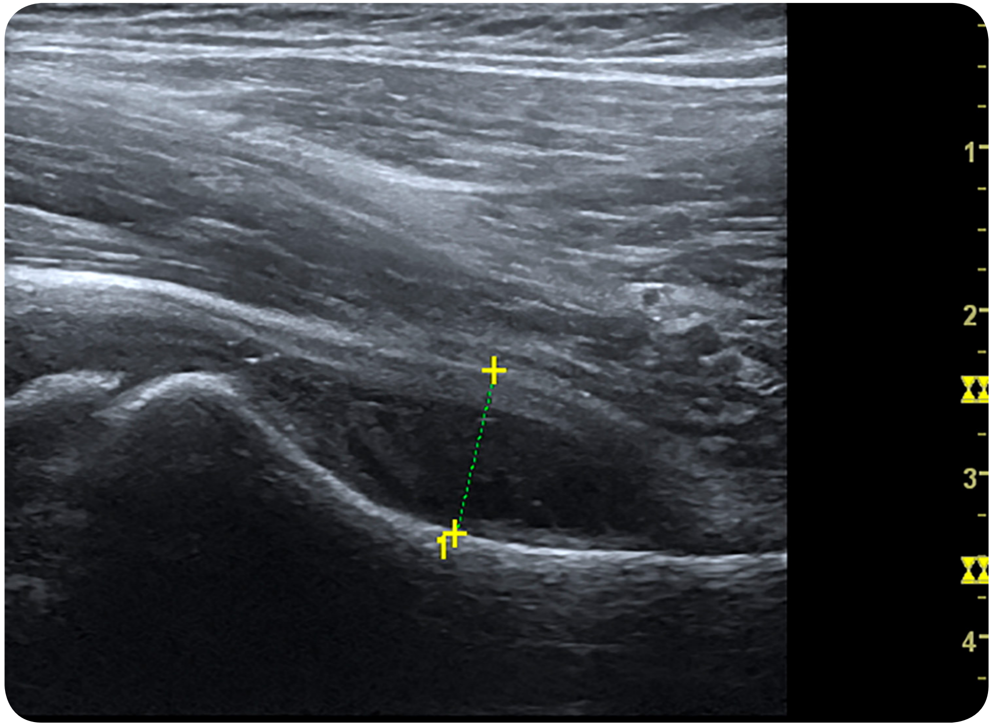
The depth should be adjusted until area of interest is centred, seen completely but is not too large or too small

Increased depth (structures below the tendon are visible)



Decreased depth (tendon is centred on the image).

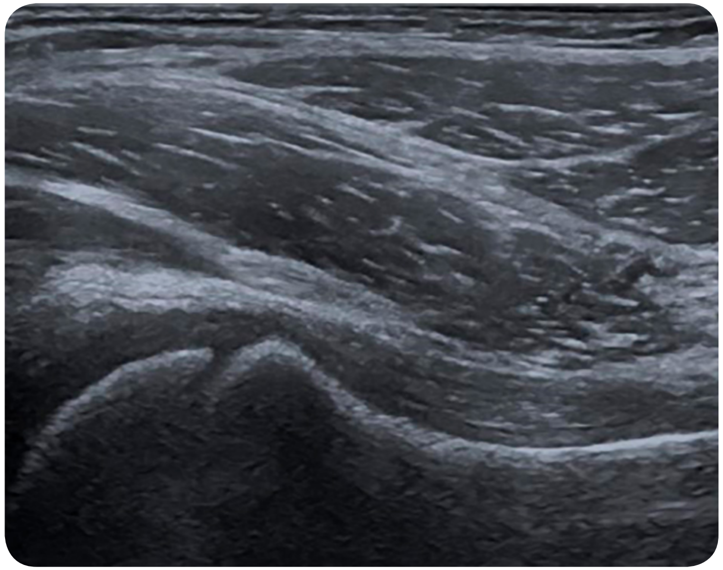
Focus



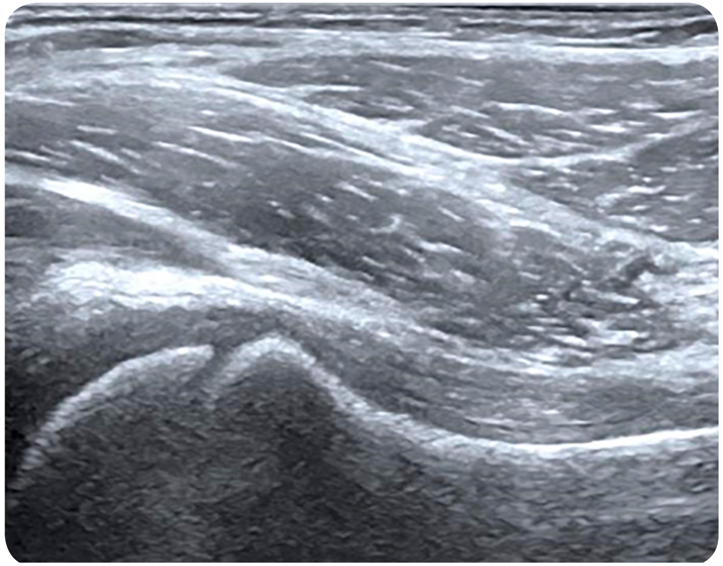
Should be positioned at the level of the area of interest (more focus points than one are possible)

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



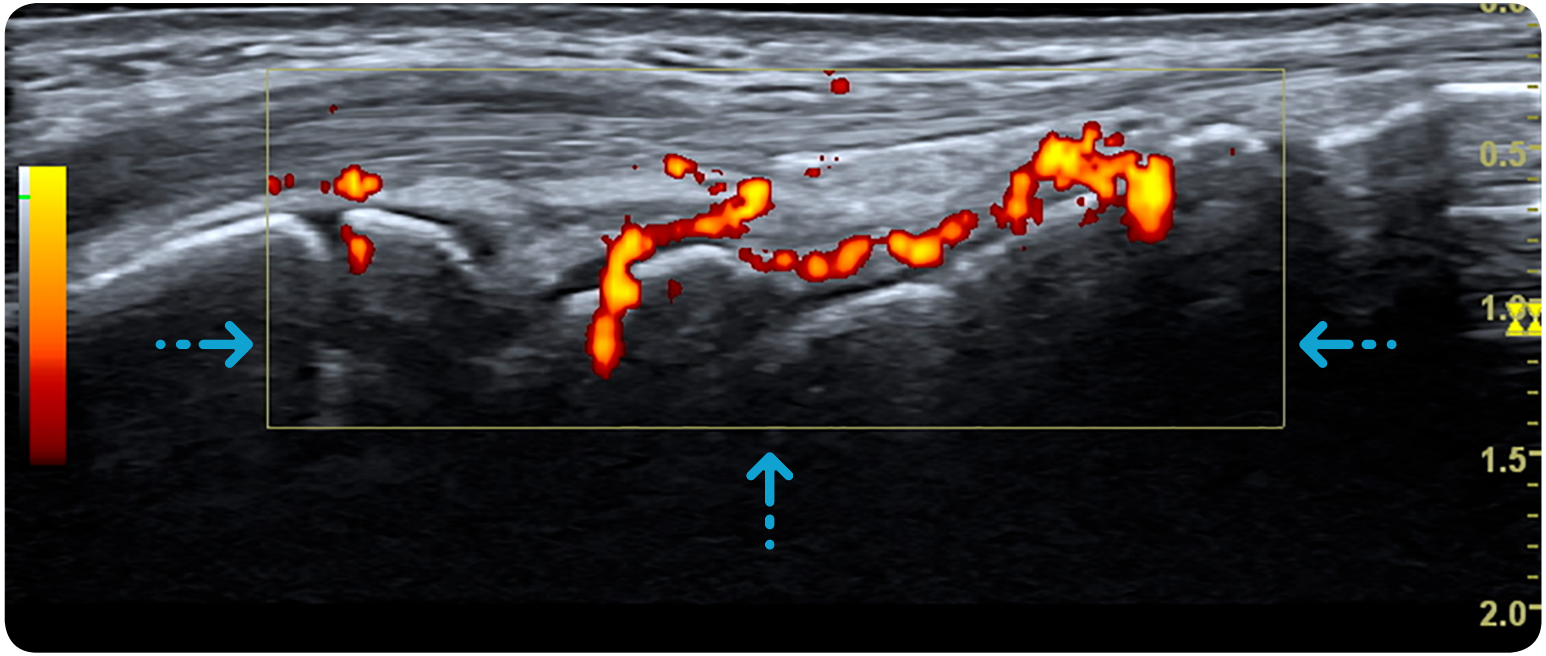
Low gain



High gain

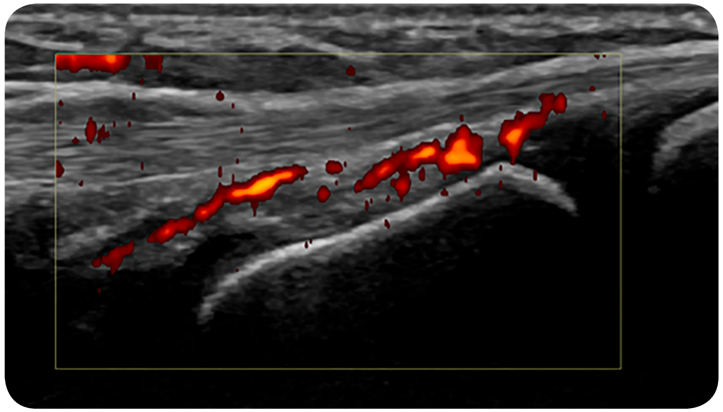
Doppler box

- 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)

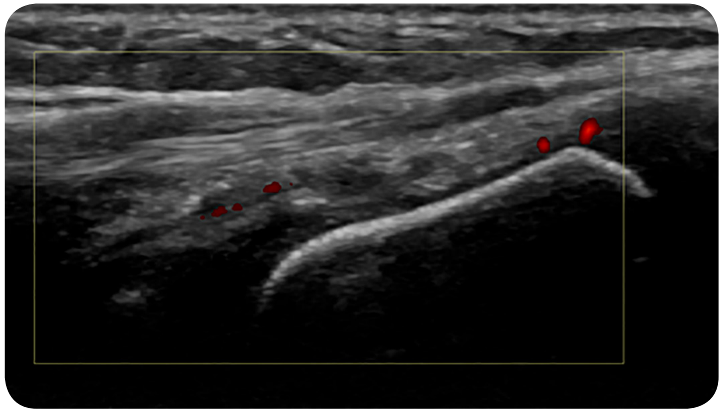


Doppler PRF

- 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).



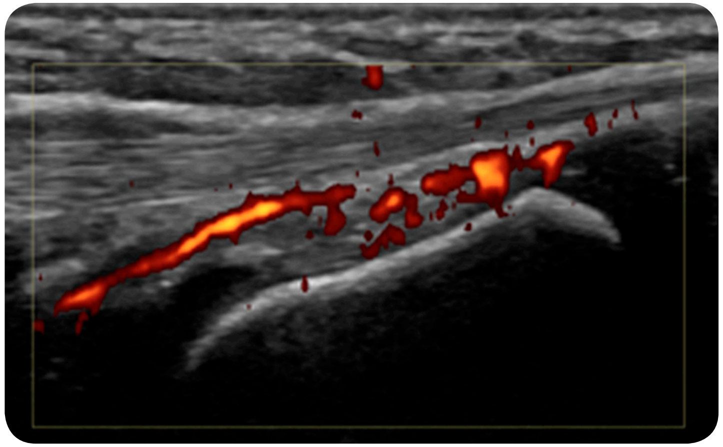
PRF 0.6 kHz (wrist)



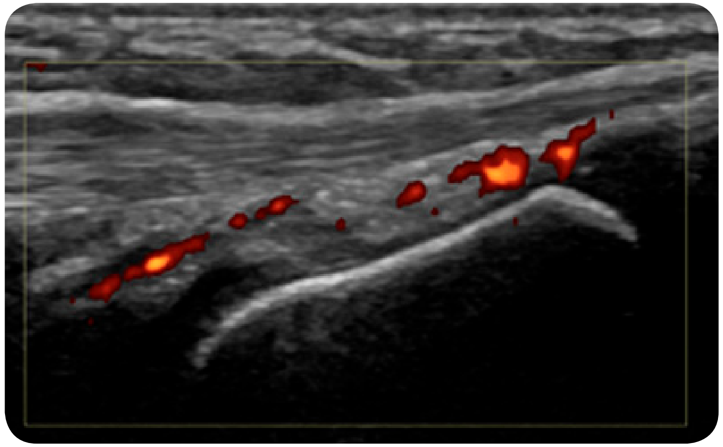
PRF 2.6 kHz (wrist)

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.



Low wall filter



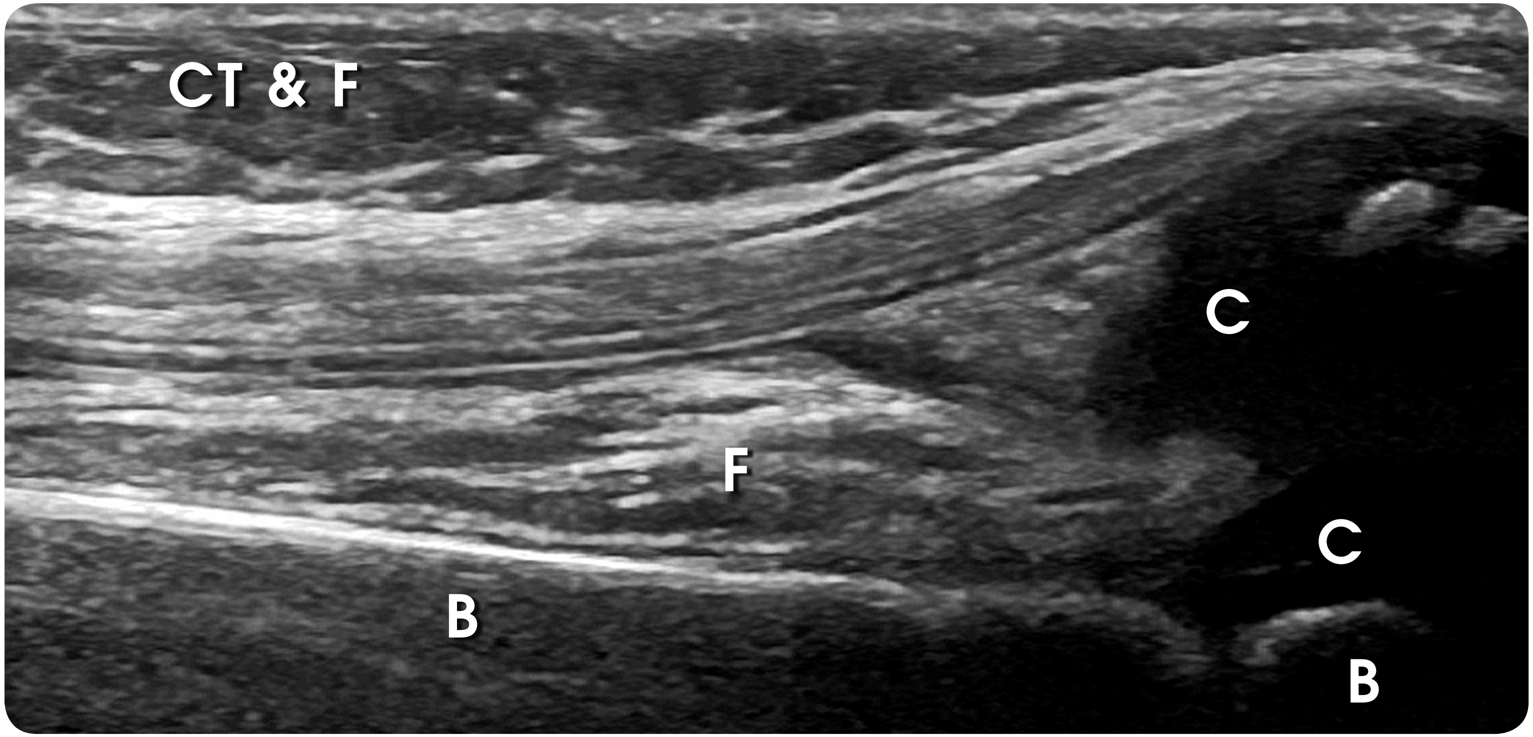
High wall filter

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)

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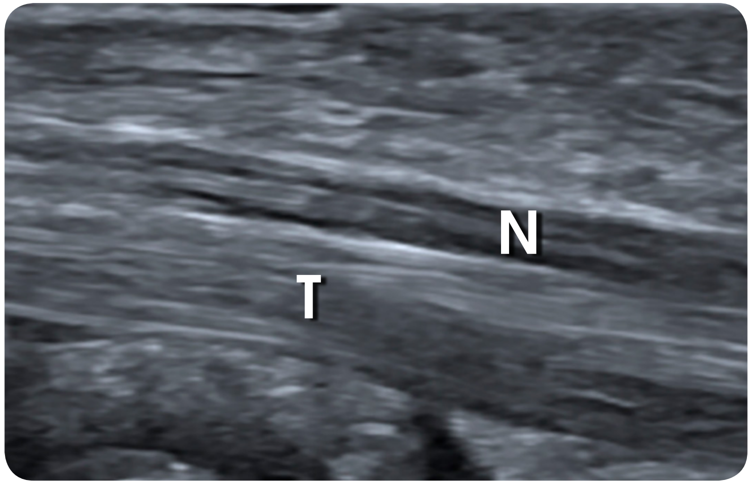
Tissue characteristics

Tendons (T)

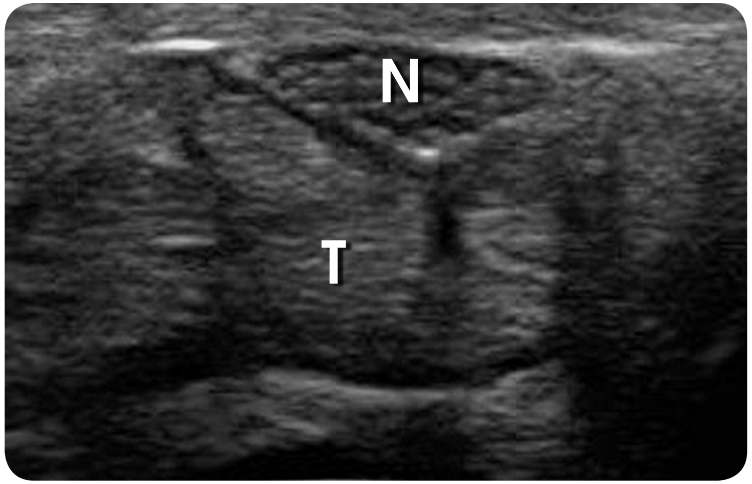
Tendons have a fibrillar pattern. The fine hyperechoic bands represent the tendon fascicles and run parallel to the transducer

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)

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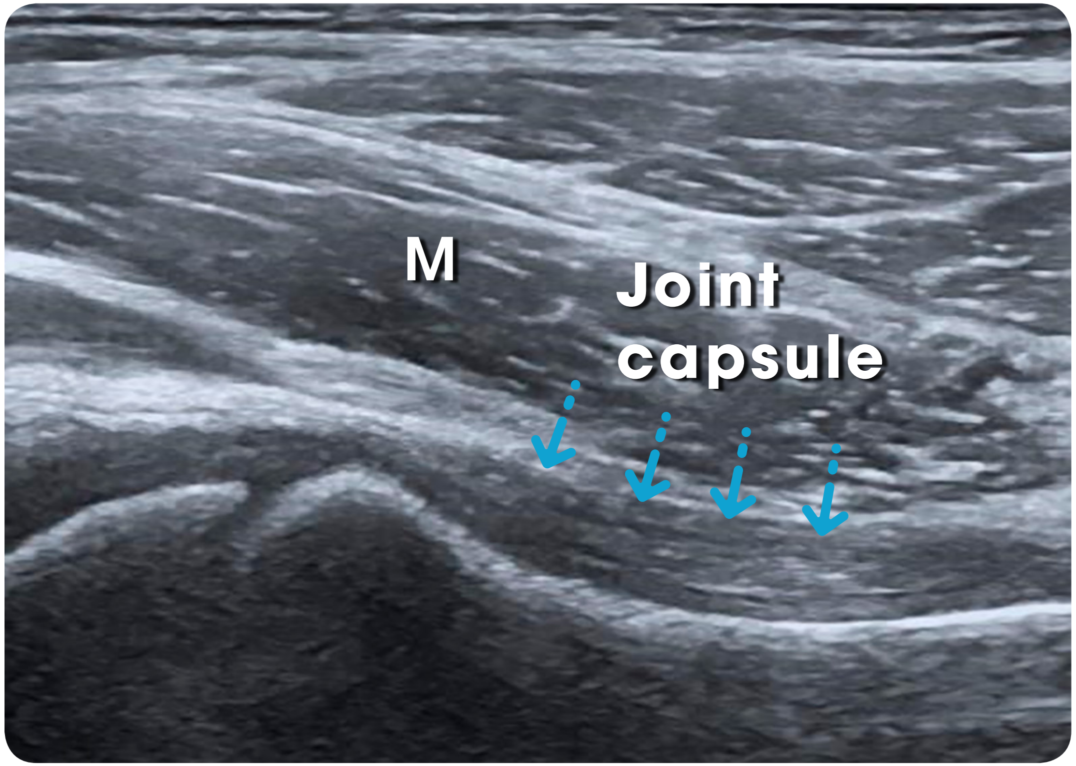
Tissue characteristics

Muscle (M)

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

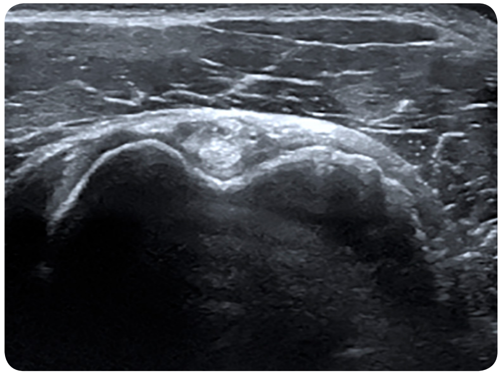
Joint capsule

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

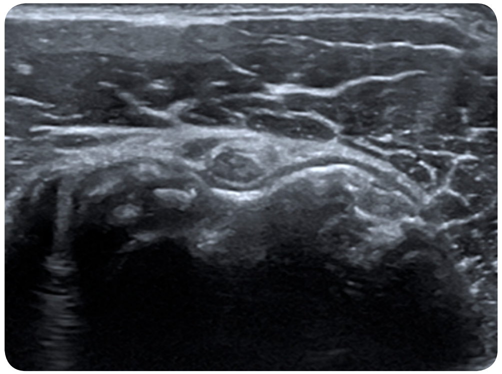


Anterior hip joint capsule and iliopsoas muscle (longitudinal)

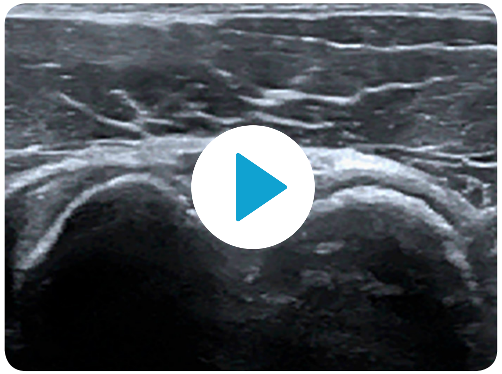
B mode - anisotropy

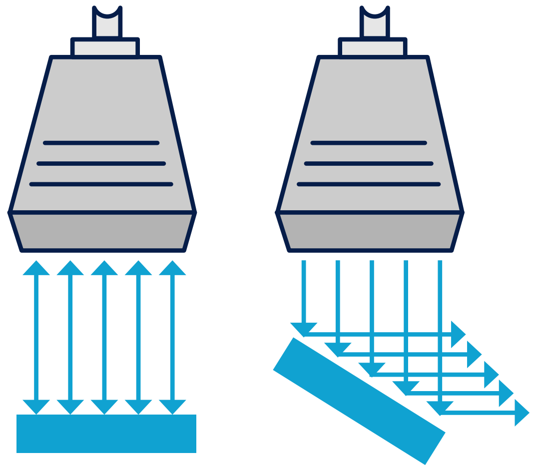


Biceps tendon, perpendicular



Biceps tendon, not perpendicular





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

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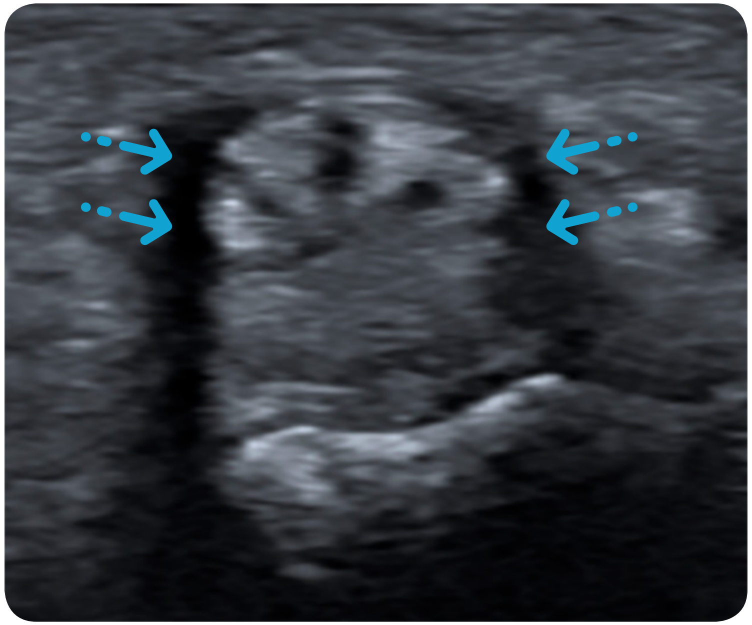
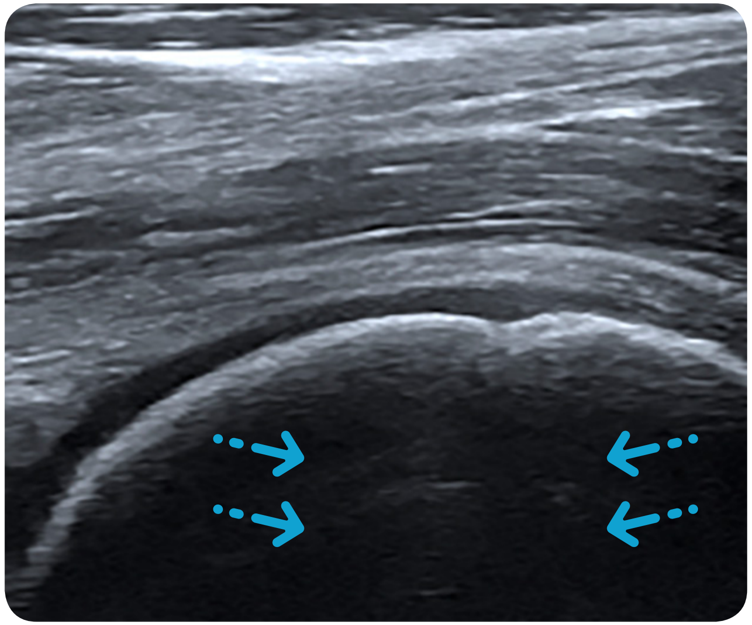
Taljanovic M et al. Semin Musculoskelet Radiol 2014;18:3–11

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)



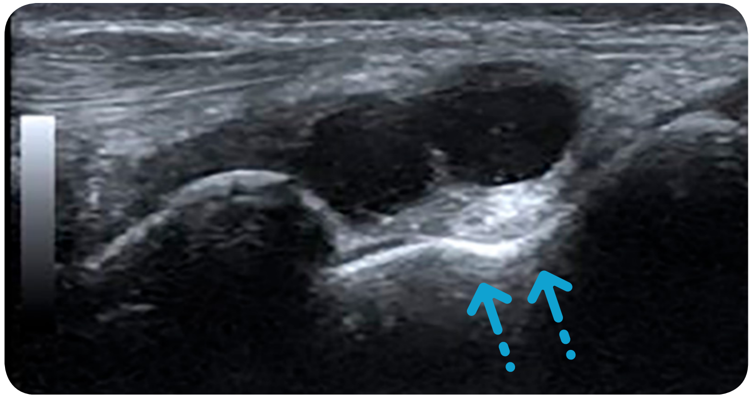
Refractile shadowing (flexor tendon/pulley)



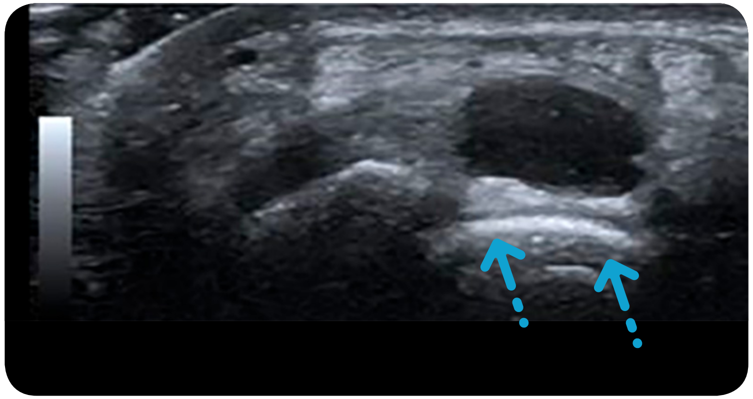
Posterior shadowing (humerus head)

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



Ganglion cyst

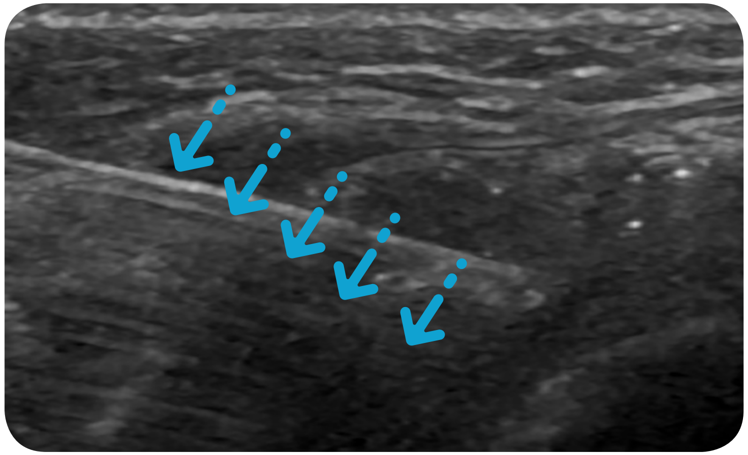


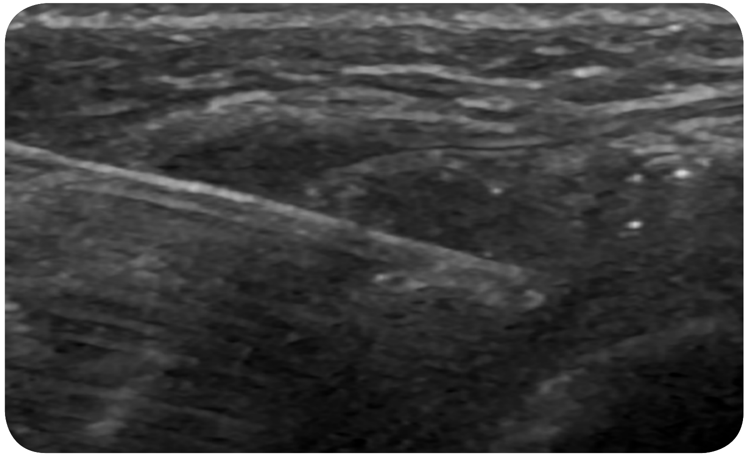
Ganglion cyst

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

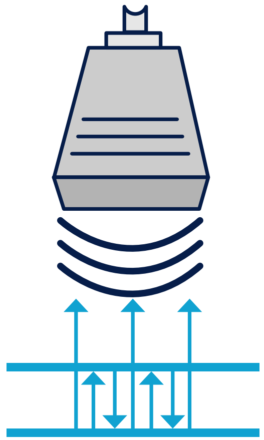
B mode - reverberations

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)



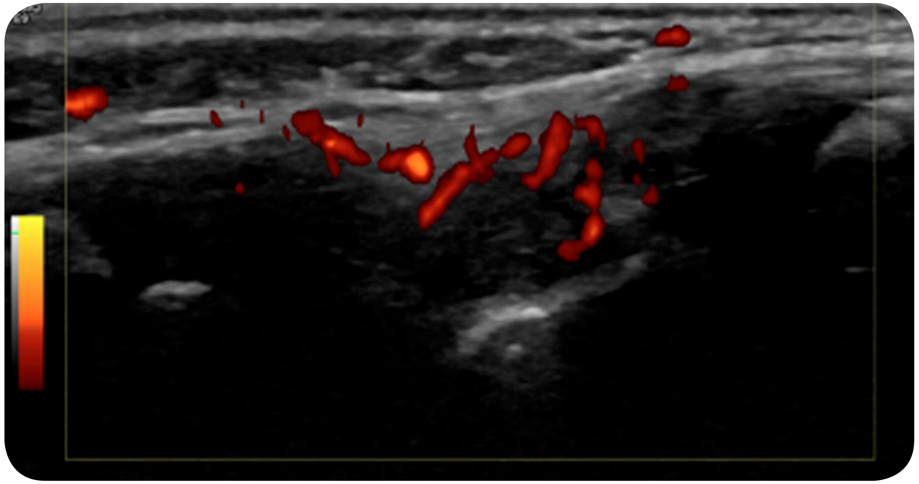
Reverberation

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

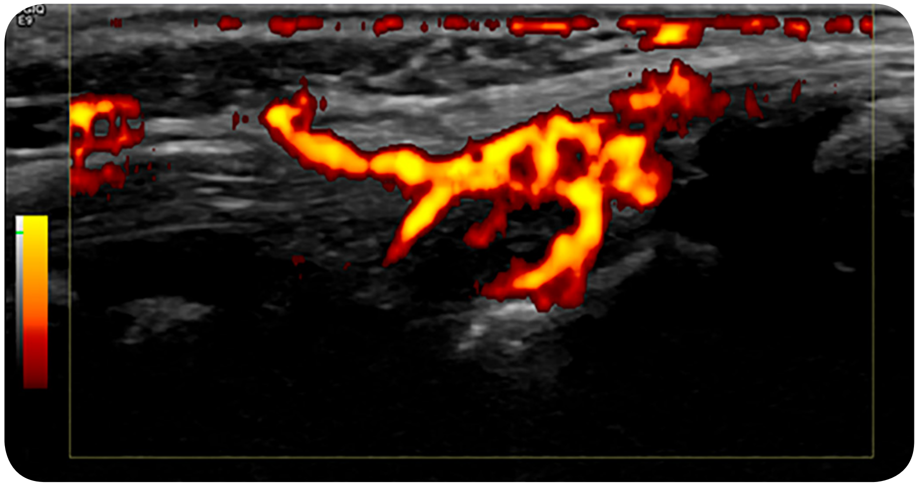
Doppler blooming

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

Vascularization in the wrist (adapted gain)



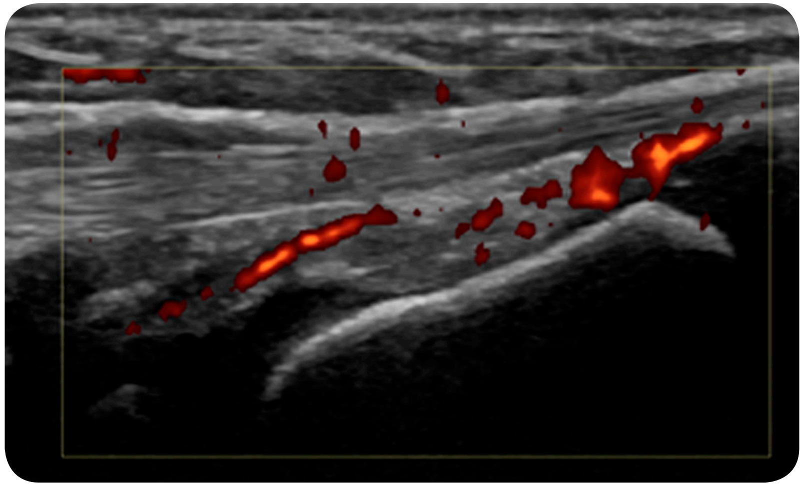
Vascularization with blooming artifact (increased gain)



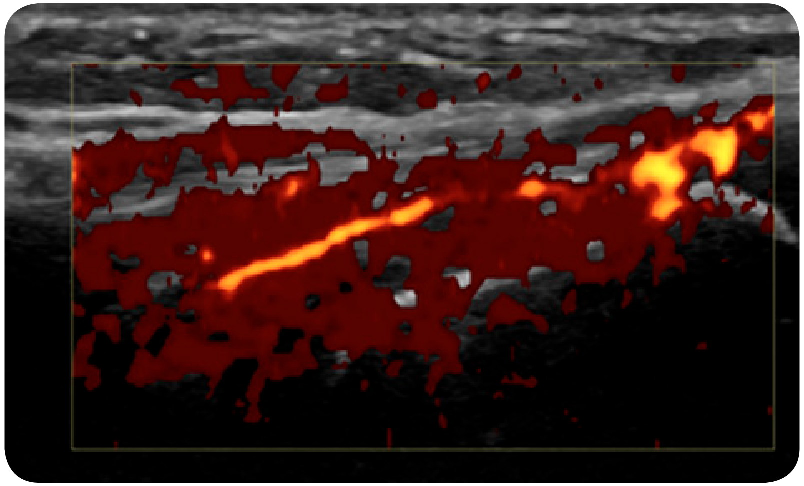
PHYSICS / PRINCIPLES
MACHINE
PROBE
TERMINOLOGY
SETTINGS
TISSUE CHARACTERISTICS
ARTIFACT
QUALITY STANDARDS

Doppler movement artifact

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



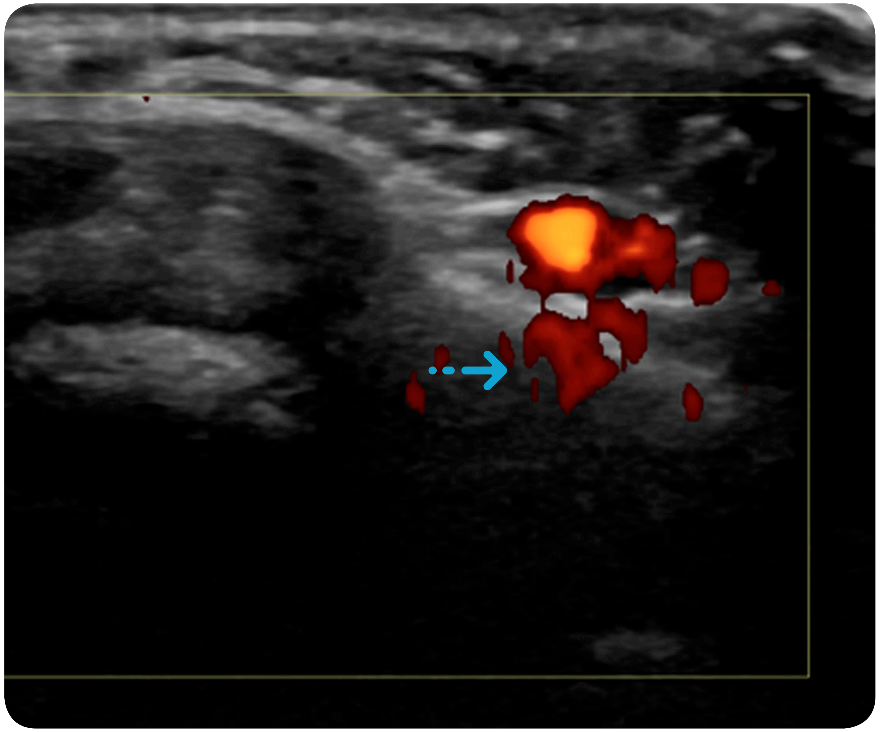
Vascularization in the wrist (calm patient)



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)

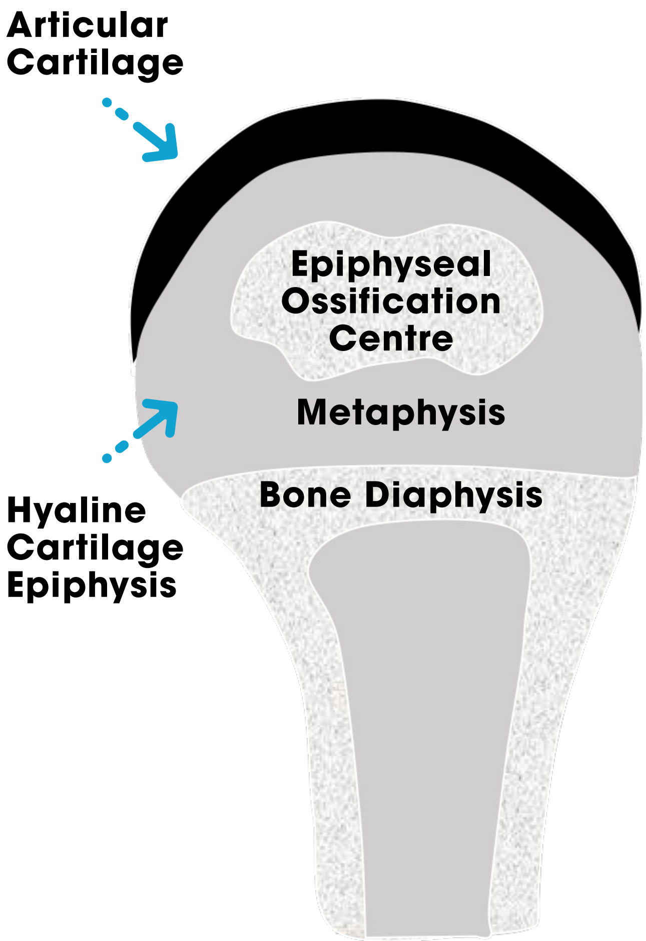
Minimum quality standards for the ultrasound machine

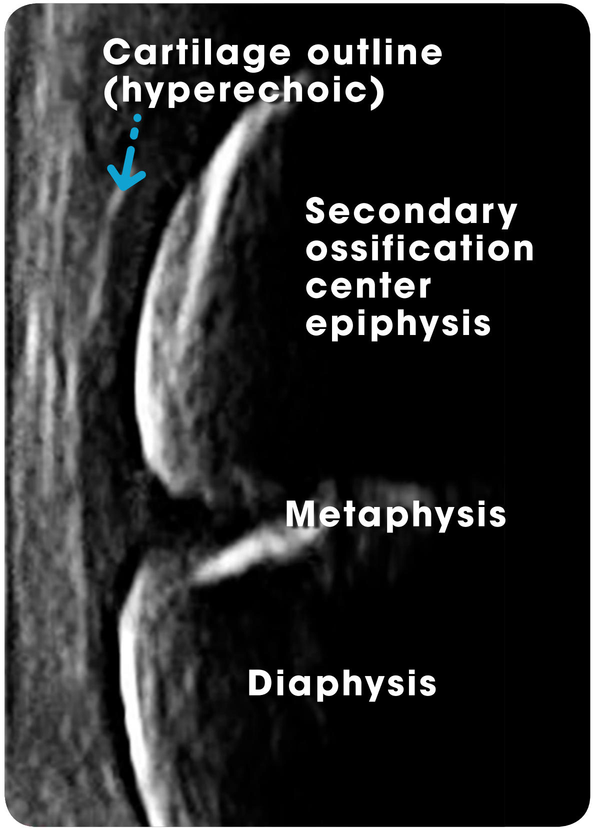
- A linear broadband transducer with a frequency of 5 to a minimum of 13 MHz (or higher)
- Optional: Convex transducer with a frequency of 4-8 Mhz (for imaging obese patients or examining deep structures)
- Optional: hockey stick transducer
- Harmonic imaging
- Spatial compound imaging
- Doppler options

Czymy Z: Standards for musculoskeletal ultrasound. J Ultrason 2017; 17: 182-187 (Ivan Lagunes)

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

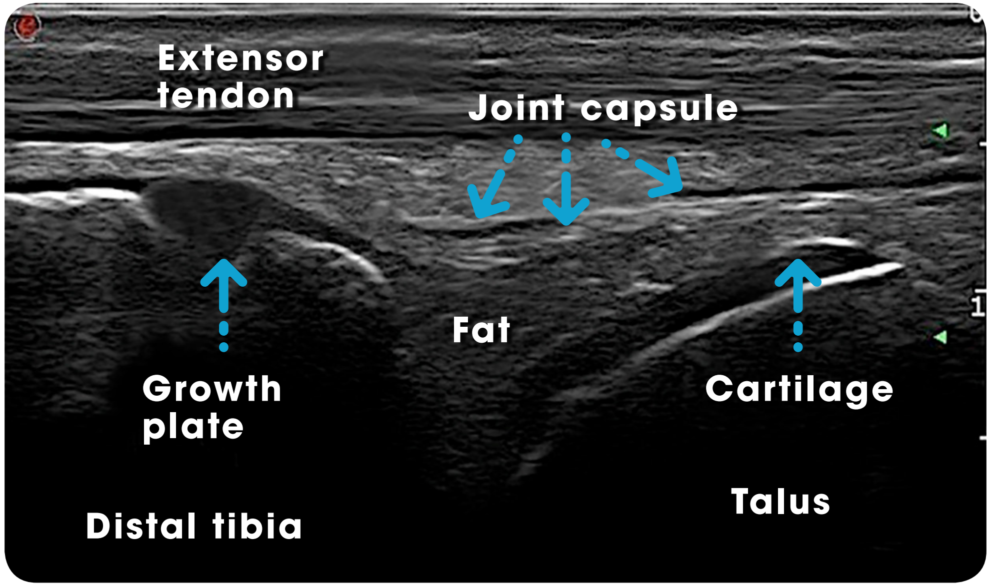


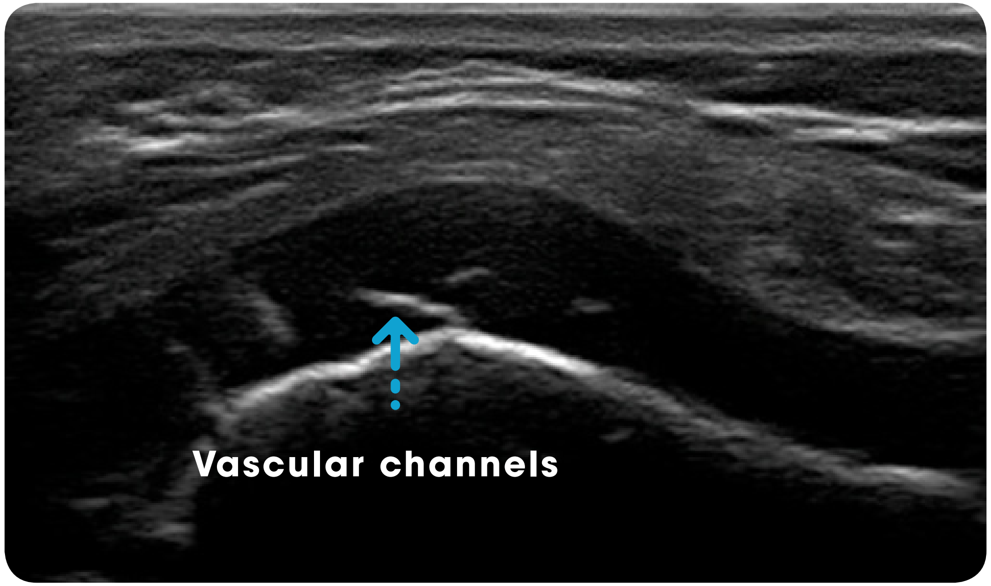


Roth J et al. Arthritis Care Res (Hoboken) 2015;67:136–142

The healthy joint – key characteristics on ultrasonography

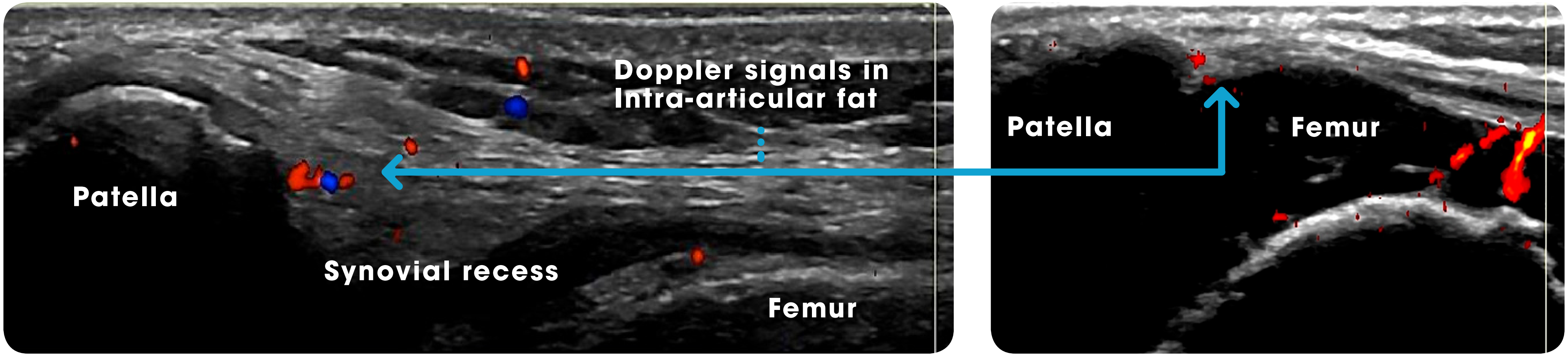
- Clearly identify the cartilage surface and note the growth plate interrupting the cortical bone[1-2]
- The joint capsule delineates the outer limit of the joint but not necessarily the synovial recess[1]
- Fat/connective tissue can be found intra-articularly but is extrasynovial[3]
- Hyperechoic dots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





1. Roth J et al. Arthritis Care Res (Hoboken) 2015;67:136–142; 2. Windschall D et al. Arthritis Care Res (Hoboken) 2017 (Epub);doi: 10.1002/acr.23335; 3. Collado P et al. Pediatr Rheumatol Online J 2018;16:23

The healthy joint – key characteristics on ultrasonography



Ultrasound images showing parapatellar views

- Doppler signals within the intra-articular fat, cartilage, and growth plate can be physiologic[2-3]

1. Roth J et al. Arthritis Care Res (Hoboken) 2015;67:136–142; 2. Windschall D et al. Arthritis Care Res (Hoboken) 2017 (Epub);doi: 10.1002/acr.23335; 3. Collado P et al. Pediatr Rheumatol Online J 2018;16:23

Normative data for synovial recesses in B mode

- Normative data on B mode for various joints have been published[1-4]
- A variable amount of distension of the synovial recess may be present in normal joints[1-4]
- The comparison with normative data should serve as guidance, but not absolute cut-off, for pathology

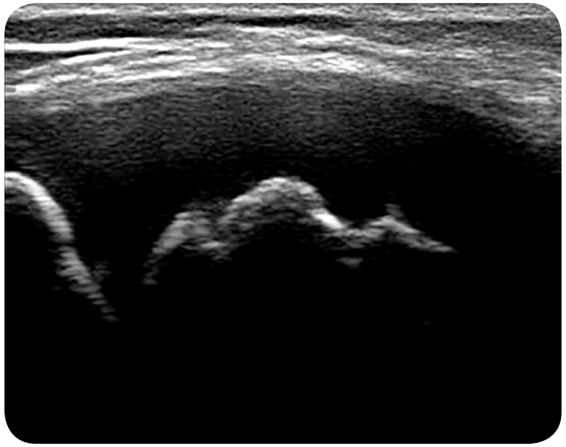
TIPS /

- 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

1. Collado P et al. Arthritis Care Res (Hoboken) 2016;68:348–356; 2. Windschall D et al. Rheumatol Int 2016;36:1569–1577; 3. Trauzeddel RF et al. Pediatr Radiol 2017;47:1329–1336; 4. Trauzeddel R et al. Klin Padiatr 2017;229:293–301

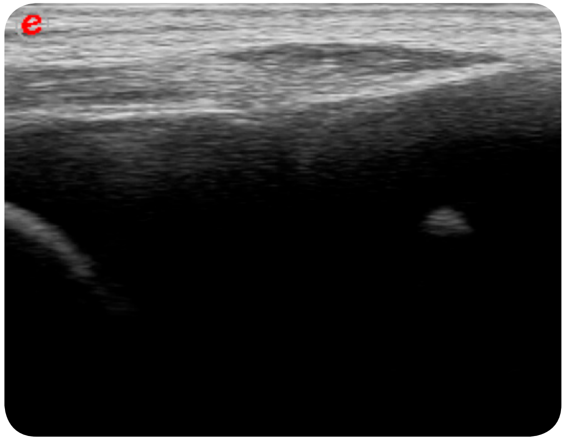
Assessment of cartilage

- 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

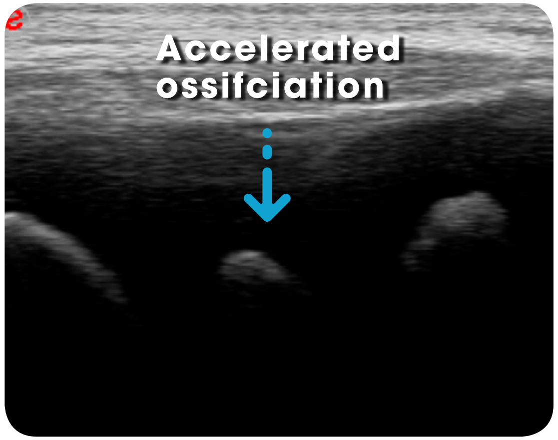


Irregular ossification center

Foot radiograph 2-year-old girl with JIA synovitis right midfoot and accelerated ossification on the right



MSUS left midfoot 2year old JIA



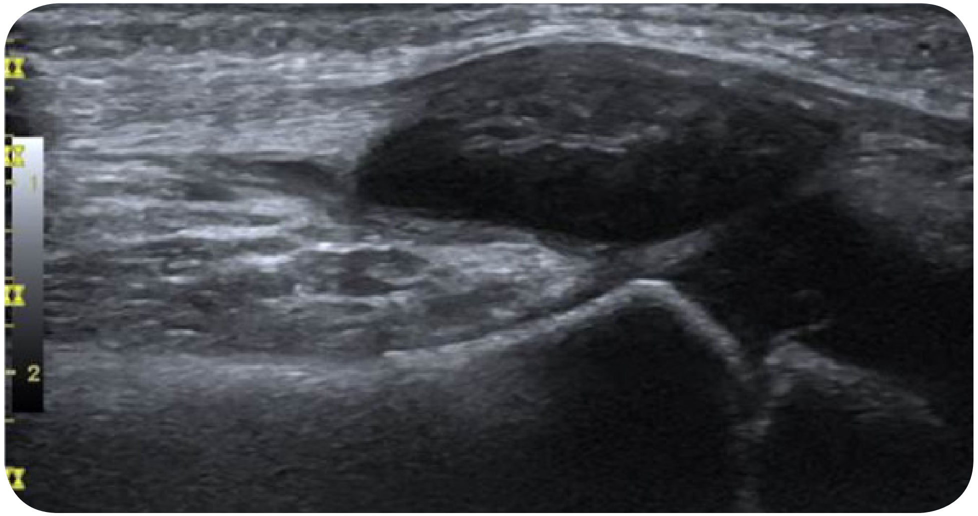
MSUS right midfoot 2 year old JIA

Roth J et al. Arthritis Care Res (Hoboken) 2015;67:136–142

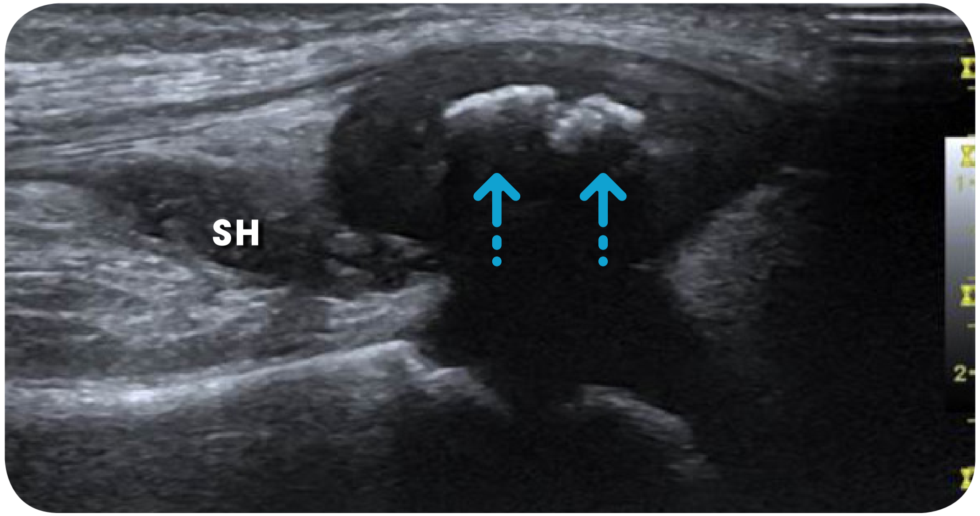
Assessment of Cartilage

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.

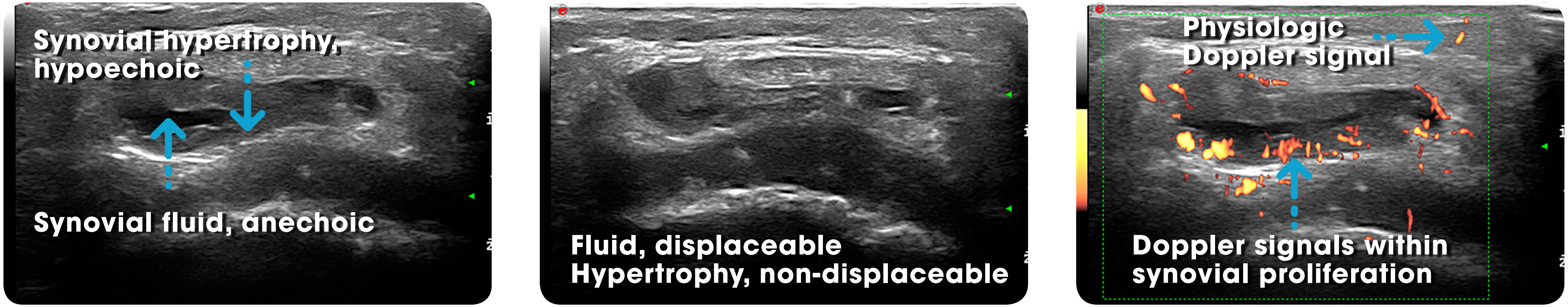


Right side



Left side

Synovitis

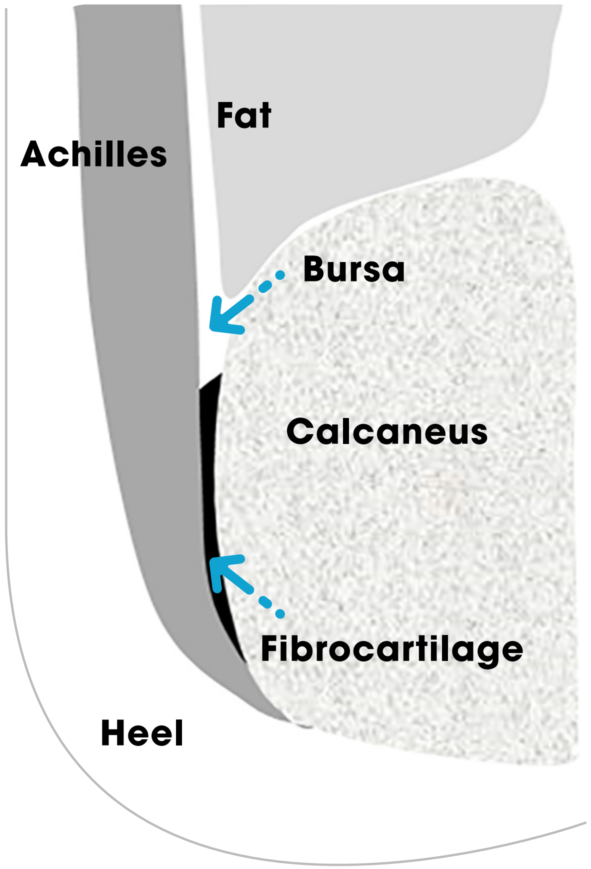


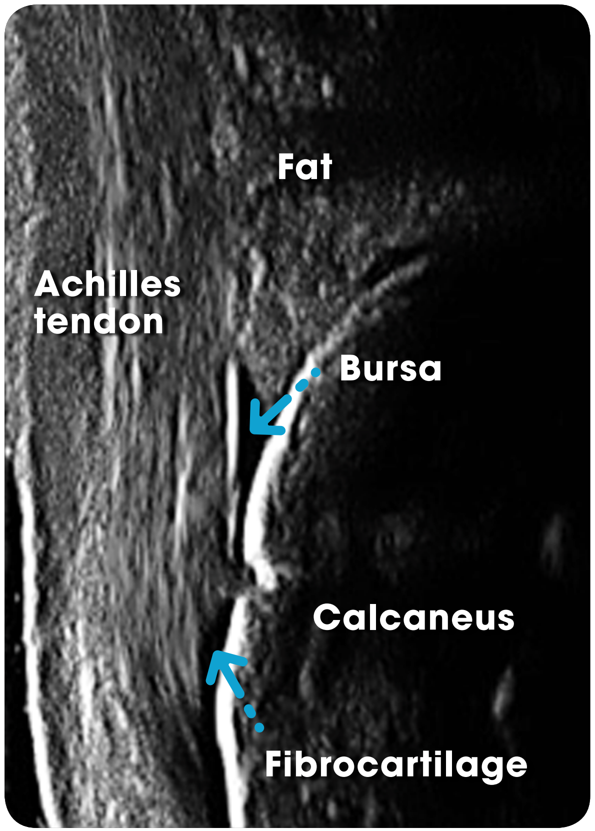
- Synovitis on ultrasonography in children can be seen on B mode and Doppler
- It will appear as hypoechoic or anechoic on B mode; fluid is displaceable and synovial hypertrophy non-displaceable
- Abnormal Doppler signals need to be within an area of synovial hypertrophy
- Physiologic Doppler signals can be present in any area of the joint

Roth J et al. Arthritis Care Res (Hoboken) 2017;69:1217–1223

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

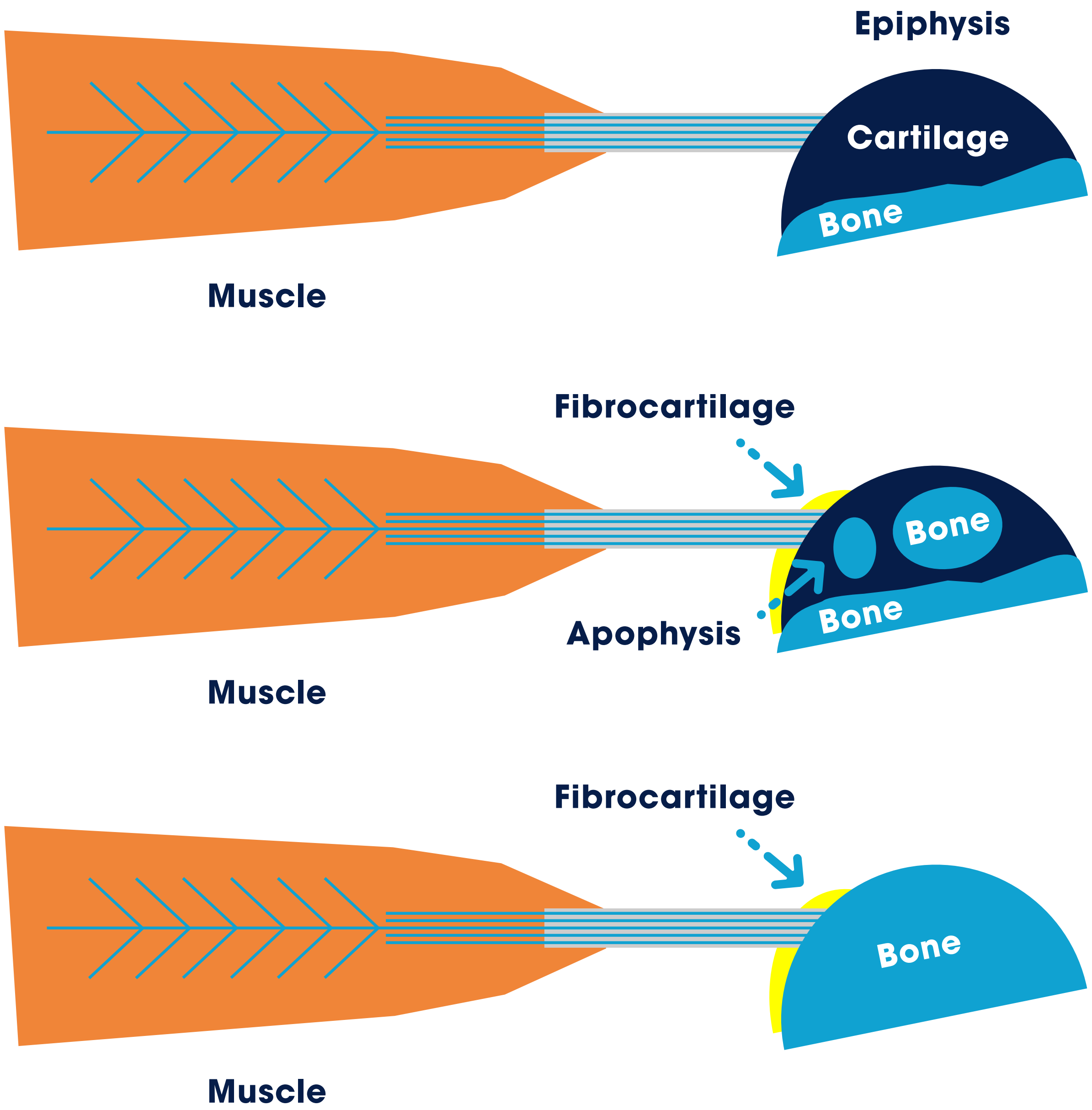




Adapted from Weiss PF et al. Curr Rheumatol Rep 2016;18:75

Maturation of the normal enthesis

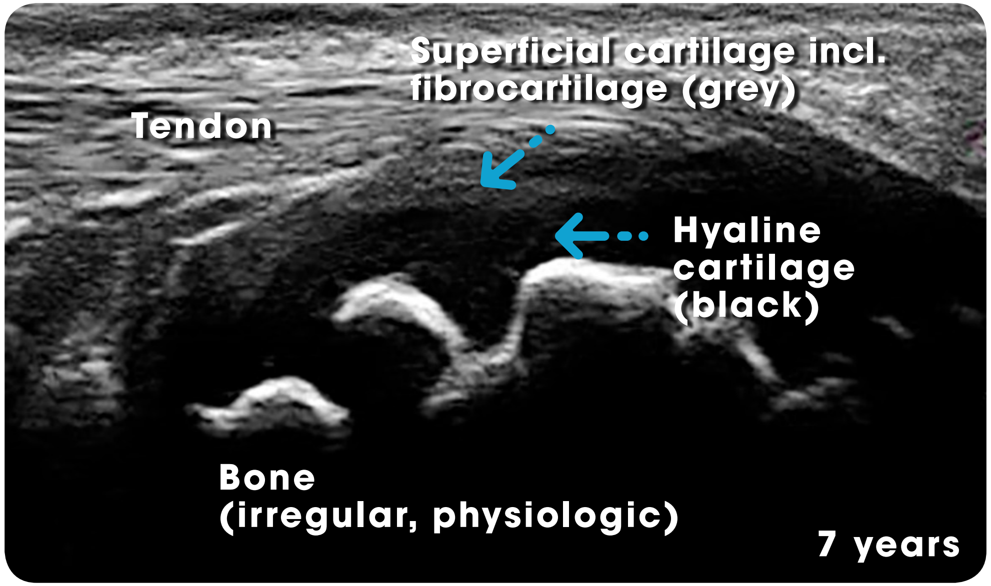
- Initially the tendon inserts into cartilage
- With increasing age a layer of fibrocartilage forms between the tendon and the hyaline cartilage
- Within the hyaline cartilage ossification centers appear
- With advancing age and maturation ossification will complete leaving only a thin layer of fibrocartilage

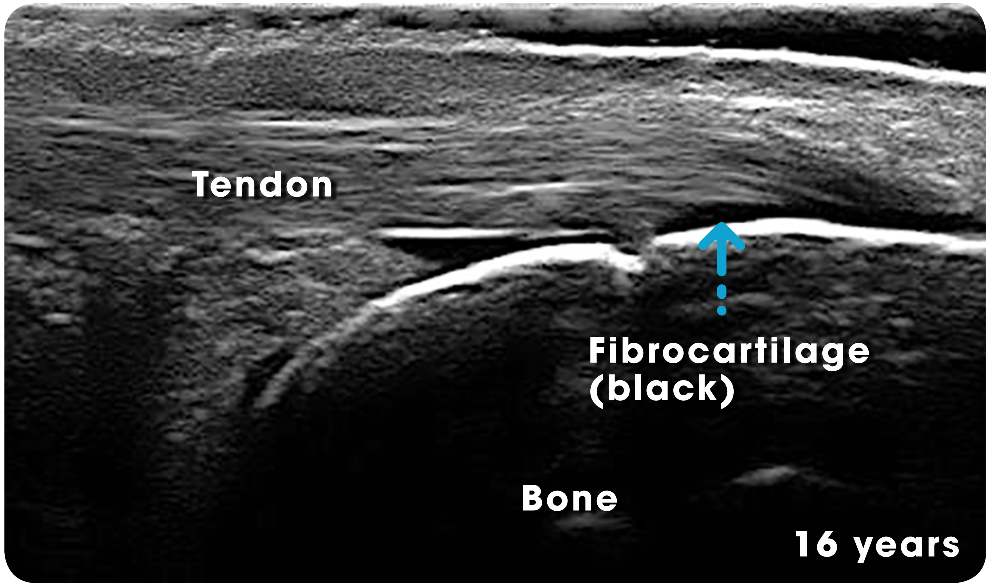


Weiss PF et al. Curr Rheumatol Rep 2016;18:75

Illustration designed, based on an illustration by Carlo Martinoli, Genoa, Italy

Maturation of the normal enthesis



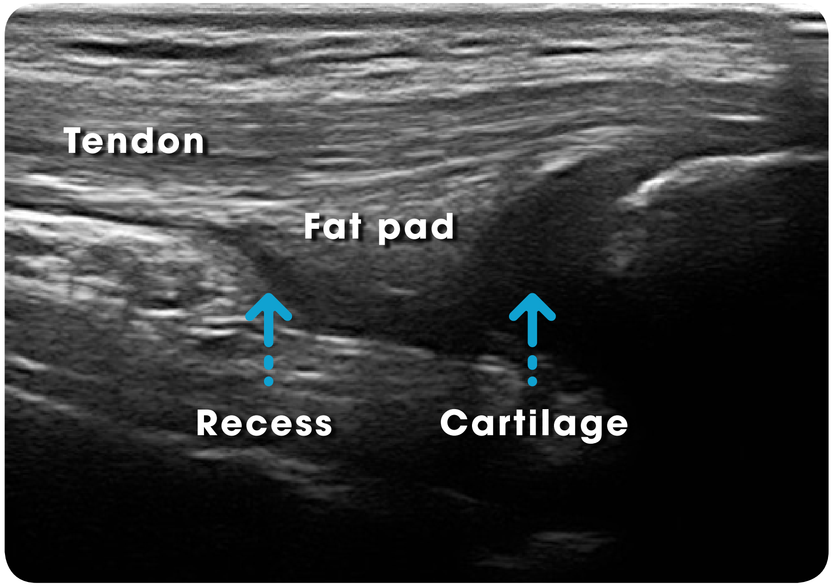


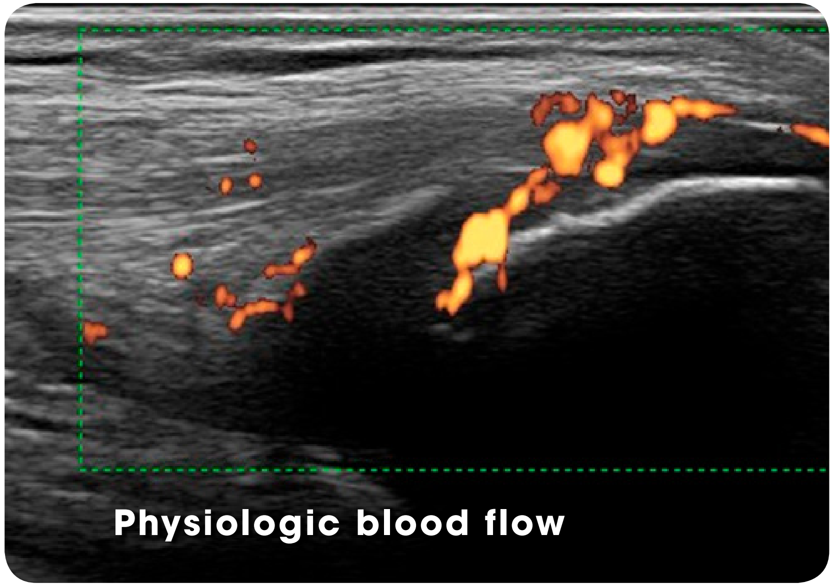
Insertion of the Achilles tendon in the posterior calcaneus

Weiss PF et al. Curr Rheumatol Rep 2016;18:75

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



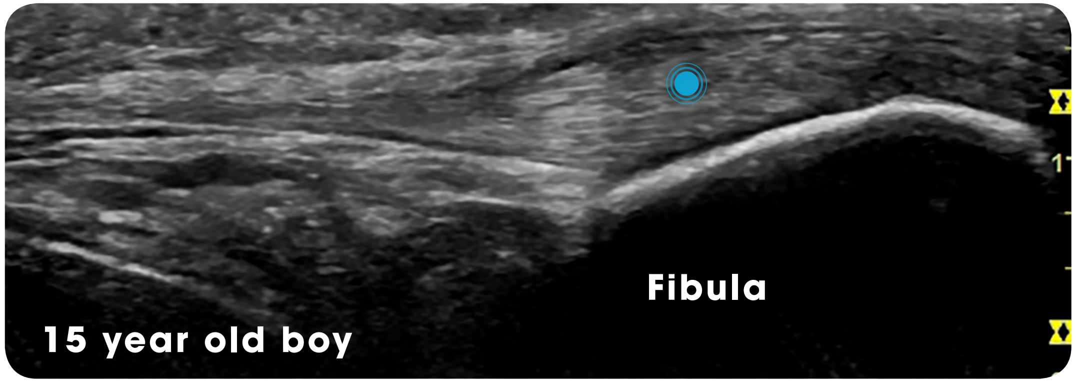


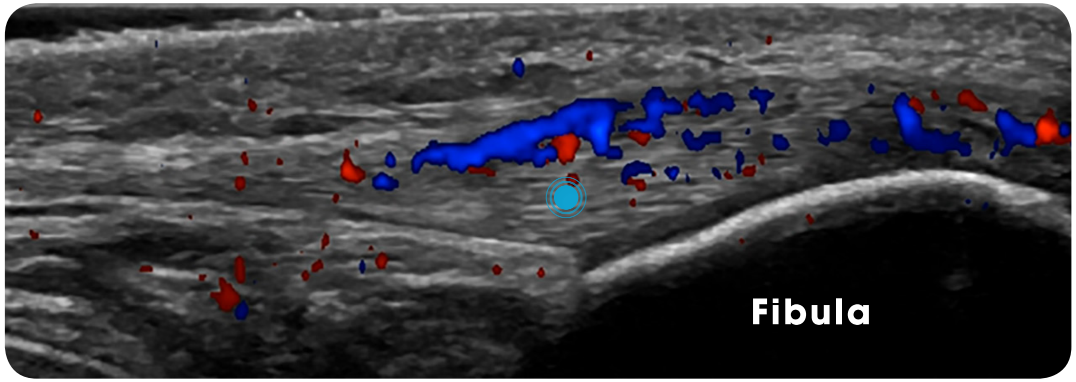
Weiss PF et al. Curr Rheumatol Rep 2016;18:75

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





Iliotibial band

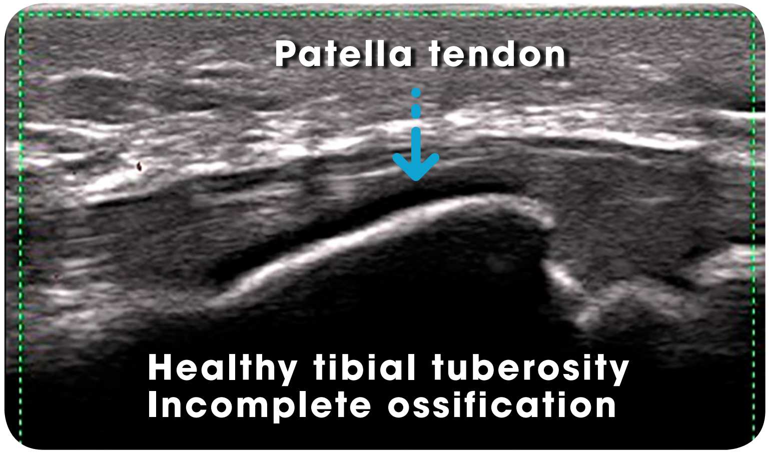
TIPS /

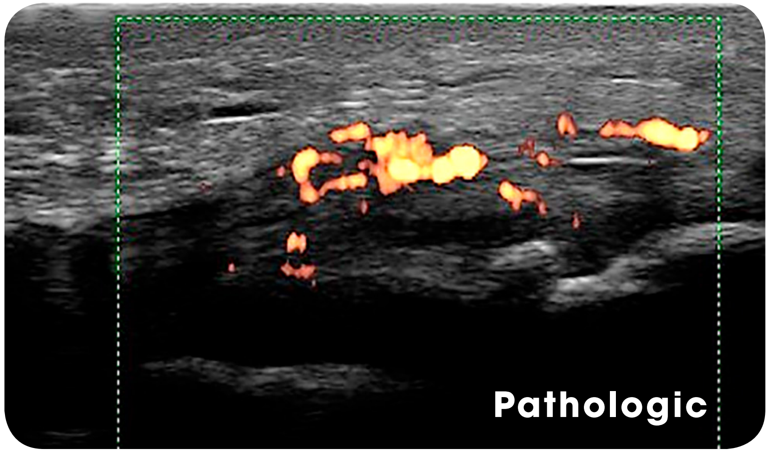
- Interpret Doppler signals cautiously taking into account the presence of B-mode abnormalities
- The distinction between mechanical lesions and enthesitis has to be done based on the clinical background
- Some entheses are more prone to mechanical lesions

Weiss PF et al. Curr Rheumatol Rep 2016;18:75

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





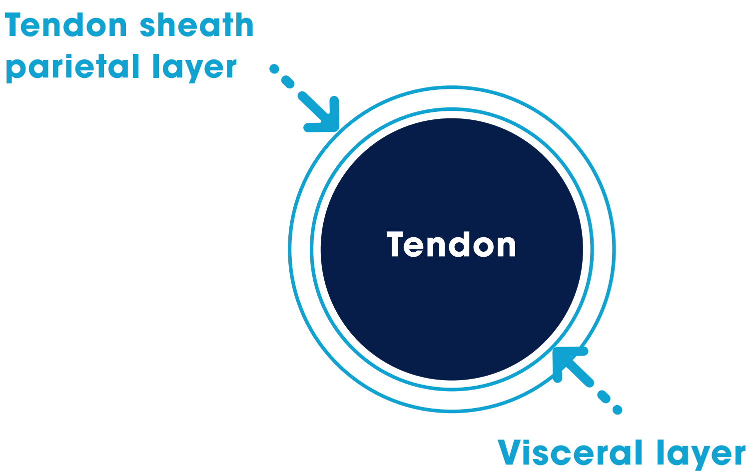
TIPS /

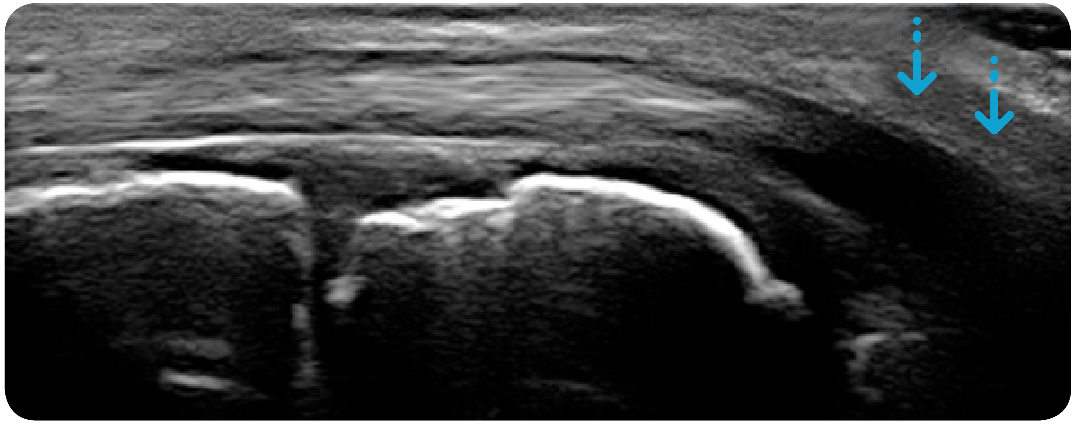
- The clinical (symptoms) and imaging correlation varies
- Presence of several ossification centers is physiologic at the posterior calcaneus, proximal 5th metatarsal, and other locations
- Apophysitis is an important differential diagnosis of enthesitis as part of spondyloarthropathy

Weiss PF et al. Curr Rheumatol Rep 2016;18:75

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





Longitudinal view of a peroneus tendon
Arrows are indicating anisotropy

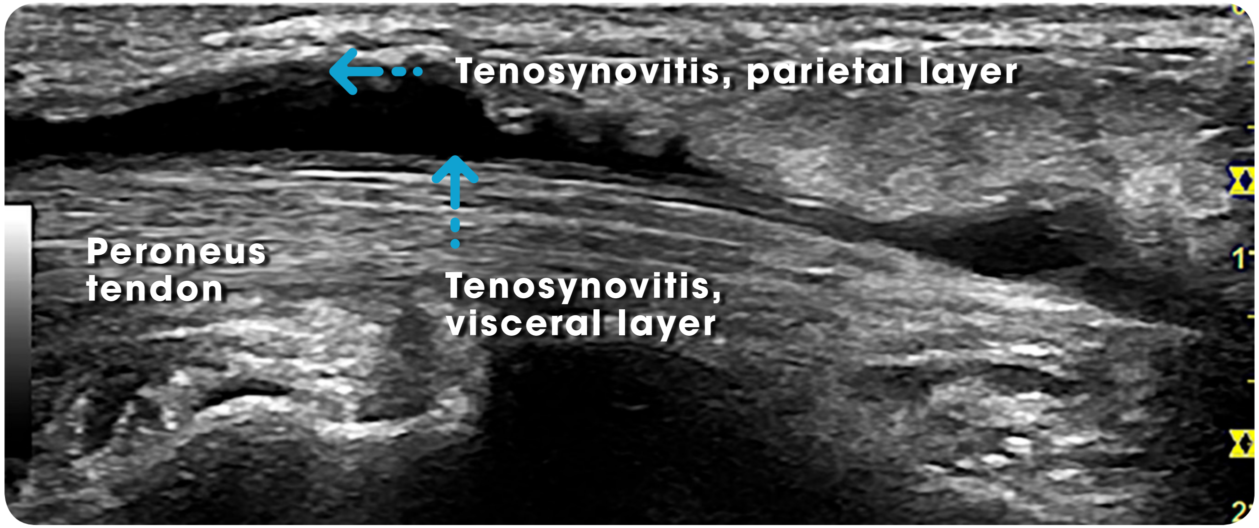
TIPS /

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

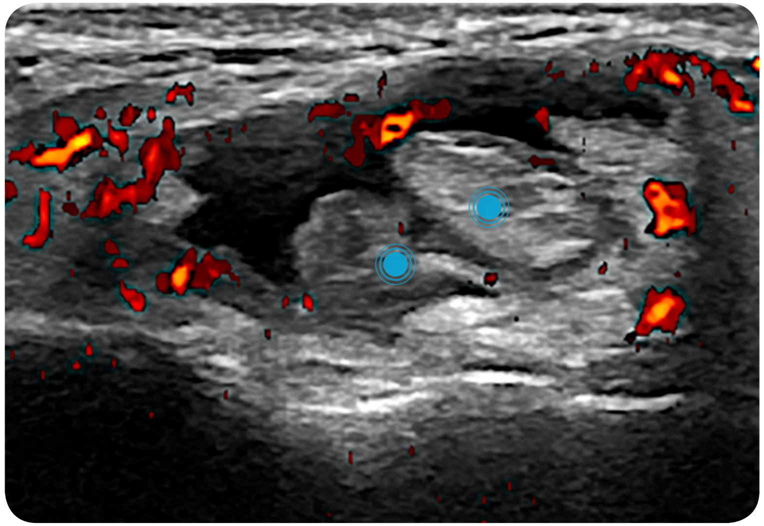
Bruyn GA et al Ann Rheum Dis 2014;73:1929–1934

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

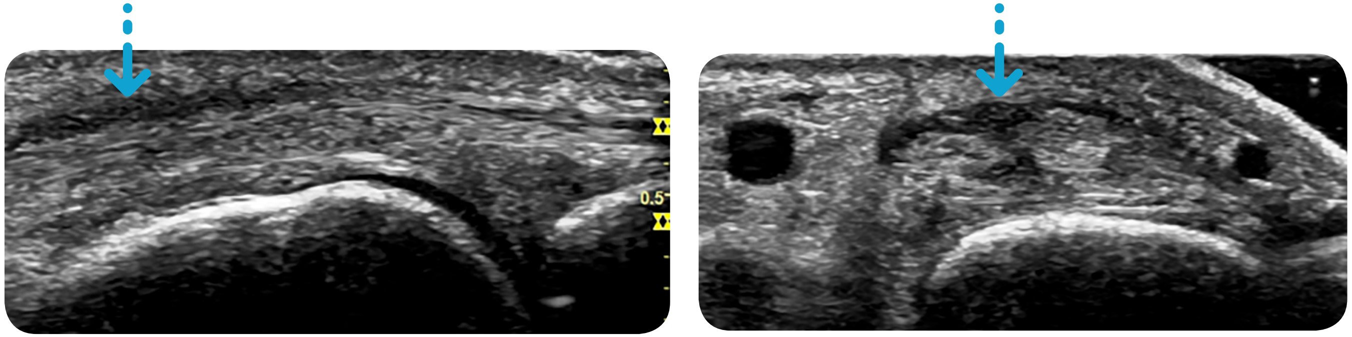
Peroneus tendons

Bruyn GA et al Ann Rheum Dis 2014;73:1929–1934

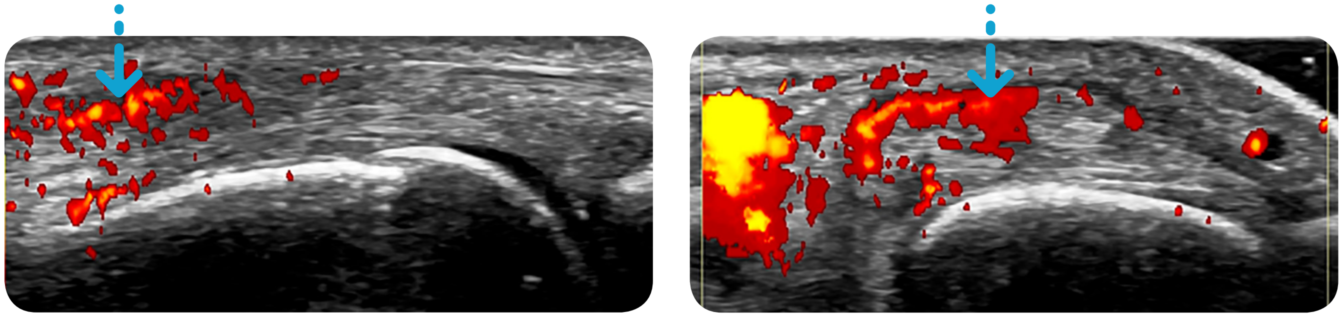
Paratenonitis

- 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, metacarpophalangeal joint 2



Doppler signals within distended paratenon



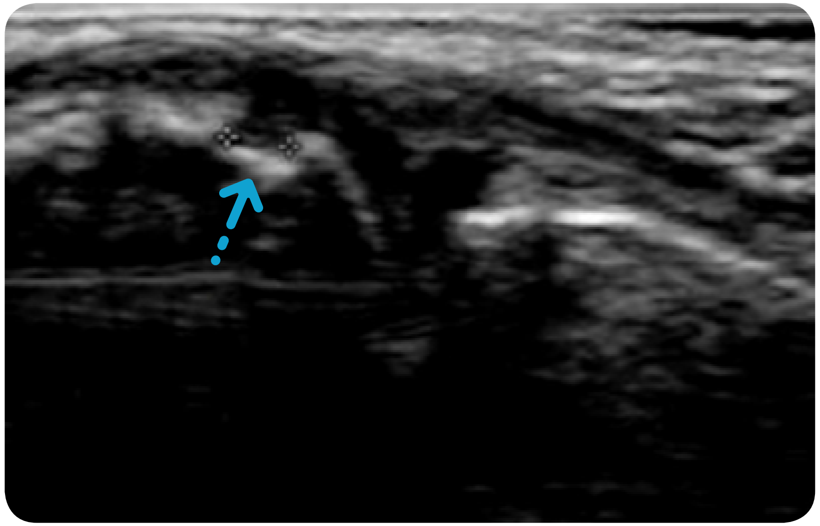
TIPS /

- 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

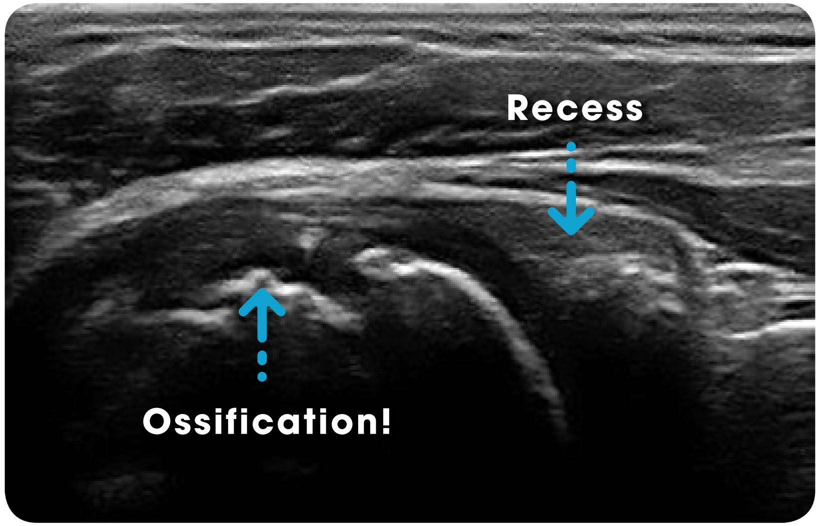
Weiss PF et al. Curr Rheumatol Rep 2016;18:75

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 that 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



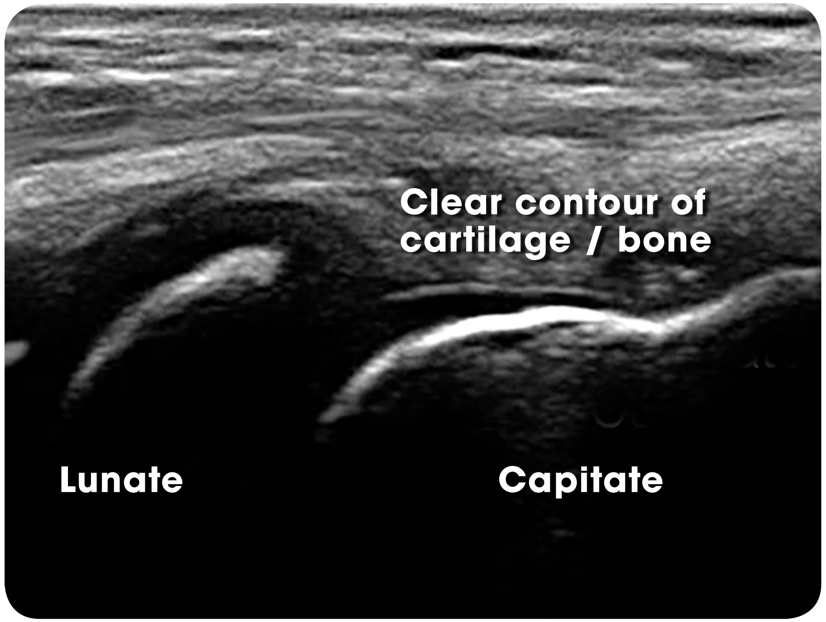
Erosion, metacarpophalangeal joint



Gaps between ossification centers, humerus

Karmazyn B et al. Pediatr Radiol 2007;37:475–482

How to scan in practice - exact positioning of the probe

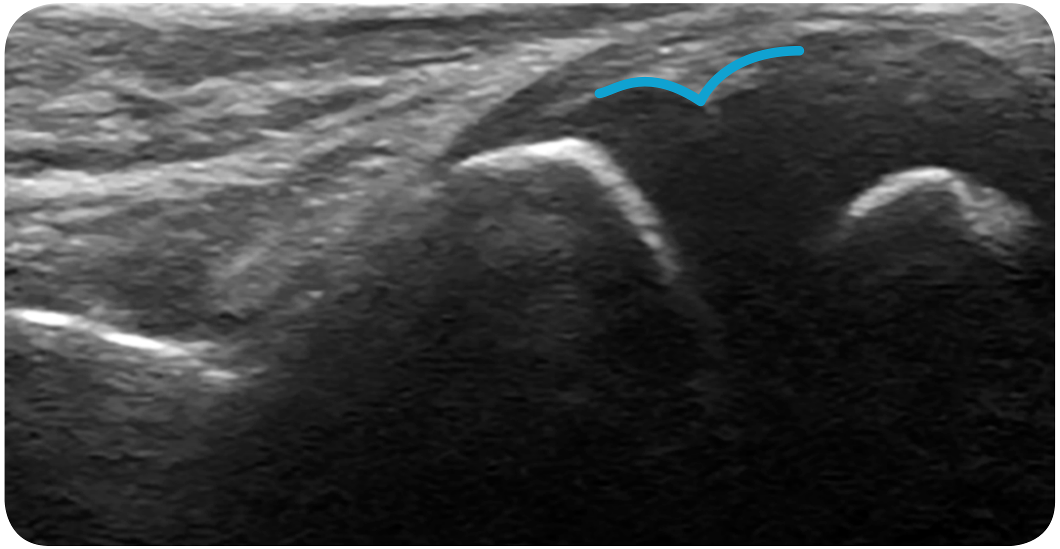


The exact positioning of the probe through angulation, rotation, and heel–toeing is necessary to obtain a clear depiction of the relevant structures

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

Roth J et al. Arthritis Care Res (Hoboken) 2015;67:136–142

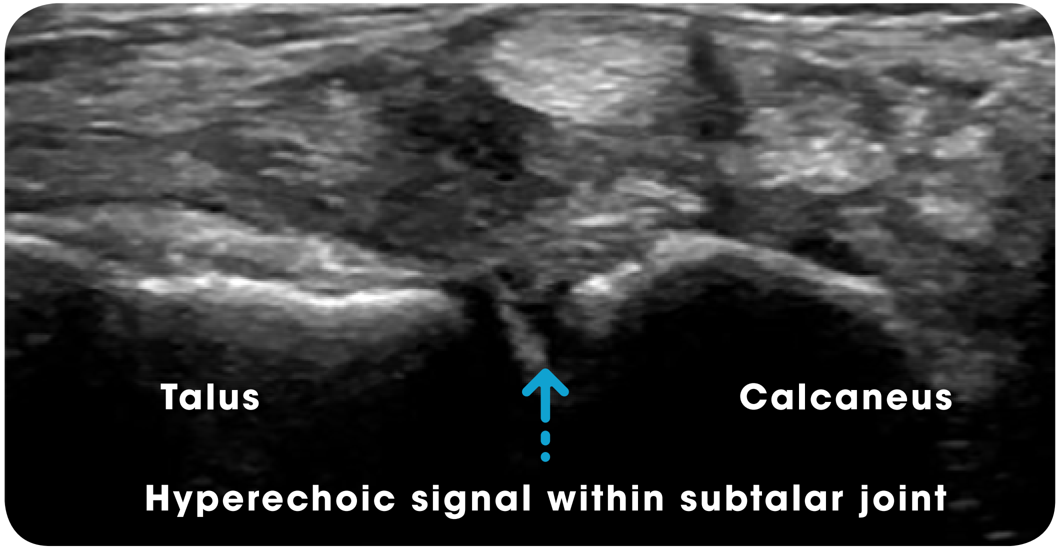
How to scan in practice - gull wing sign



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)

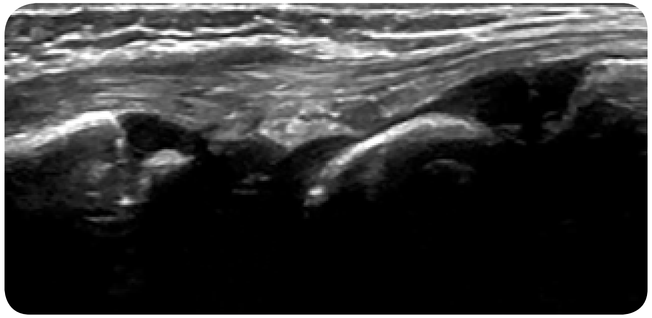
This concave shape is the opposite of what one would see in the case of an effusion, where it would be convex

How to scan in practice - tornado sign

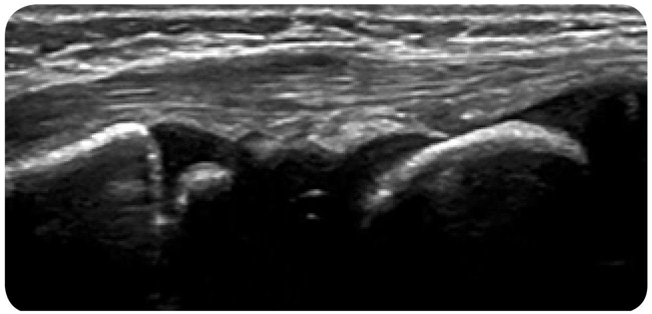


In the absence of synovial fluid a white reflection can be seen descending into the joint space between the cartilage of the immature bone – this is called the tornado sign

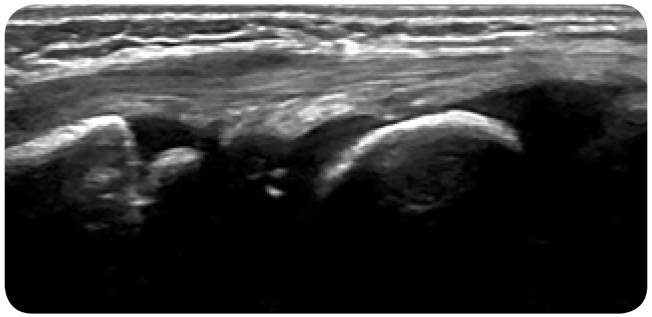
How to scan in practice - move the joint to clarify findings



Extension



Neutral



Flexion

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

TIPS /

- 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:
  » Roth J et al Arthritis Care Res. 2015;67:136–42.
  » Collado p et al Ped Rheumatol Online J. 2018 Apr 10;16(1):23.
  » Windschall D e al, Arthritis Care Res (Hoboken). 2017 Aug 4
  » Ting T et al Arthritis Care Res (Hoboken). 2018 Sep 7.
  » Collado et al Rheumatology 2013;52:1477148
  » Collado P et al. Arthritis Care Res. 2016;68:348–56.
  » Lanni S et al Arthritis Care Res (Hoboken). 2016 Sep;68(9):1346-53.
  » Möller I et al. Annals of the Rheumatic Diseases 2017;76:1974-1979.
- 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.

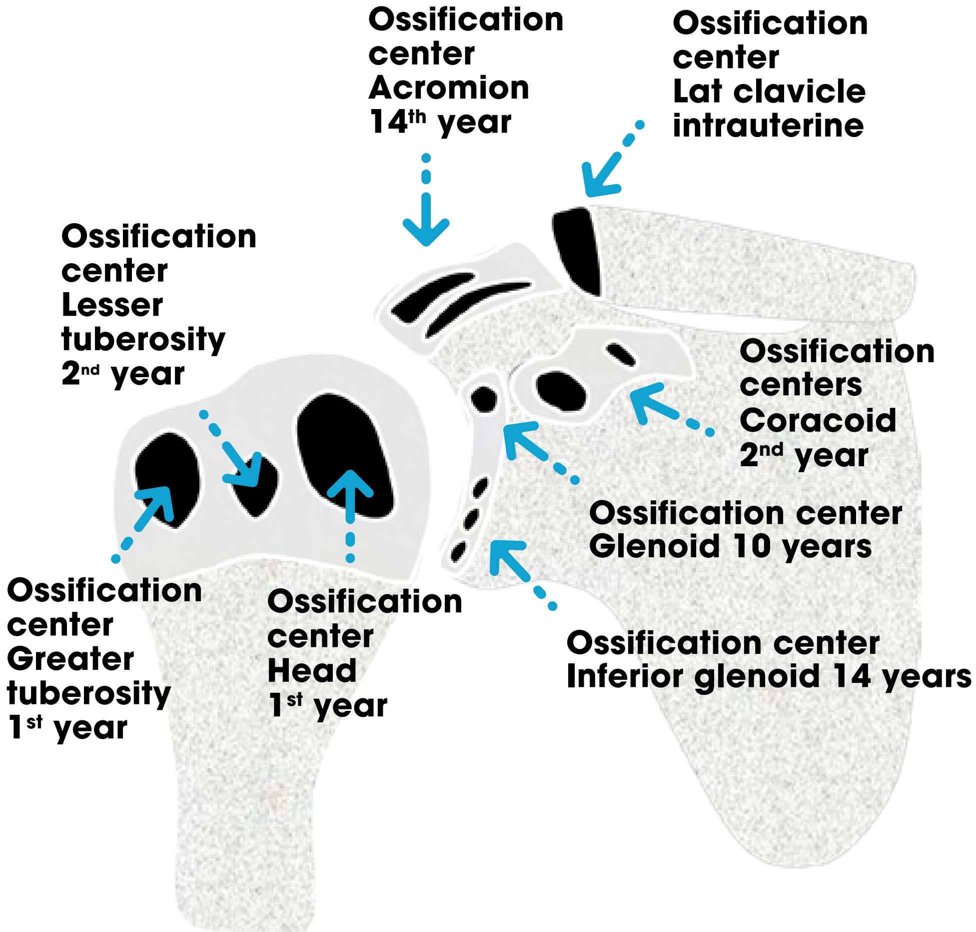
Shoulder Ossification

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
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

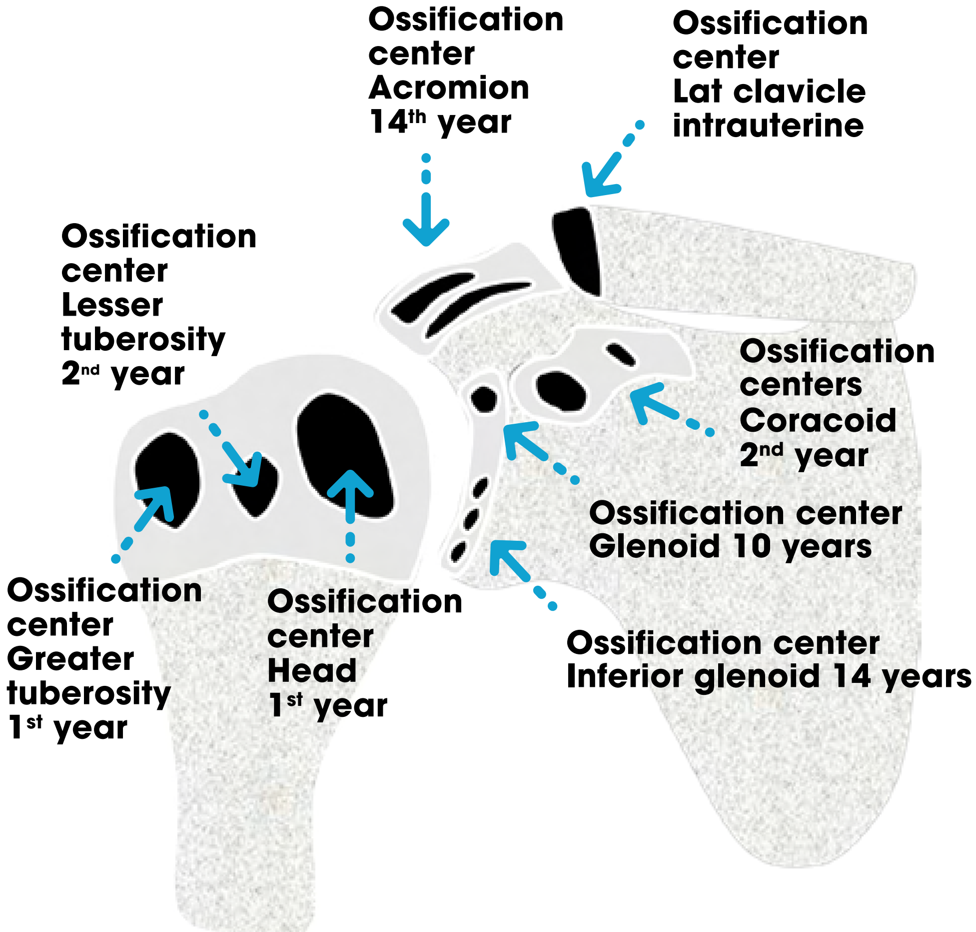
Shoulder Ossification

HUMERAL HEAD

OSSIFICATION CENTERS OF THE CLAVICLE APPEAR:

Lateral end: 5 weeks in utero
Medial end: 15 years

OSSIFICATION CENTERS OF THE SCAPULA APPEAR:



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

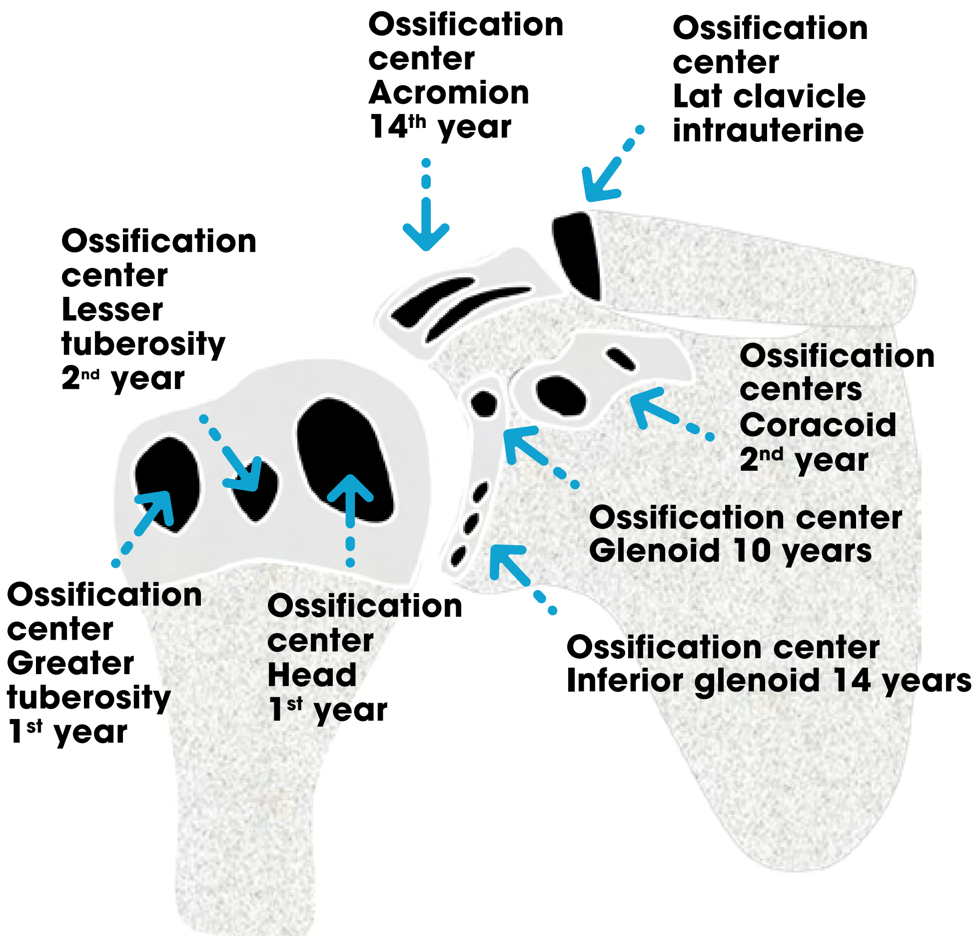
Shoulder Ossification

HUMERAL HEAD

OSSIFICATION CENTERS OF THE CLAVICLE APPEAR:

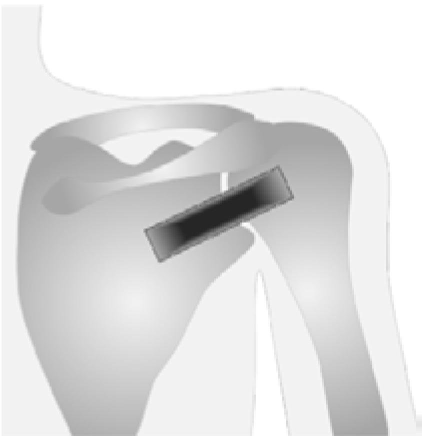
OSSIFICATION CENTERS OF THE SCAPULA APPEAR:

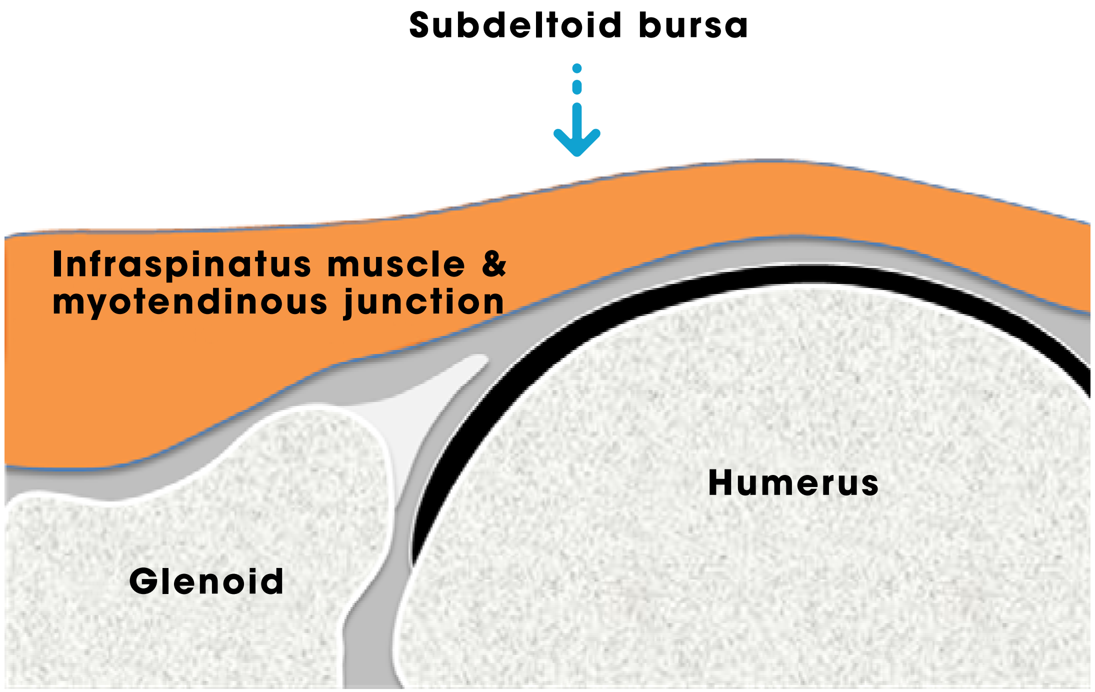
Body: 8 weeks in utero
Coracoid process (two centers): 12-18 months
Glenoid: 10-11 years
Inferior angle: 14-20 years (puberty)
Acromion (three centers): 14-20 years (puberty)
Medial border: 14-20 years (puberty)



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

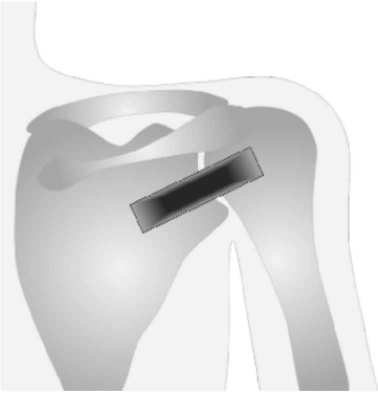
Scanning the shoulder - glenohumeral posterior

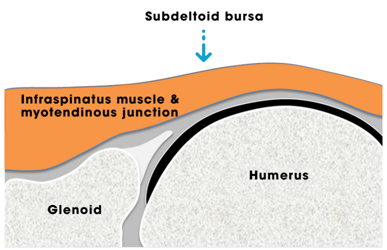




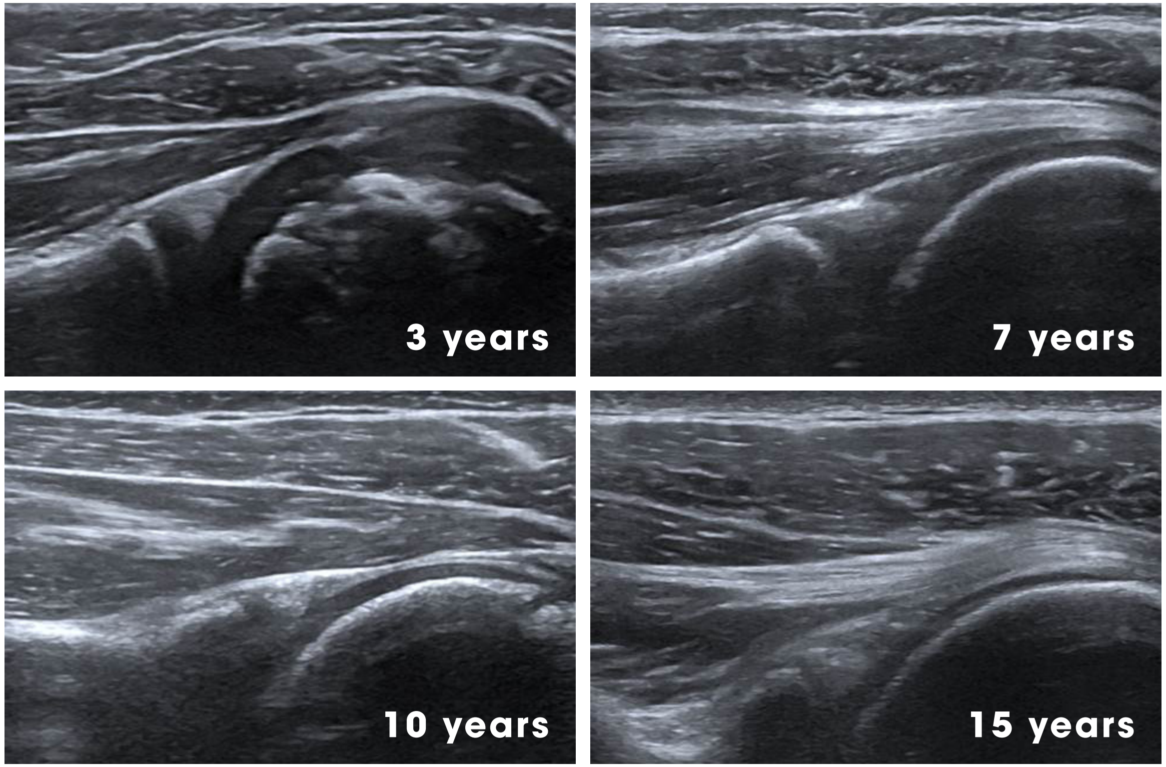
TIP / Examine the dorsal shoulder joint dynamically with 90° flexion of the elbow joint and external rotation of the shoulder

Scanning the shoulder - glenohumeral posterior





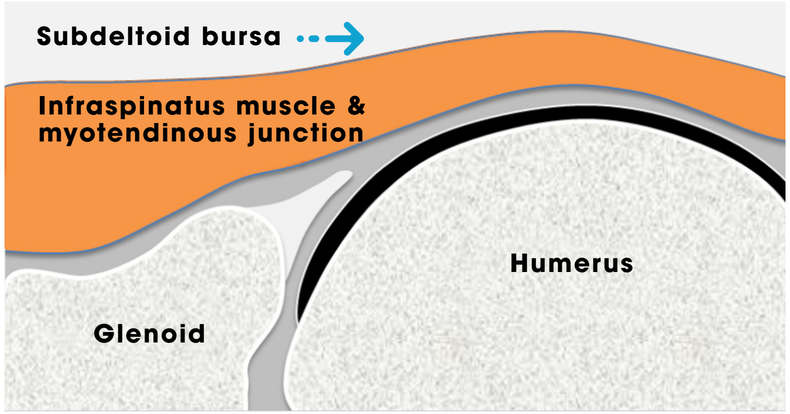
HEALTHY PATHOLOGY

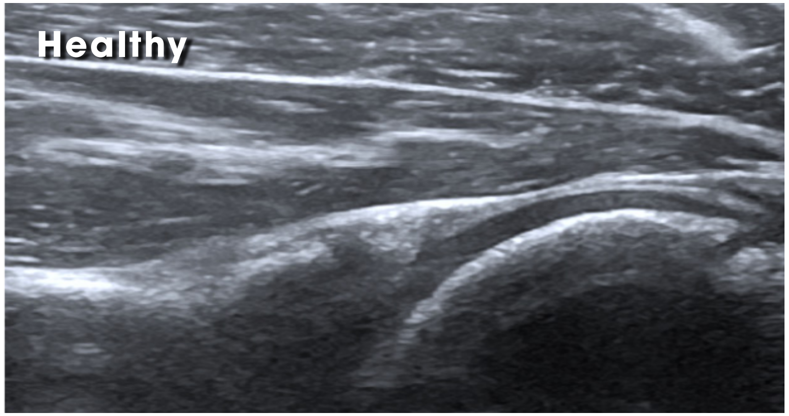


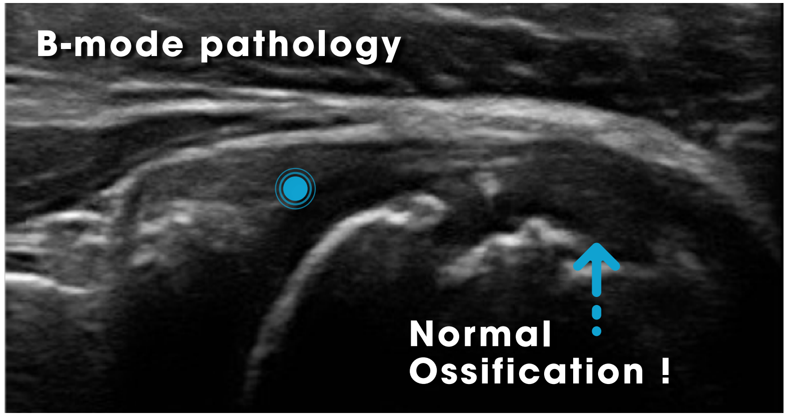
TIP / Examine the dorsal shoulder joint dynamically with 90° flexion of the elbow joint and external rotation of the shoulder

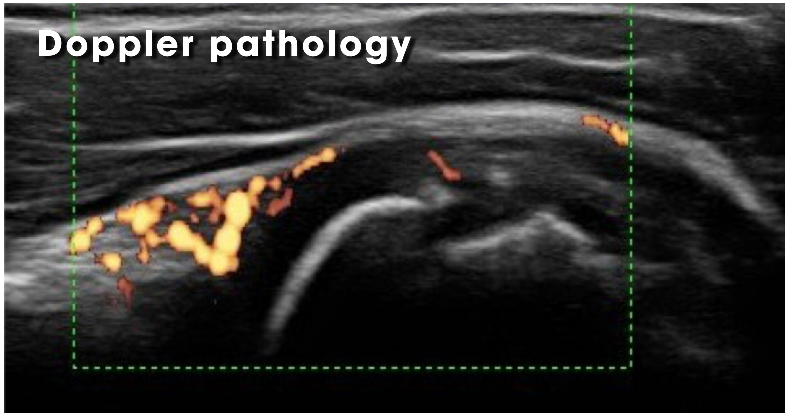
Scanning the shoulder - glenohumeral posterior

HEALTHY PATHOLOGY







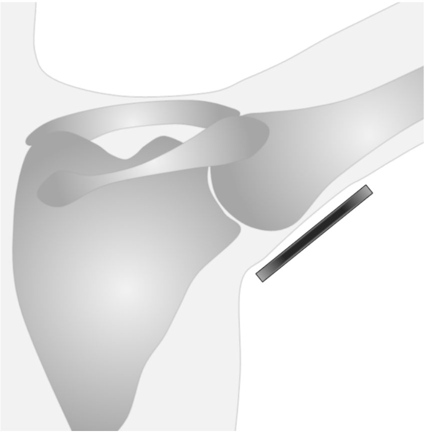


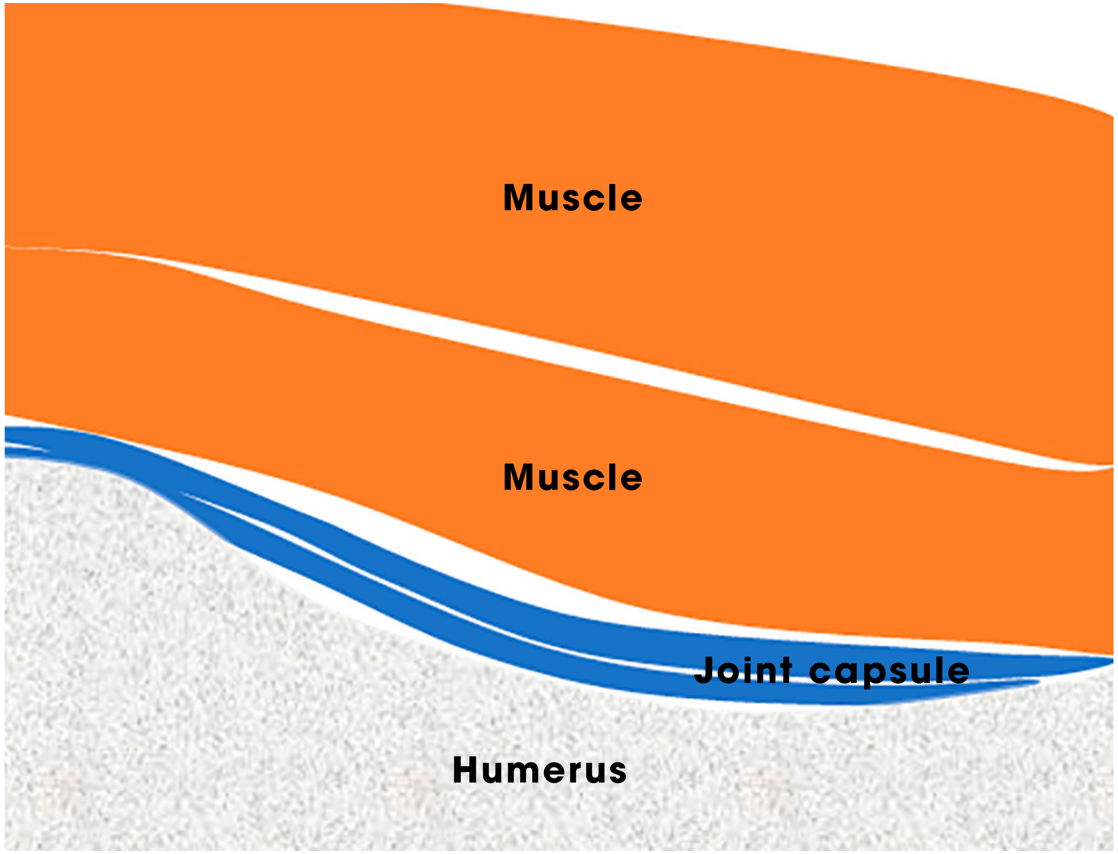
Synovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

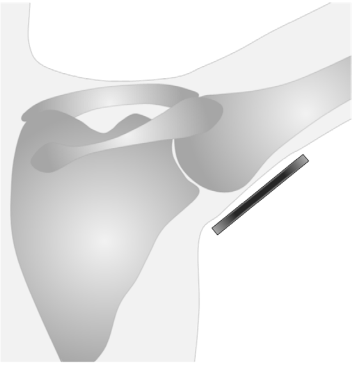
Scanning the shoulder - glenohumeral axillary

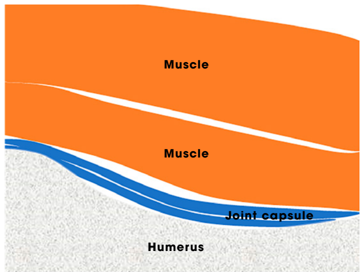




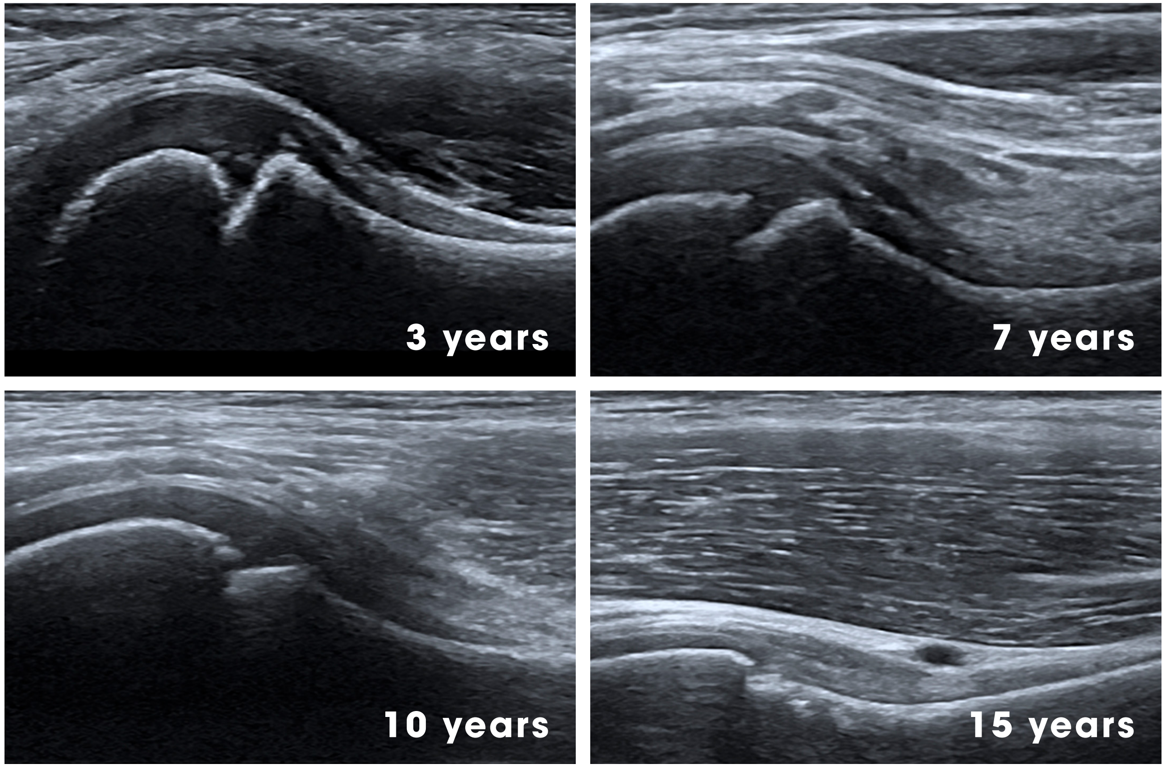
TIP / The axillary scan is very easy and may help to detect effusion in the shoulder joint

Scanning the shoulder - glenohumeral axillary





HEALTHY PATHOLOGY

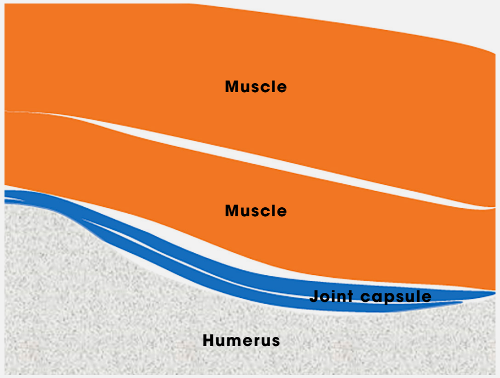


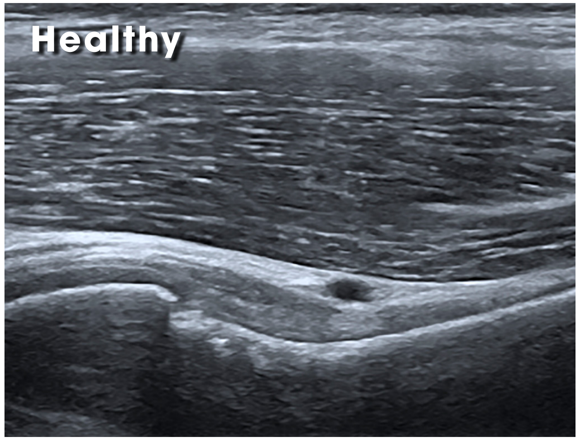
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

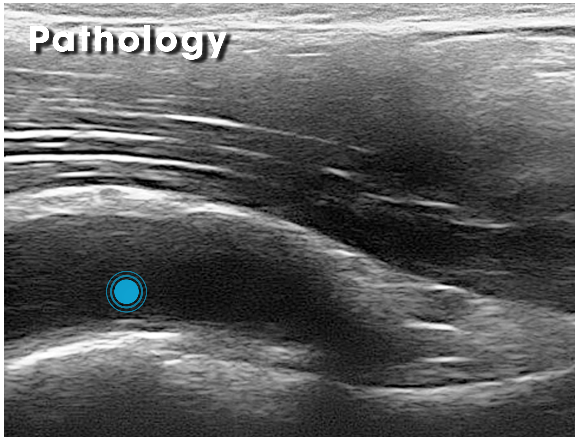
TIP / The axillary scan is very easy and may help to detect effusion in the shoulder joint

Scanning the shoulder - glenohumeral axillary

HEALTHY PATHOLOGY



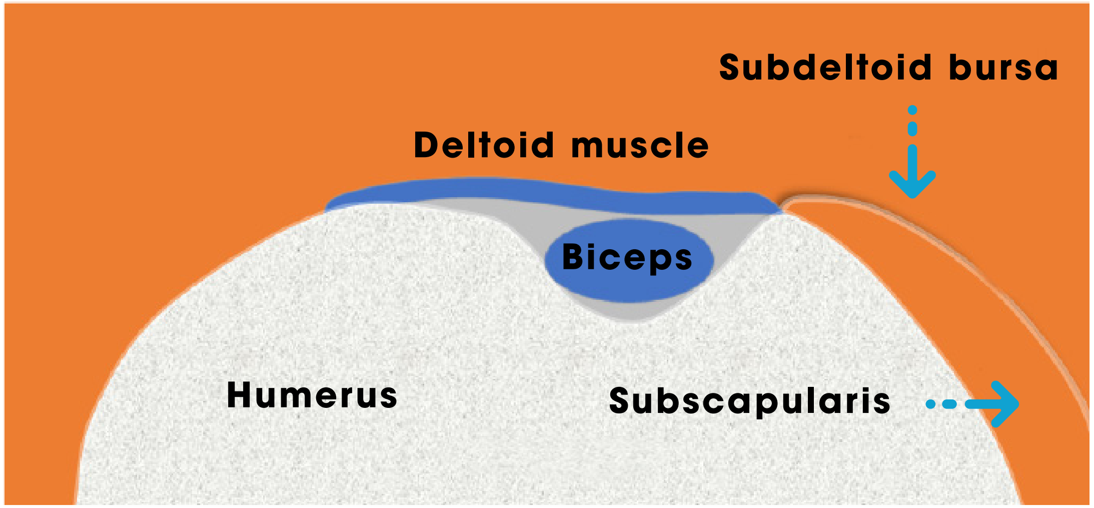


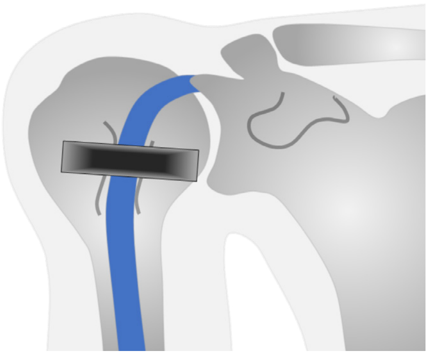


Effusion

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

Scanning the shoulder - biceps tendon



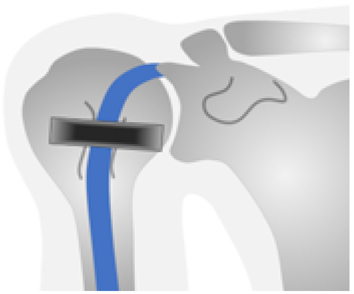


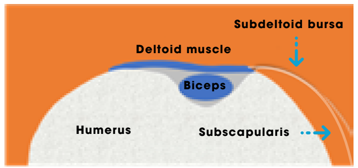
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

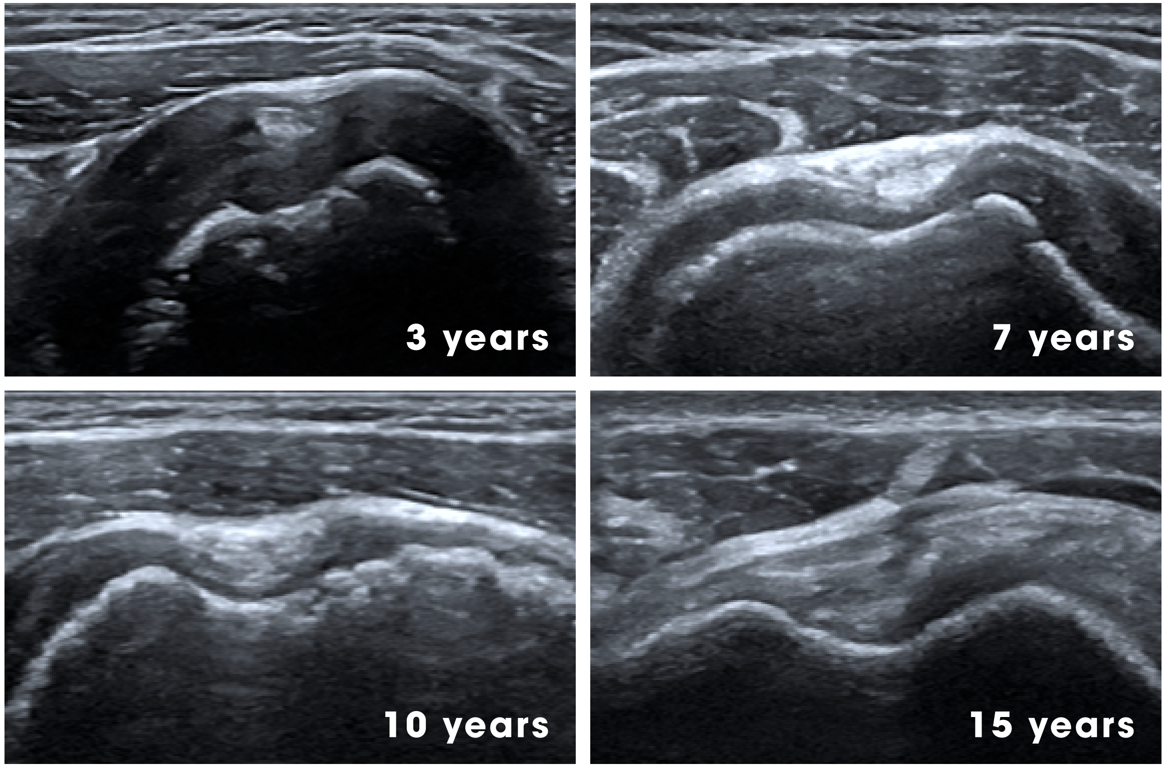
TIP / In younger children the hyperechoic biceps tendon runs on top of thick hypo- or an-echoic cartilage

Scanning the shoulder - biceps tendon

HEALTHY PATHOLOGY



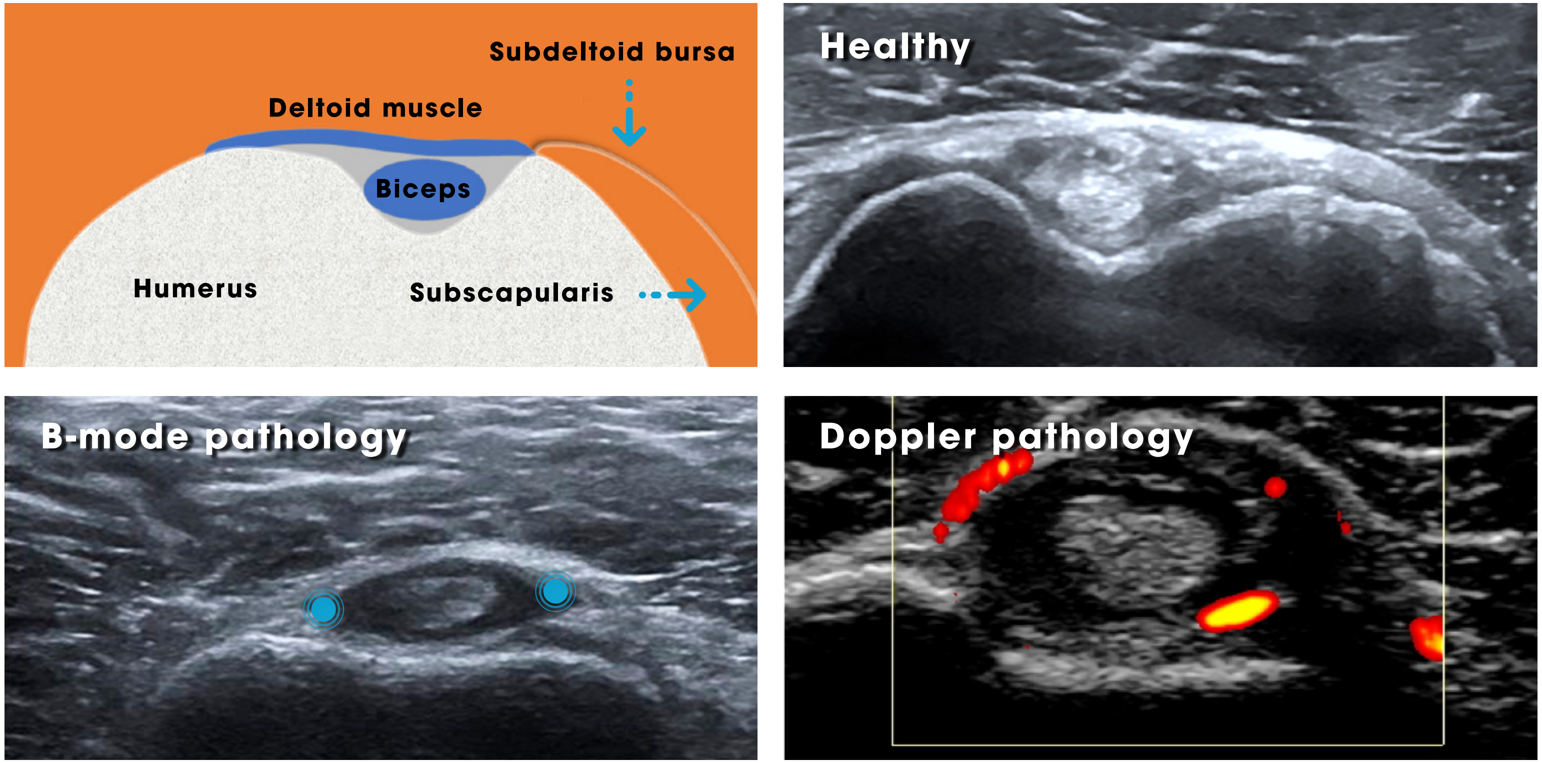




TIP / In younger children the hyperechoic biceps tendon runs on top of thick hypo- or an-echoic cartilage

Scanning the shoulder - biceps tendon

HEALTHY | PATHOLOGY

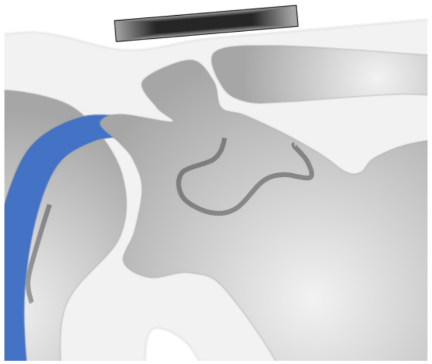


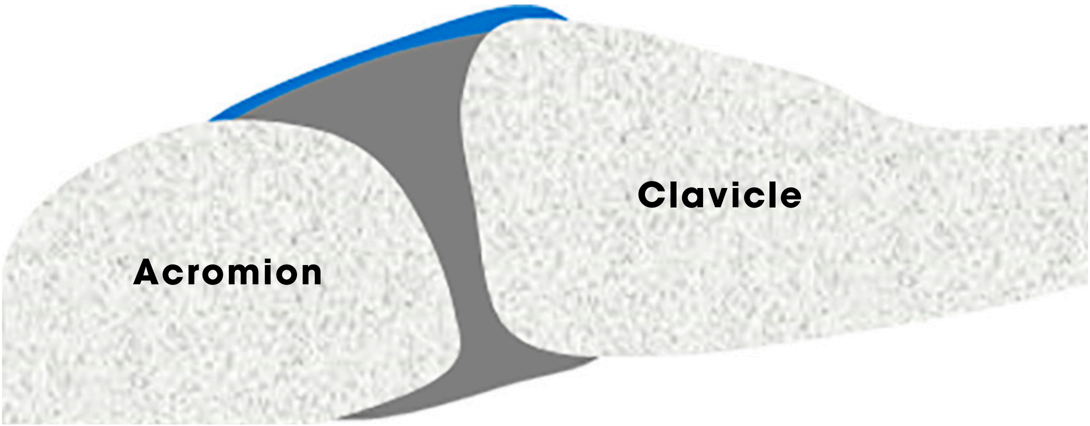
Fluid around the biceps tendon

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

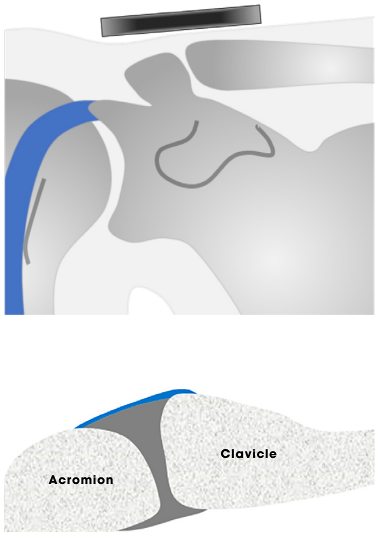
Scanning the shoulder - acromioclavicular joint

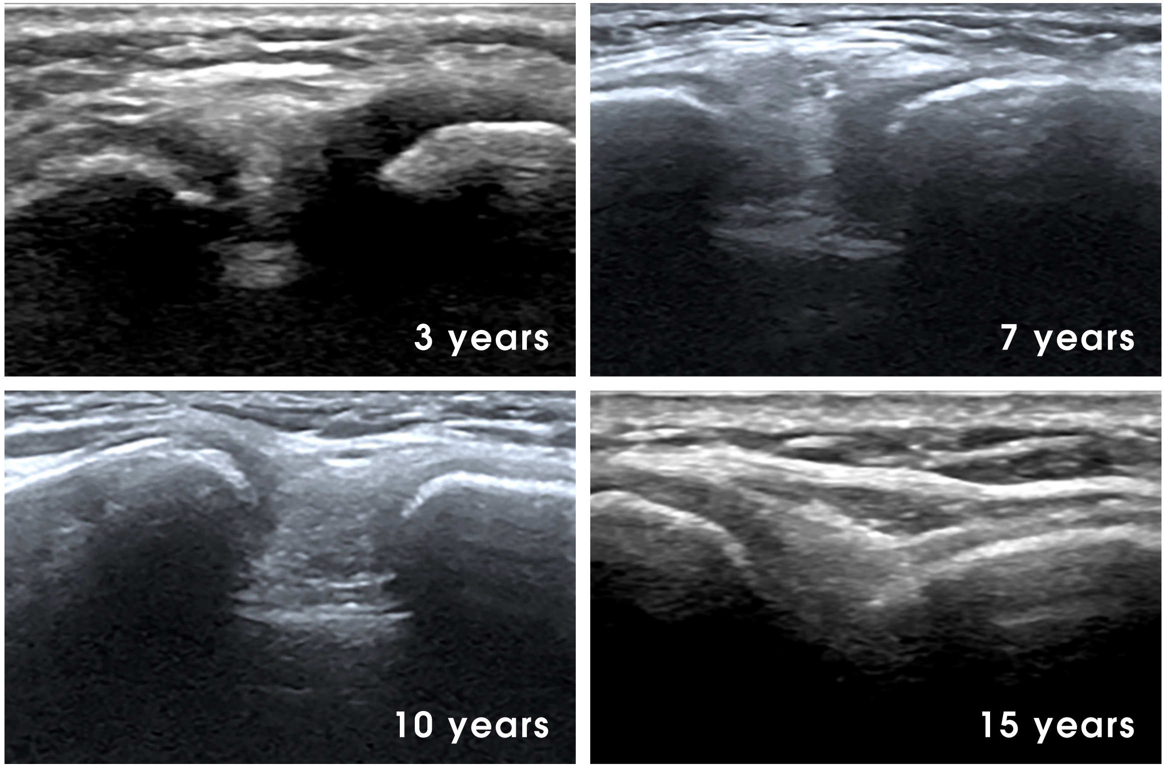




TIP / Palpating the clavicle and acromion helps to position the probe easily

Scanning the shoulder - acromioclavicular joint

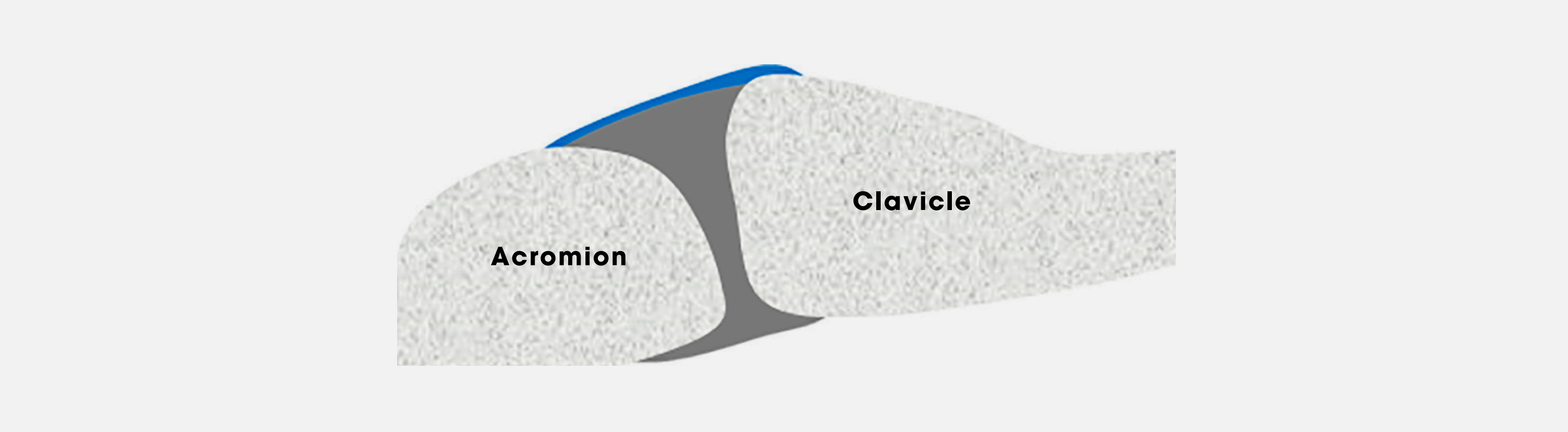


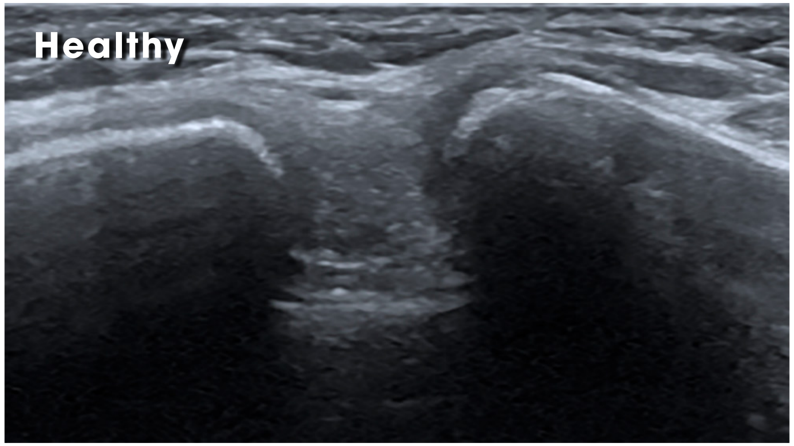


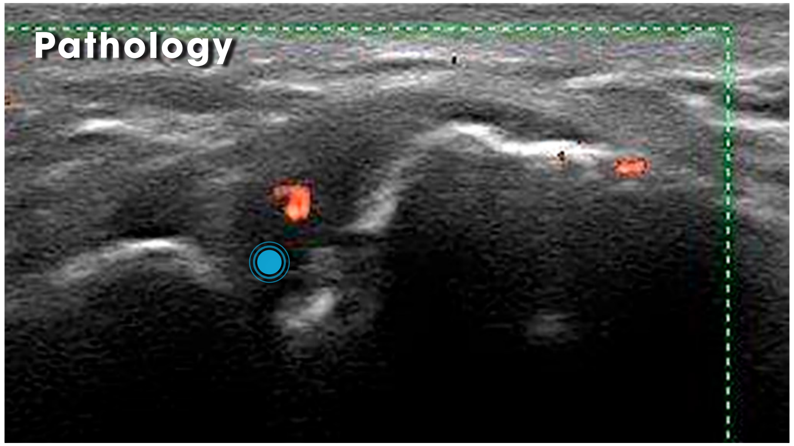
TIP / Palpating the clavicle and acromion helps to position the probe easily

Scanning the shoulder - acromioclavicular joint

HEALTHY PATHOLOGY



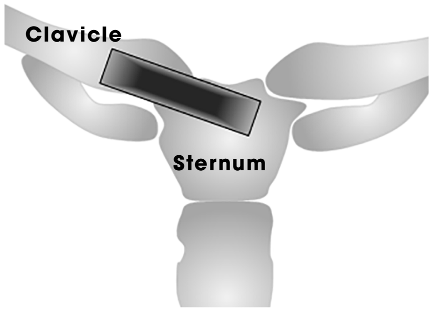


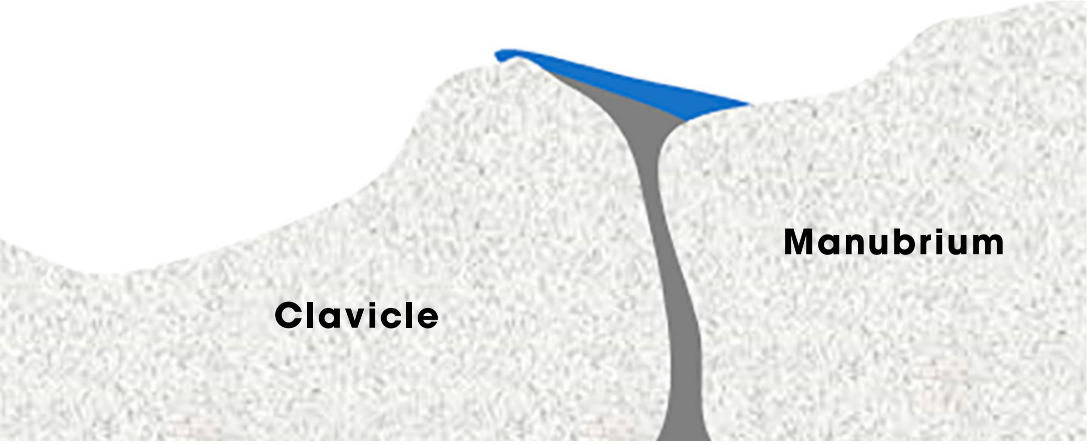


Effusion, Doppler signal and irregular bone

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the shoulder - sternoclavicular joint



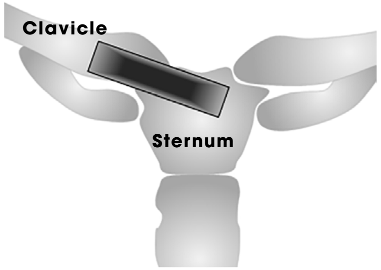


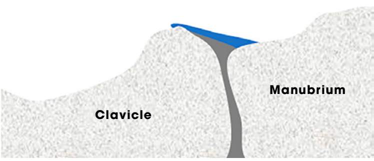
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

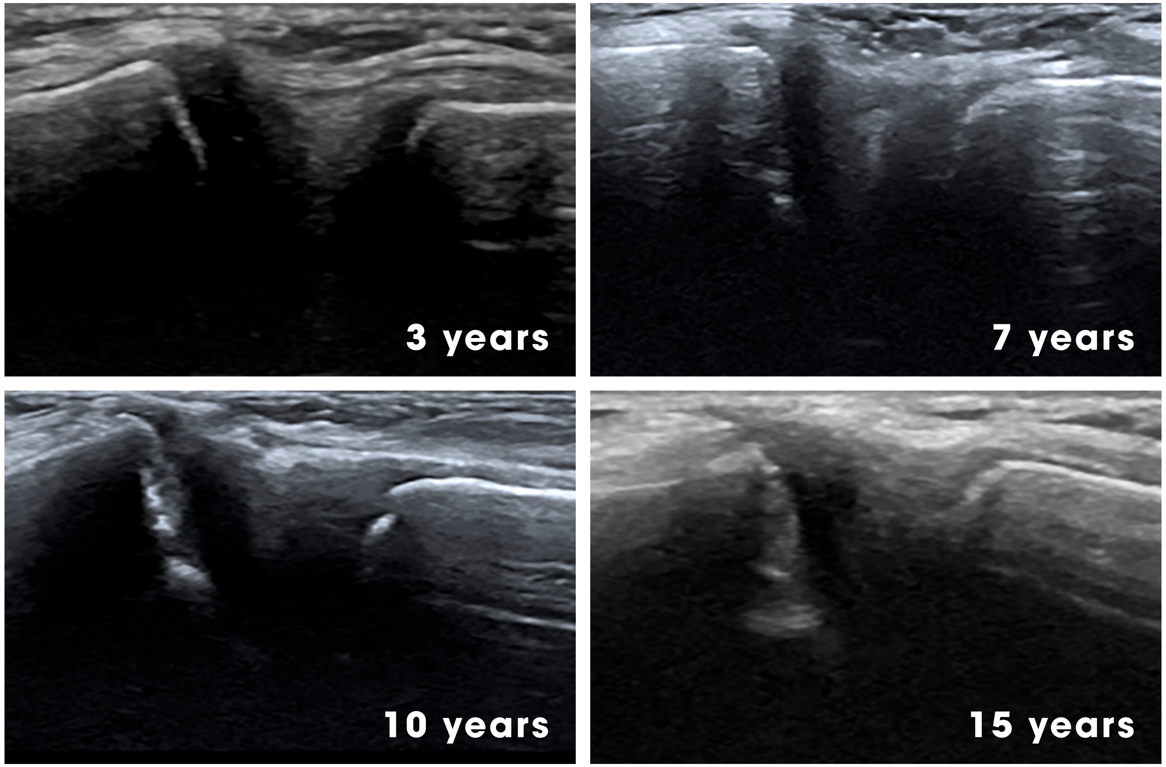
TIP / Use enough gel to keep your probe in contact with the sternoclavicular joint

Scanning the shoulder - sternoclavicular joint

HEALTHY | PATHOLOGY



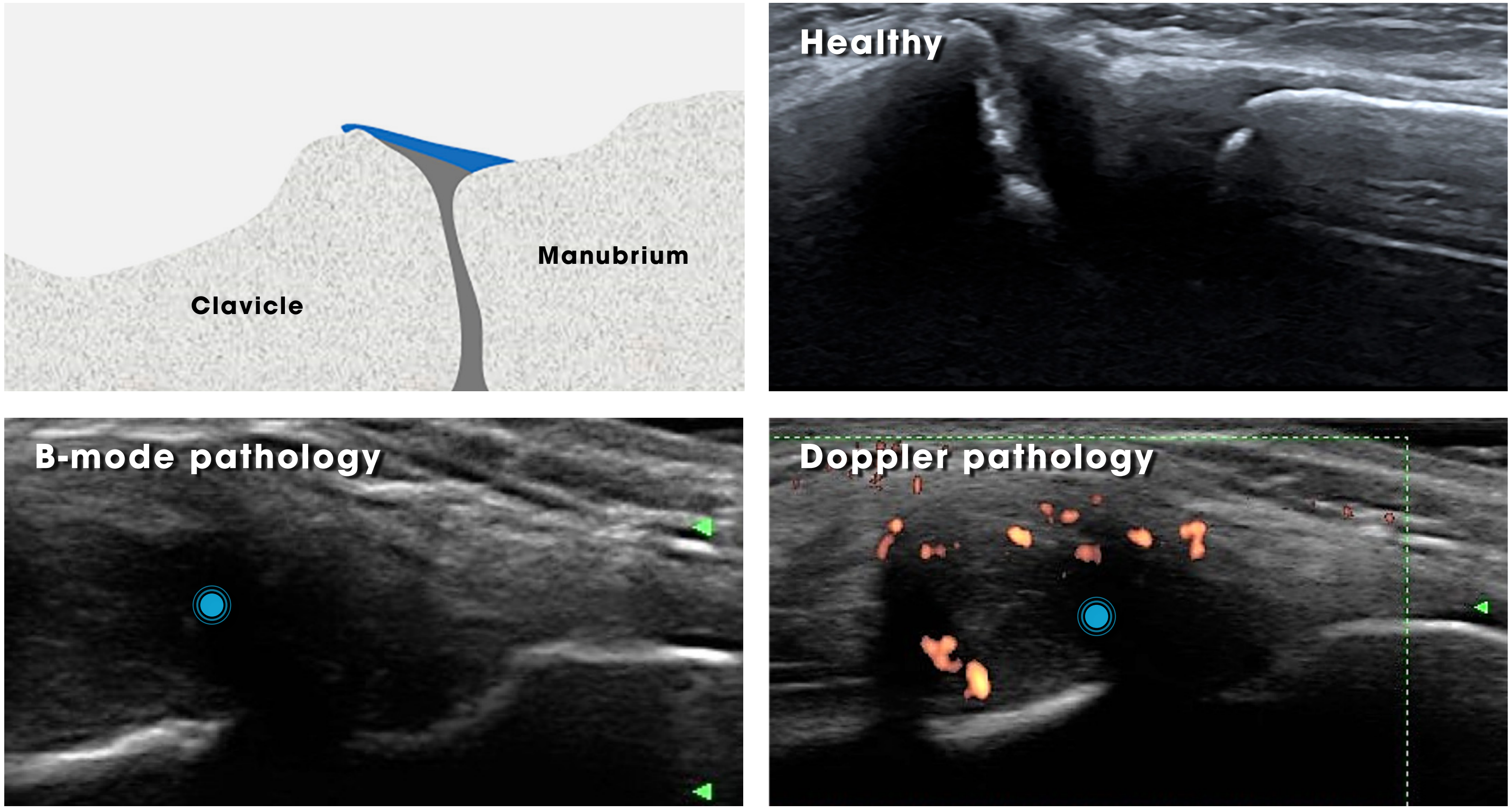




SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Use enough gel to keep your probe in contact with the sternoclavicular joint

Scanning the shoulder - sternoclavicular joint

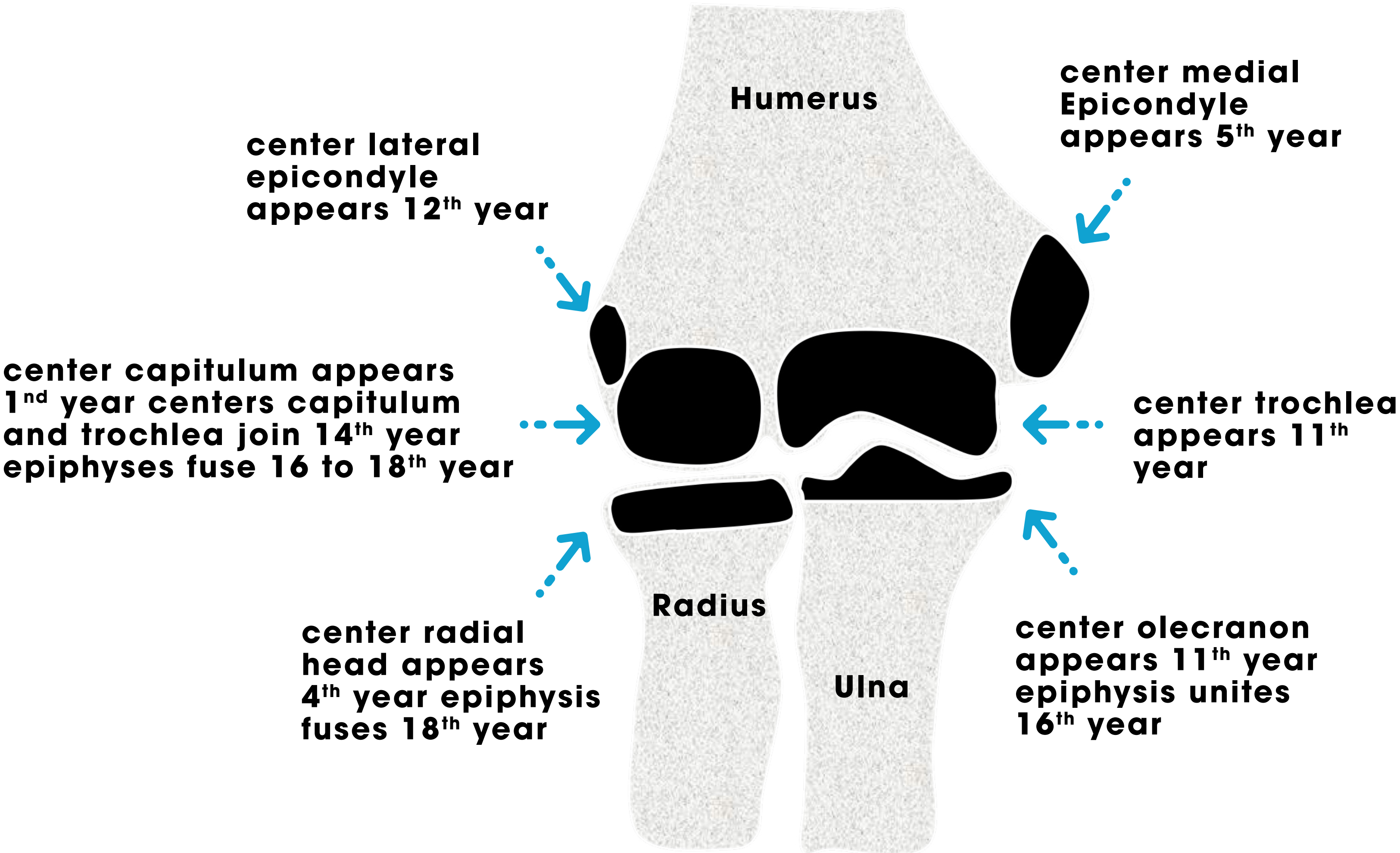


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Effusion and increased Doppler signals suggestive of synovitis

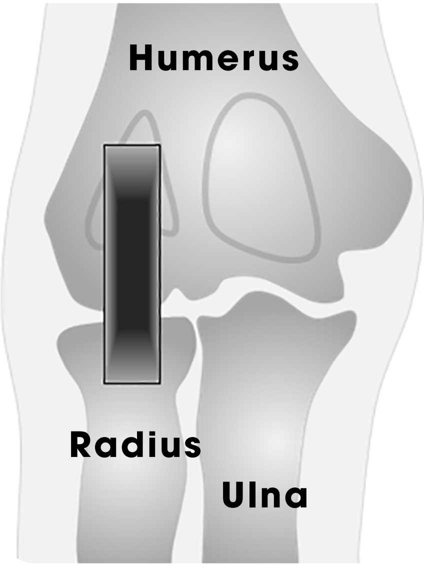
Windschall D, Trauzeddel R. Arthritis und Rheuma 2012;32:35–41

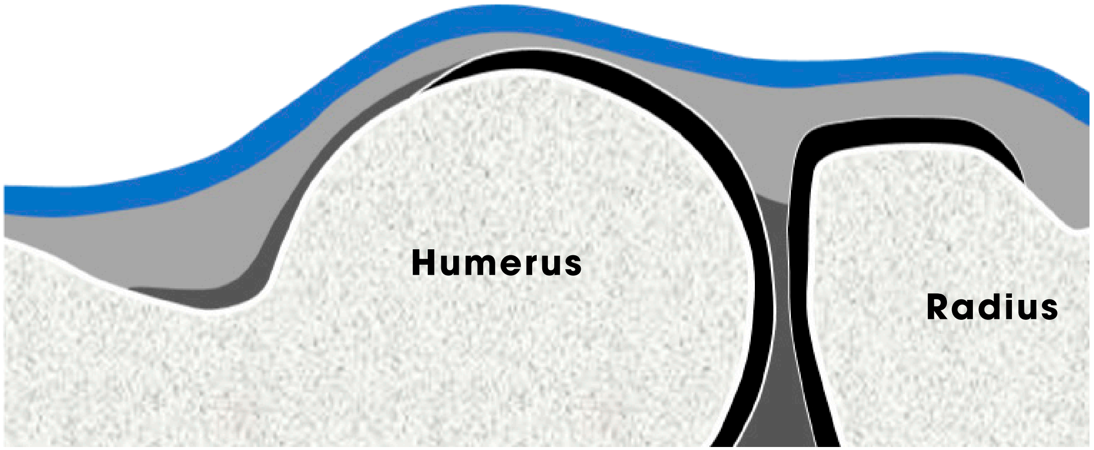
Elbow Ossification



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the elbow - anterior 1

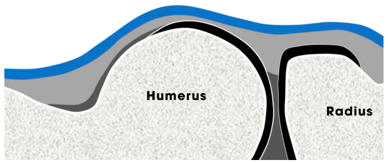




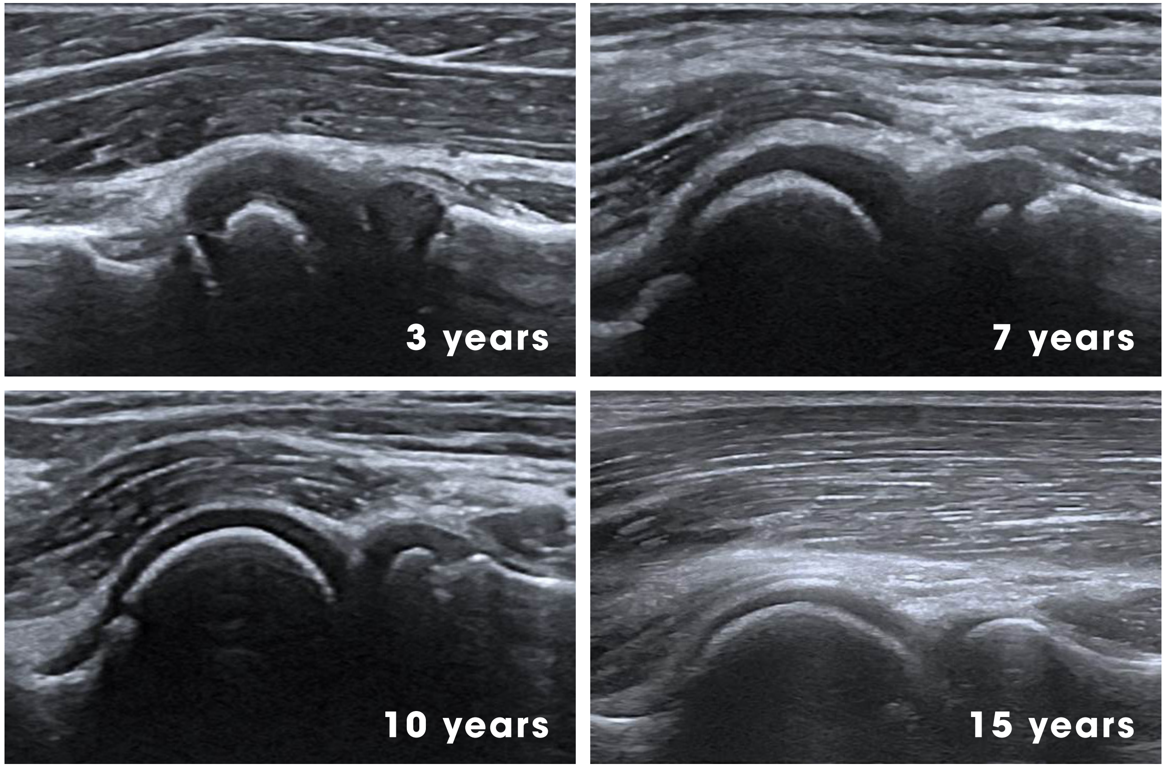
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / The brachioradialis muscle runs straight across the humeroradial joint

Scanning the elbow - anterior 1



HEALTHY PATHOLOGY

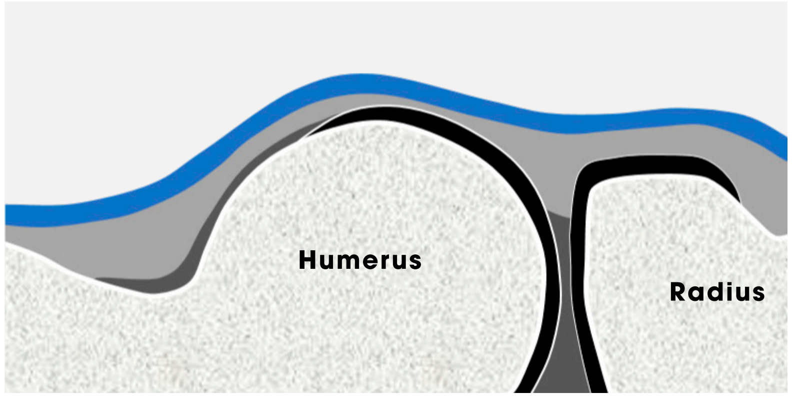


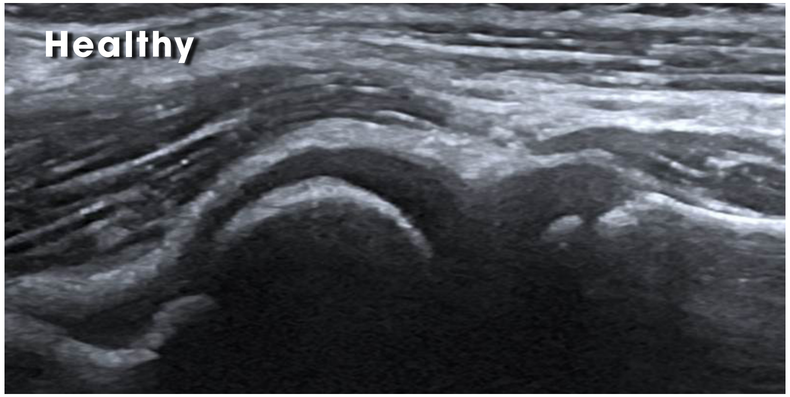
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

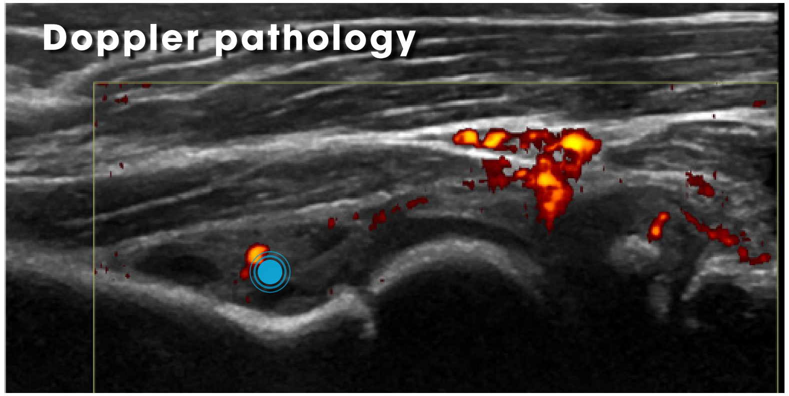
TIP / The brachioradialis muscle runs straight across the humeroradial joint

Scanning the elbow - anterior 1

HEALTHY PATHOLOGY





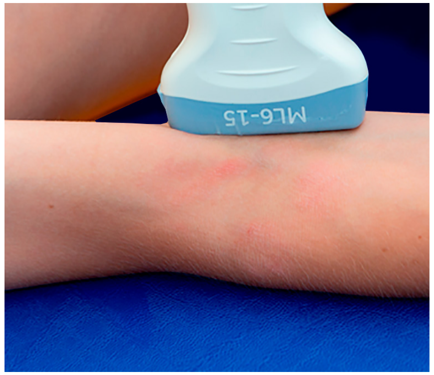


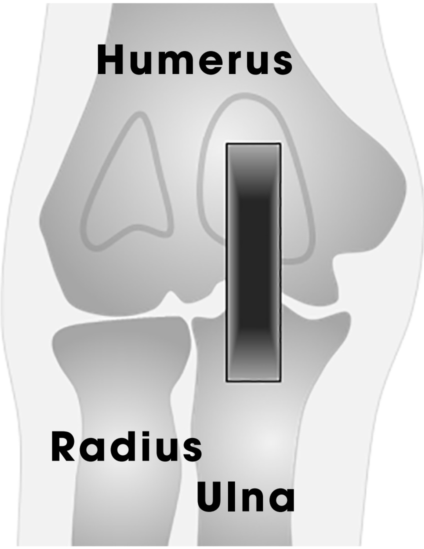
Effusion and synovitis

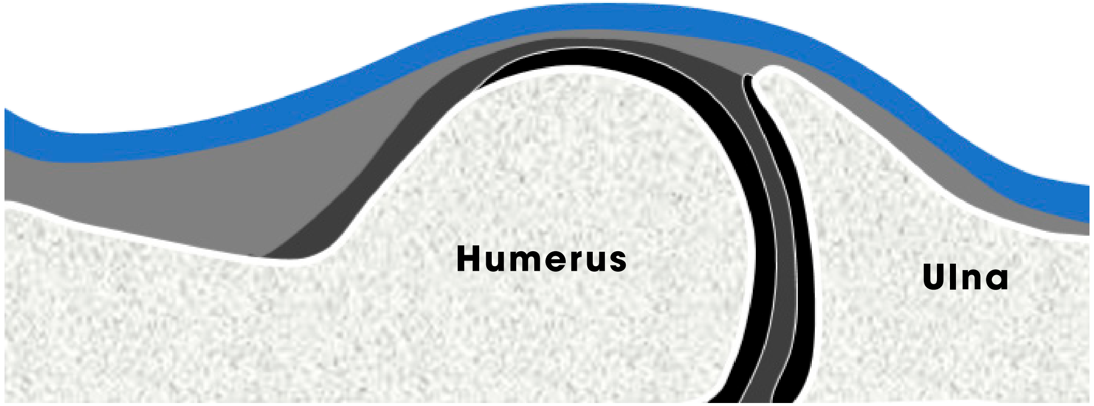
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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



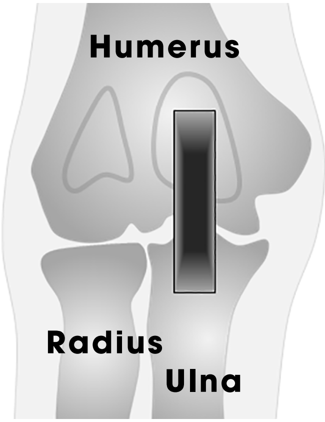


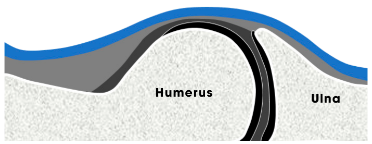


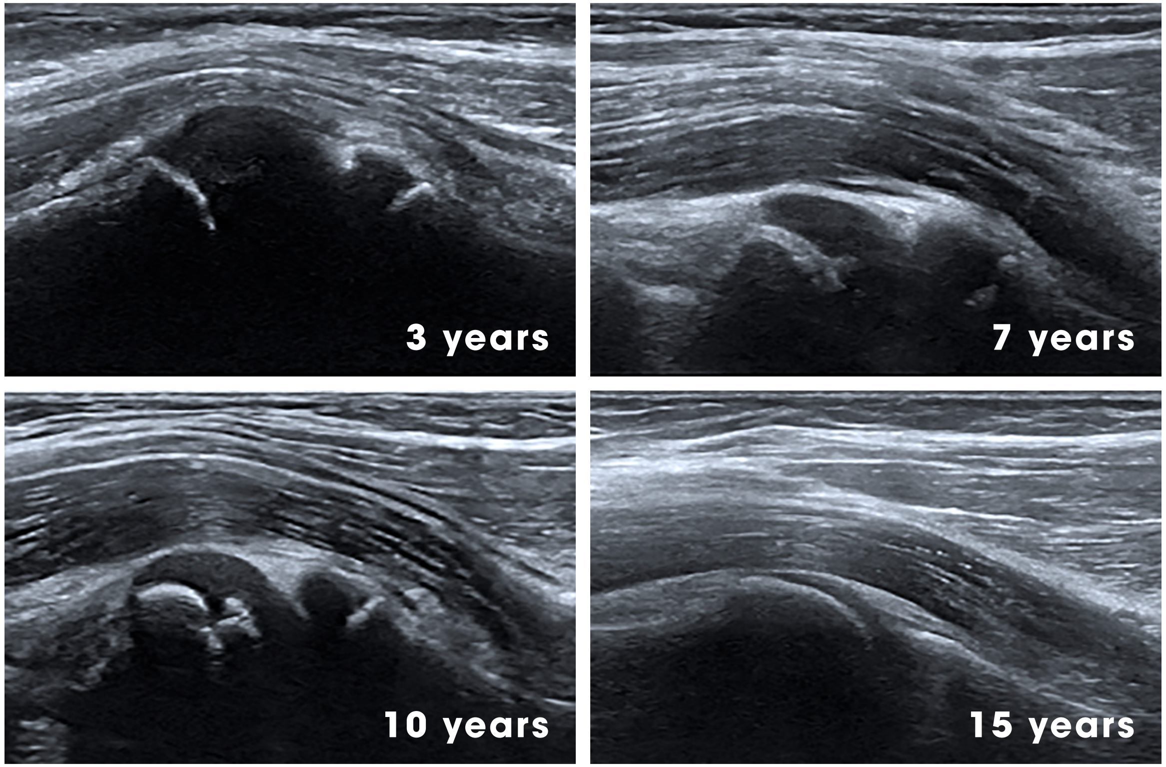
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the elbow - anterior 2

HEALTHY PATHOLOGY



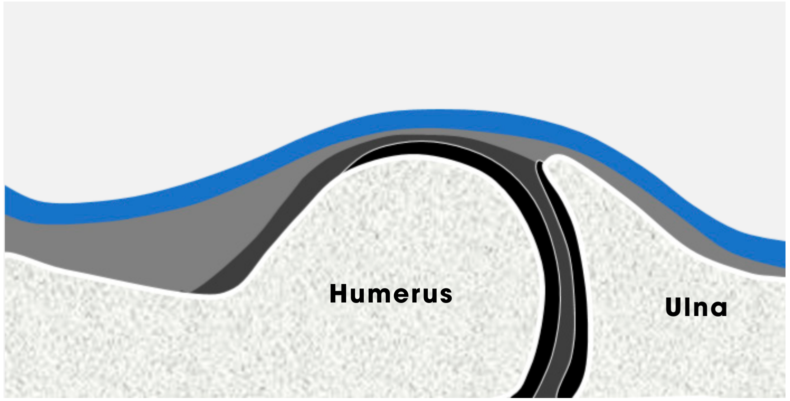


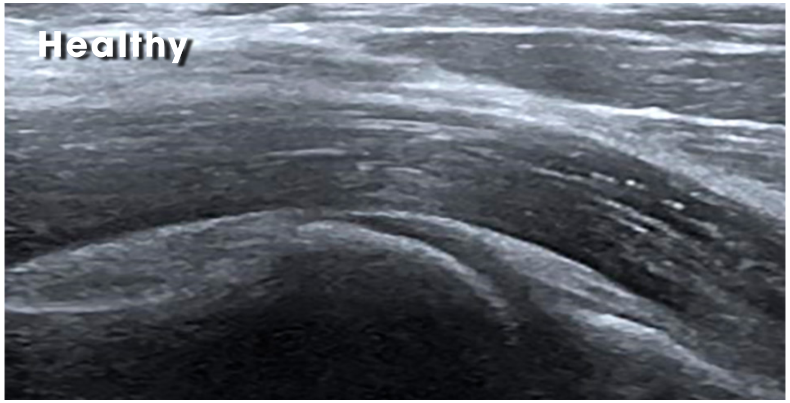


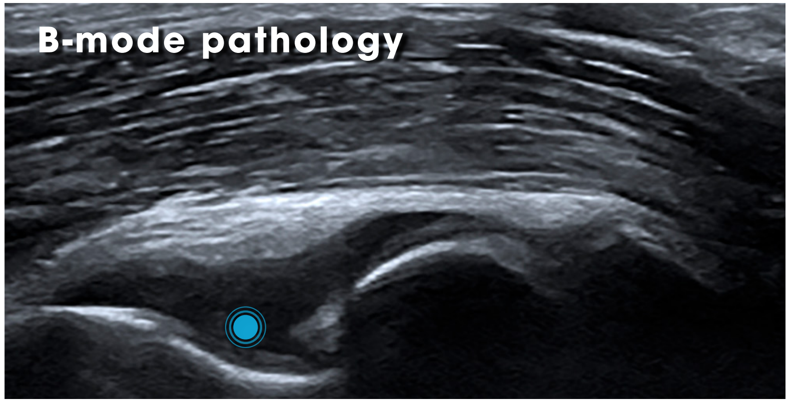
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

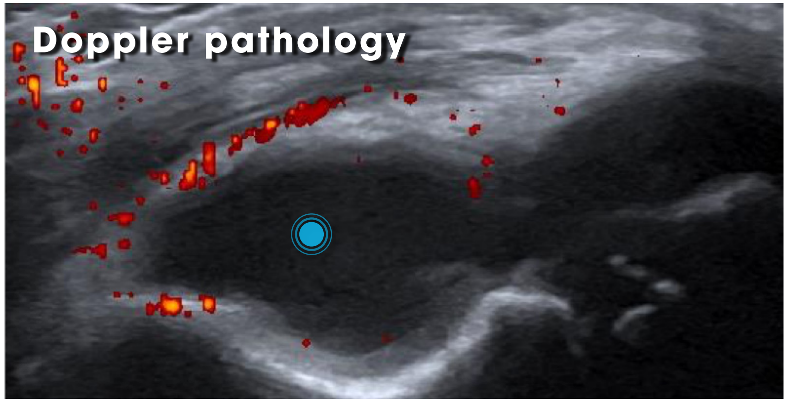
Scanning the elbow - anterior 2

HEALTHY PATHOLOGY







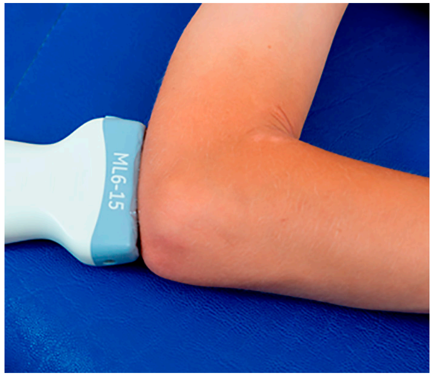


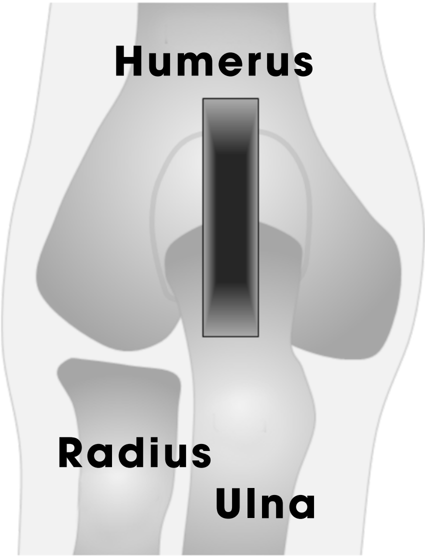
Effusion and synovitis

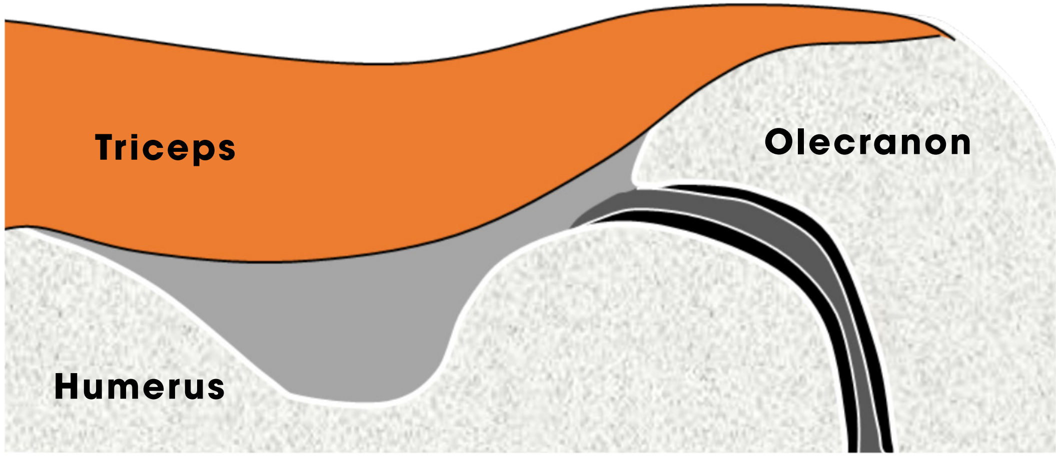
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

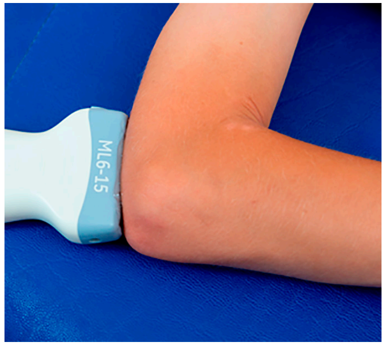


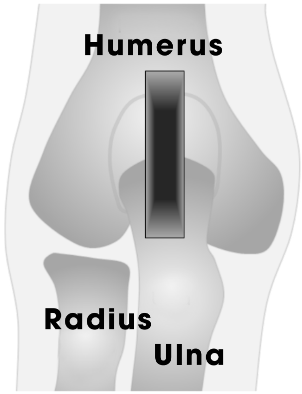


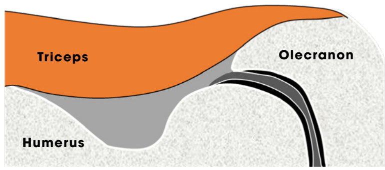


TIP / The dorsal elbow joint has to be examined in 90° flexion

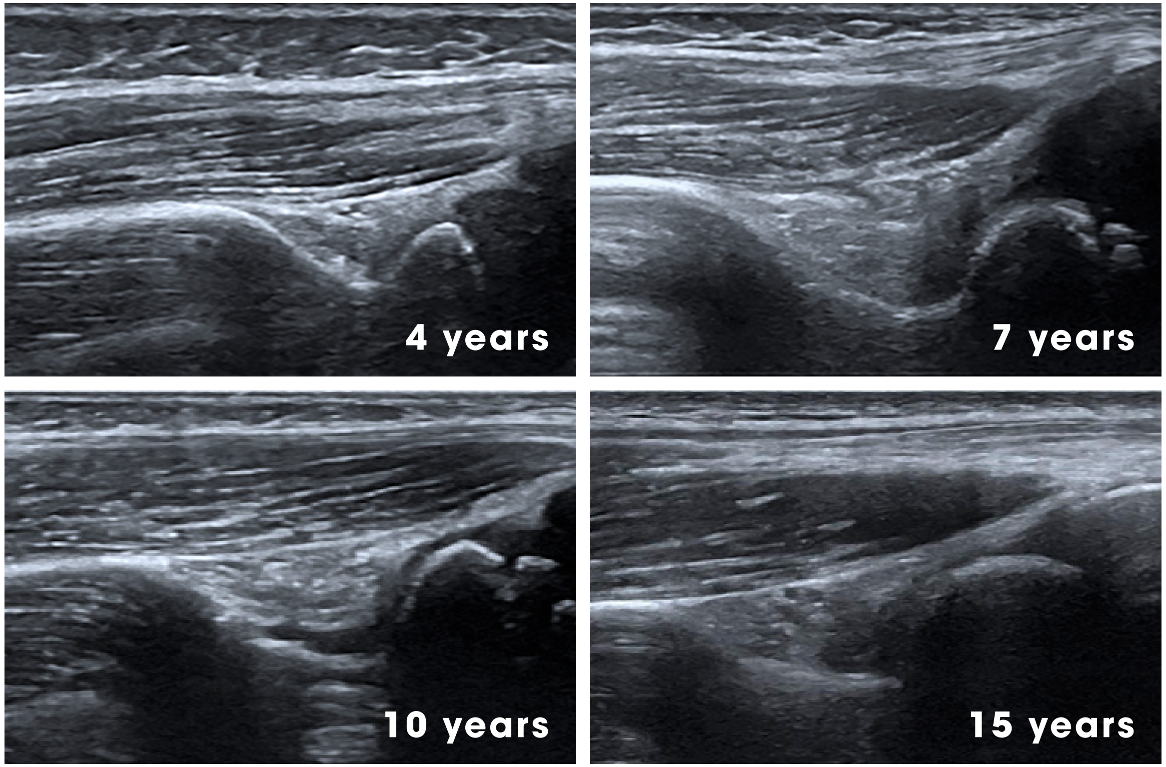
Scanning the elbow - posterior







HEALTHY PATHOLOGY

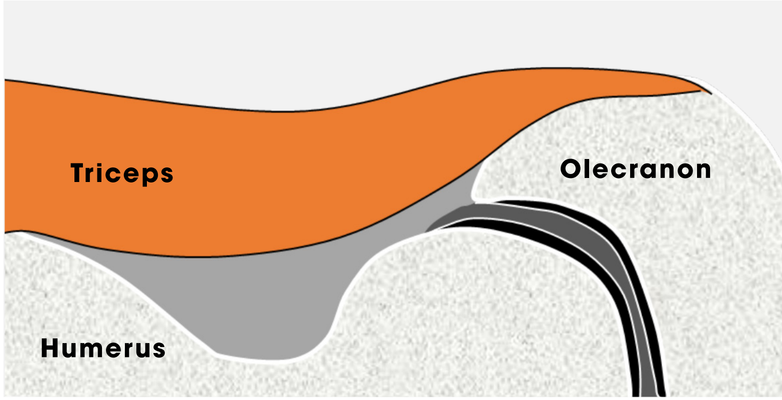


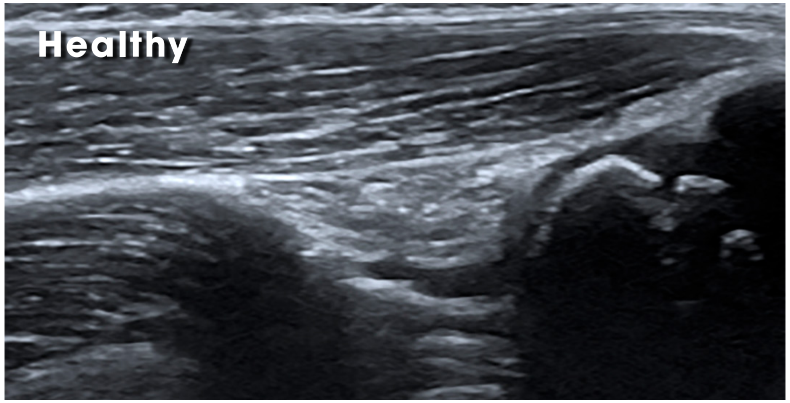
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

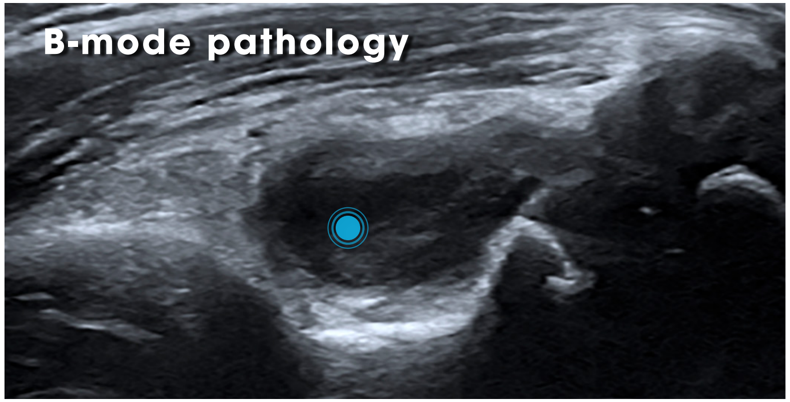
TIP / The dorsal elbow joint has to be examined in 90° flexion

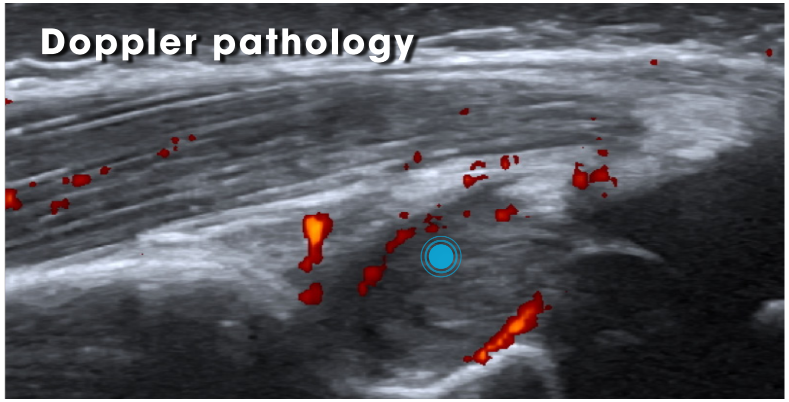
Scanning the elbow - posterior

HEALTHY PATHOLOGY







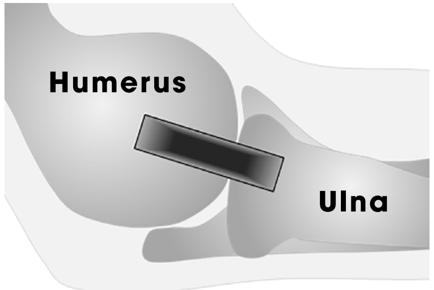


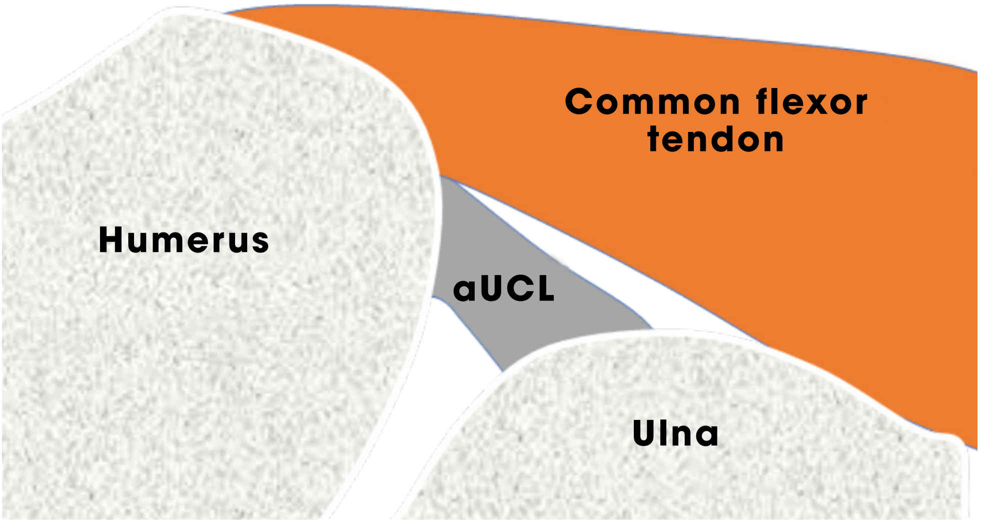
Effusion and fluid, synovial proliferation and increased Doppler suggestive of synovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

Scanning the elbow - medial enthesis





aUCL, anterior bundle of the ulnar collateral ligament

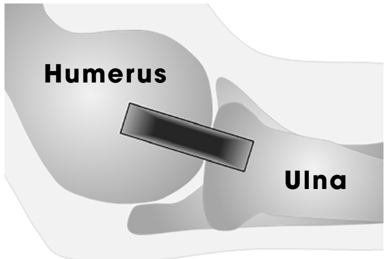
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

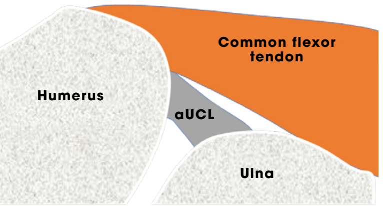
TIP / In order to scan the the common flexor tendon it may be helpful to bring the forarm in supination with mild flexion at the elbow

Scanning the elbow - medial enthesis

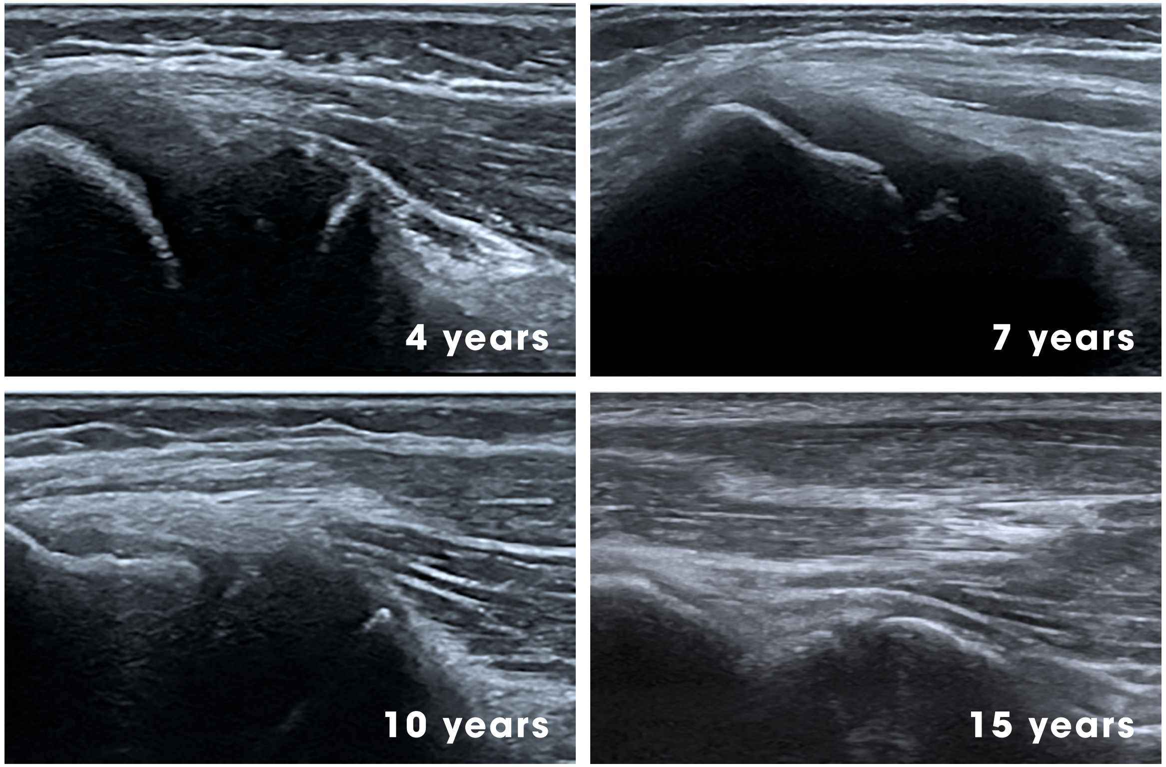
HEALTHY PATHOLOGY

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT





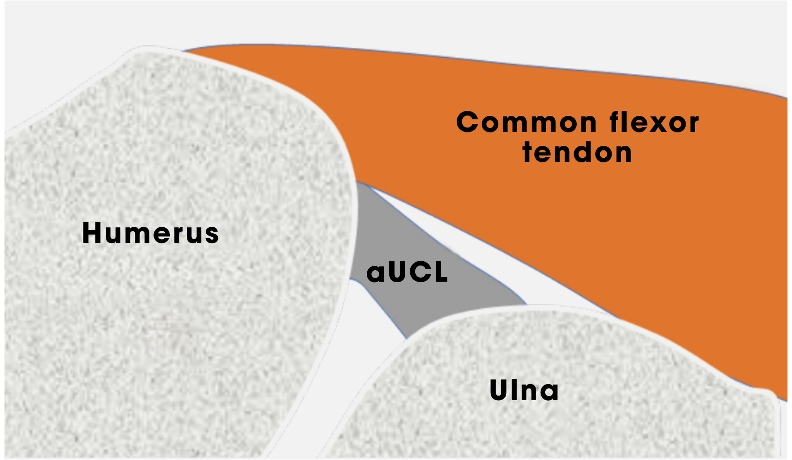
aUCL, anterior bundle of the ulnar collateral ligament

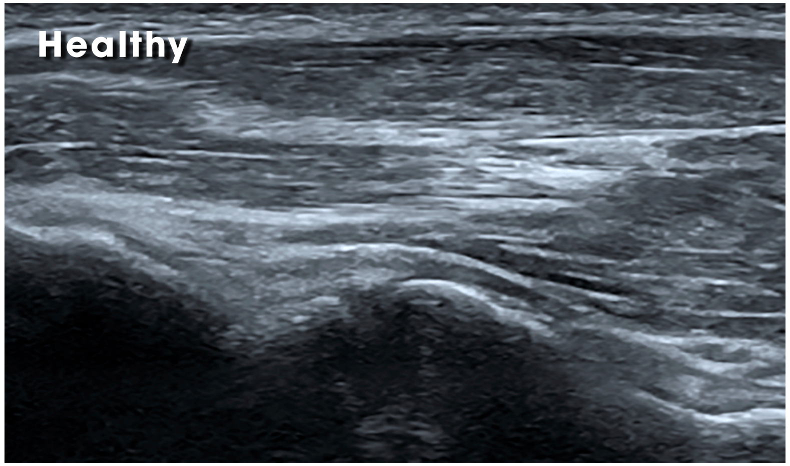


TIP / In order to scan the the common flexor tendon it may be helpful to bring the forarm in supination with mild flexion at the elbow

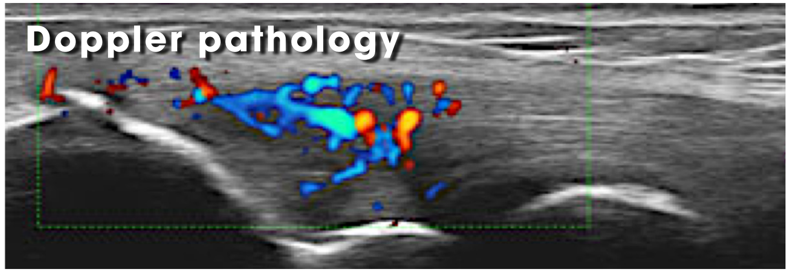
Scanning the elbow - medial enthesis

HEALTHY PATHOLOGY



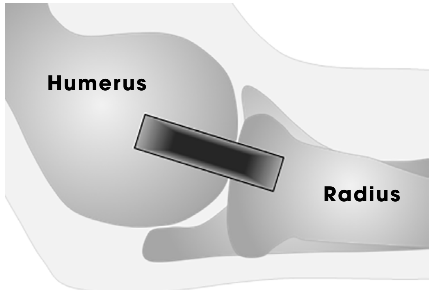


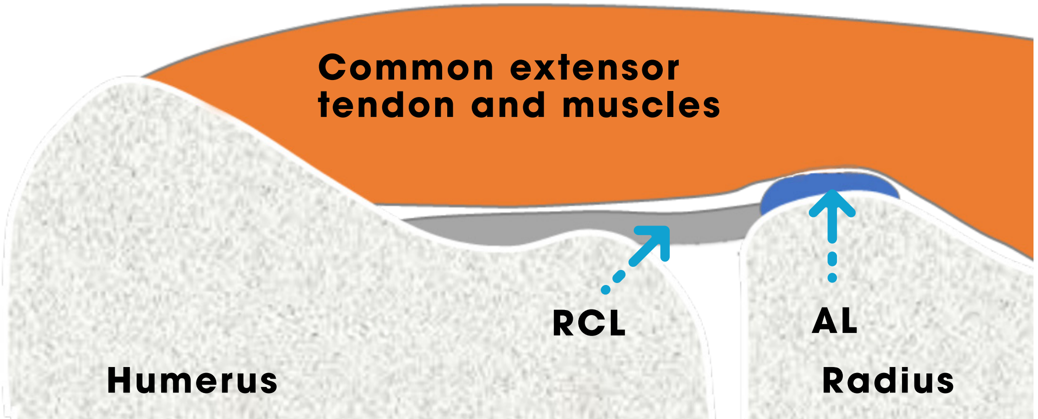
aUCL, anterior bundle of the ulnar collateral ligament



Inhomogeneous echotexture of the tendon and enthesis with Doppler suggestive of enthesopathy

Scanning the elbow - lateral enthesis

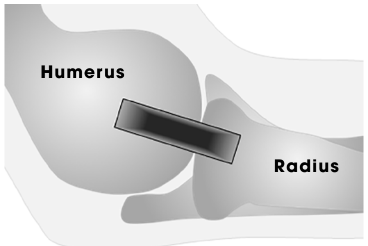


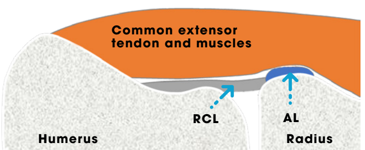


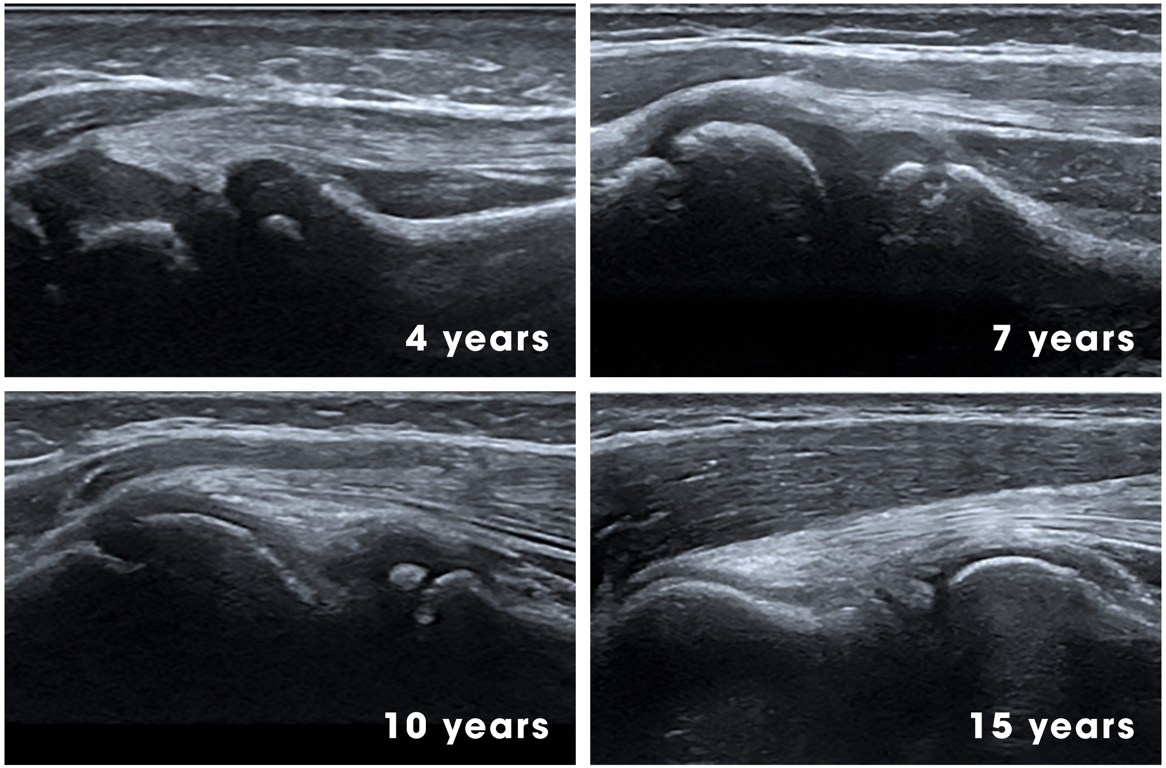
AL, Annular Ligament
RCL, Radial Collateral Ligament

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

Scanning the elbow - lateral enthesis



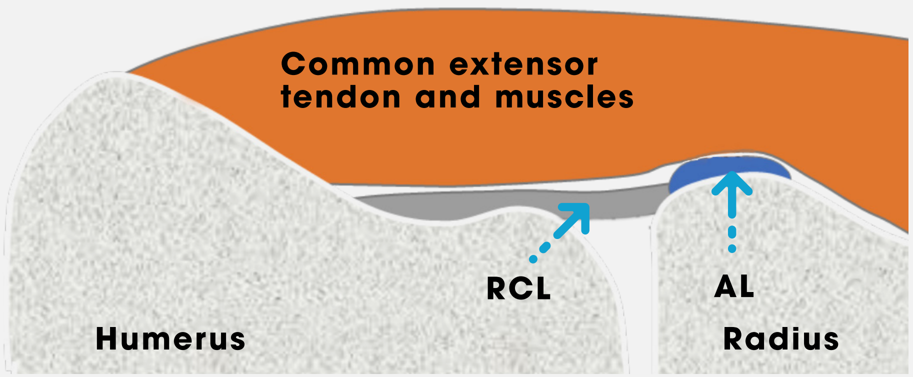


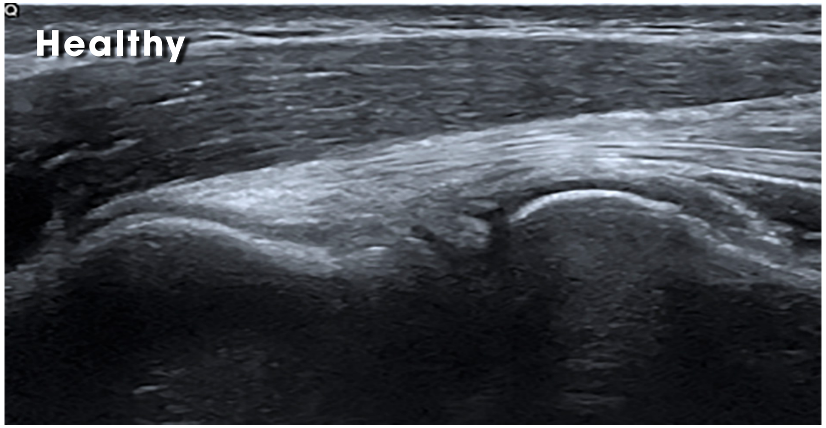


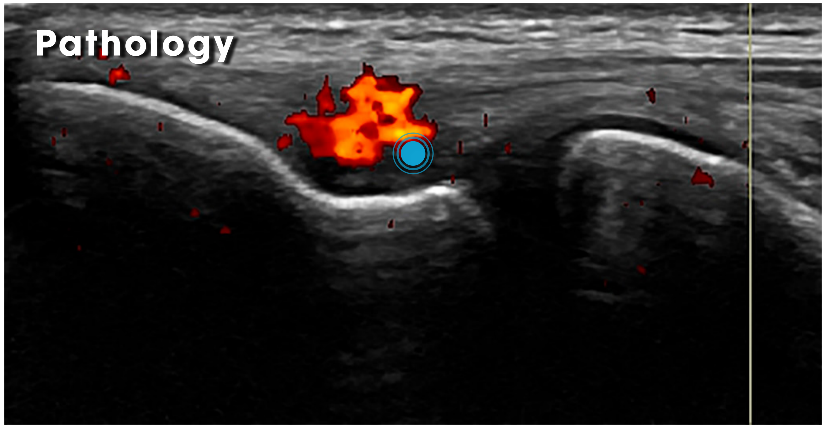
TIP / The lateral enthesis can be scanned in supination or pronation of the forearm

Scanning the elbow - lateral enthesis

HEALTHY PATHOLOGY



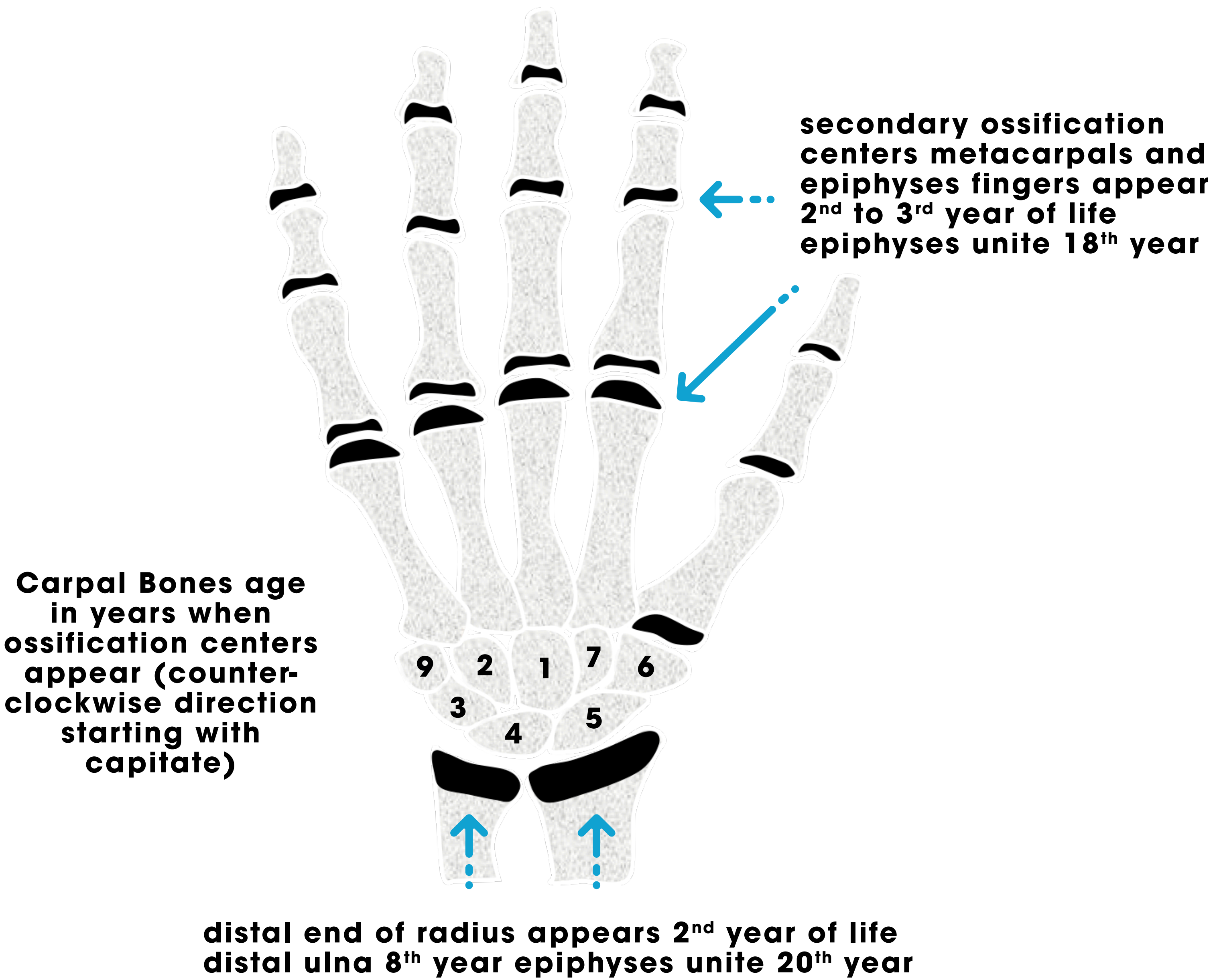




Enthesitis with hypervascularization

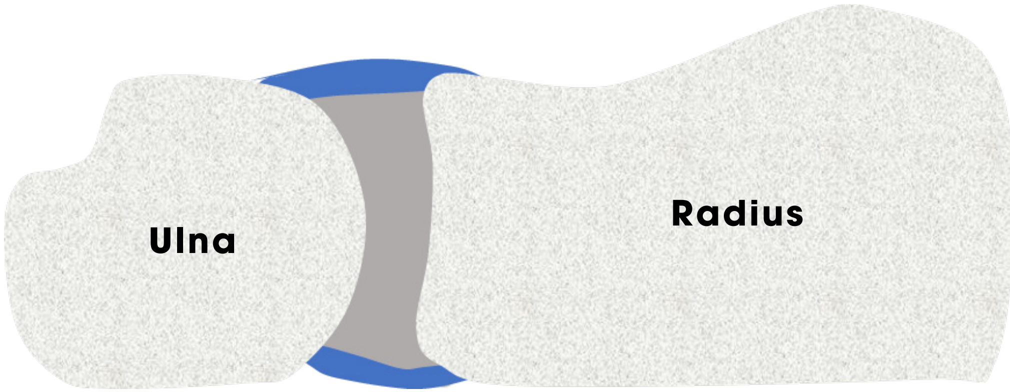
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

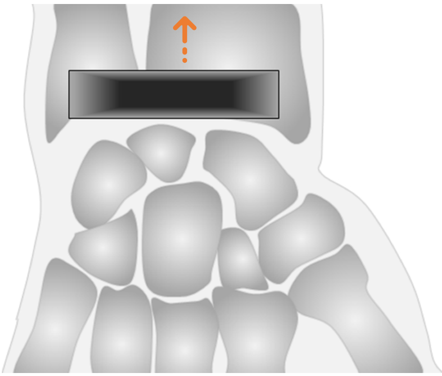
Wrist and hand ossification



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - radio ulnar joint

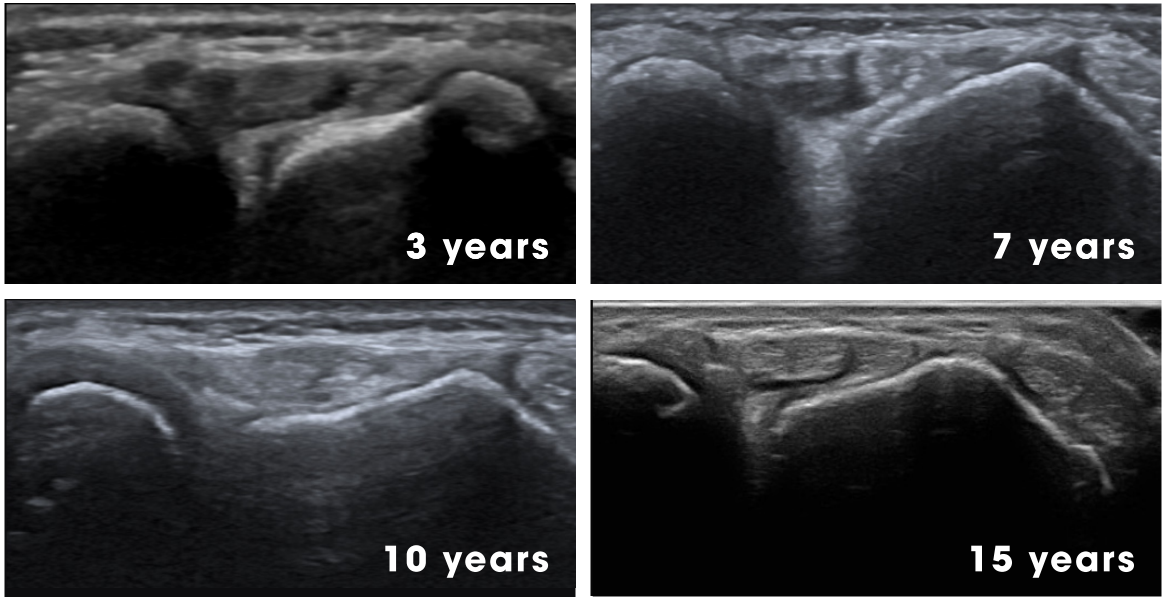


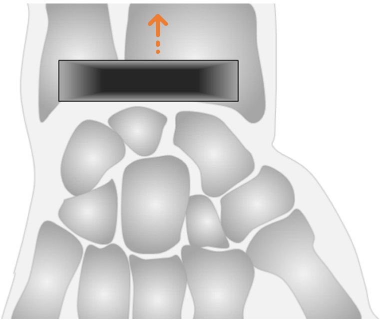


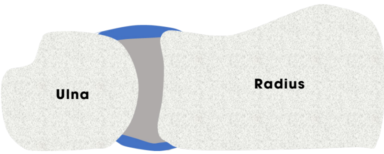
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - radio ulnar joint

HEALTHY PATHOLOGY



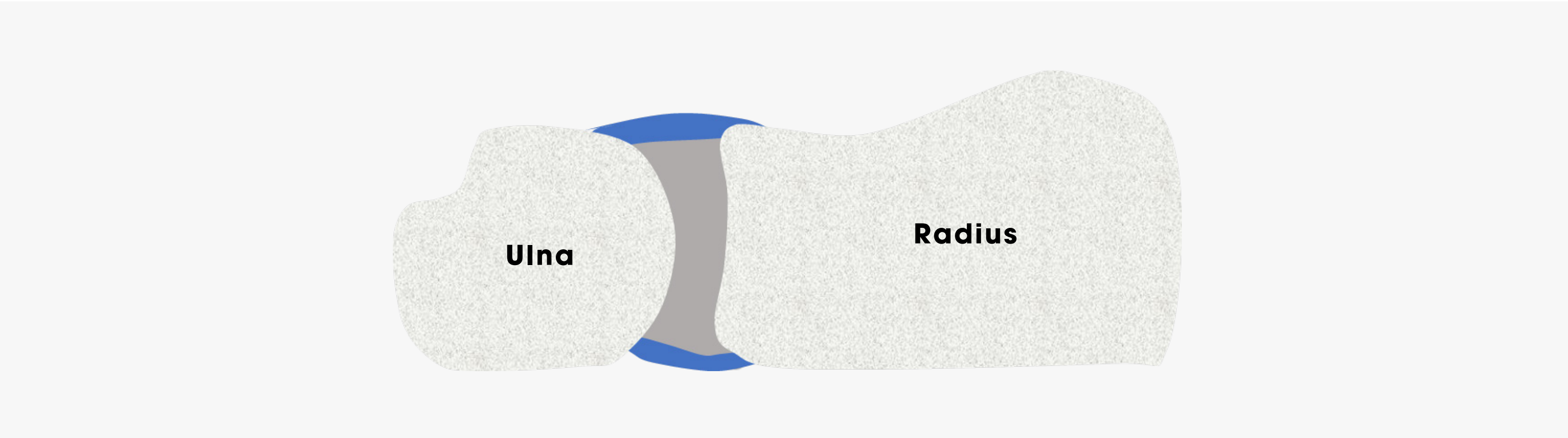


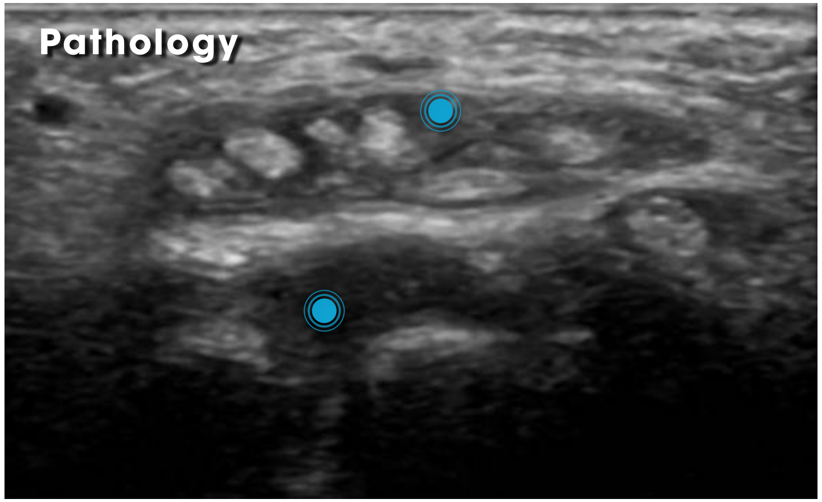


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - radio ulnar joint

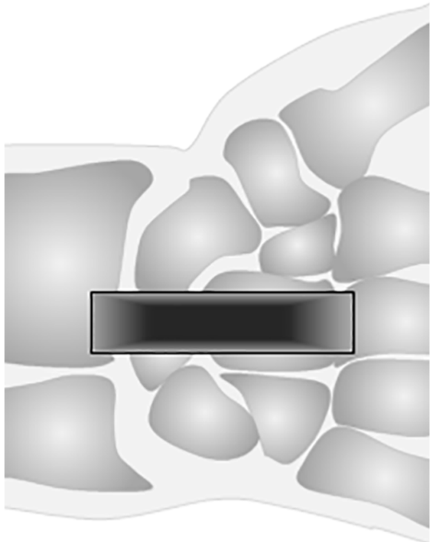
HEALTHY PATHOLOGY

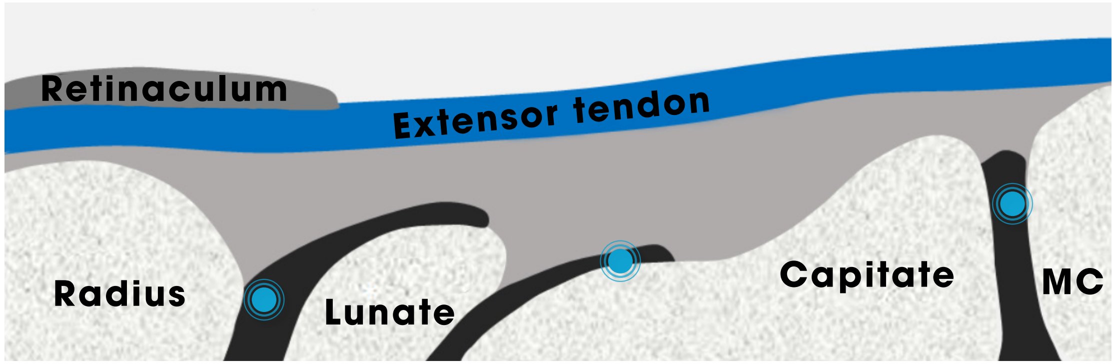




Extensor tenosynovitis and radioulnar synovitis

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in midline





Physiologic synovial recesses

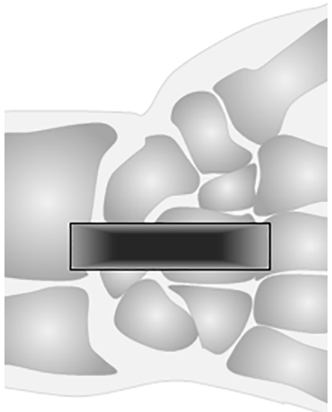
MC, metacarpal

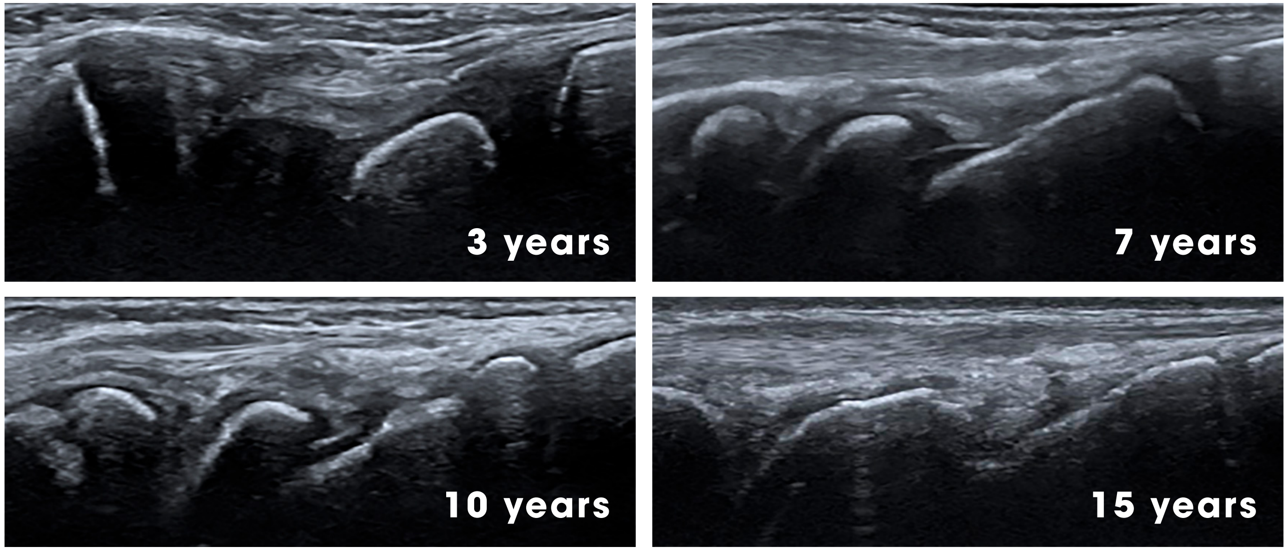
TIPS /

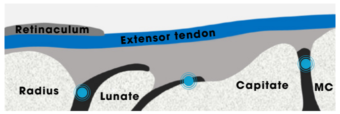
- Os lunatum and os capitatum are very useful as anatomic landmarks
- Assess during mild flexion and extension

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in midline

HEALTHY | PATHOLOGY







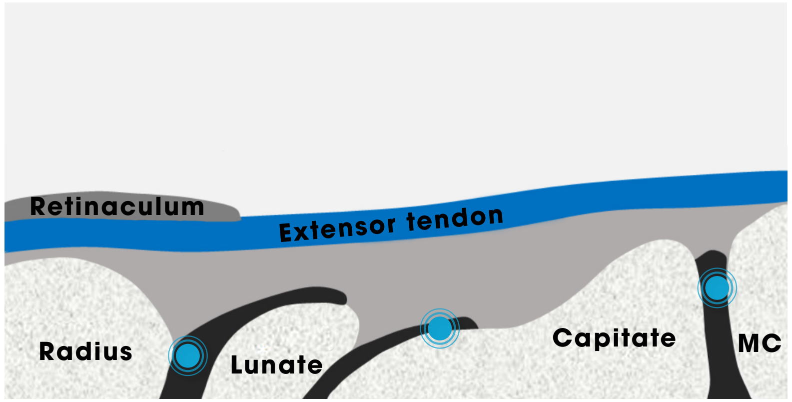
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

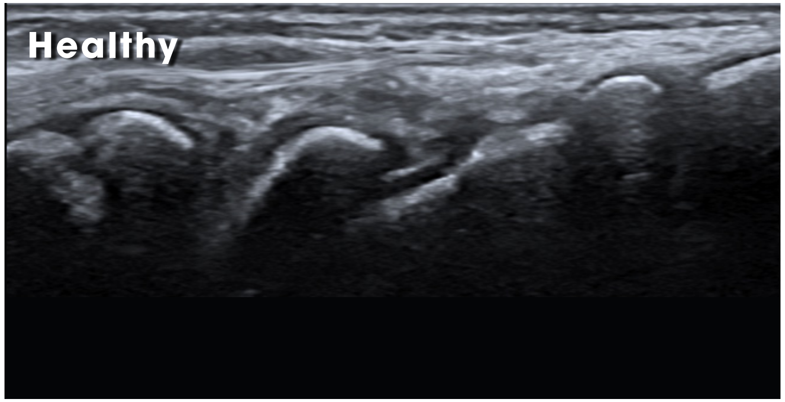
TIPS /

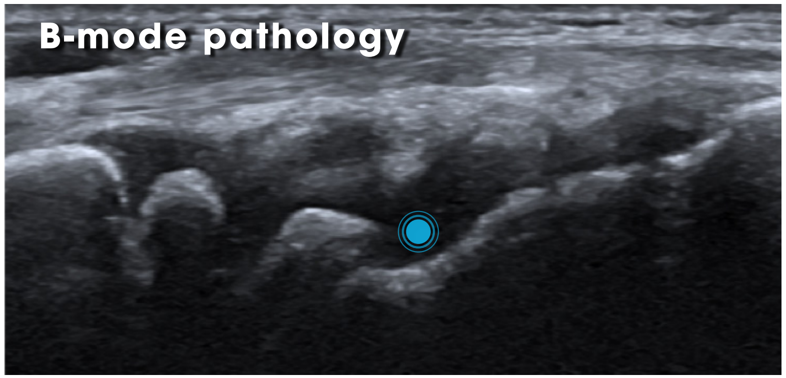
- Os lunatum and os capitatum are very useful as anatomic landmarks
- Assess during mild flexion and extension

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in midline

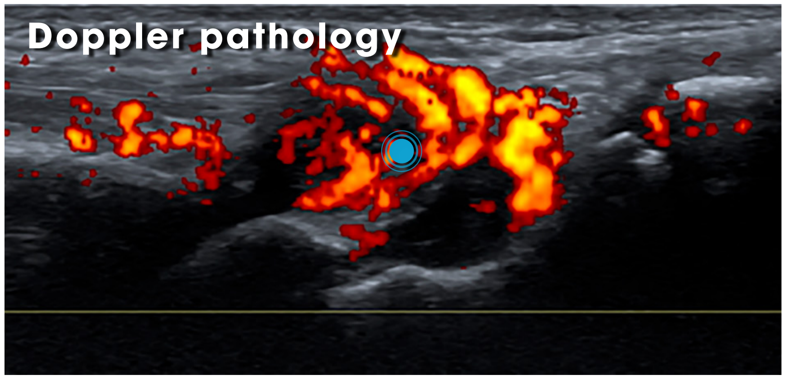
HEALTHY | PATHOLOGY







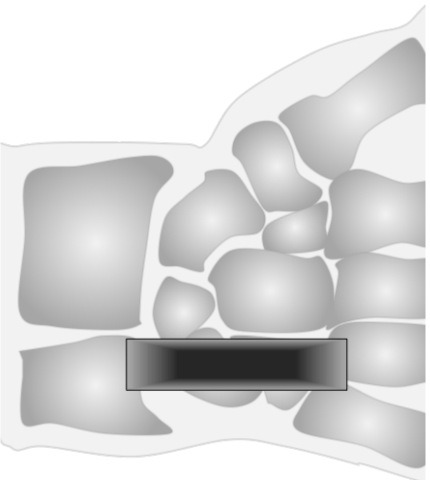
Effusion and synovitis in the radiocarpal, midcarpal and carpometacarpal joint

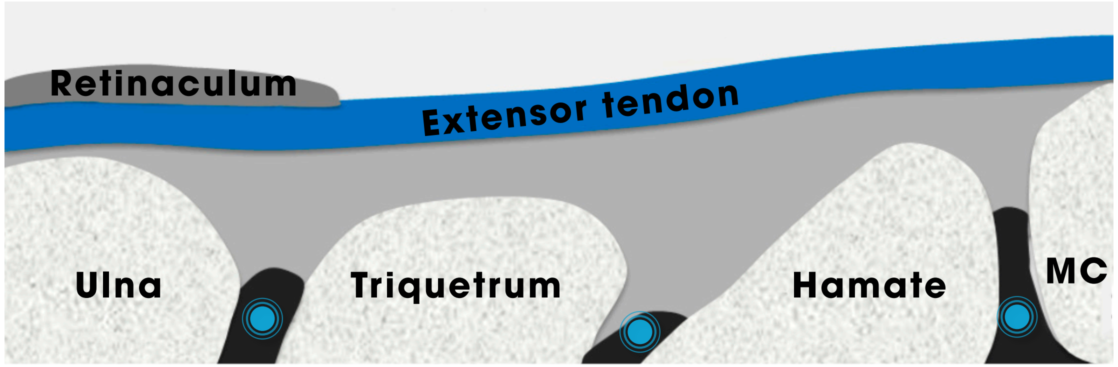


Effusion and synovitis in the radiocarpal, midcarpal and carpometacarpal joint with hypervascularization

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in ulnar





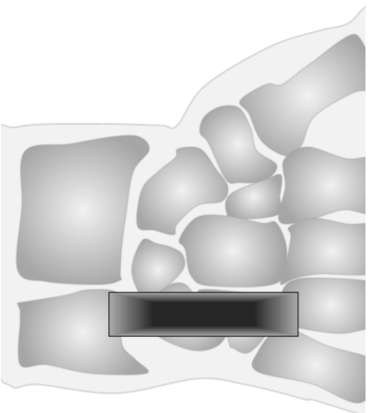
Physiologic synovial recesses

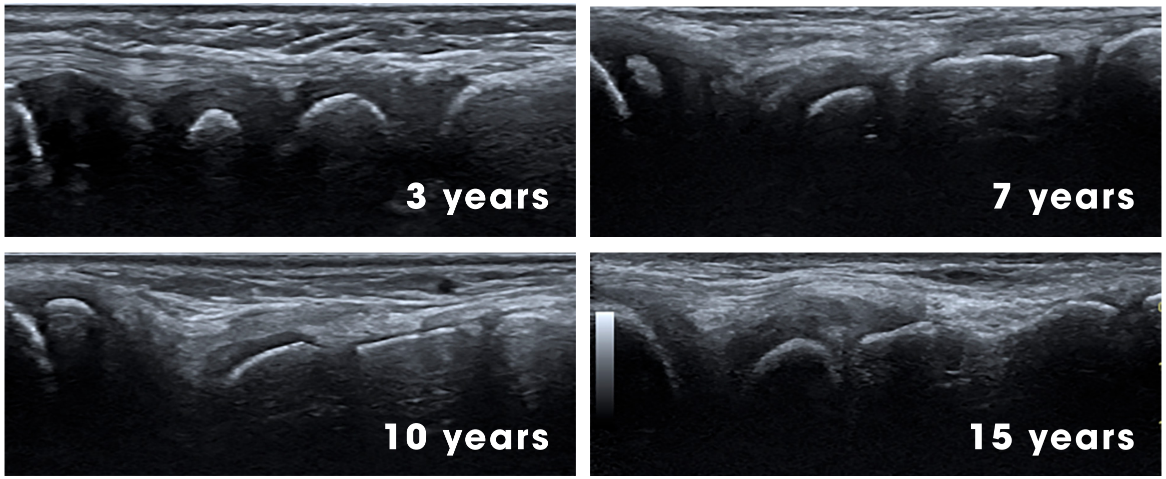
MC, metacarpal

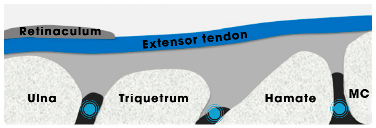
TIP / Slide from midline to the ulnar side and use os triquetrum and os hamatum as anatomic landmarks

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in ulnar

HEALTHY PATHOLOGY



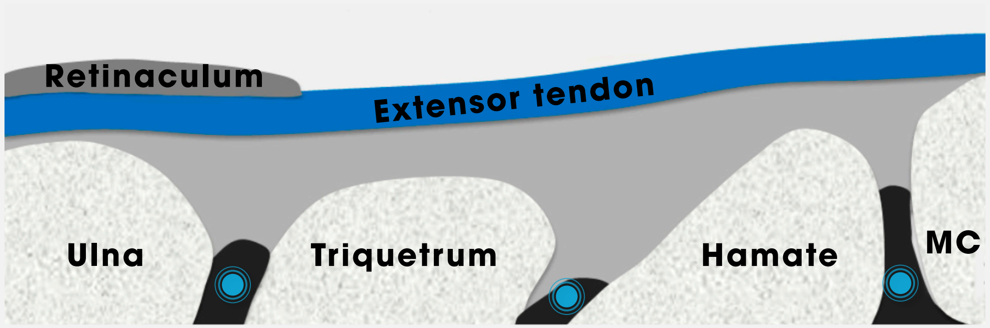


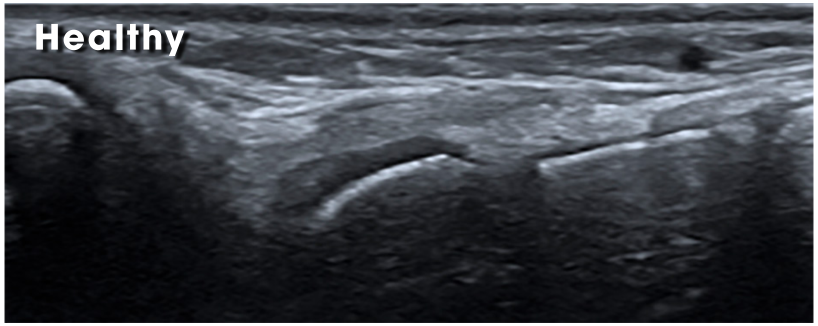


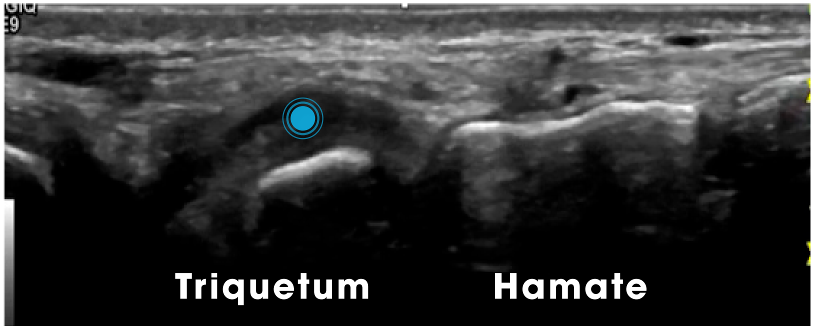
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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



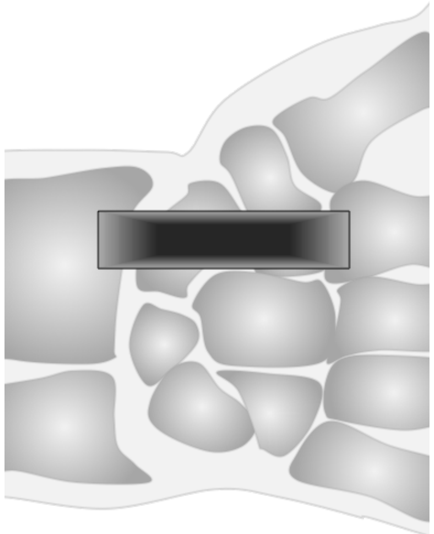


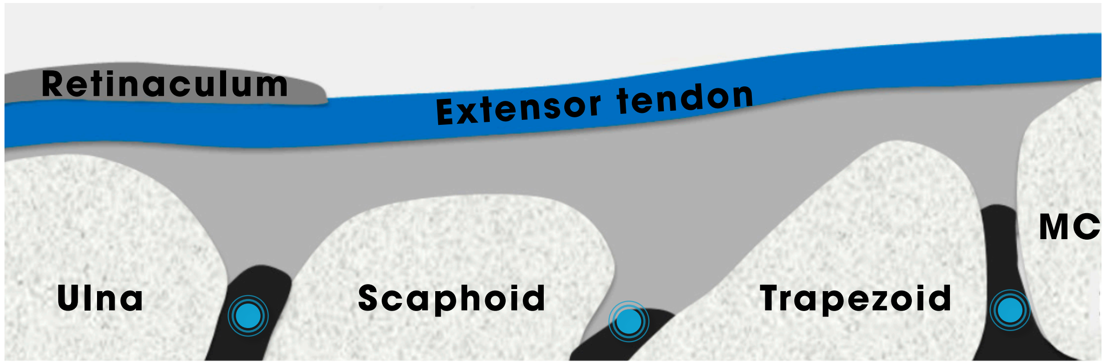


Synovitis around Triquetrum

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in radial





Physiologic synovial recesses

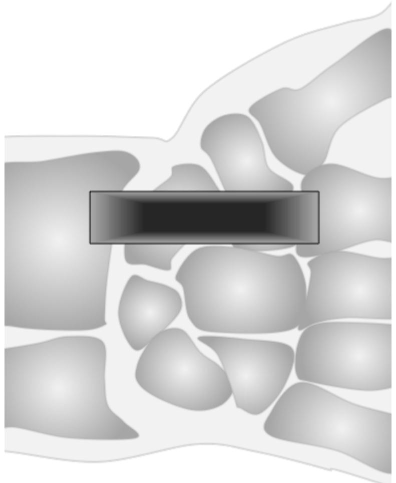
MC, metacarpal

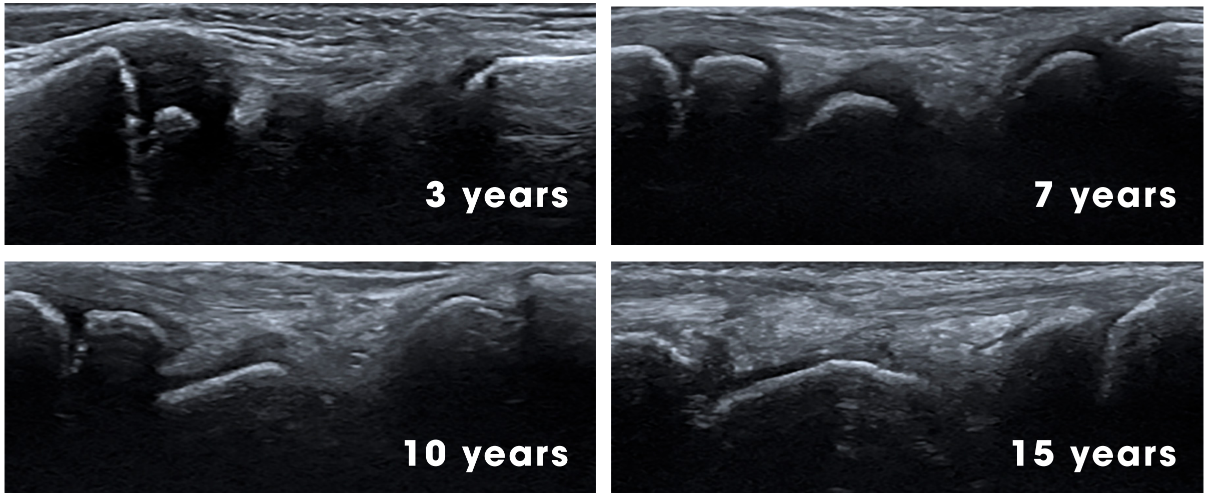
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

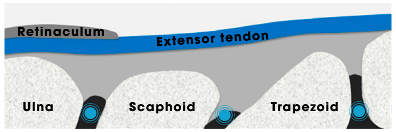
TIP / Slide from midline to the radial side and use os scaphoideum and os trapezoideum as anatomic landmarks

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in radial

HEALTHY | PATHOLOGY





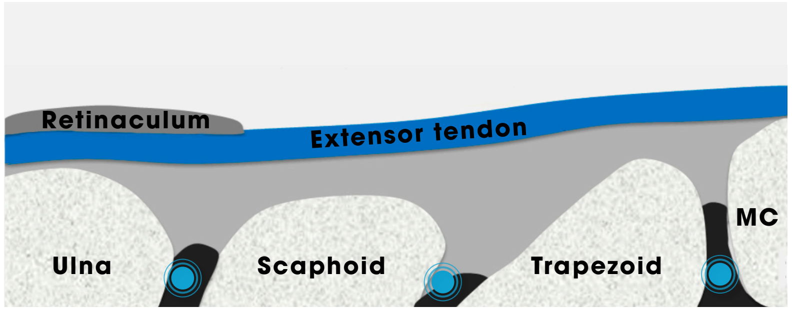


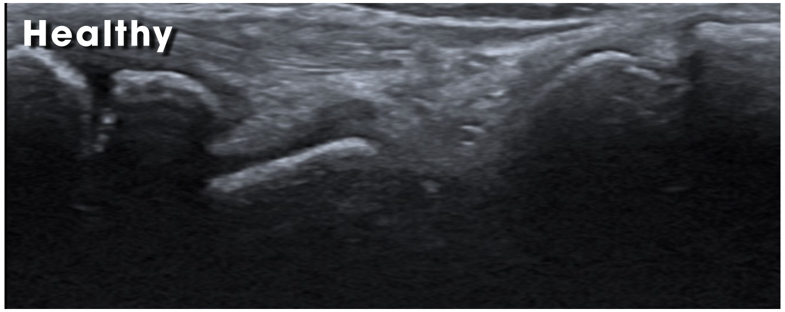
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

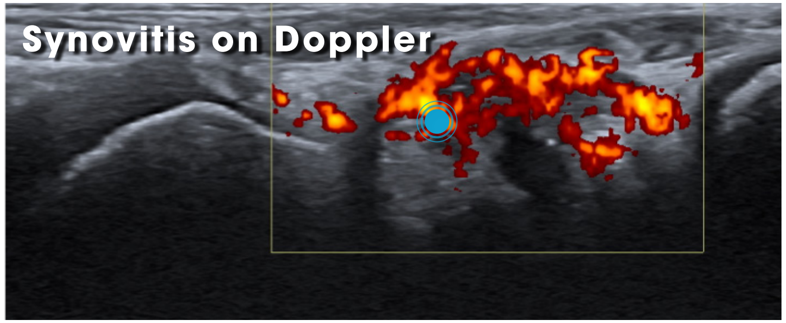
TIP / Slide from midline to the radial side and use os scaphoideum and os trapezoideum as anatomic landmarks

Scanning the wrist - radiocarpal/midcarpal/carpometacarpal in radial

HEALTHY | PATHOLOGY







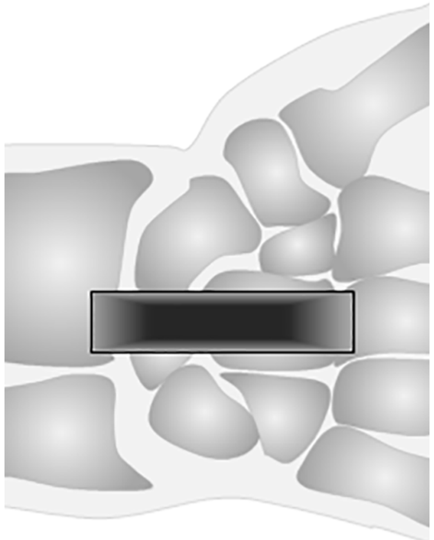
Ganglion cyst

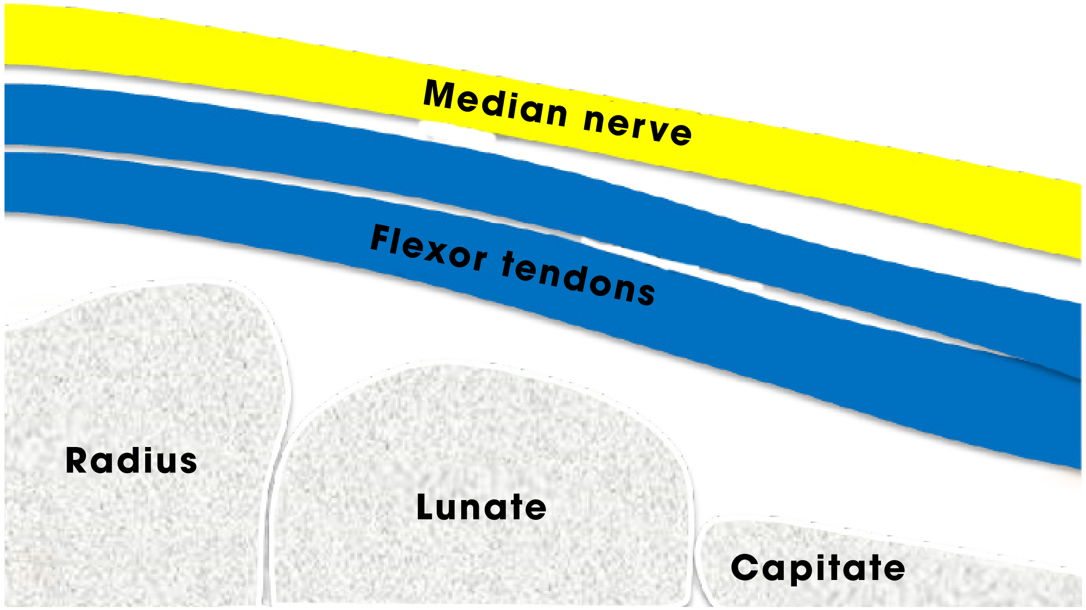
Typical: posterior enhancement communication with joint but extrasynovial location (tissue deep to it and superficial to bone)

Synovial proliferation with significantly increased Doppler signals

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - palmar long midline

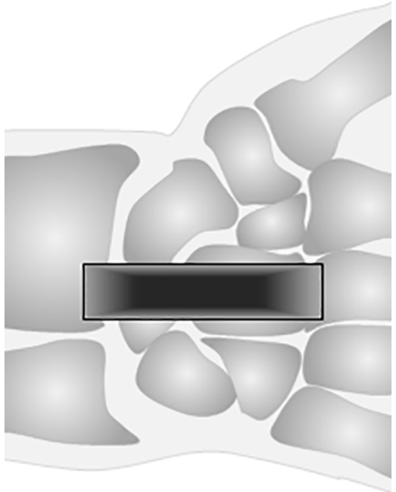


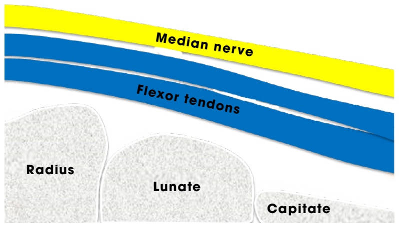


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

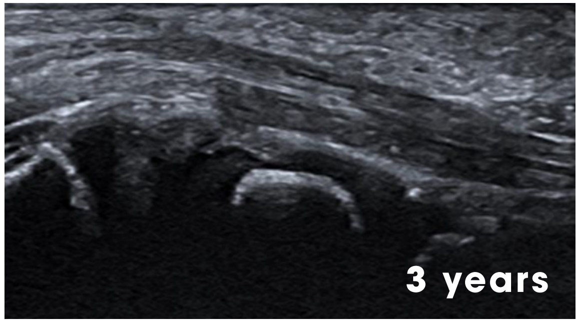
TIP / The median nerve runs parallel on top of the flexor tendons

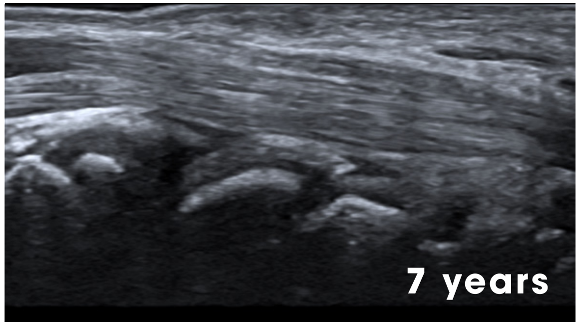
Scanning the wrist - palmar long midline

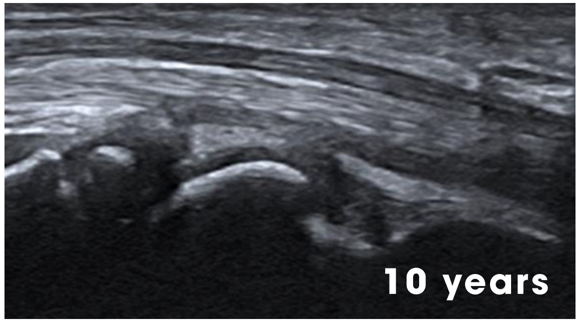


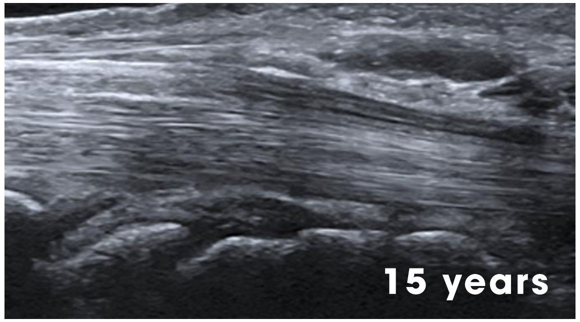


HEALTHY PATHOLOGY





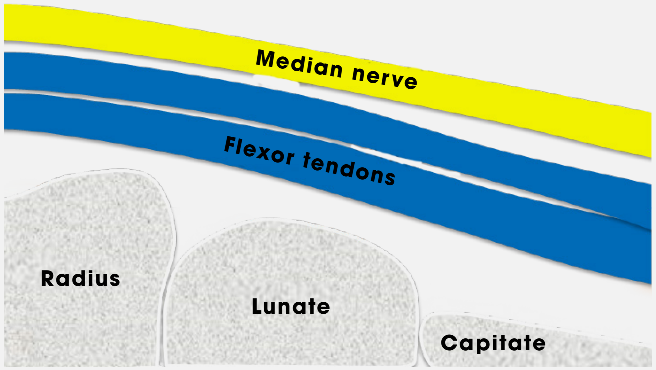


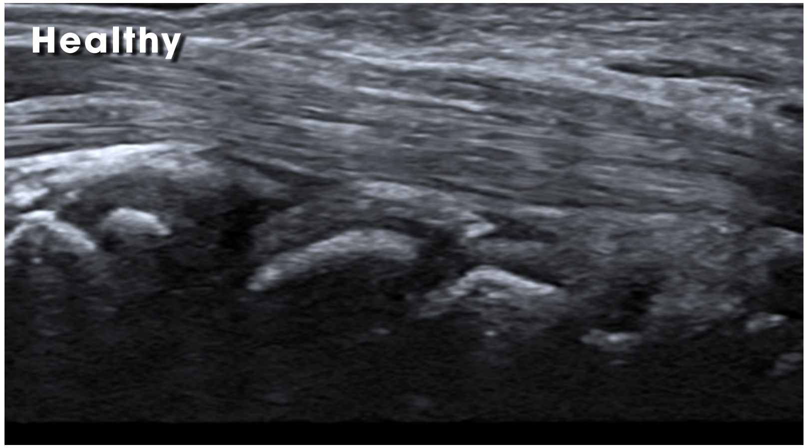


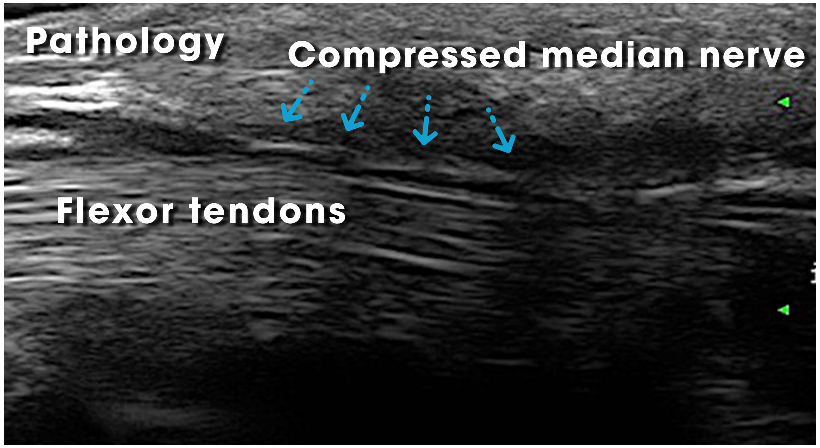
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the wrist - palmar long midline

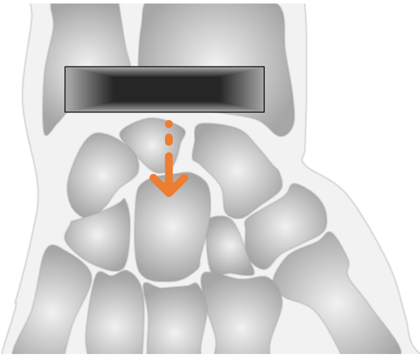
HEALTHY PATHOLOGY



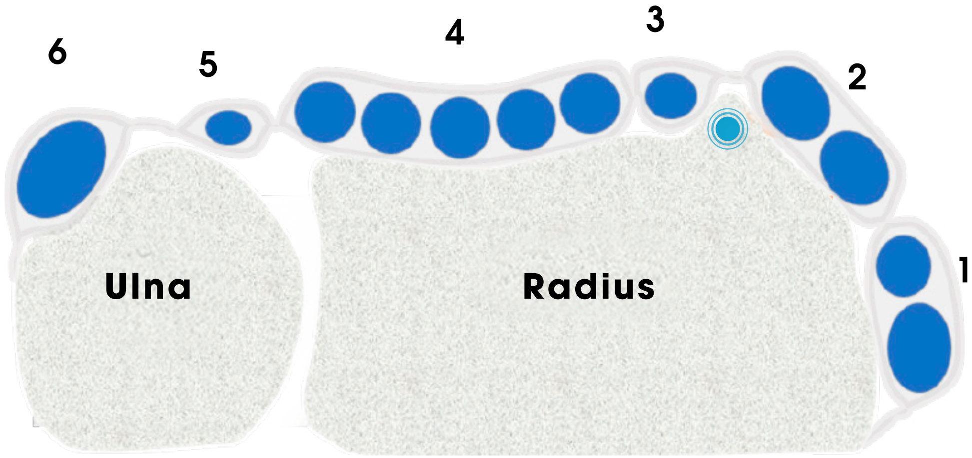




Scanning the wrist - extensor tendons



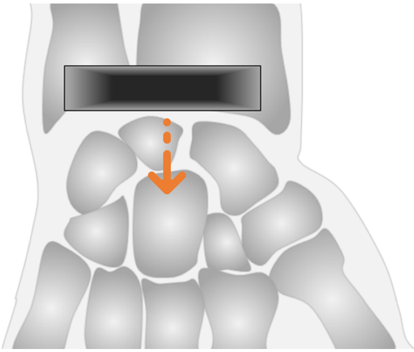
1-6 = Extensor tendon compartments

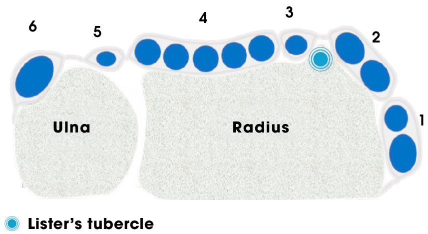


Lister's tubercle

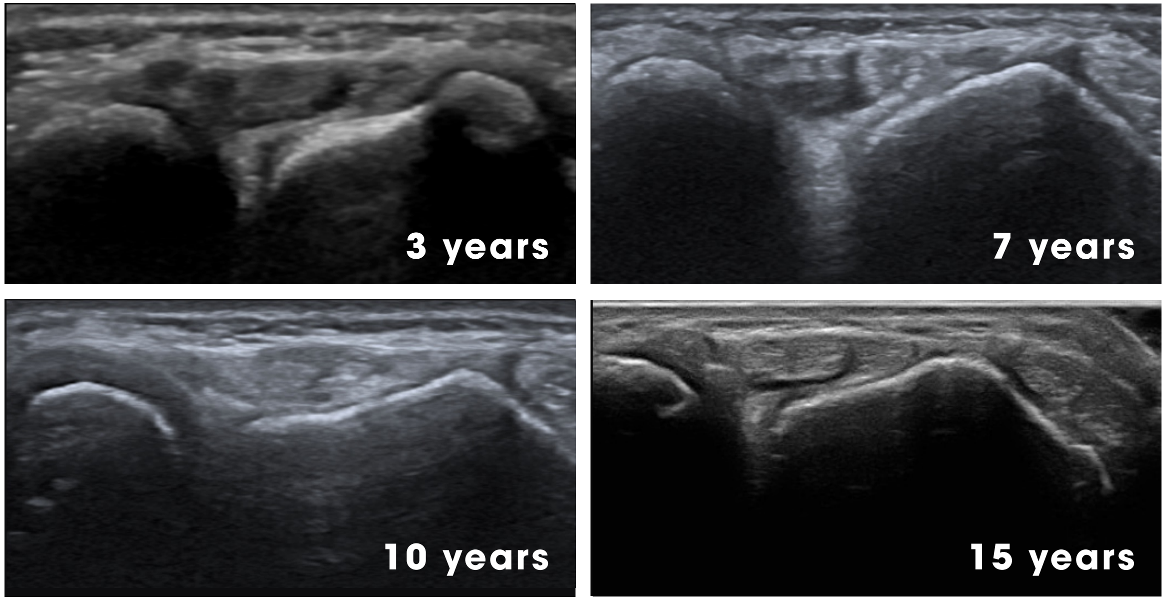
TIP / If you see hypoechoic or anechoic areas in the region of the tendons verify for anisotropy or the distal extension of the muscle

Scanning the wrist - extensor tendons





HEALTHY PATHOLOGY

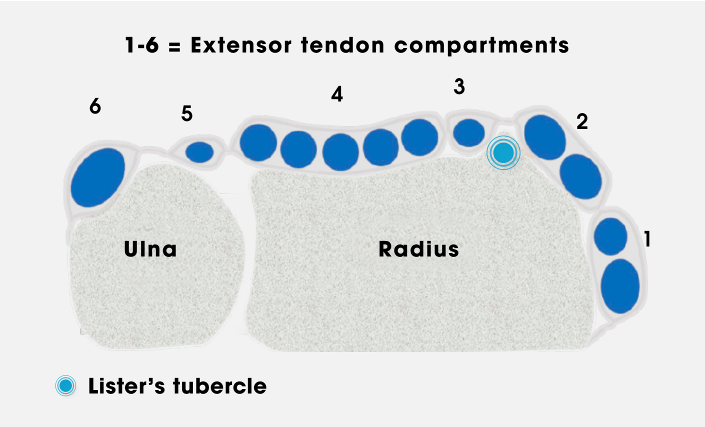


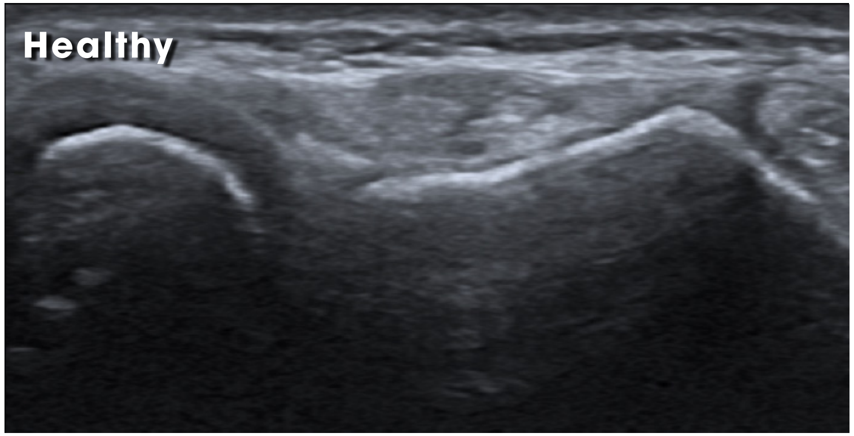
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

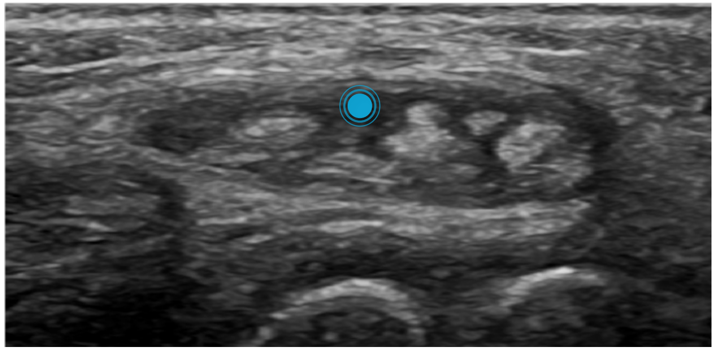
TIP / If you see hypoechoic or anechoic areas in the region of the tendons verify for anisotropy or the distal extension of the muscle

Scanning the wrist - extensor tendons

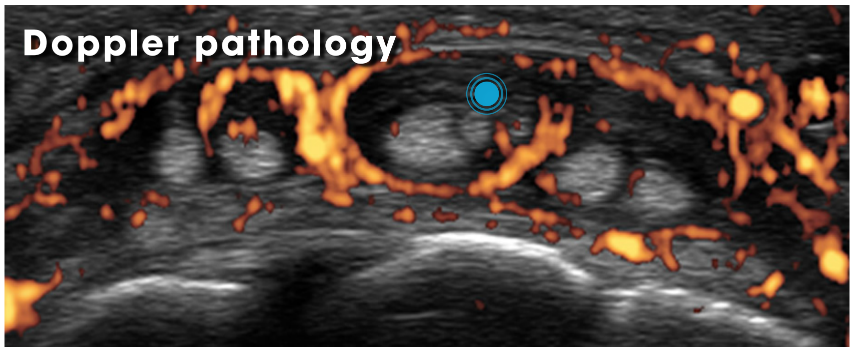
HEALTHY PATHOLOGY







Extensor tenosynovitis

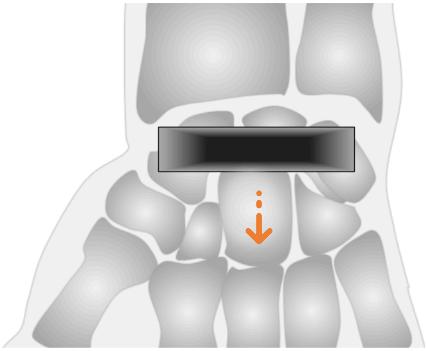


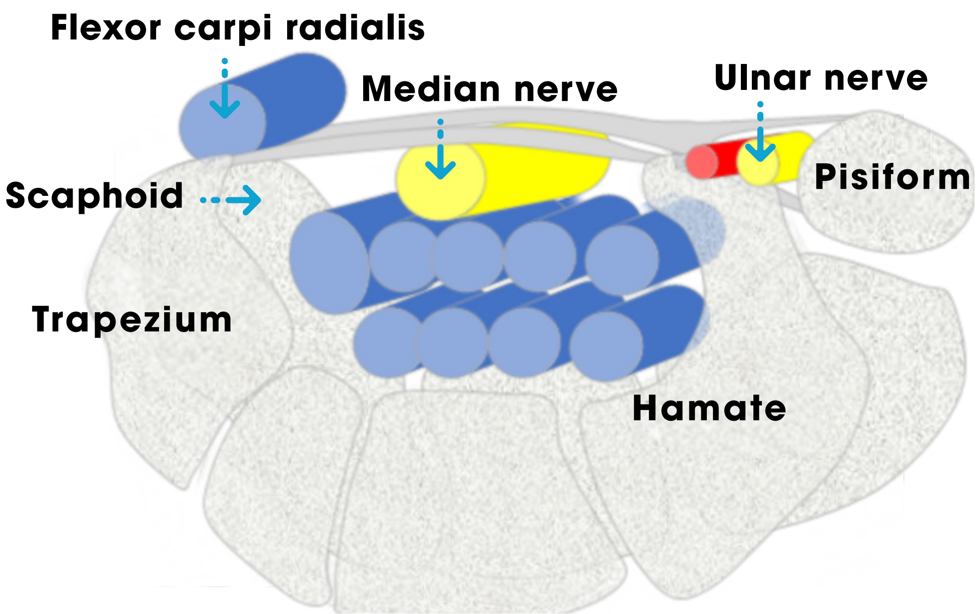
Extensor tenosynovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

Scanning the wrist - flexor tendons

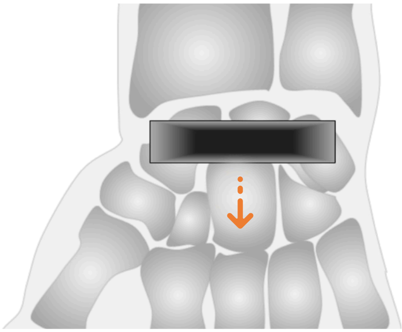


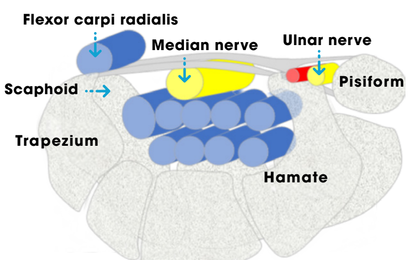


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

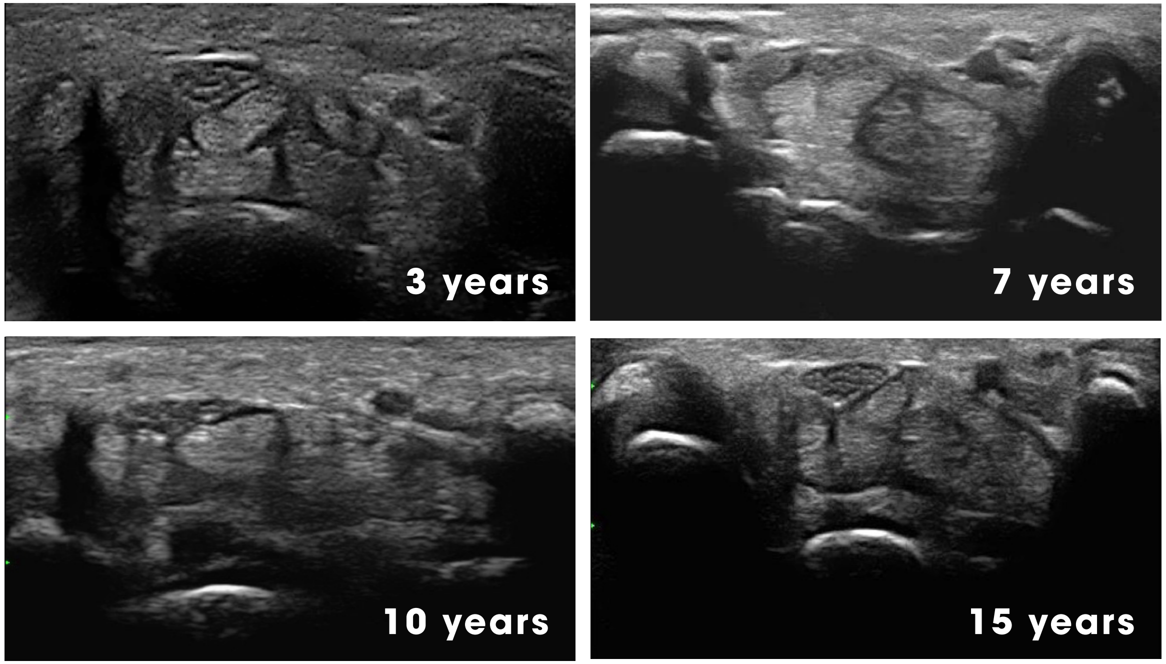
TIP / Avoid anisotropy of the flexor tendons

Scanning the wrist - flexor tendons





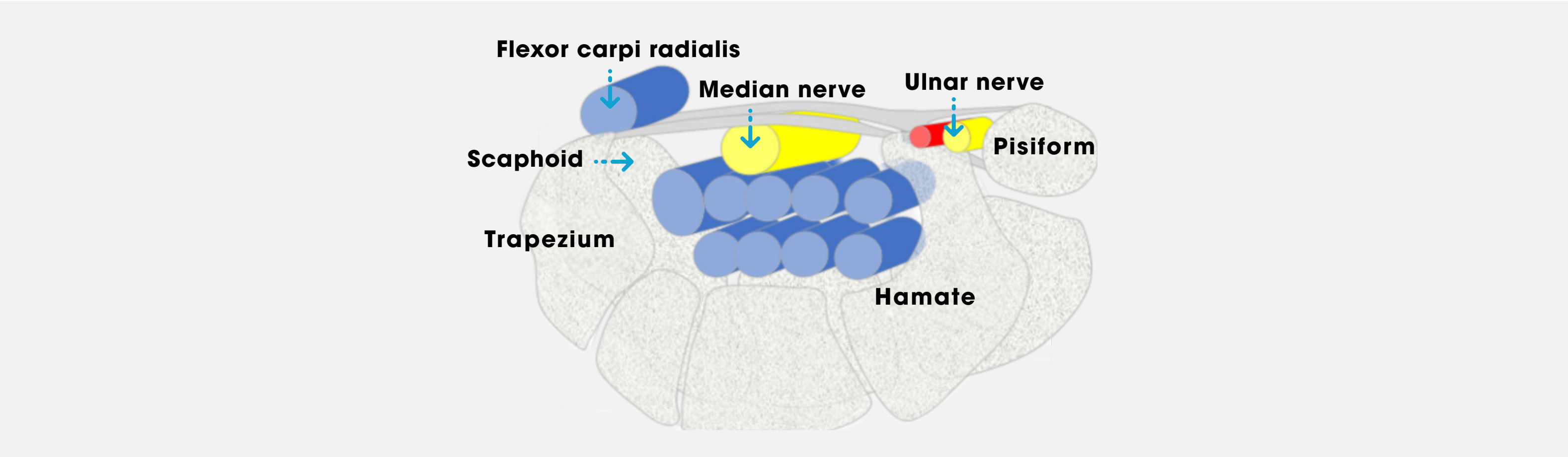
HEALTHY PATHOLOGY

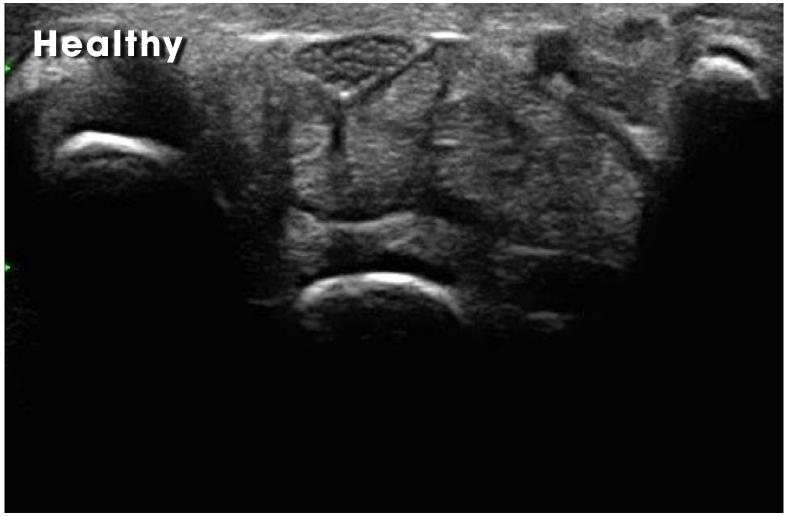


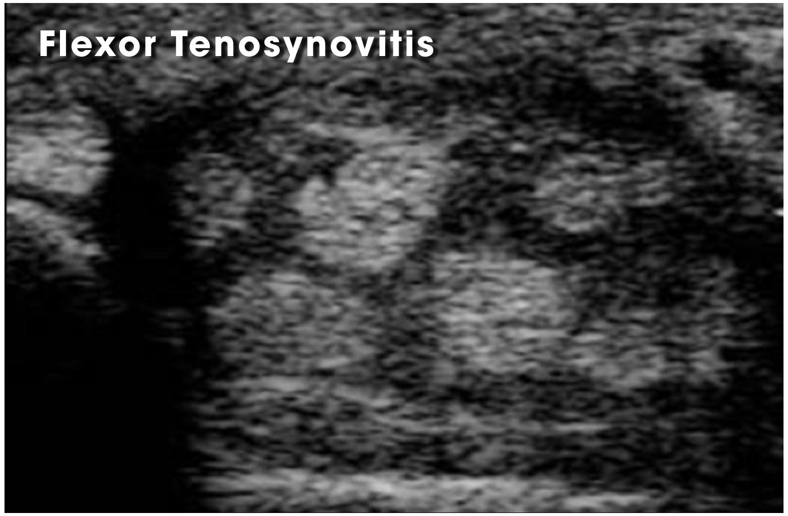
TIP / Avoid anisotropy of the flexor tendons

Scanning the wrist - flexor tendons

HEALTHY PATHOLOGY





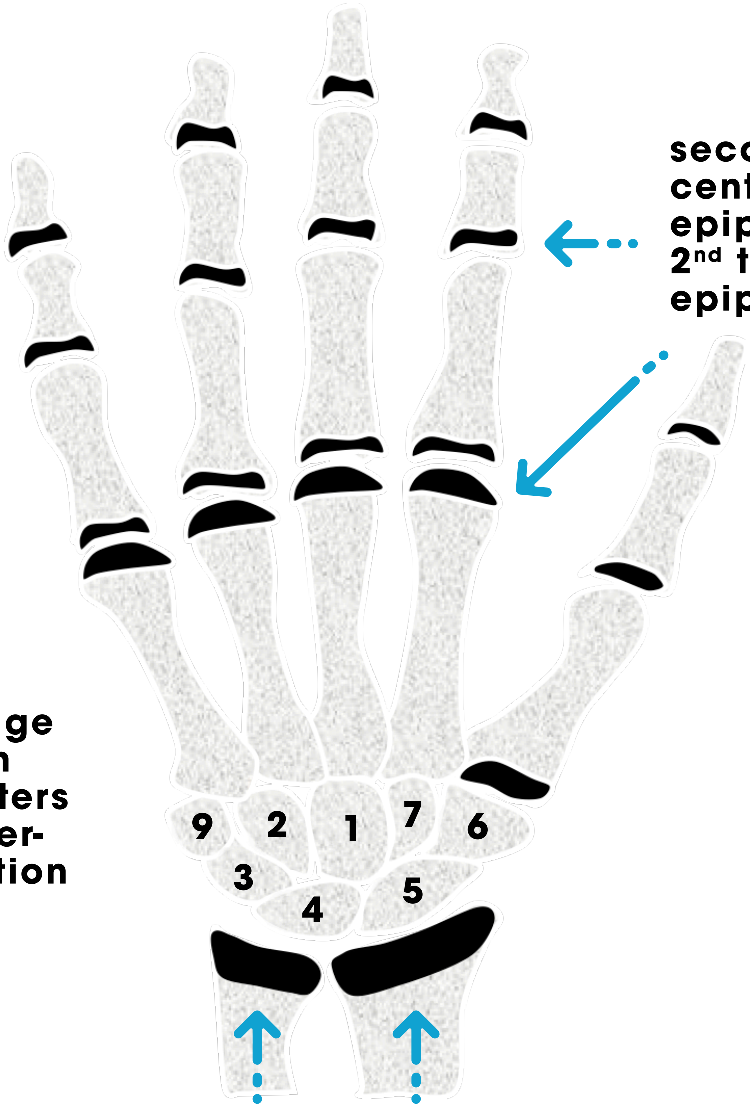


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Finger ossification

secondary ossification centers metacarpals and epiphyses fingers appear 2^{nd} to 3^{rd} year of life epiphyses unite 18^{th} year

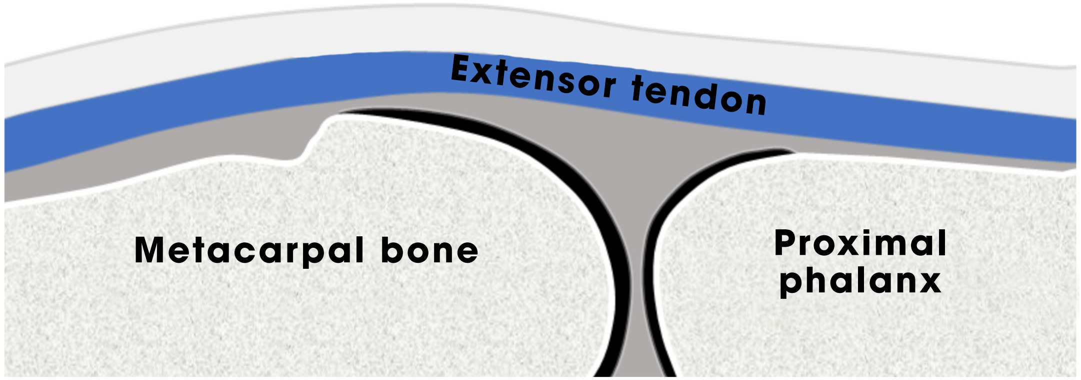
Carpal Bones age in years when ossification centers appear (counter-clockwise direction starting with capitate)



distal end of radius appears 2^{nd} year of life distal ulna 8^{th} year epiphyses unite 20^{th} year

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the finger - dorsal long metacarpophalangeal joints

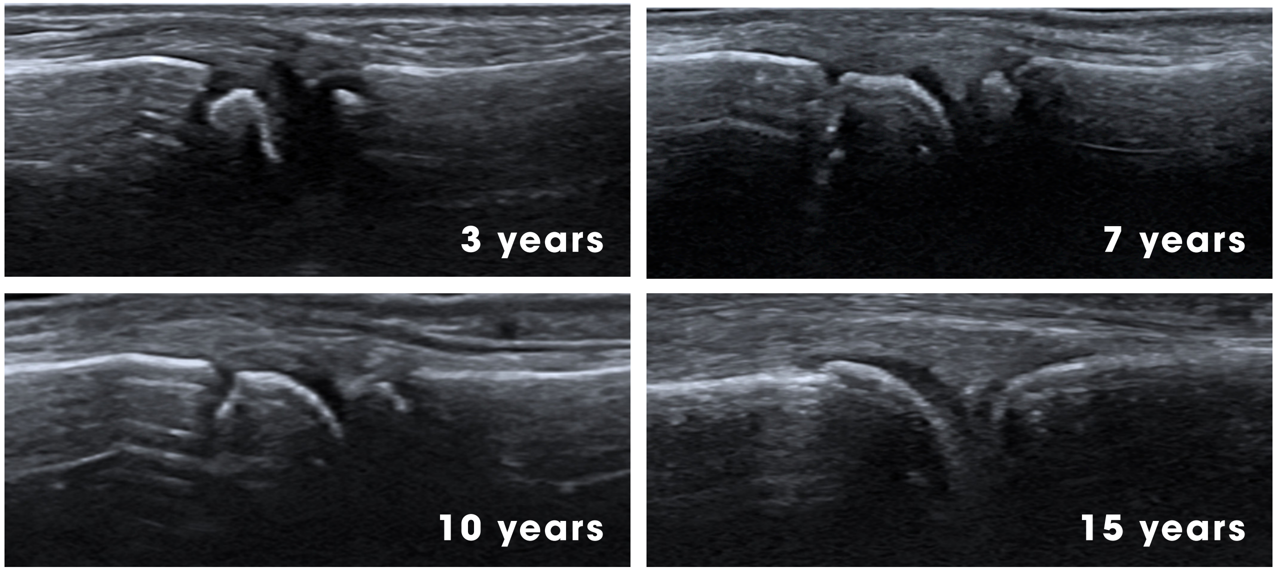


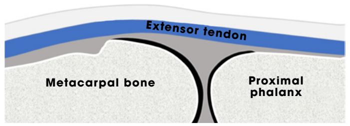
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Smaller hockey-stick probes are very useful for the small finger joints

Scanning the finger - dorsal long metacarpophalangeal joints

HEALTHY
PATHOLOGY



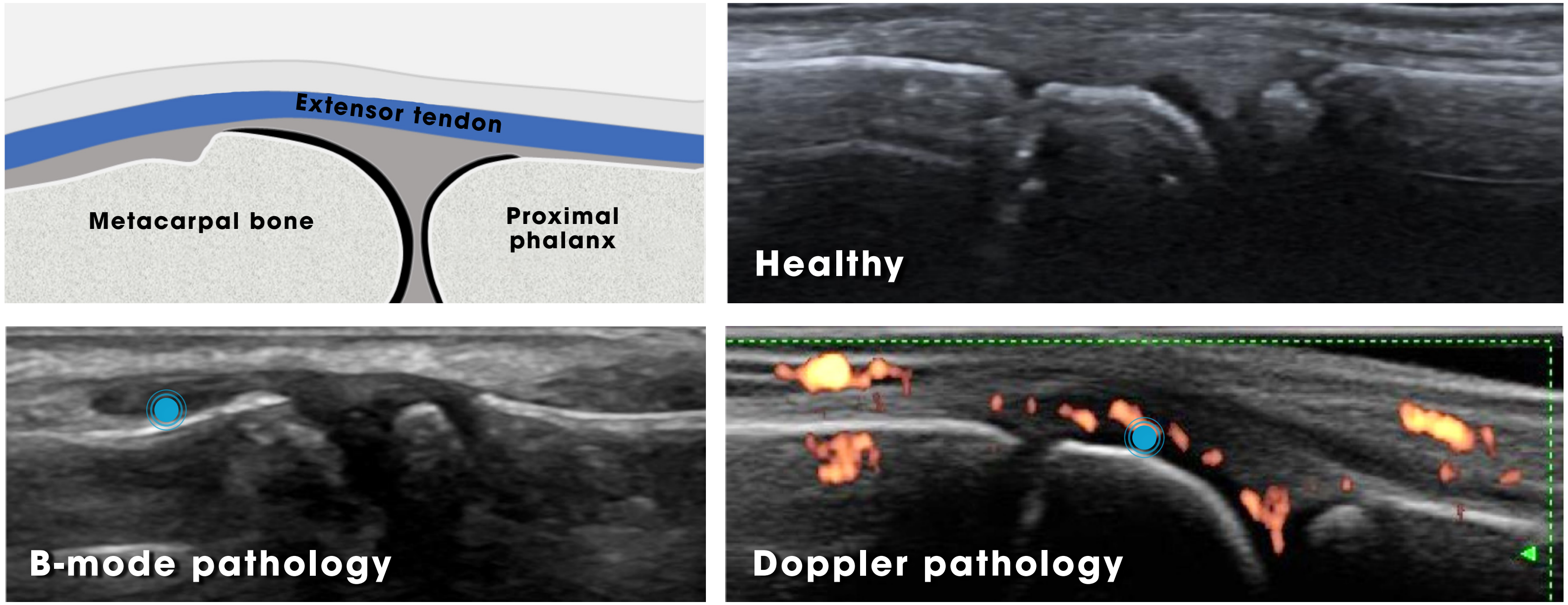


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Smaller hockey-stick probes are very useful for the small finger joints

Scanning the finger - dorsal long metacarpophalangeal joints

HEALTHY PATHOLOGY



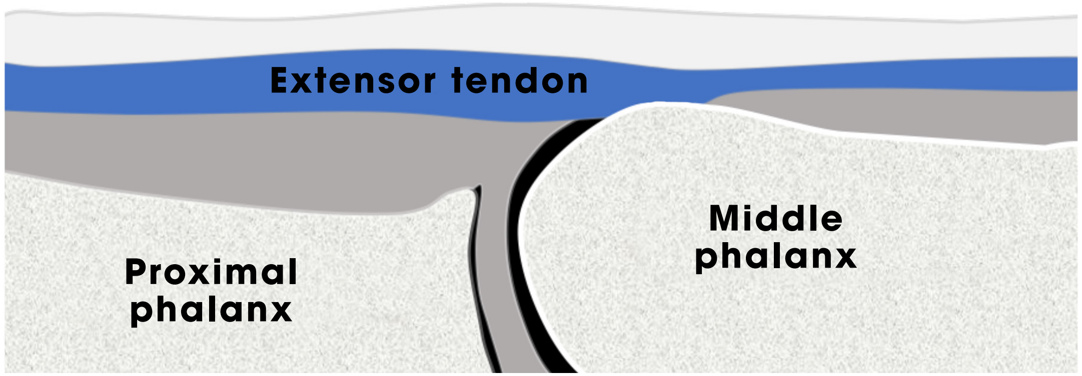
Effusion

Intrasynovial Doppler signals

TIPS /

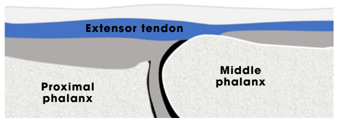
- The synovial distension tends to extend proximally
- Due to the compression of the extensor tendon synovial distension is often more visible medial and lateral to the extensor tendon and can also be nicely demonstrated on a transverse view
- In the Doppler image shown here there is very minimal distension of the synovial recess but clear intrasynovial Doppler signals

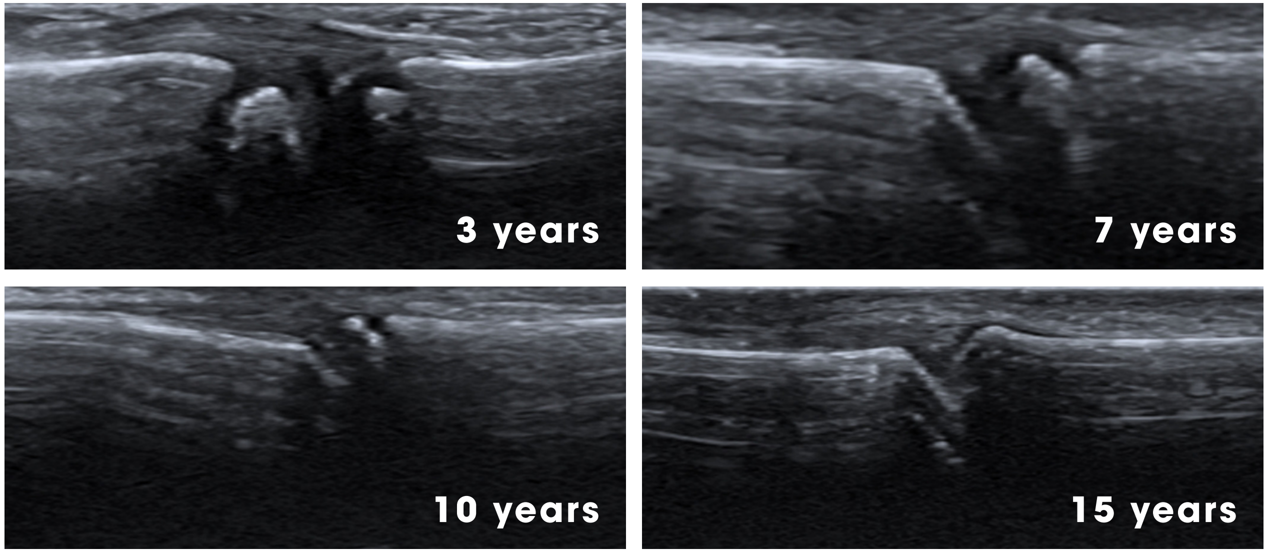
Scanning the finger - dorsal long proximal interphalangeal joints



Scanning the finger - dorsal long proximal interphalangeal joints

HEALTHY PATHOLOGY



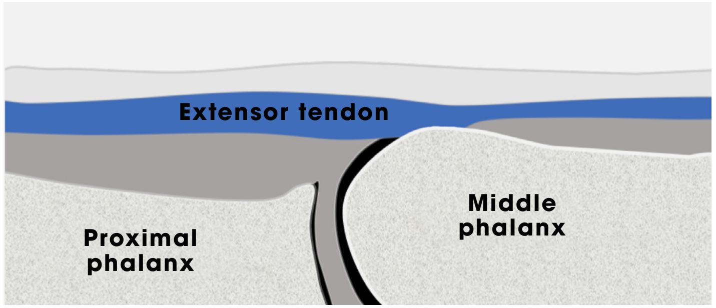


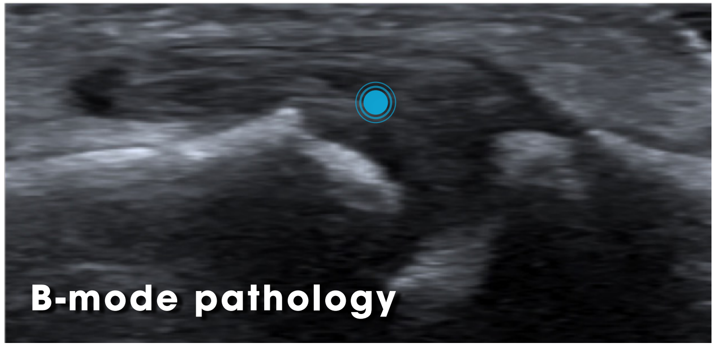
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

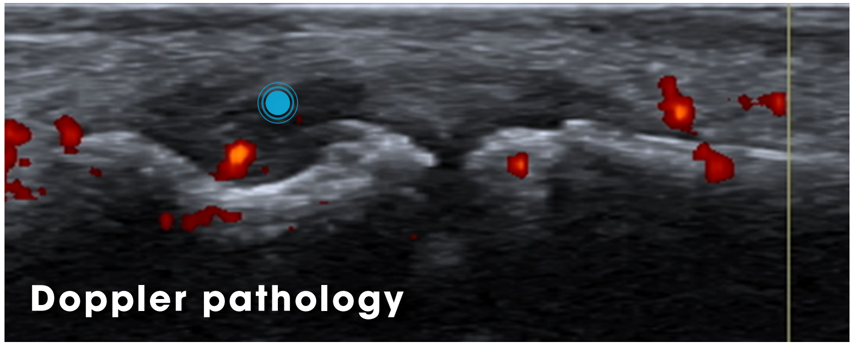
TIP / In addition to the joint visualize the insertion of the extensor tendon

Scanning the finger - dorsal long proximal interphalangeal joints

HEALTHY | PATHOLOGY







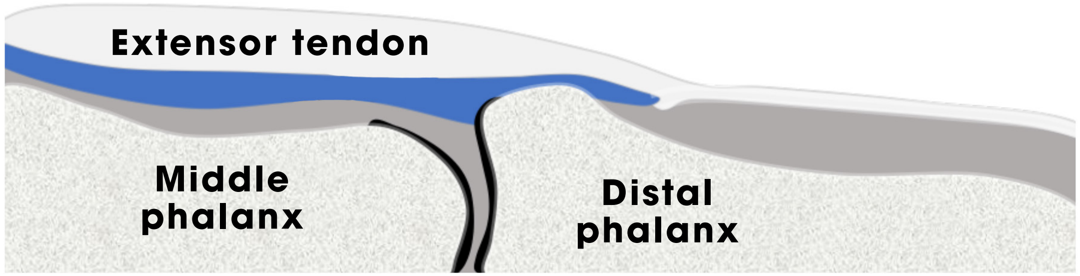
Effusion and synovitis

Irregular bone with a pathological vessel and synovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

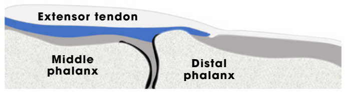
TIP / Erosions have to be confirmed in two perpendicular planes

Scanning the finger - dorsal long distal interphalangeal joints

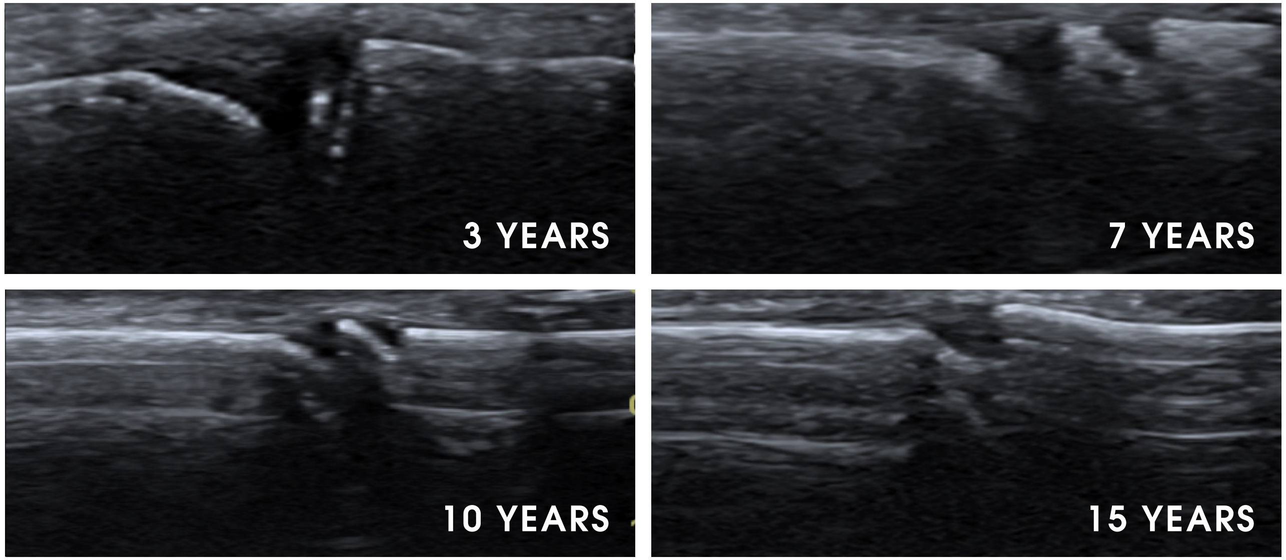


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the finger - dorsal long distal interphalangeal joints



HEALTHY PATHOLOGY

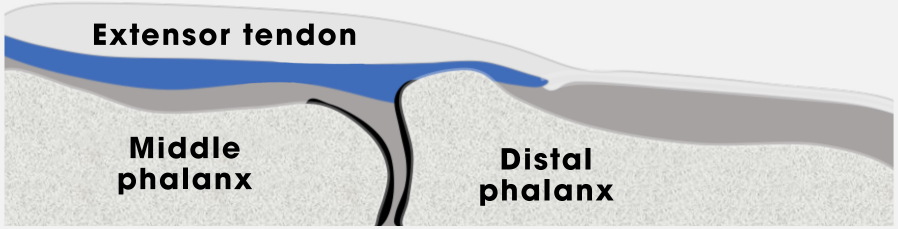


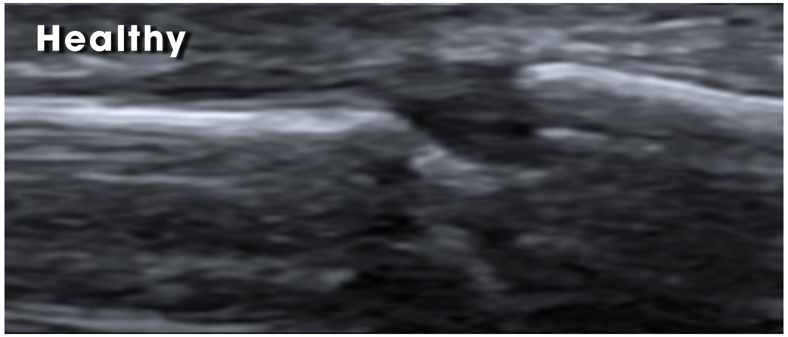
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

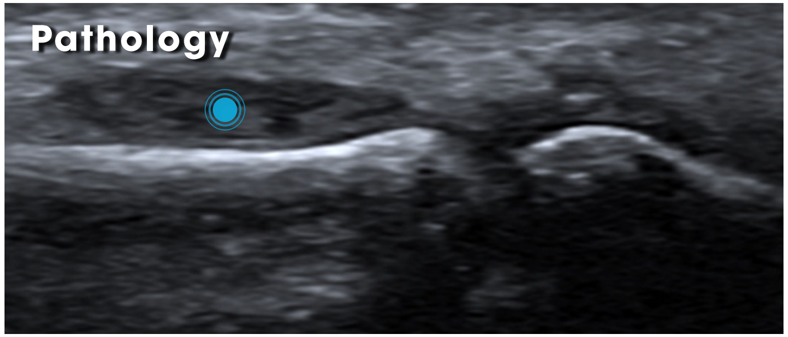
TIP / Smaller hockey-stick probes are very useful for the small finger joints

Scanning the finger - dorsal long distal interphalangeal joints

HEALTHY | PATHOLOGY





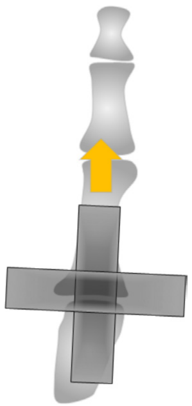


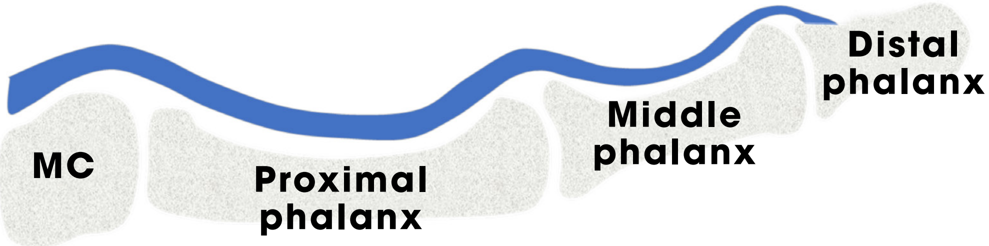
Effusion and synovial hypertrophy

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Smaller hockey-stick probes are very useful for the small finger joints

Scanning the finger - palmar long metacarpophalangeal joints





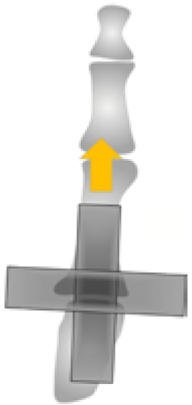
MC, metacarpal

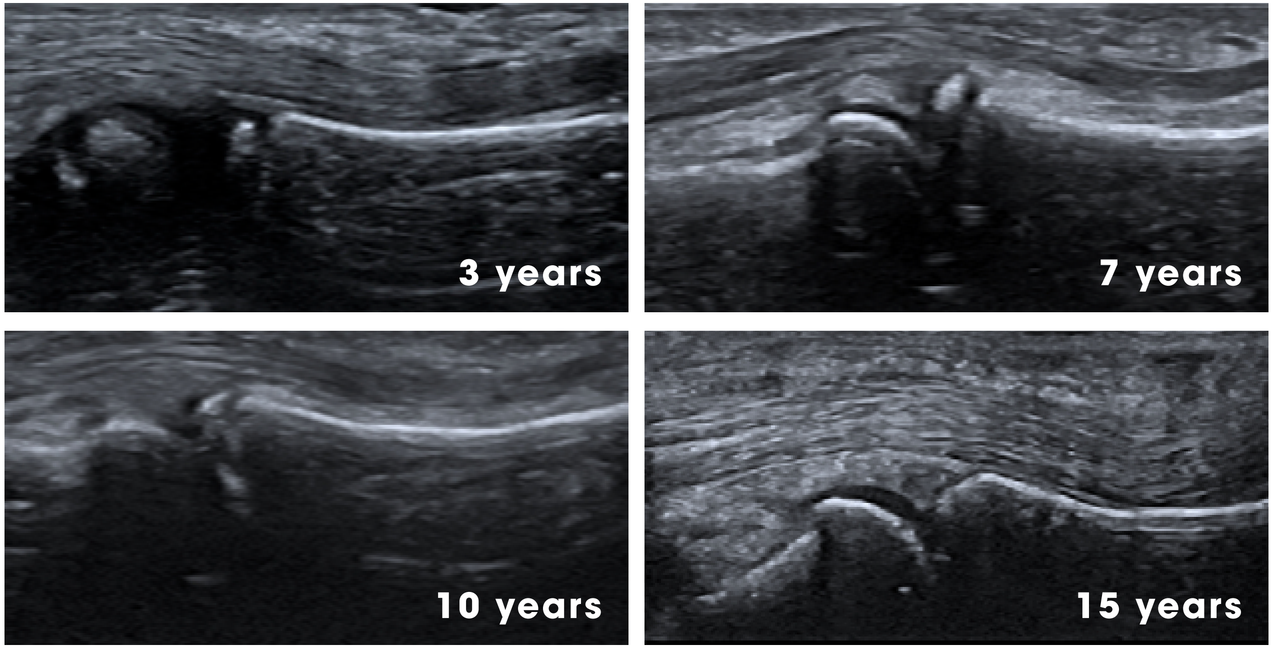
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

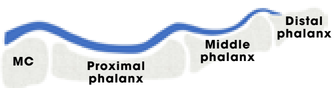
TIP / Examine dynamically with finger flexion

Scanning the finger - palmar long metacarpophalangeal joints

HEALTHY | PATHOLOGY





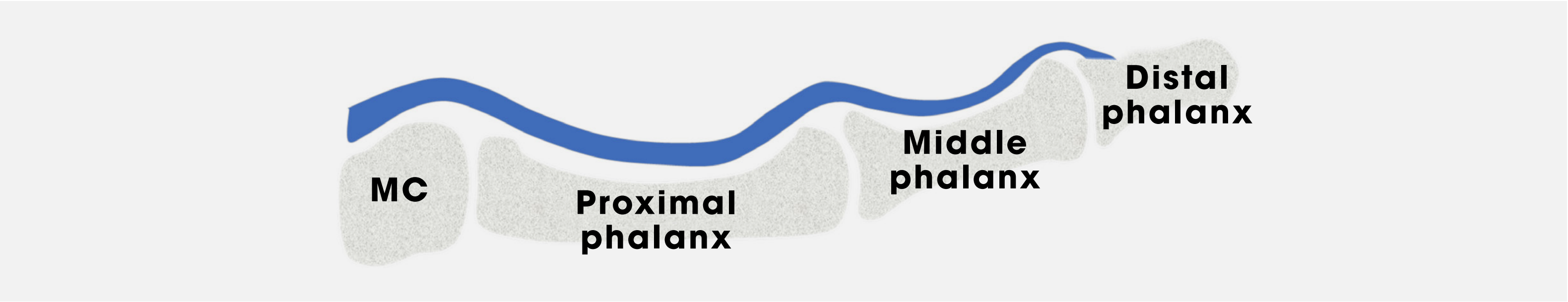


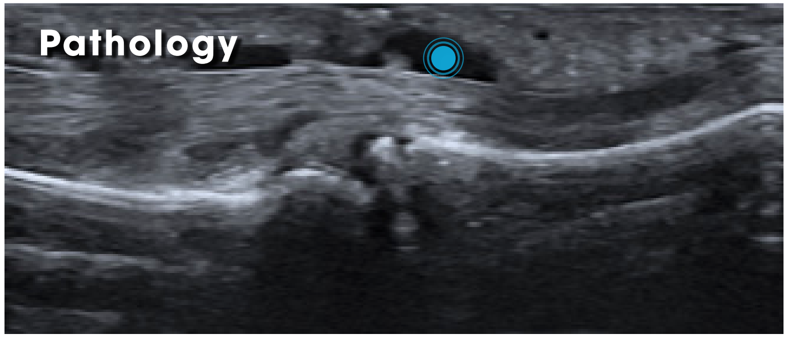
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Examine dynamically with finger flexion

Scanning the finger - palmar long metacarpophalangeal joints

HEALTHY PATHOLOGY

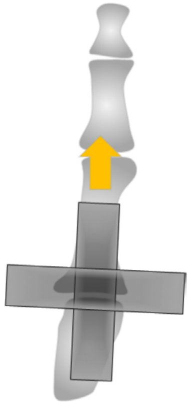


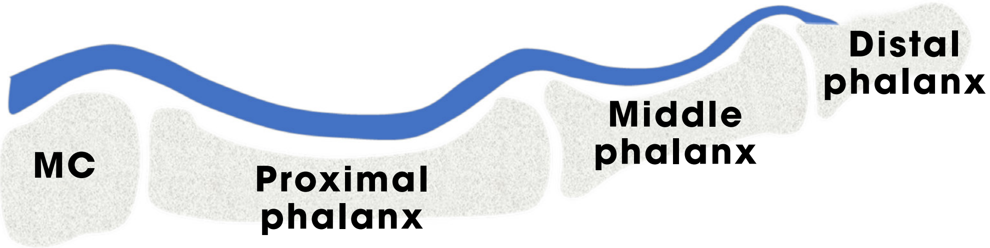


Flexor tenosynovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the finger - palmar long proximal interphalangeal joints





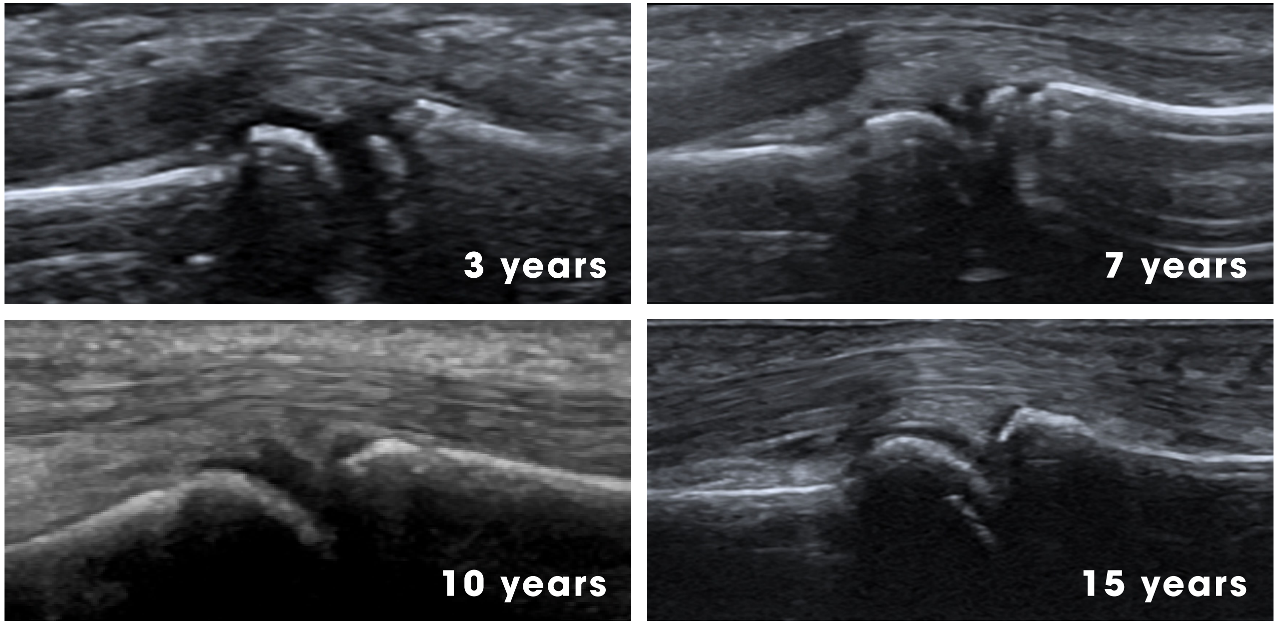
MC, metacarpal

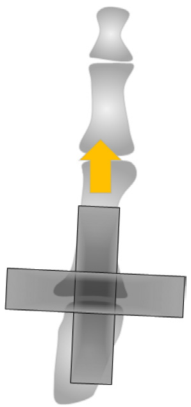
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

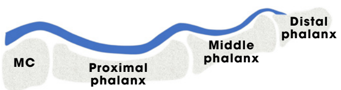
TIP / A small amount of fluid in the volar joint recess may be seen as a physiological finding

Scanning the finger - palmar long proximal interphalangeal joints

HEALTHY PATHOLOGY



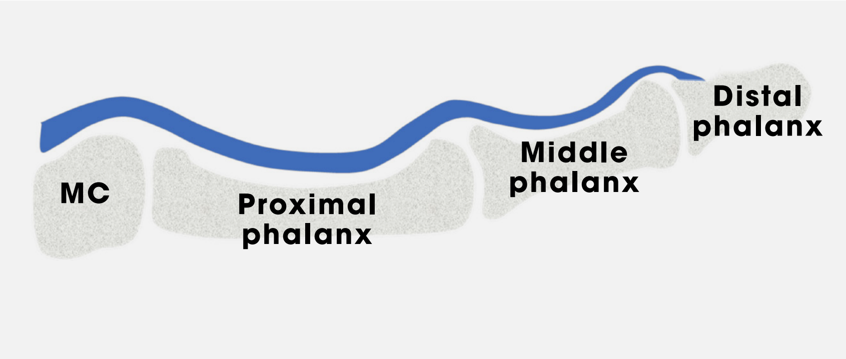


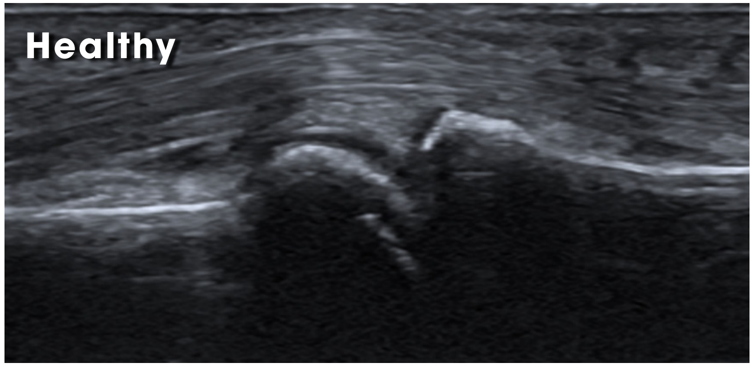


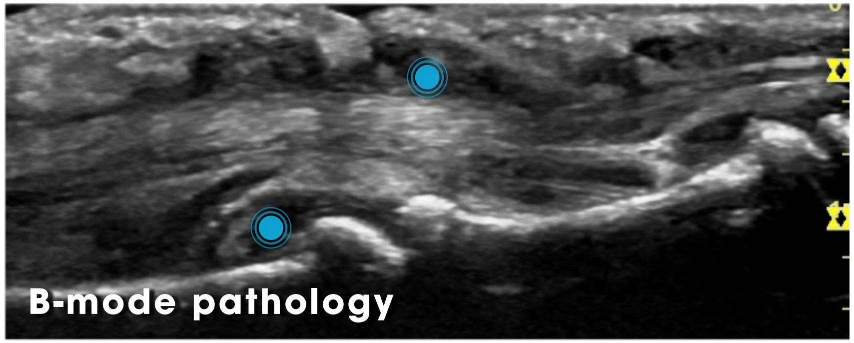
TIP / A small amount of fluid in the volar joint recess may be seen as a physiological finding

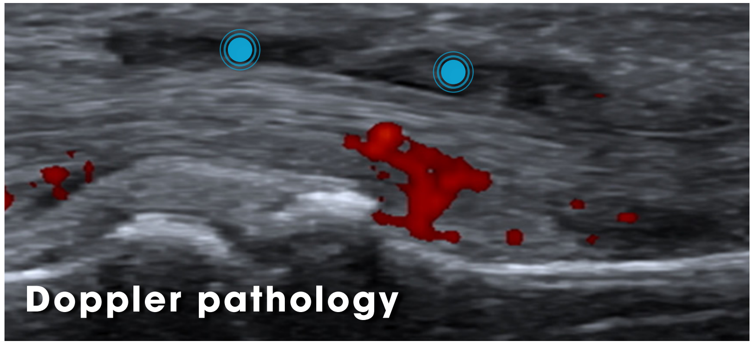
Scanning the finger - palmar long proximal interphalangeal joints

HEALTHY PATHOLOGY









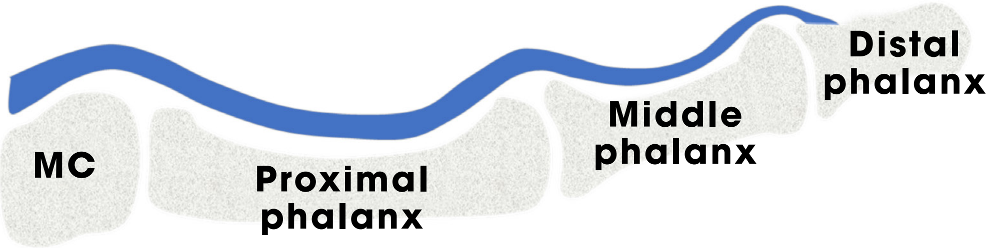
Flexor synovitis and tenosynovitis

Flexor tenosynovitis

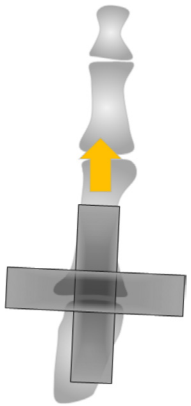
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Flexor tenosynovitis may occur in all subgroups of JIA

Scanning the finger - palmar long distal interphalangeal joints



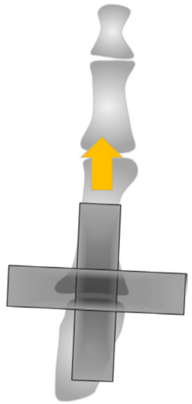
MC, metacarpal

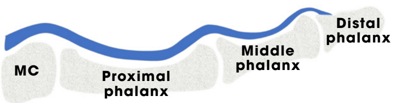


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

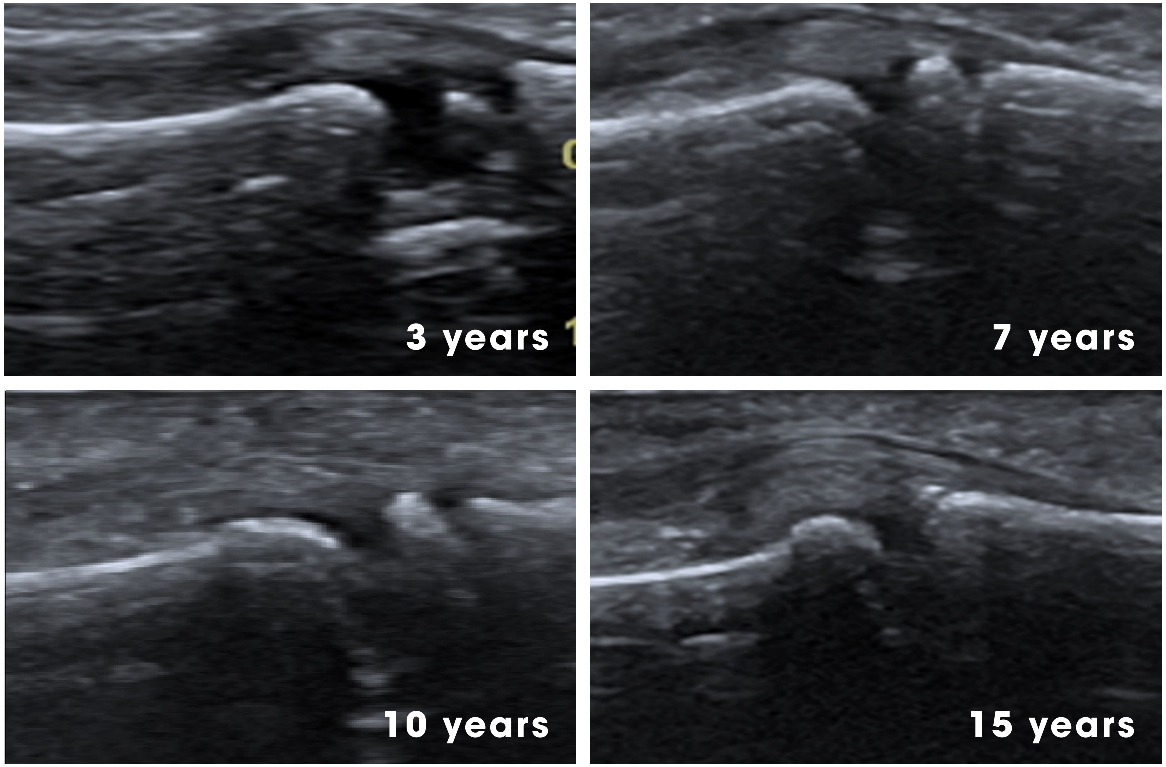
TIP / A small amount of fluid in the volar joint recess may be seen as a physiological finding

Scanning the finger - palmar long distal interphalangeal joints





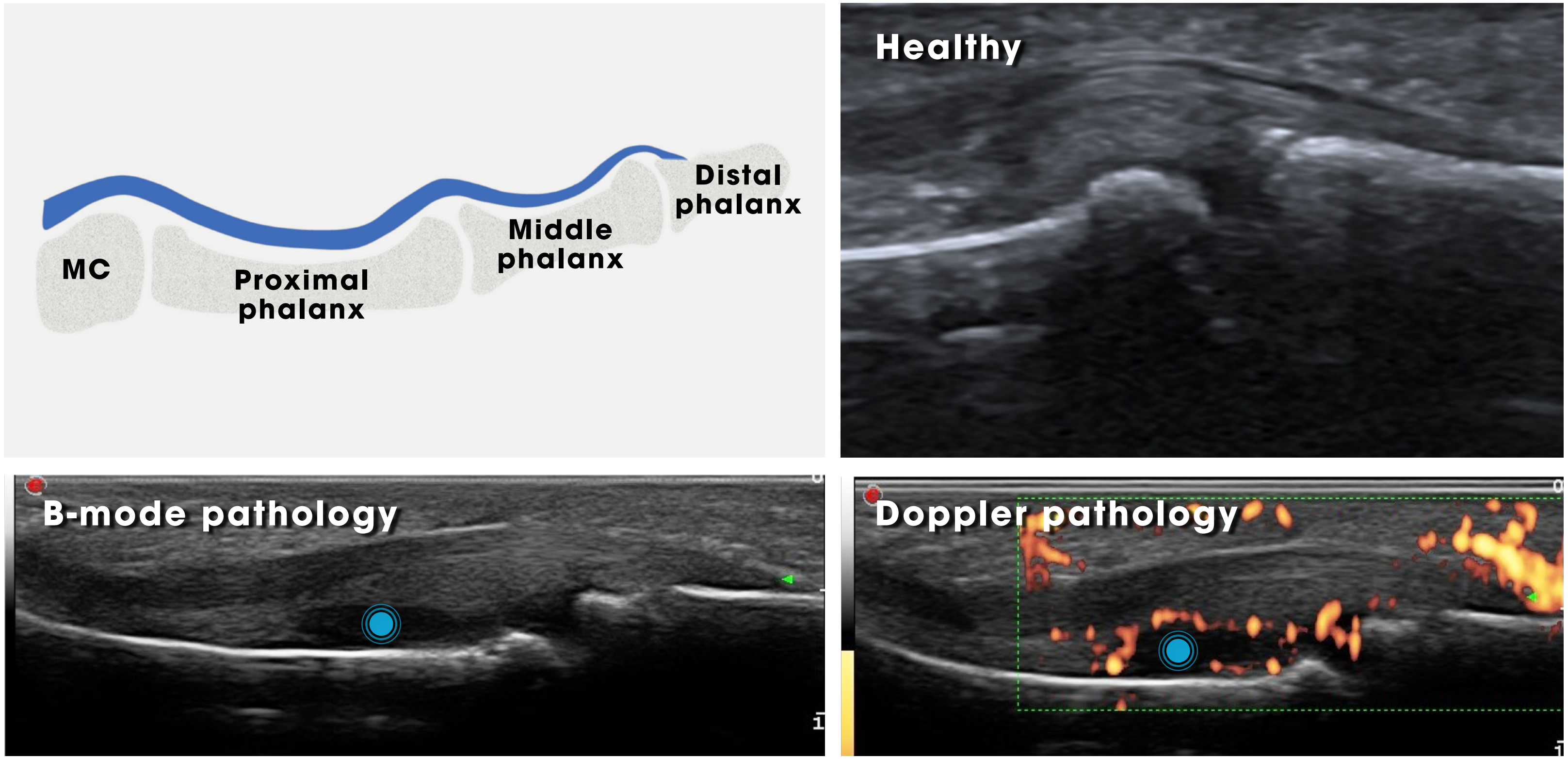
HEALTHY PATHOLOGY



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the finger - palmar long distal interphalangeal joints

HEALTHY PATHOLOGY



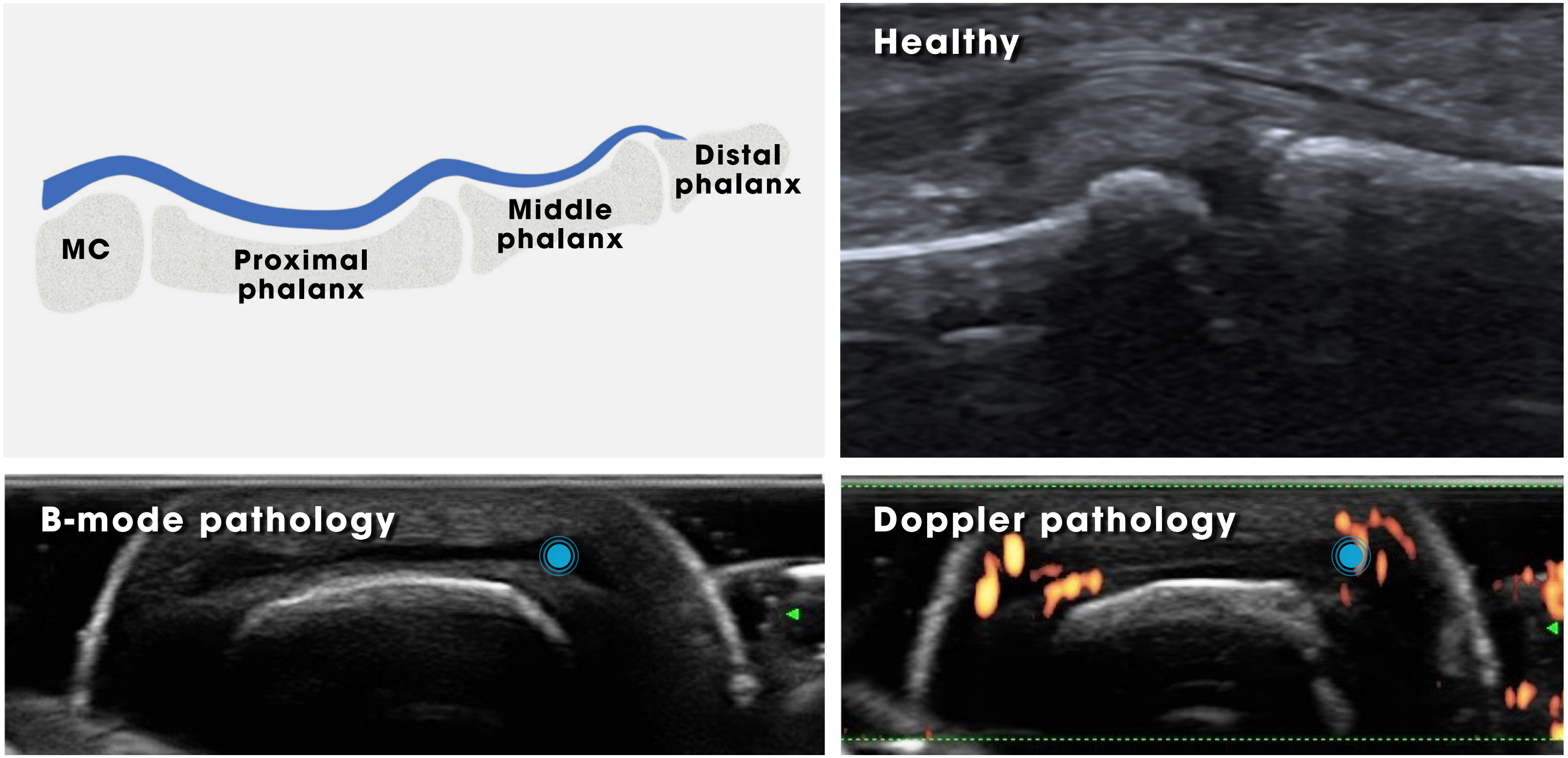
Synovial distension and increased Doppler signals

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / 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

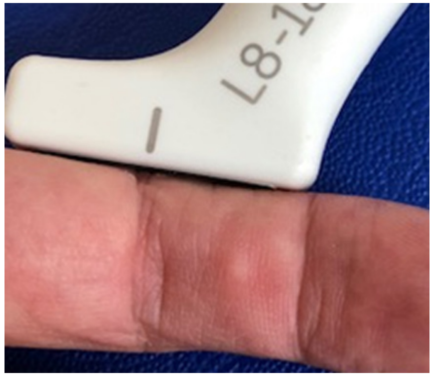


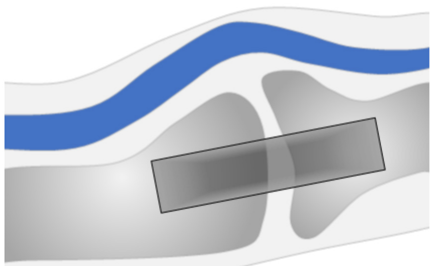
Synovial distension and increased Doppler signals in transverse view

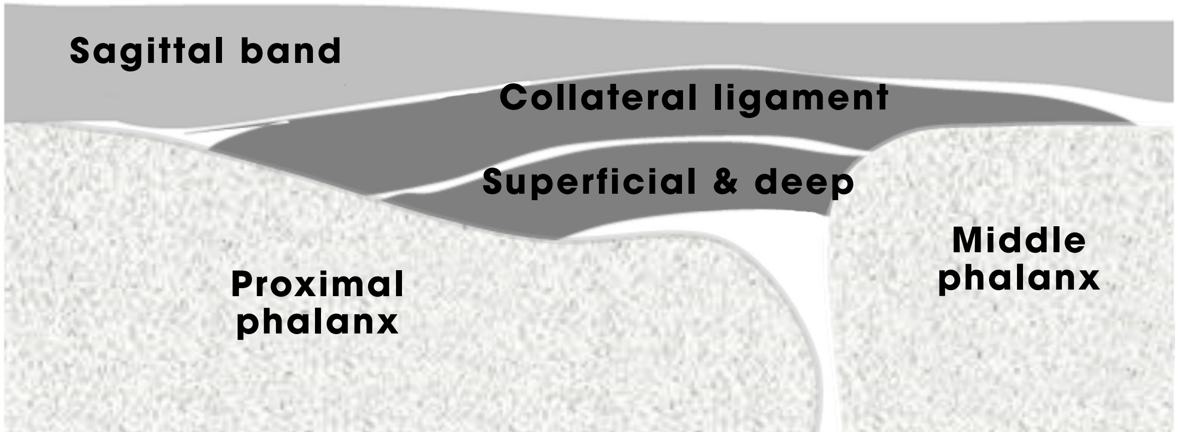
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / If pathology is identified on a longitudinal scan, it will need to be confirmed on the transverse scan

Scanning the finger - collateral ligament

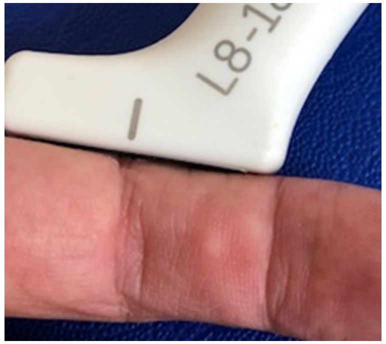


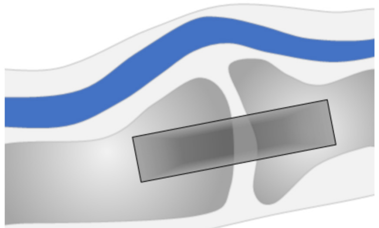


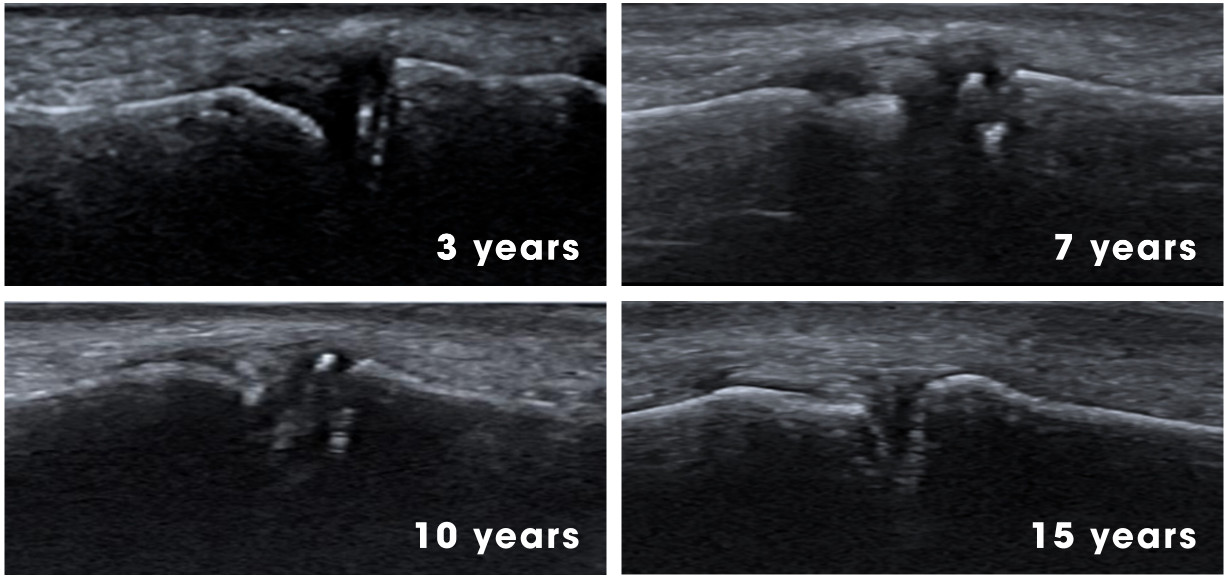


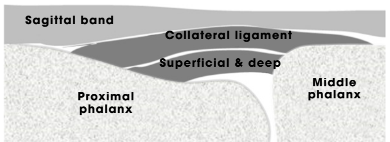
Scanning the finger - collateral ligament

HEALTHY PATHOLOGY



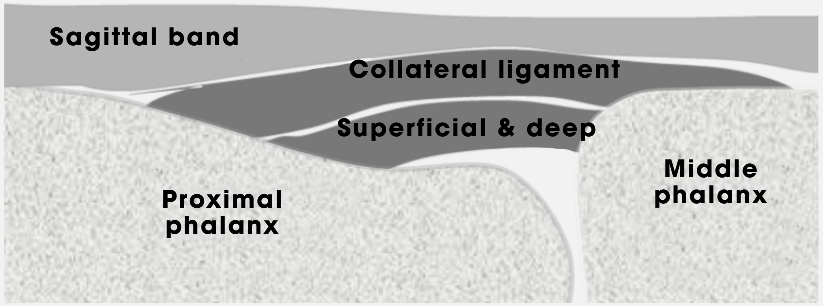


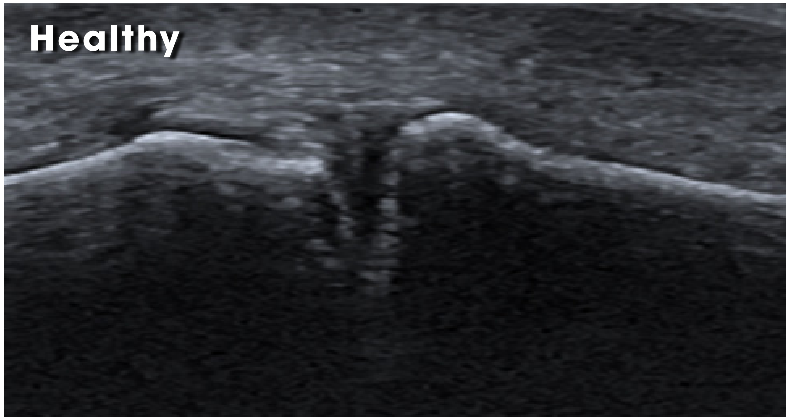


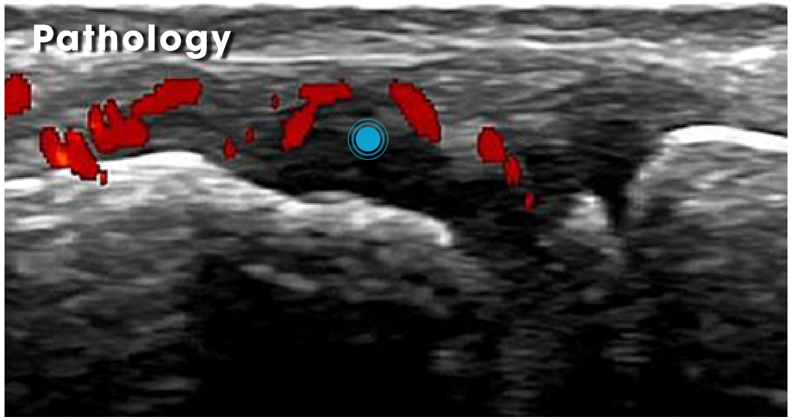


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the finger - collateral ligament

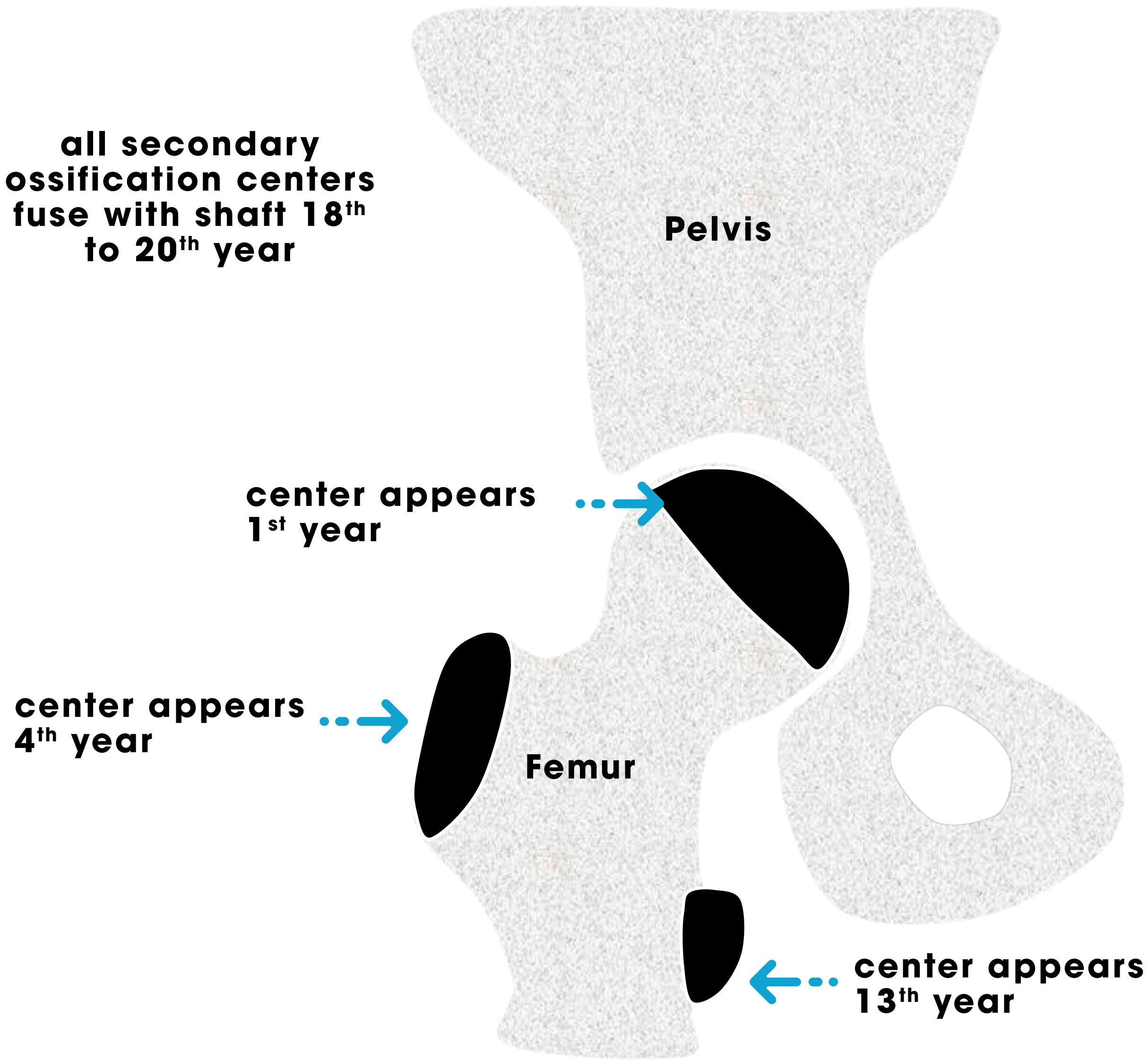






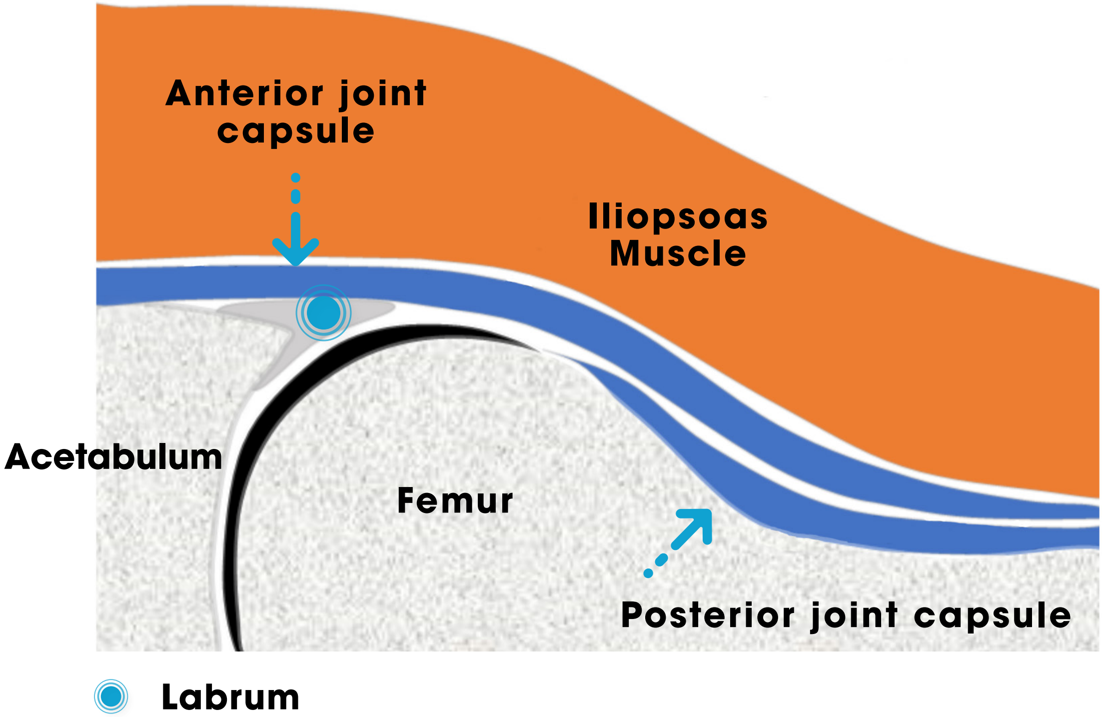
Enthesitis with hypervascularization

Femur ossification



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

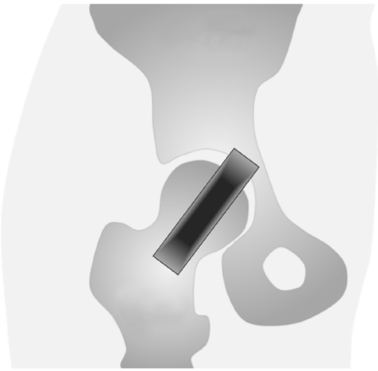
Scanning the hip - anterior long

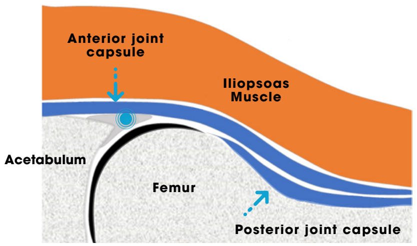


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

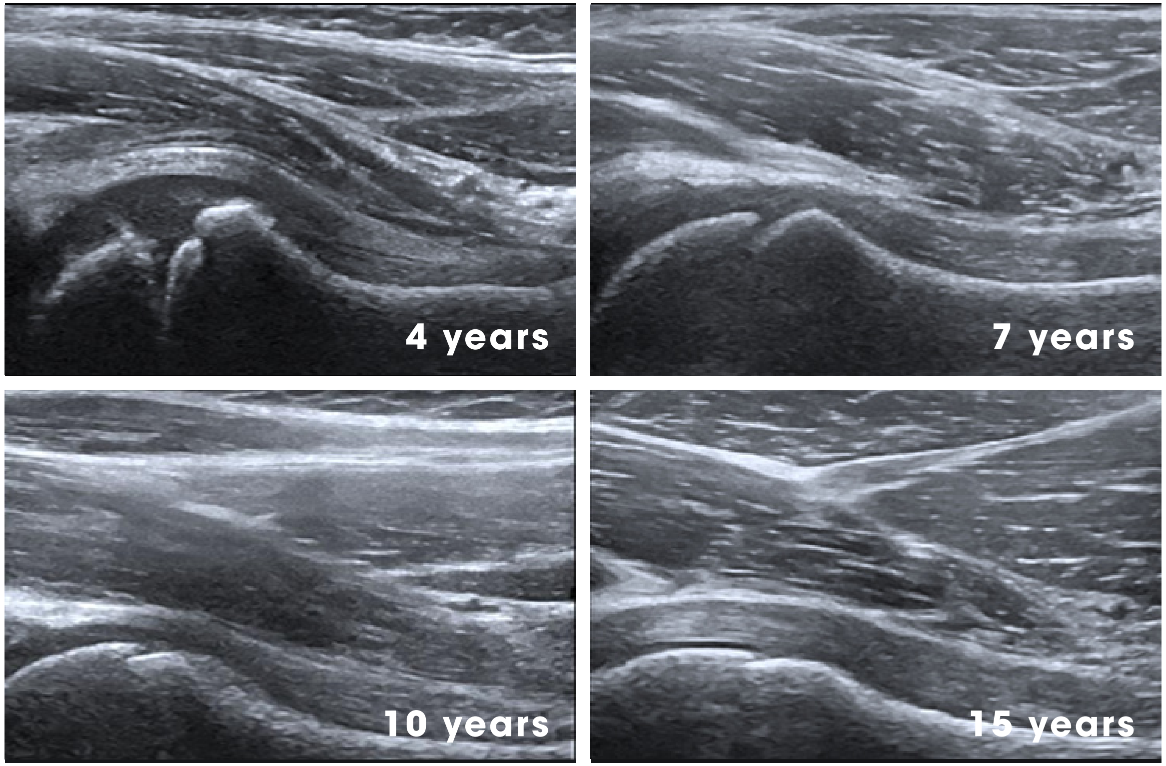
TIP / In older children use lower frequencies to clearly visualize all structures of the anterior recess

Scanning the hip - anterior long





HEALTHY PATHOLOGY

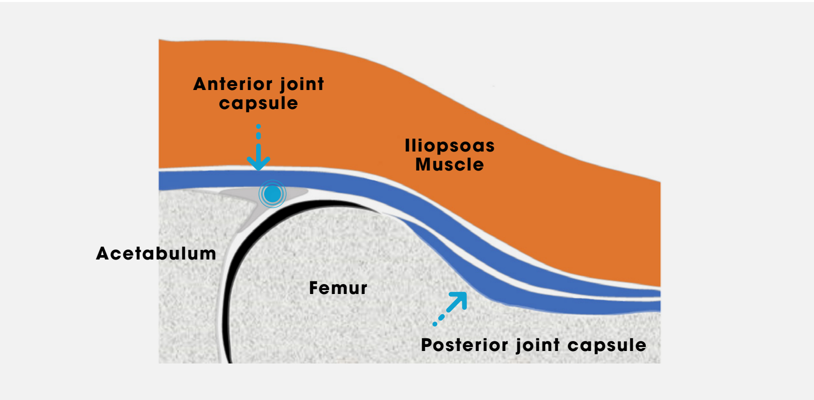


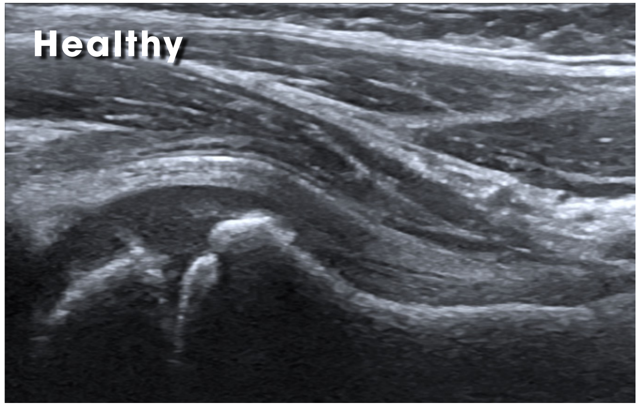
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

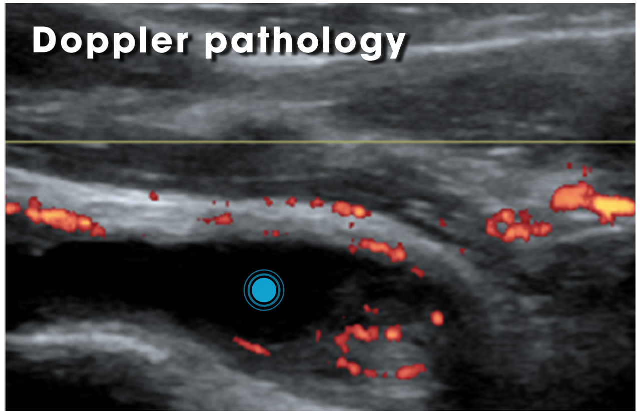
TIP / In older children use lower frequencies to clearly visualize all structures of the anterior recess. Pay attention to the patient's position. The sonographic configuration of the capsule varies with leg position and should be in external rotation

Scanning the hip - anterior long

HEALTHY PATHOLOGY





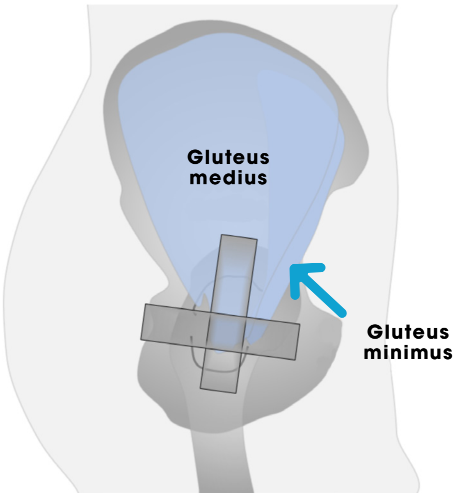


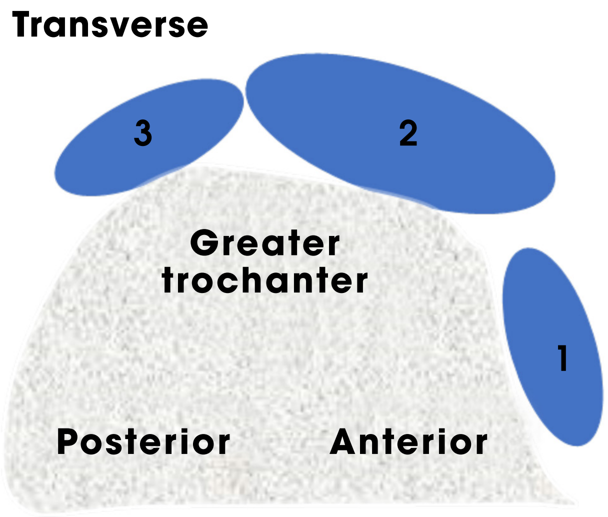
Effusion and synovial hypervascularization

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

Scanning the hip - greater trochanter transverse

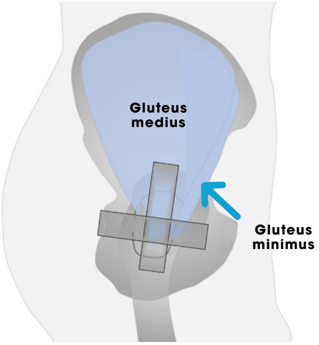


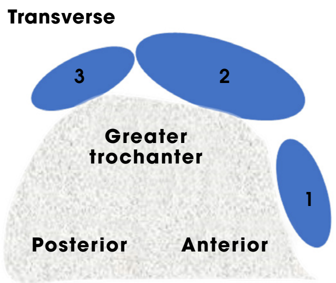


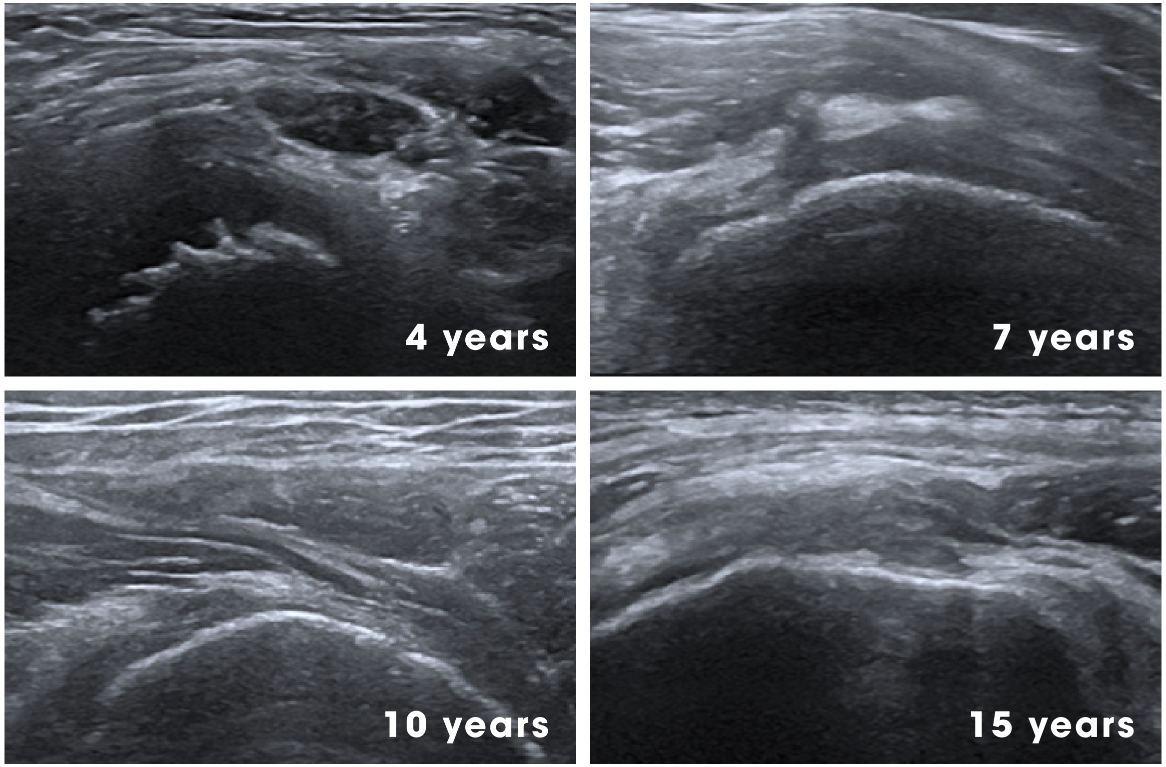
1 = Gluteus minimus
2 & 3 = Gluteus medius

TIP / The transverse scan helps to identify the different muscles/tendons

Scanning the hip - greater trochanter transverse

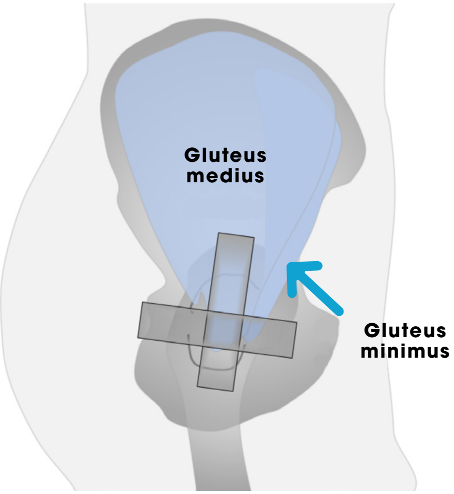




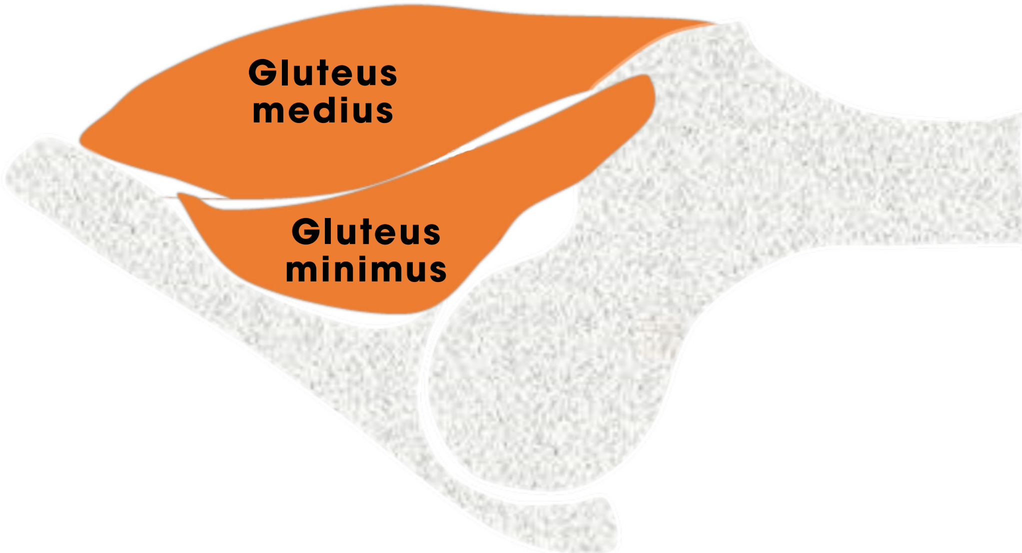


TIP / The transverse scan helps to identify the different muscles and muscle tendons. Avoid anisotropy

Scanning the hip - greater trochanter longitudinal



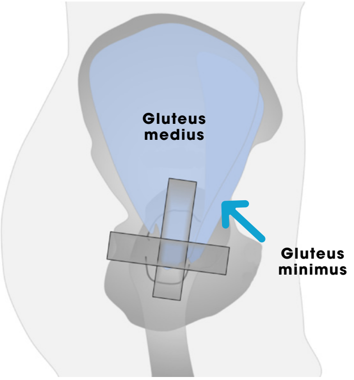
Longitudinal

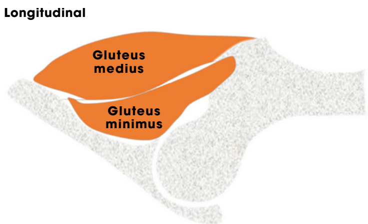


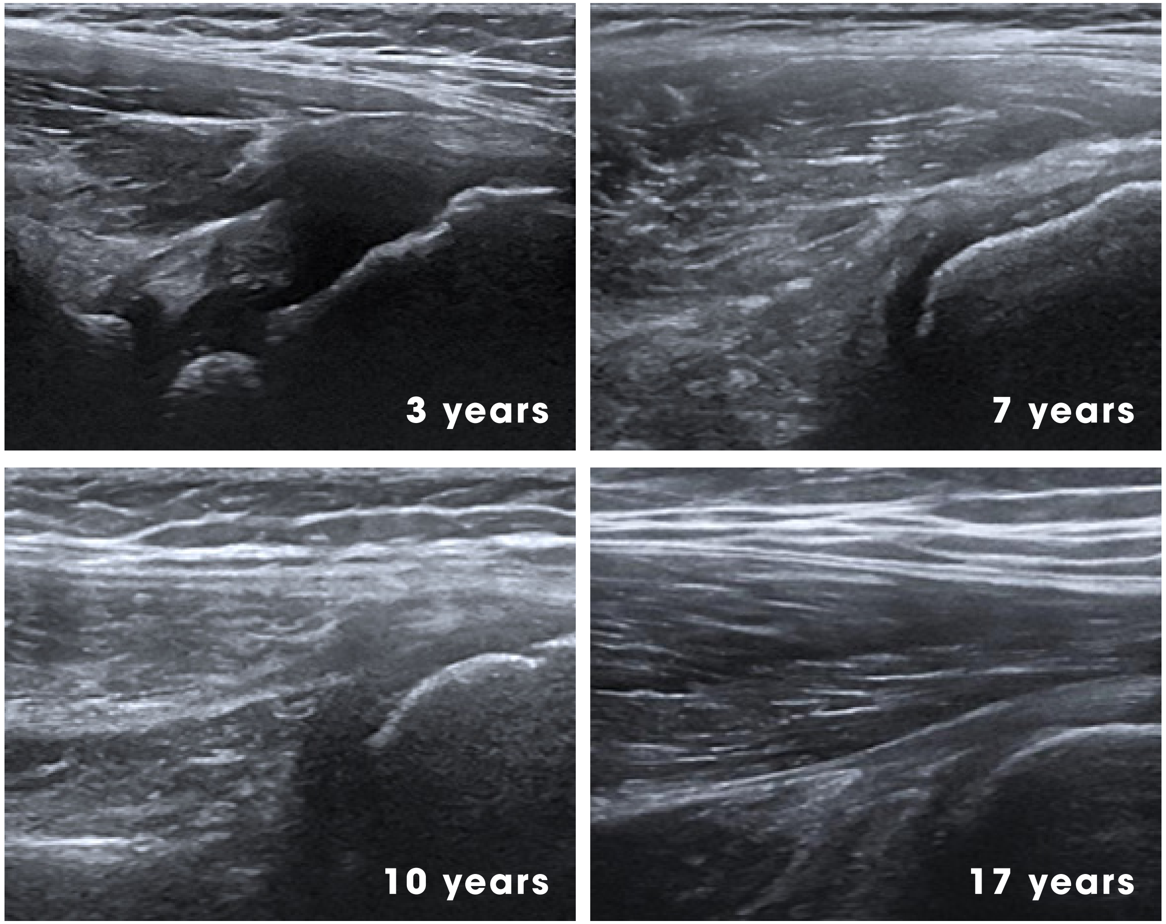
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the hip - greater trochanter longitudinal

HEALTHY PATHOLOGY





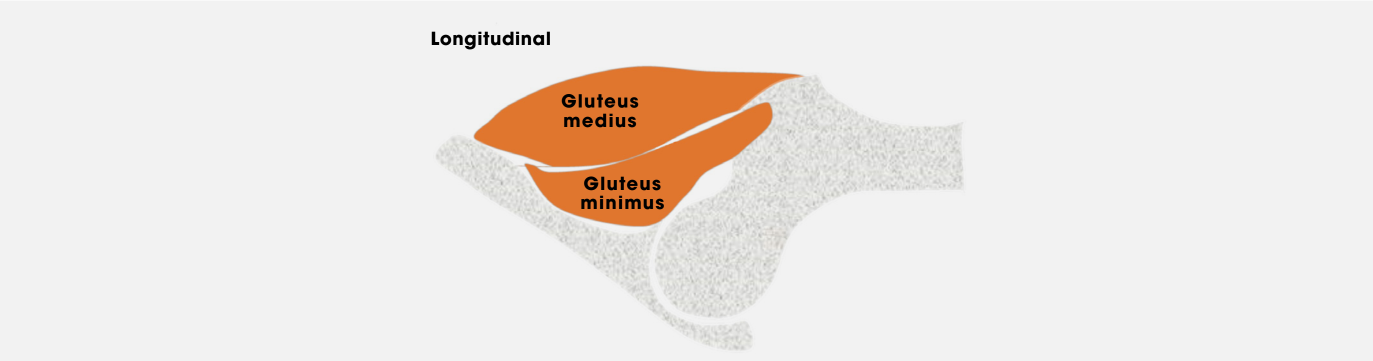


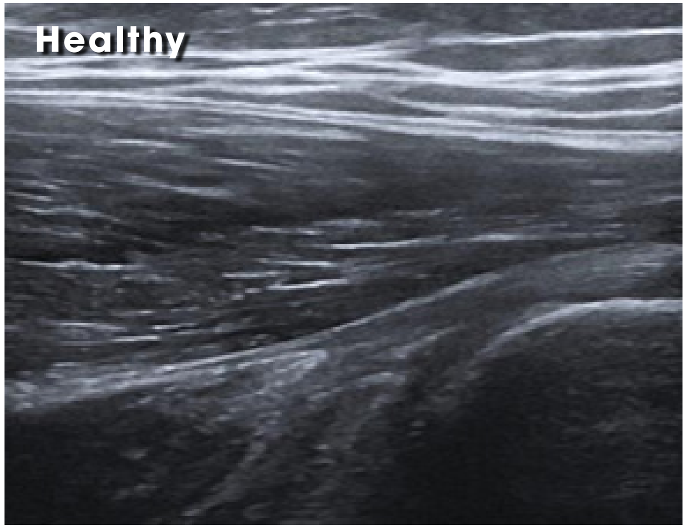
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Consider trochanteric enthesitis or bursitis in the case of pain in this region

Scanning the hip - greater trochanter longitudinal

HEALTHY PATHOLOGY

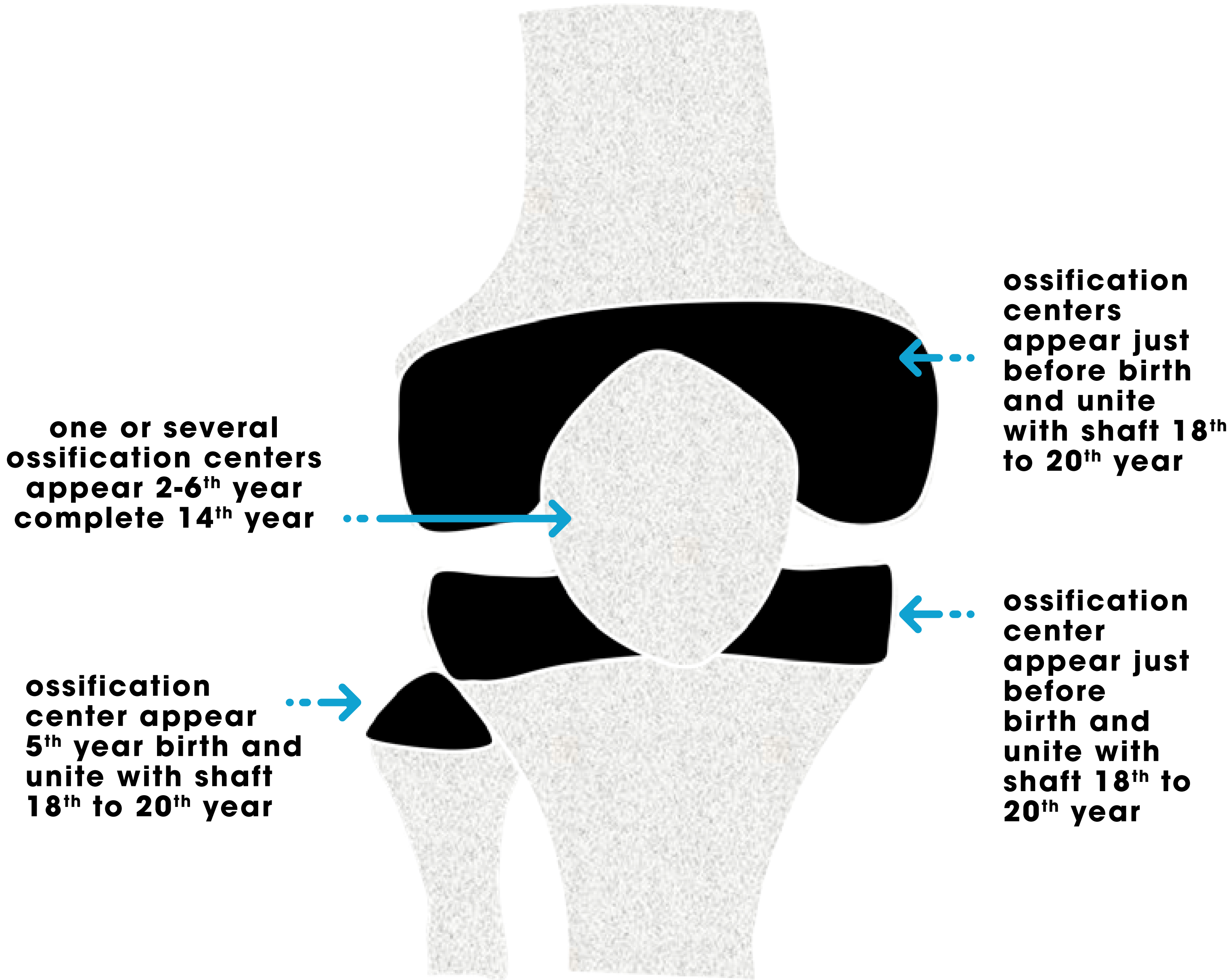




Trochanteric bursitis

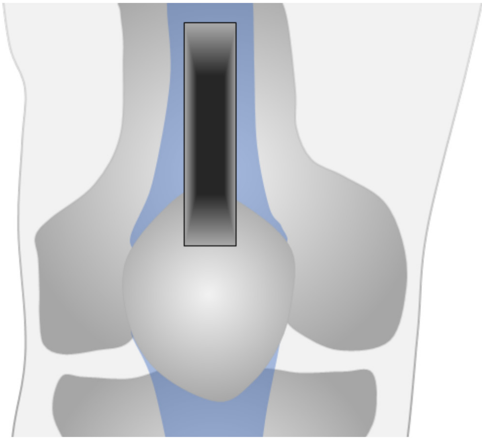
TIP / Consider trochanteric enthesitis or bursitis in the case of pain in this region

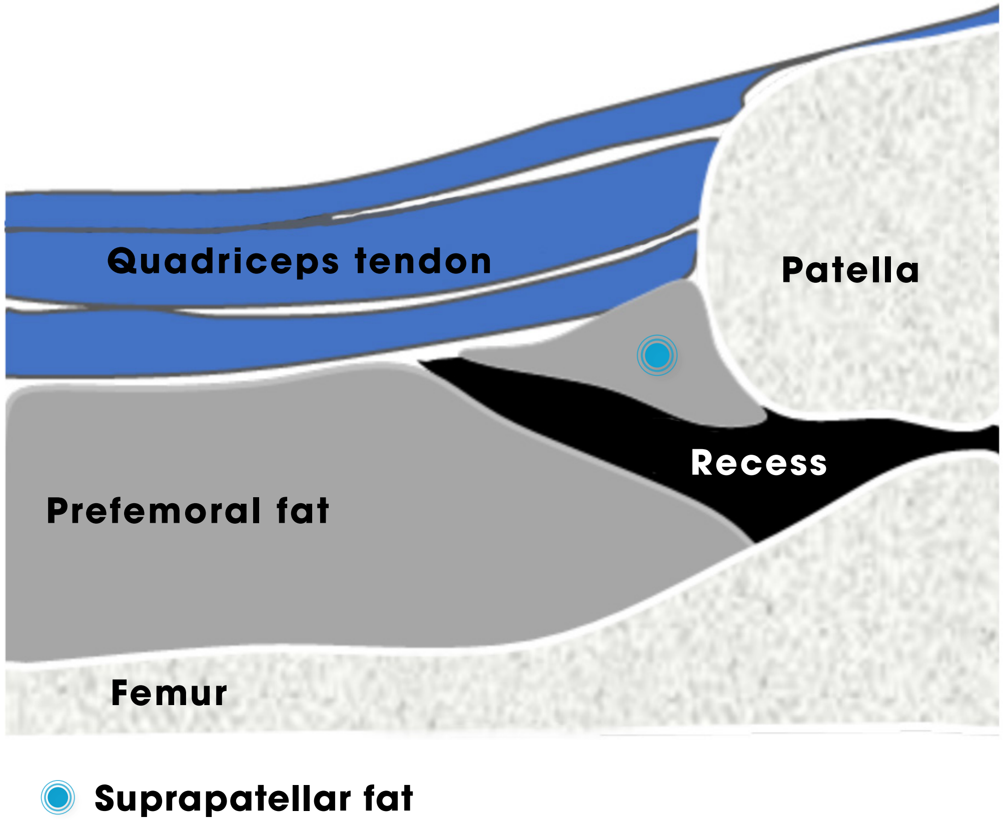
Knee ossification



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the knee - suprapatellar long





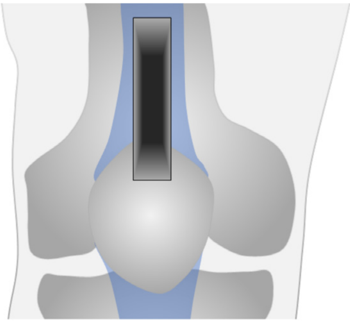
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

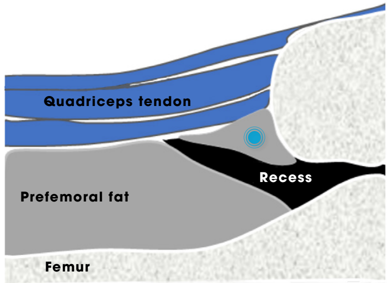
TIP / Bend and flex the knee 3 times before doing the scan in a 30° flexion position

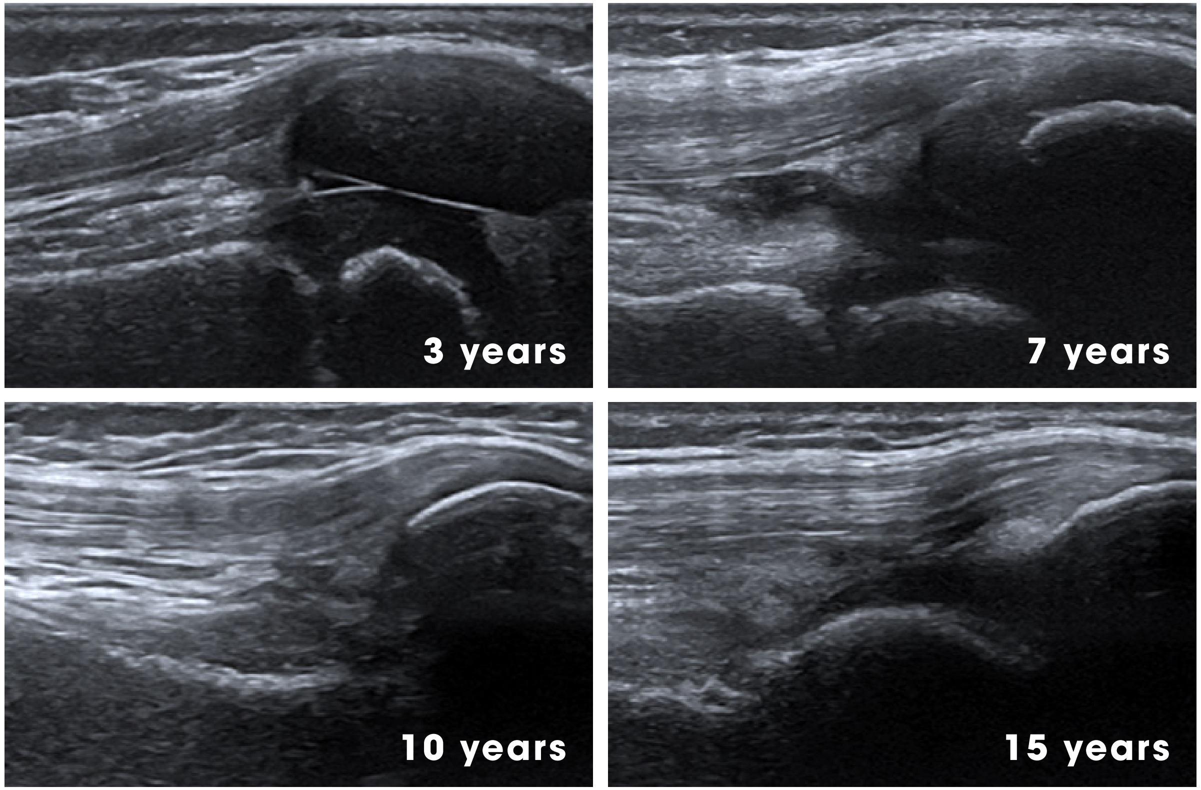
All knee illustrations were designed based on illustrations by Carlo Martinoli, Genoa.

Scanning the knee - suprapatellar long

HEALTHY PATHOLOGY





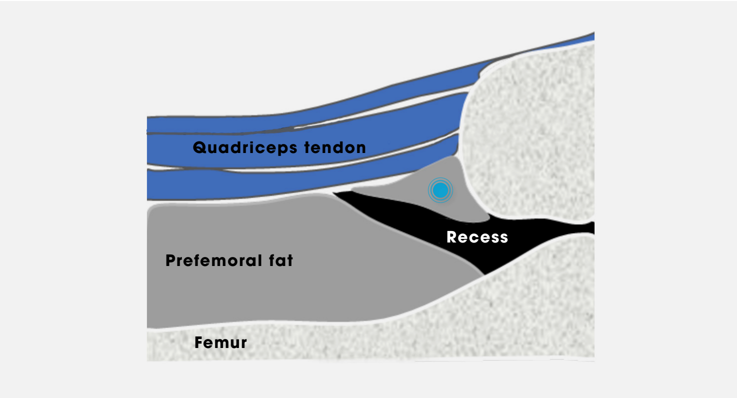


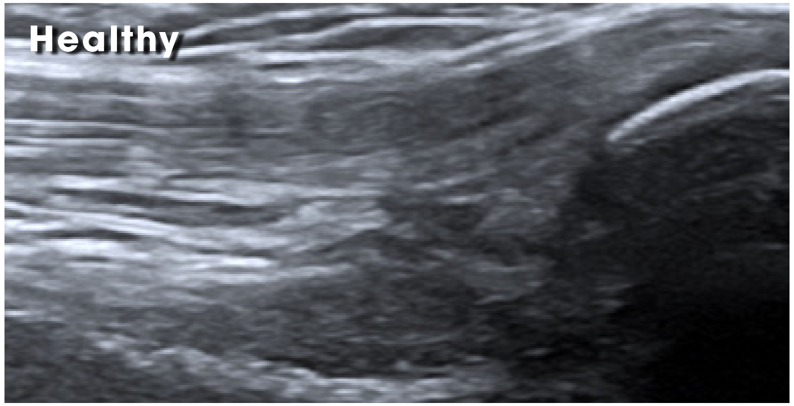
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

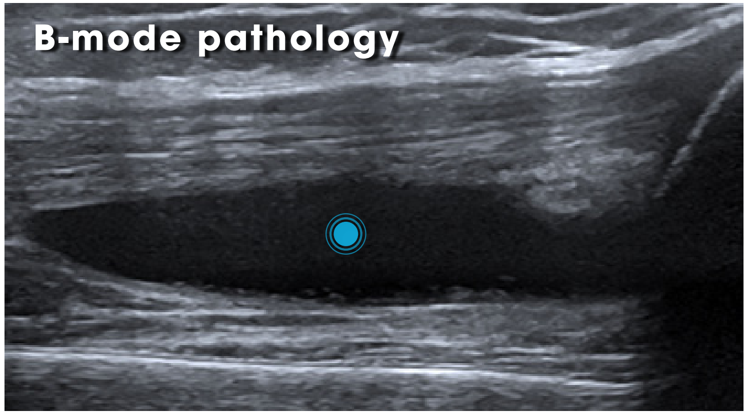
TIP / Physiological fluid may be visible in the suprapatellar recess

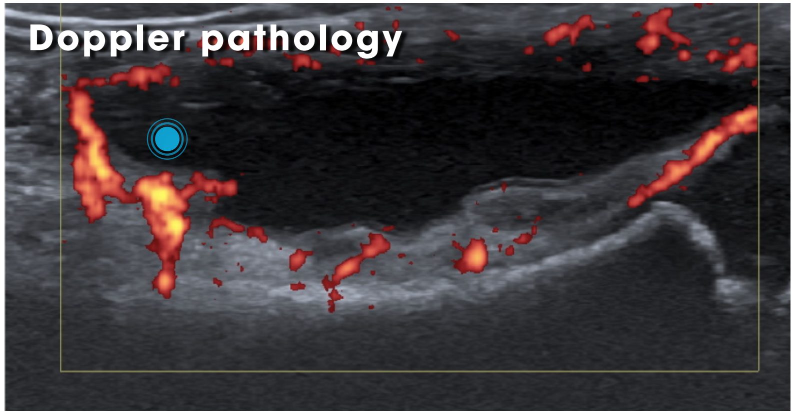
Scanning the knee - suprapatellar long

HEALTHY PATHOLOGY









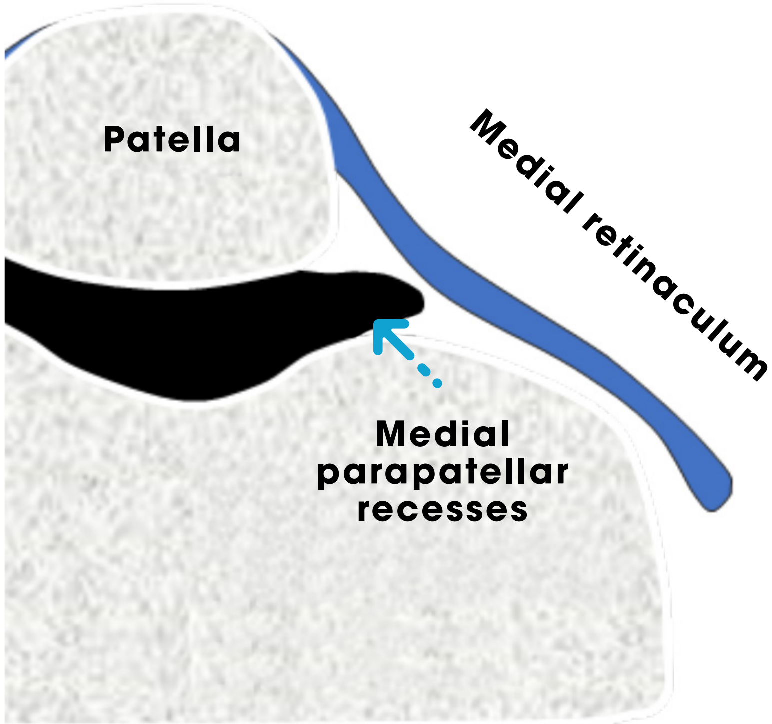
Effusion

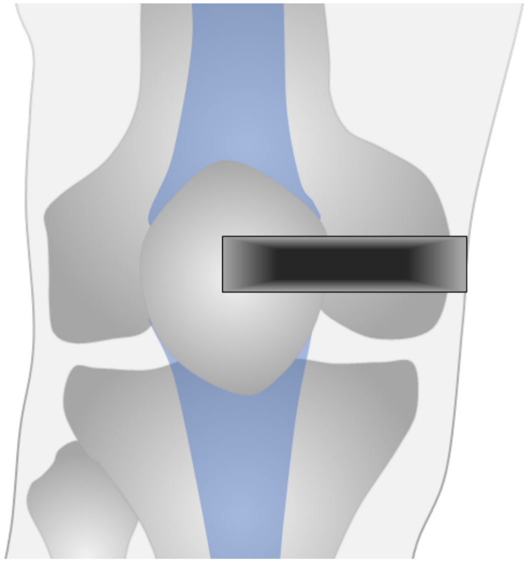
Effusion and increased Doppler signals

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

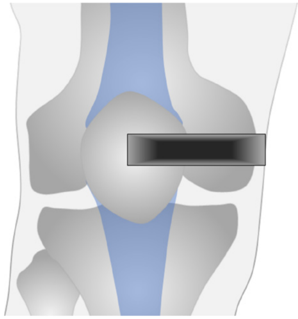
TIP / Dynamic examination helps to detect smaller amounts of fluid

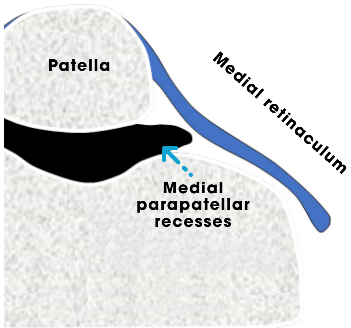
Scanning the knee - parapatellar medial



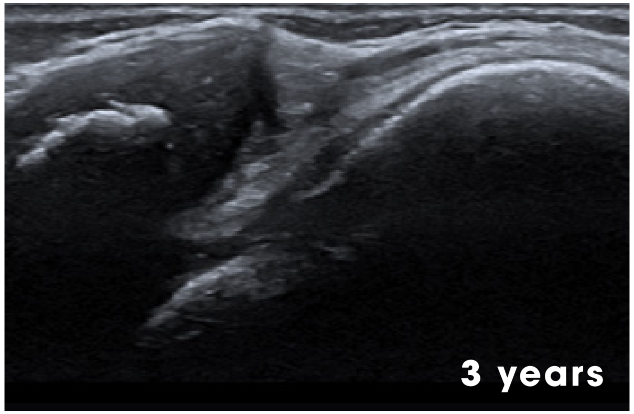


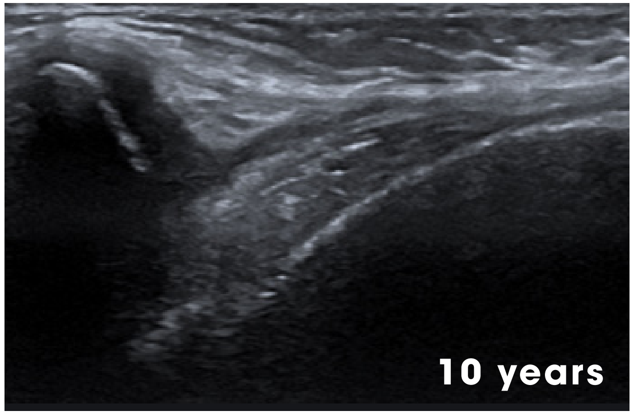
Scanning the knee - parapatellar medial

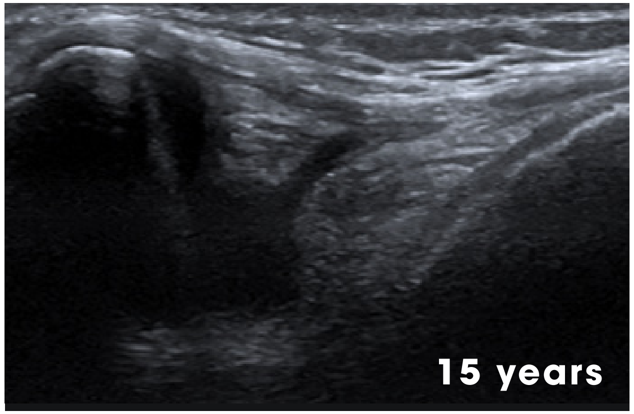




HEALTHY PATHOLOGY



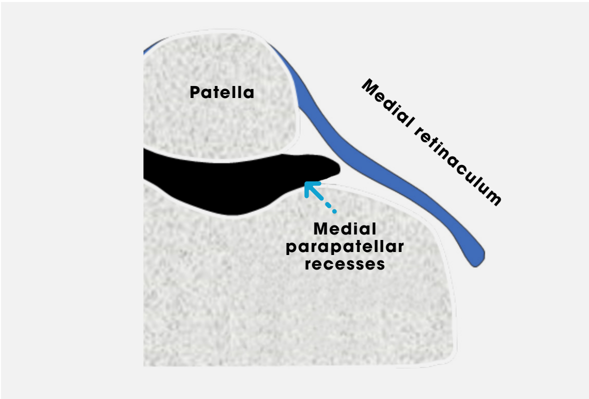


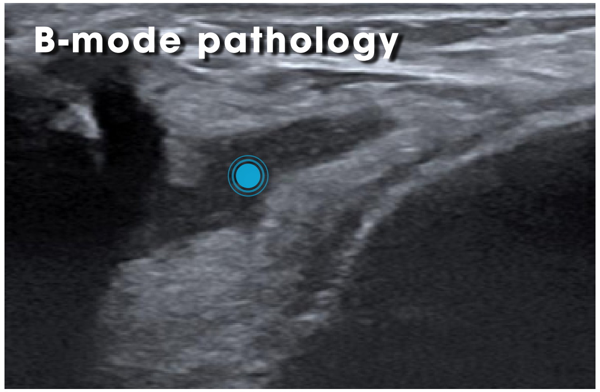


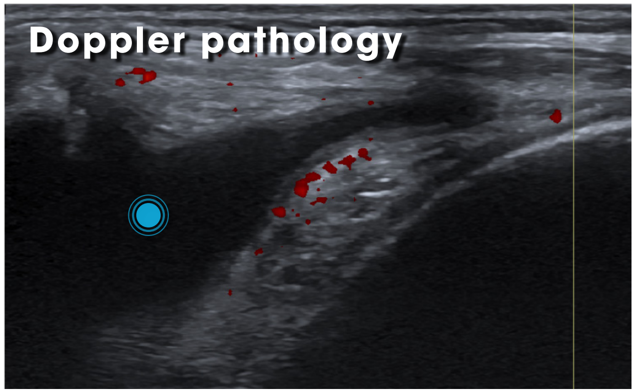
TIP / A small amount of fluid is often detected in healthy children

Scanning the knee - parapatellar medial

HEALTHY | PATHOLOGY







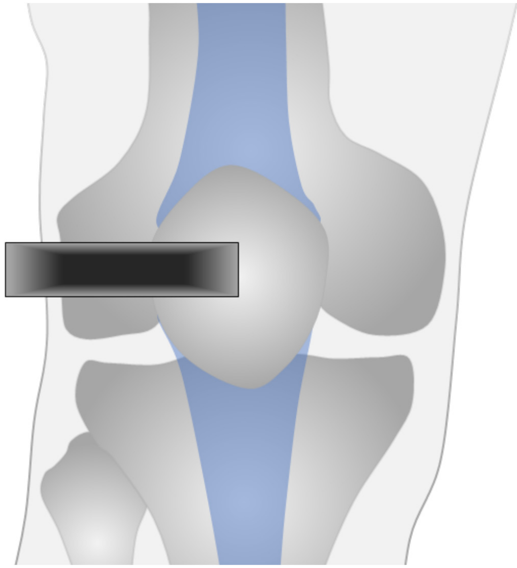
Effusion

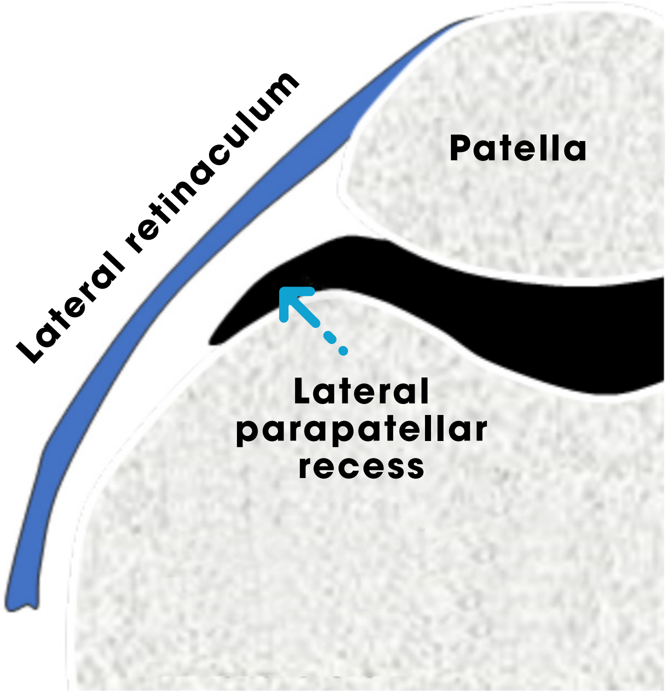
Effusion and increased Doppler signals

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

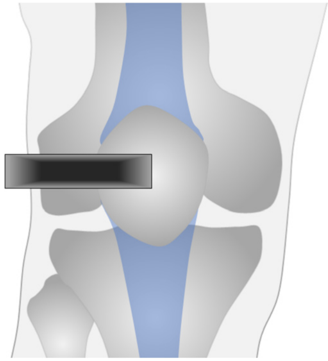
TIP / The parapatellar medial scan is very helpful to detect synovial hypertrophy and much more sensitive to detect hypervascularization in the knee on Doppler than the suprapatellar scan

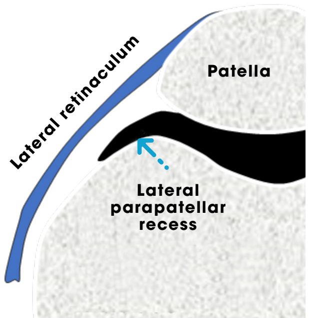
Scanning the knee - parapatellar lateral



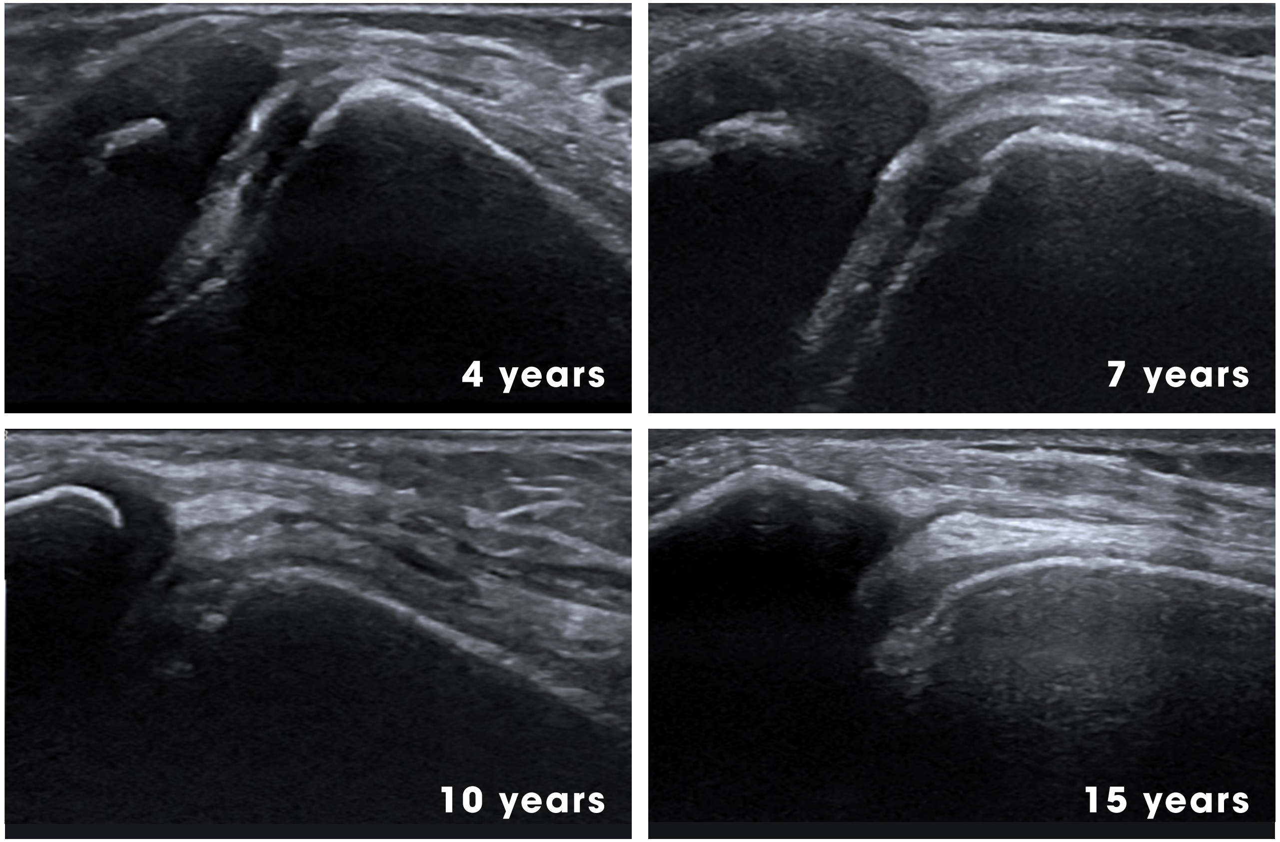


Scanning the knee - parapatellar lateral





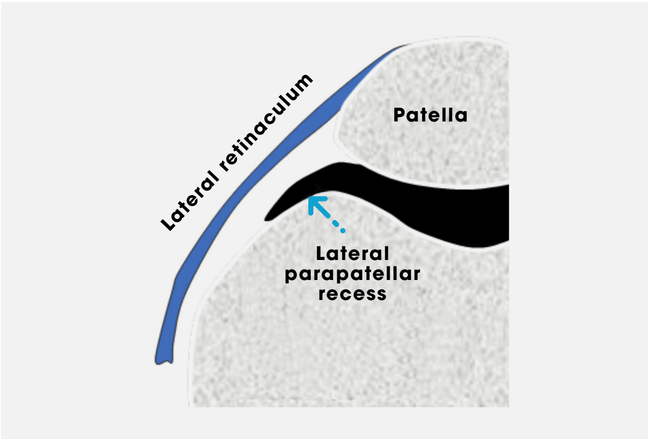
HEALTHY PATHOLOGY

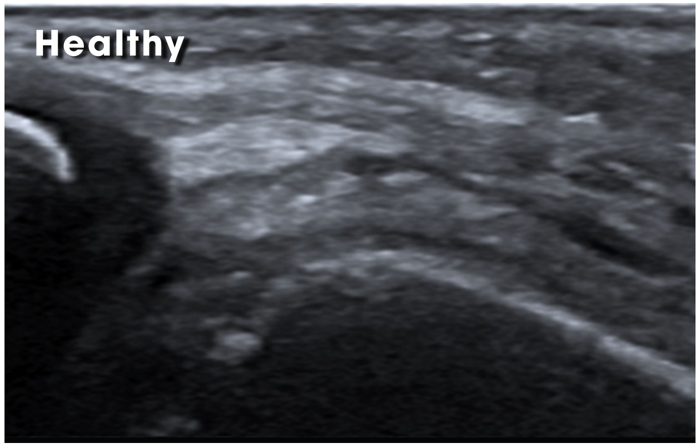


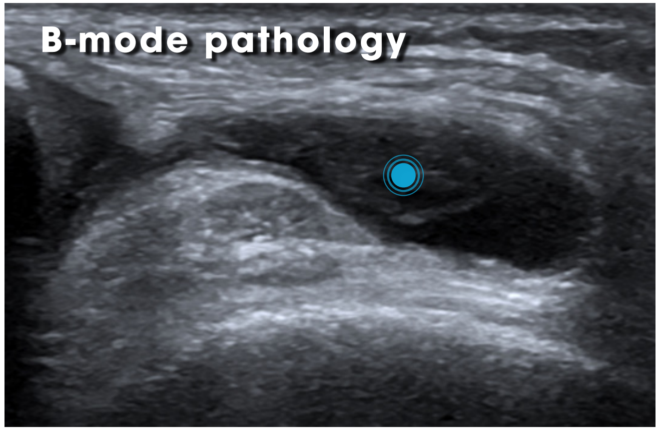
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

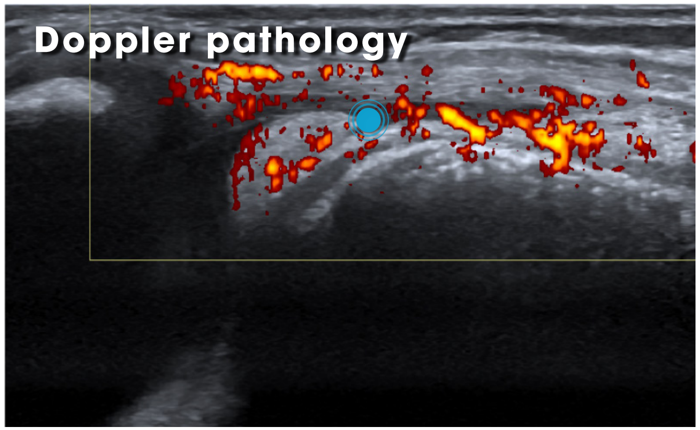
TIP / A small amount of fluid is often detected in healthy children

Scanning the knee - parapatellar lateral







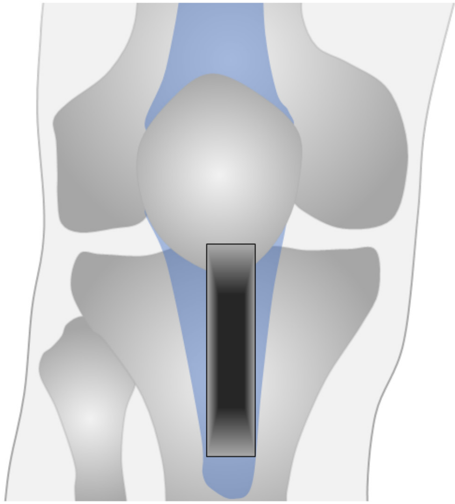


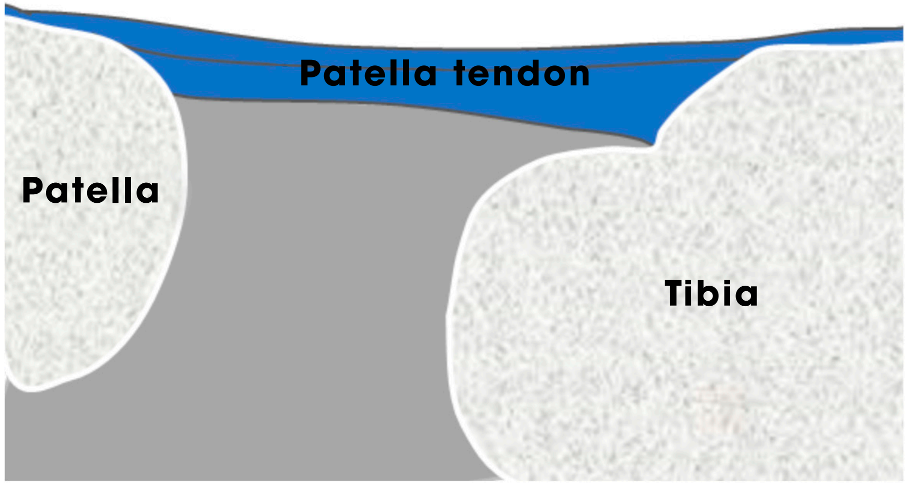
Effusion

Synovial proliferation with increased Doppler signals

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

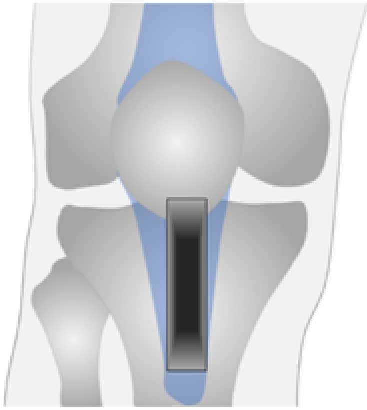
Scanning the knee - infrapatellar long

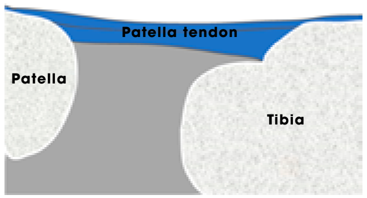




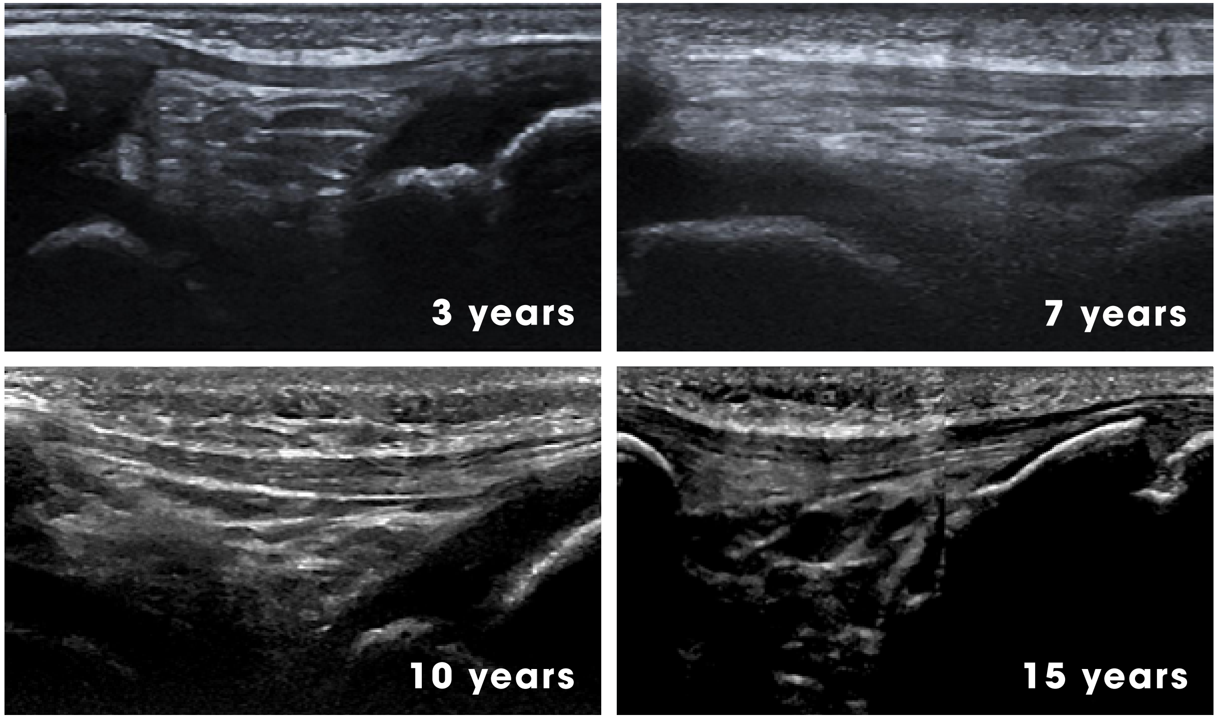
TIP / Dynamic examination is helpful to detect bursitis and enthesitis

Scanning the knee - infrapatellar long





HEALTHY PATHOLOGY

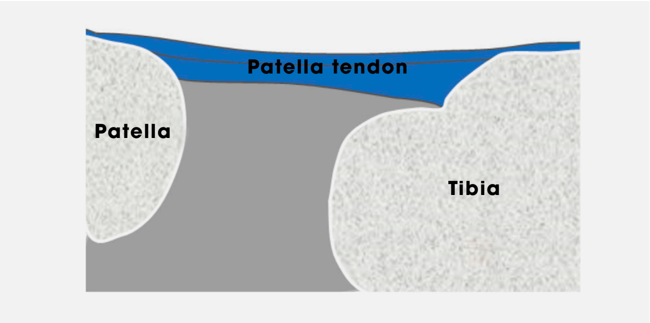


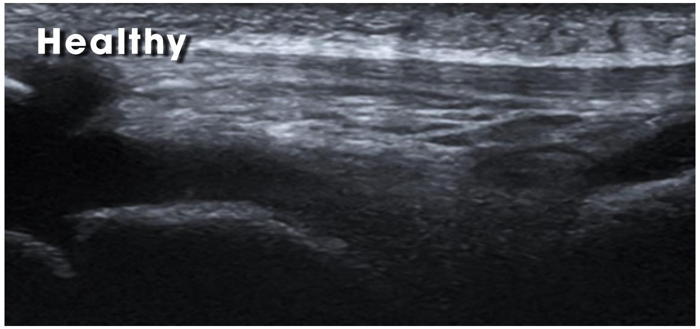
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Dynamic examination is helpful to detect bursitis and enthesitis

Scanning the knee - infrapatellar long

HEALTHY PATHOLOGY

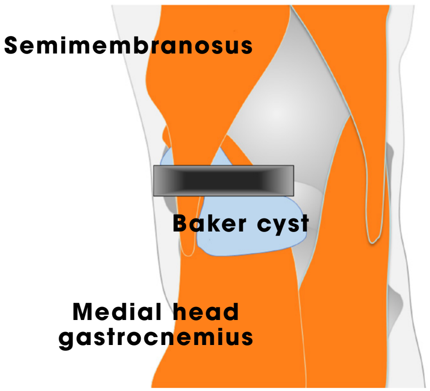


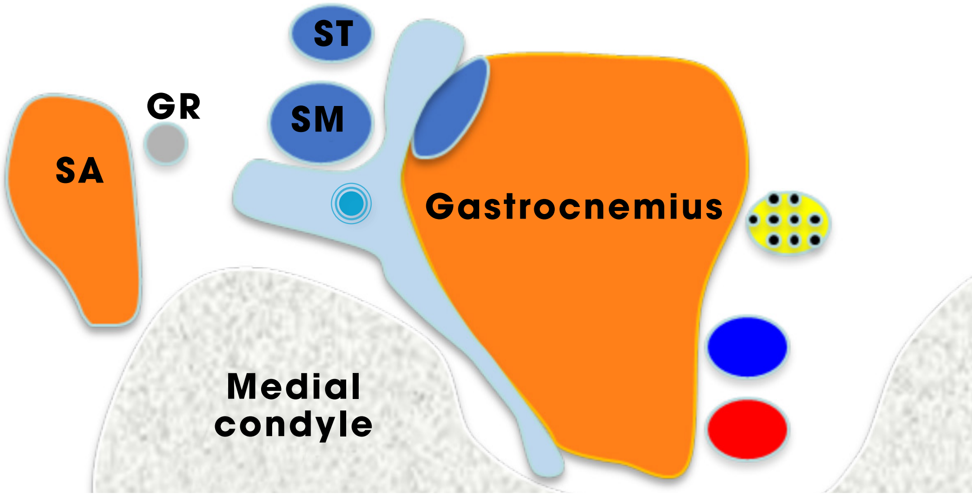


Bursitis infrapatellaris profunda

TIP / Bursitis infrapatellaris profunda can be found in children with JIA

Scanning the knee - transverse posterior





GR, gracilis tendon; SA, sartorius muscle;
SM, semimembranosus tendon;
ST, semitendinosus tendon

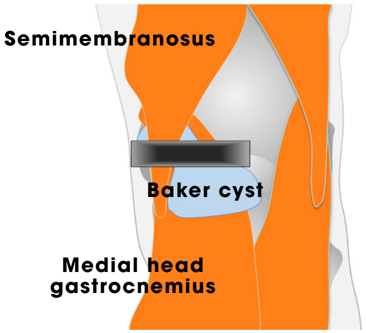
Baker cyst

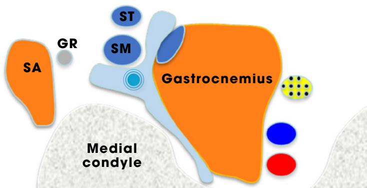
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Check the whole intercondylar region dynamically

Illustration designed based on illustration by Carlo Martinoli, Genoa

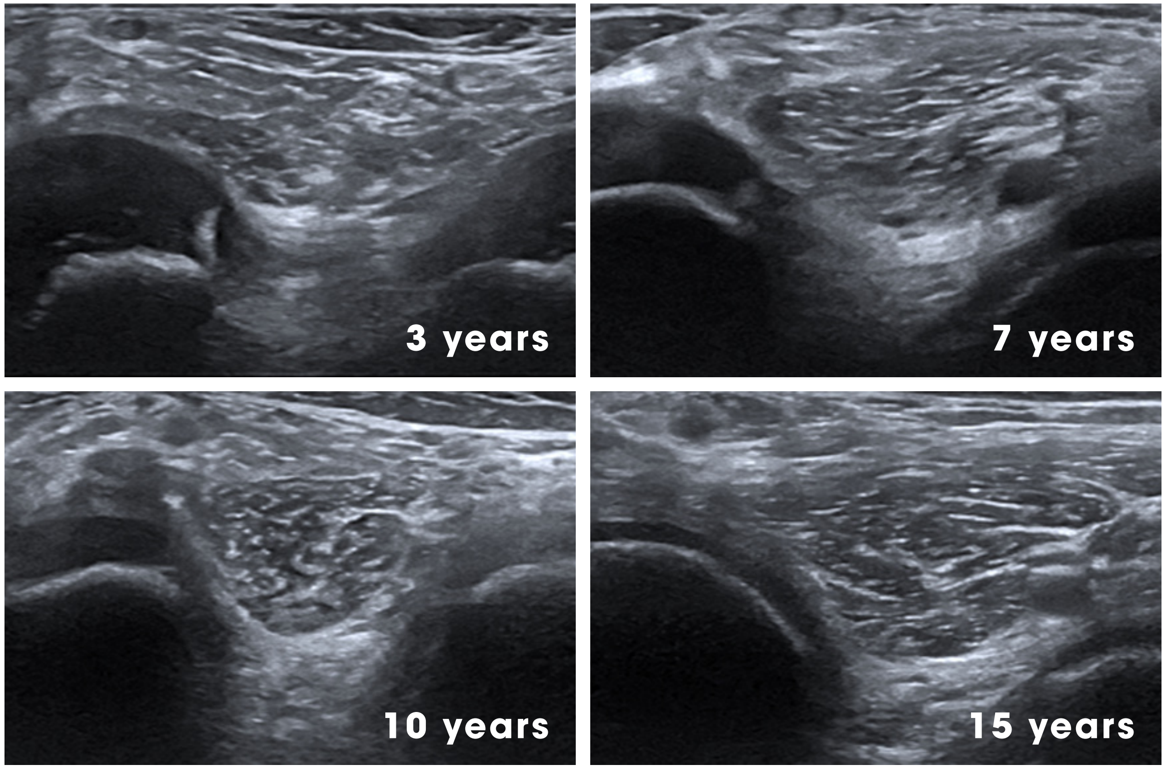
Scanning the knee - transverse posterior





GR, gracilis tendon; SA, sartorius muscle; SM, semimembranosus tendon; ST, semitendinosus tendon
● Baker cyst

HEALTHY | PATHOLOGY

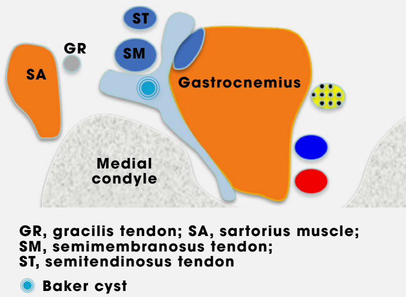


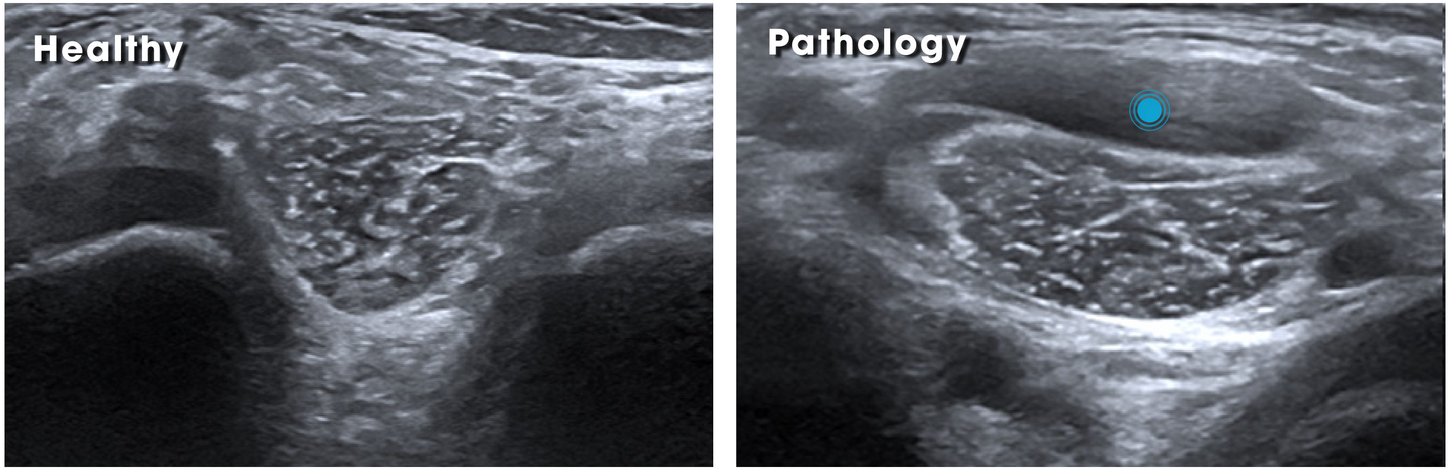
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Check the whole intercondylar region dynamically

Scanning the knee - transverse posterior

HEALTHY PATHOLOGY

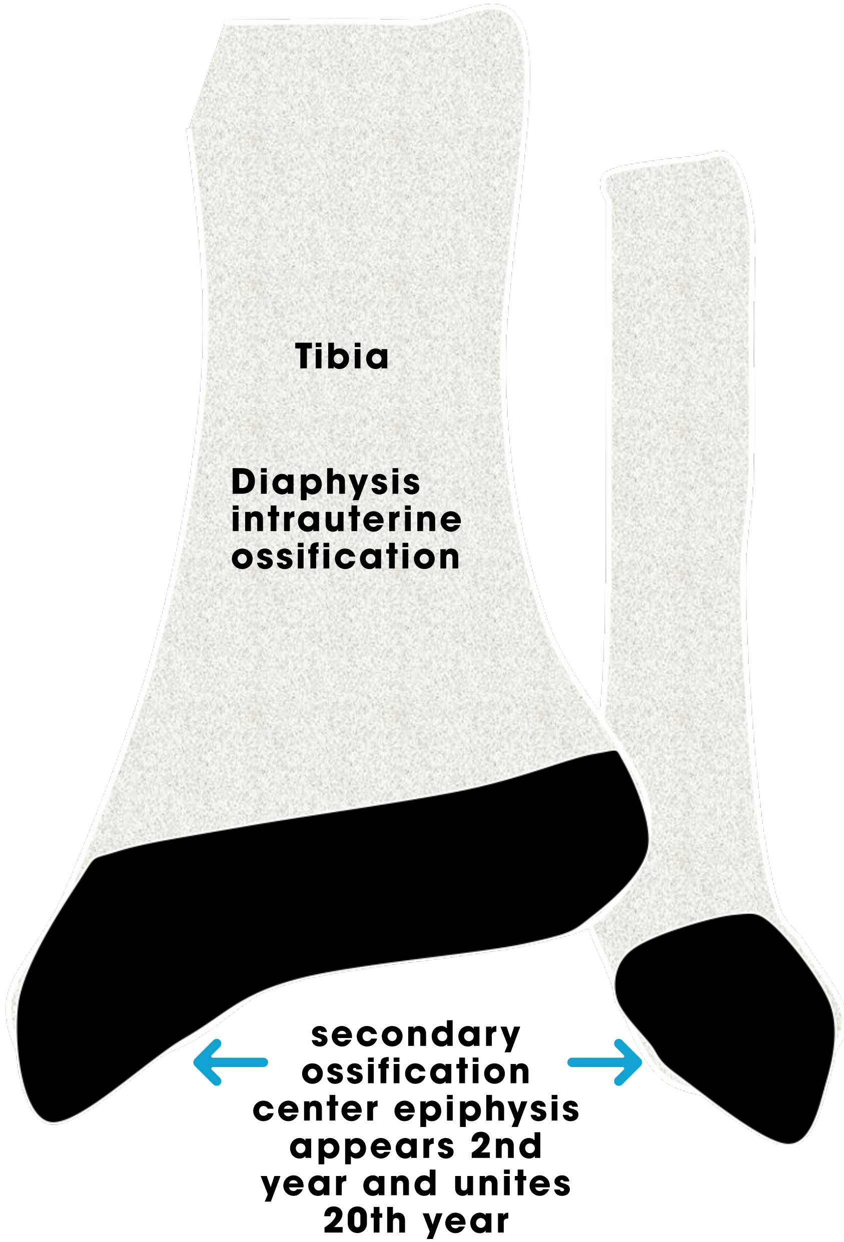




Popliteal cyst (Baker‘s cyst)

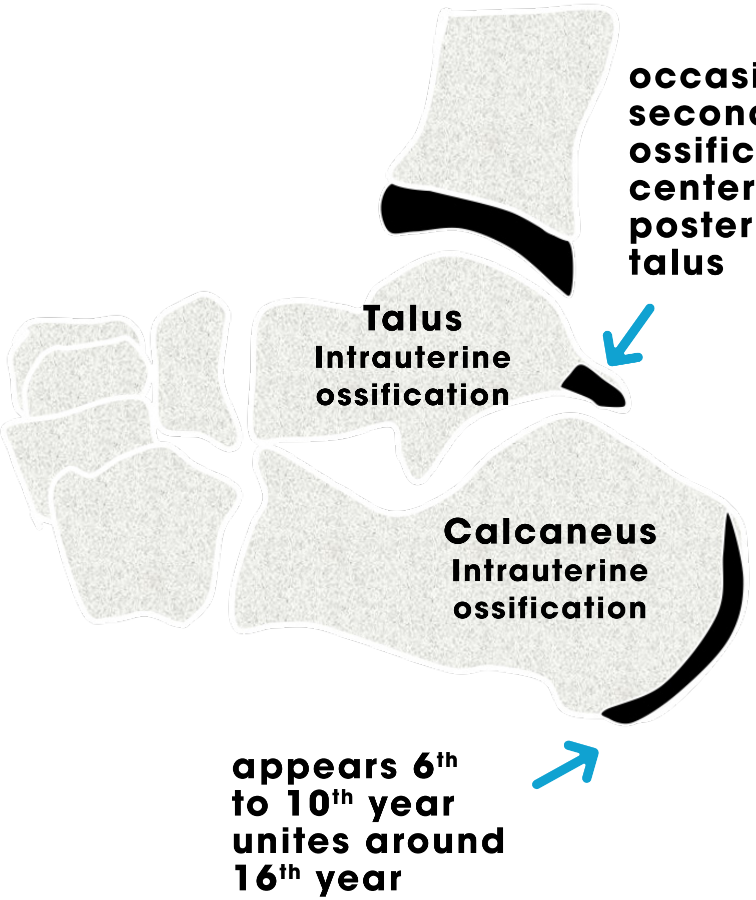
TIP / The echostructure and dimension of popliteal cysts can be variable

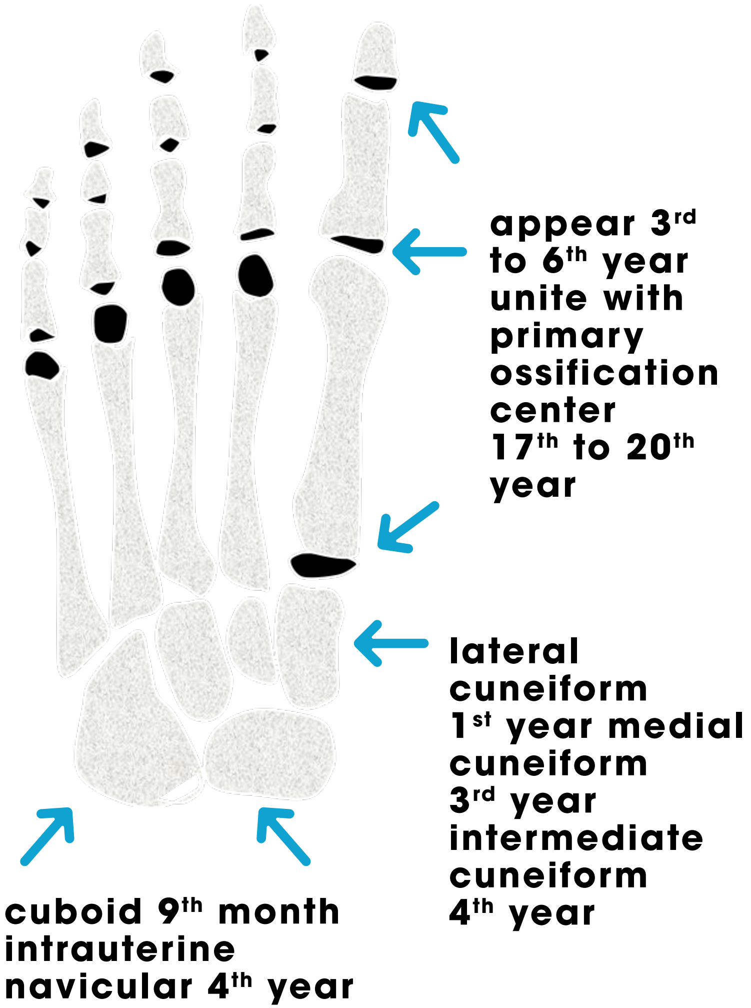
Ankle and foot ossification I



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

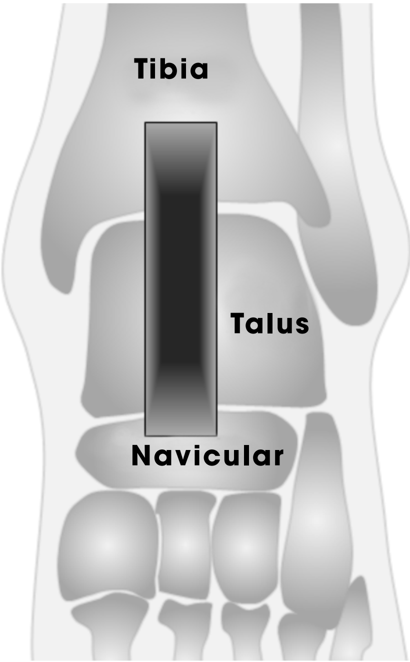
Ankle and foot ossification II

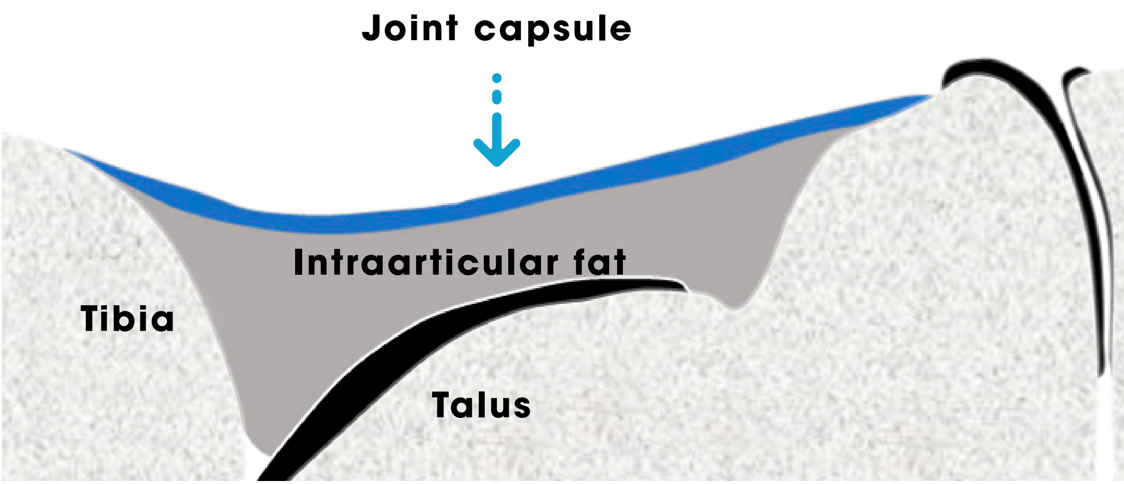




SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

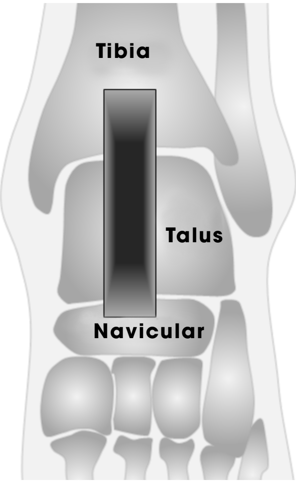
Scanning the ankle - tibiotalar long

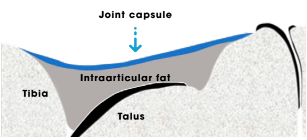




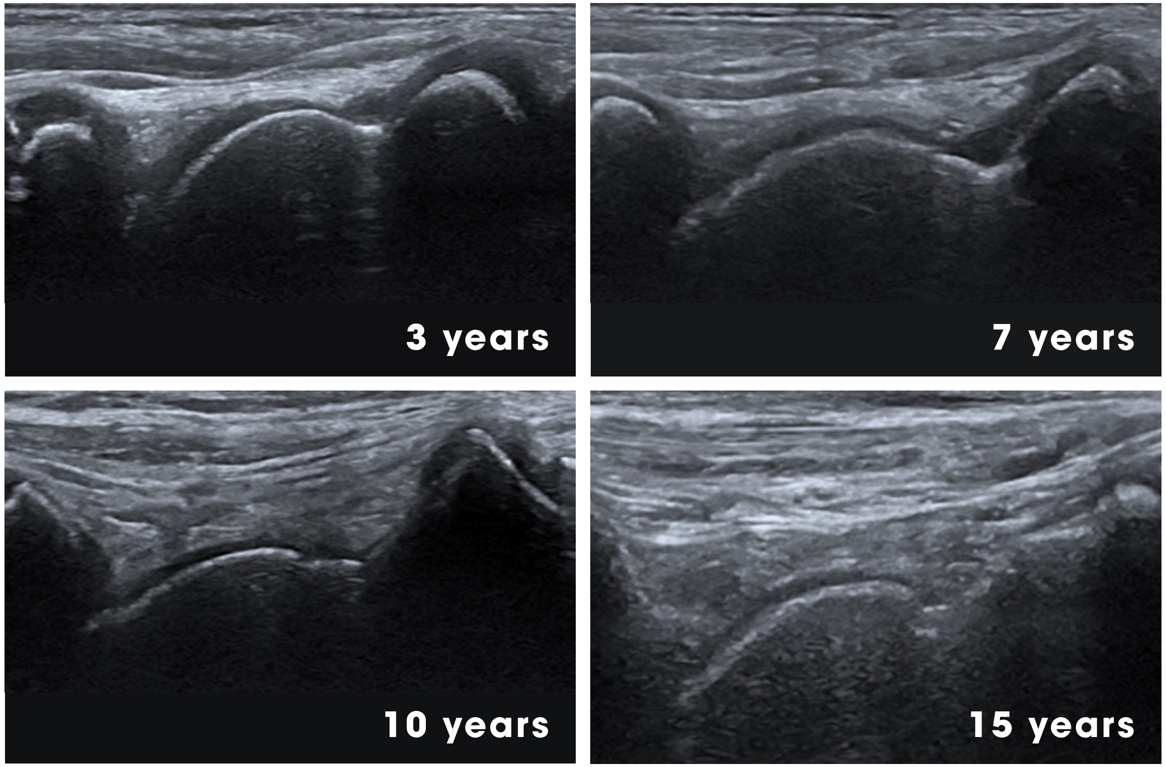
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the ankle - tibiotalar long





HEALTHY PATHOLOGY



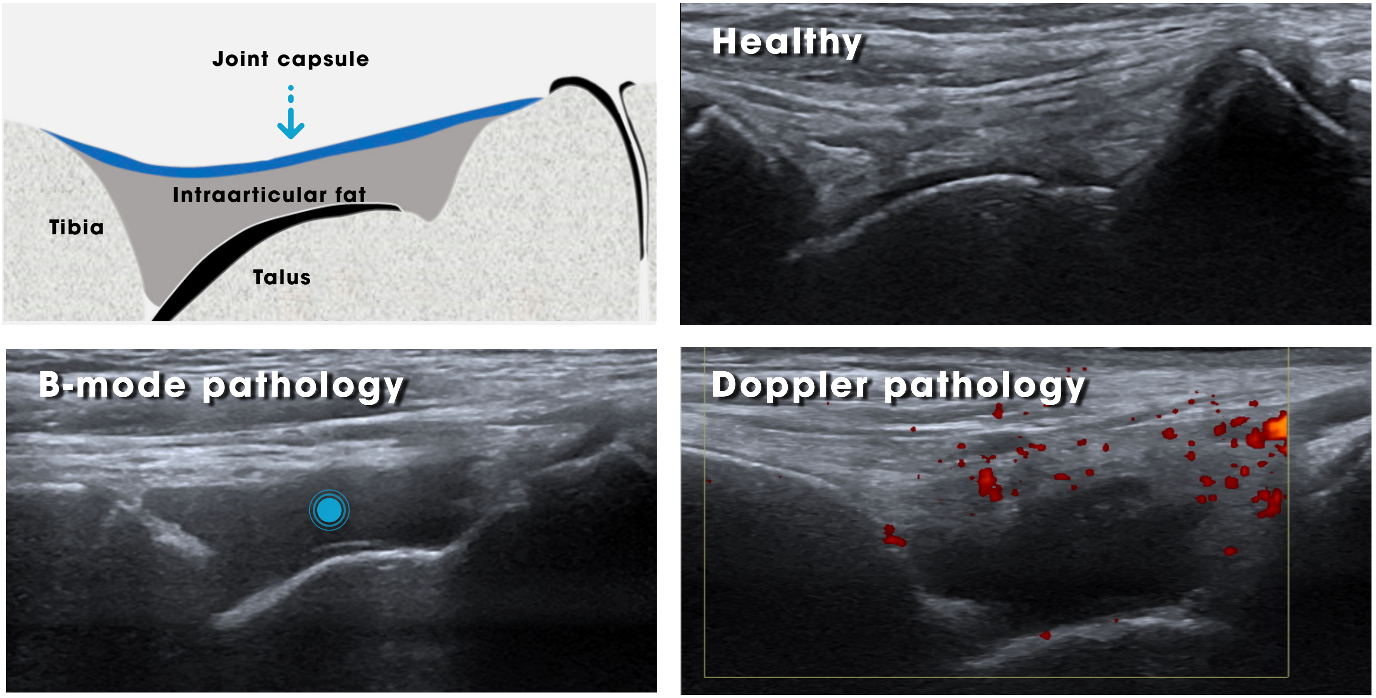
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIPS /

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

Scanning the ankle - tibiotalar long

HEALTHY | PATHOLOGY

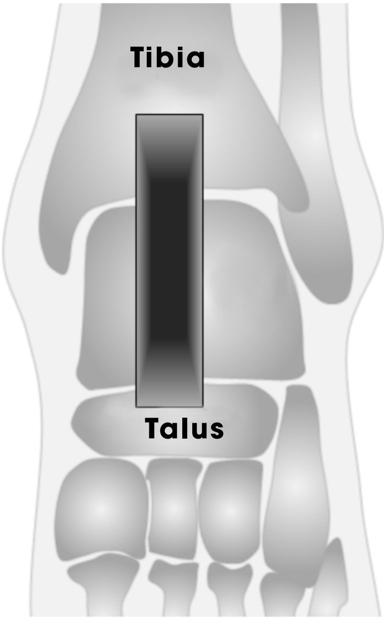


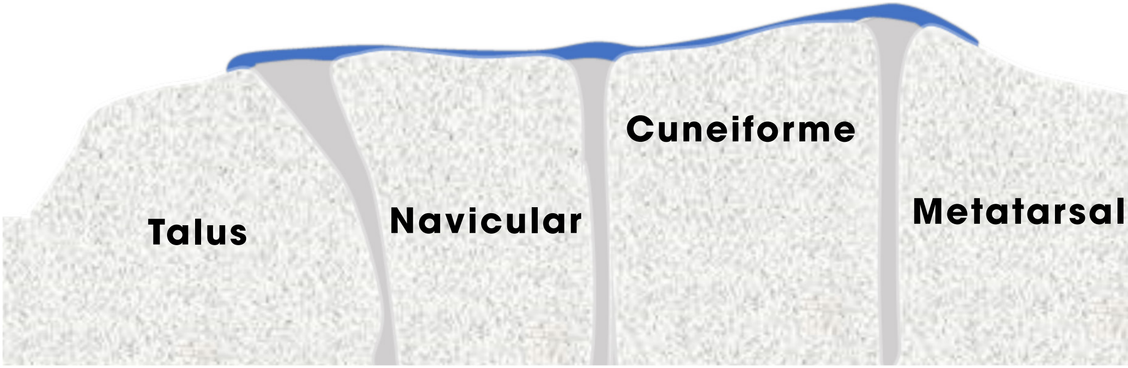
Tibiotalar synovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

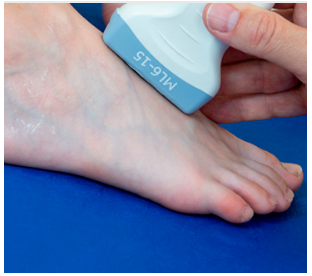


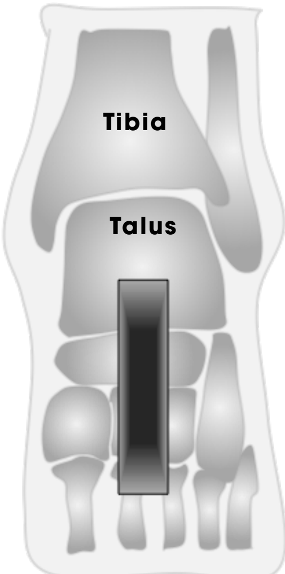


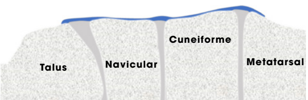
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Move the probe medially and laterally to cover the entire midfoot area

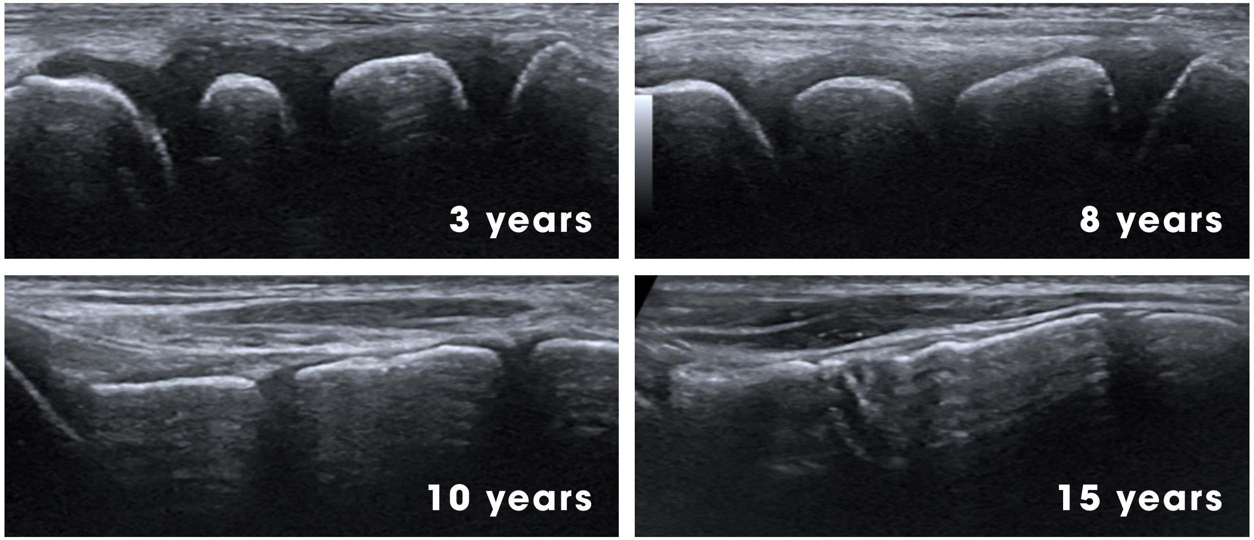
Scanning the ankle - midfoot long







HEALTHY
PATHOLOGY

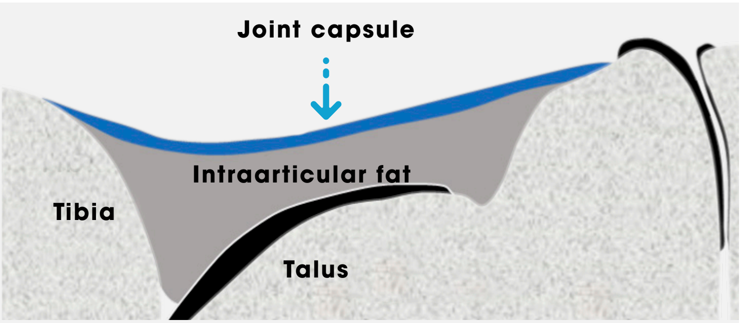


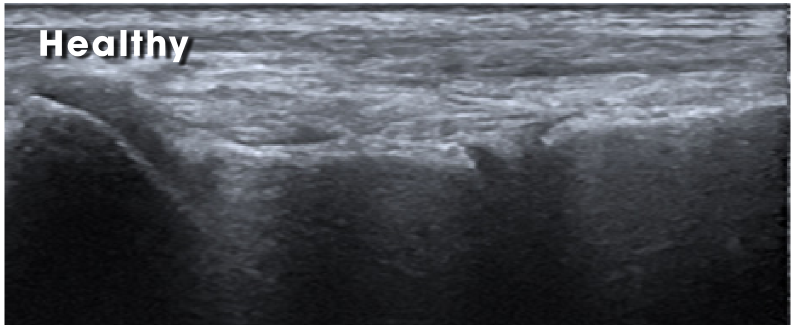
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Move the probe medially and laterally to cover the entire midfoot area

Scanning the ankle - midfoot long

HEALTHY PATHOLOGY



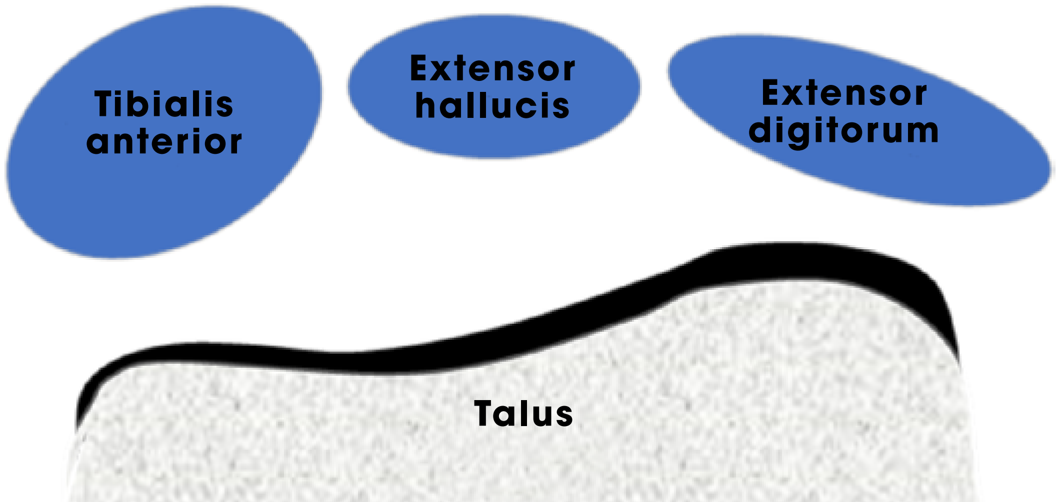


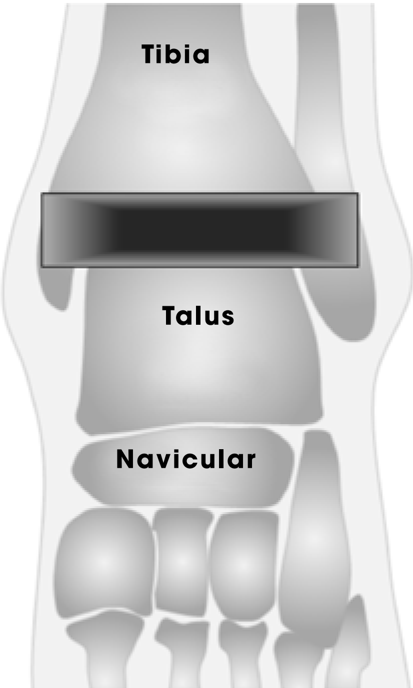
Midfoot synovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

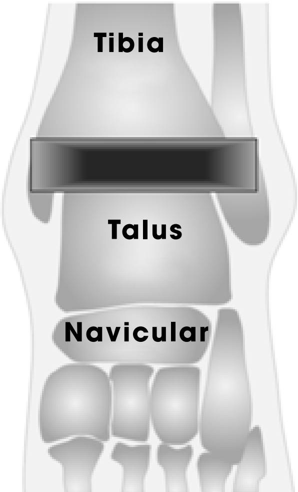
TIP / Move the midfoot to detect small amounts of effusion

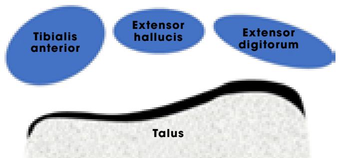
Scanning the ankle - anterior tendons in transverse



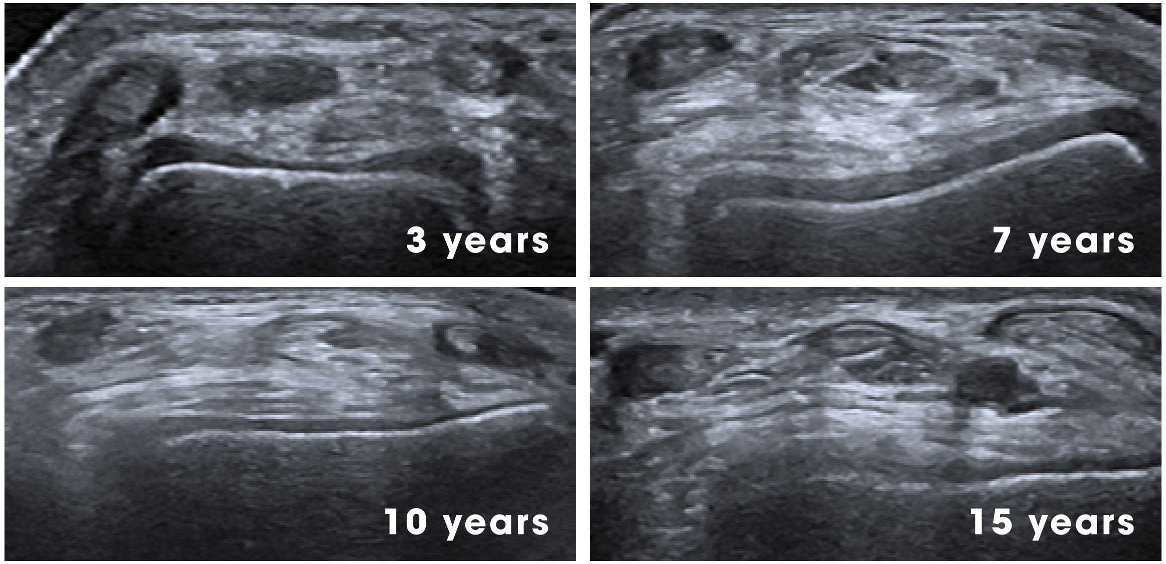


Scanning the ankle - anterior tendons in transverse





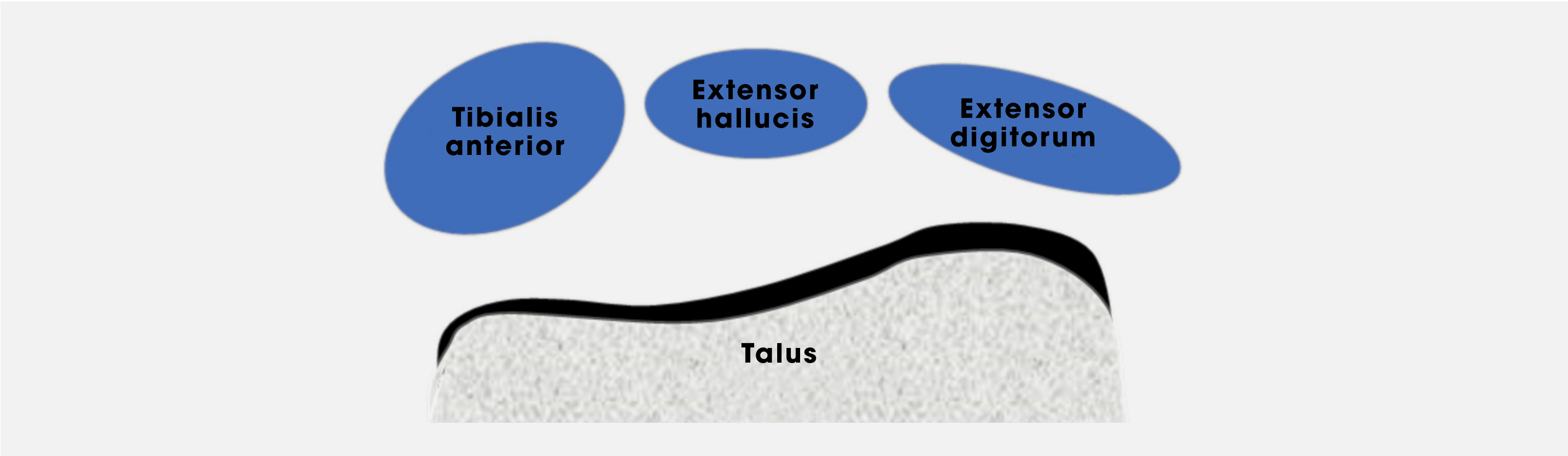
HEALTHY PATHOLOGY

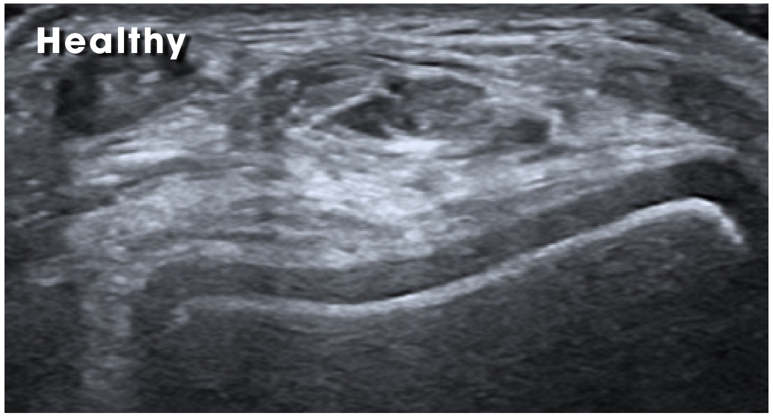


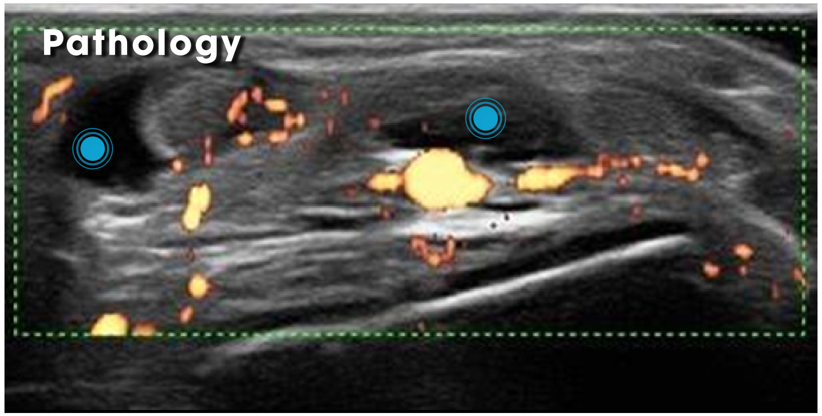
TIP / The myotendinous junction especially for the extensor hallucis longus can be quite distal and should not be confused with tenosynovitis

Scanning the ankle - anterior tendons in transverse

HEALTHY PATHOLOGY

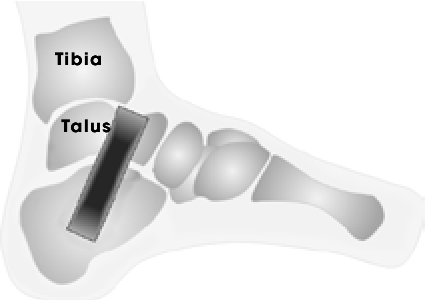


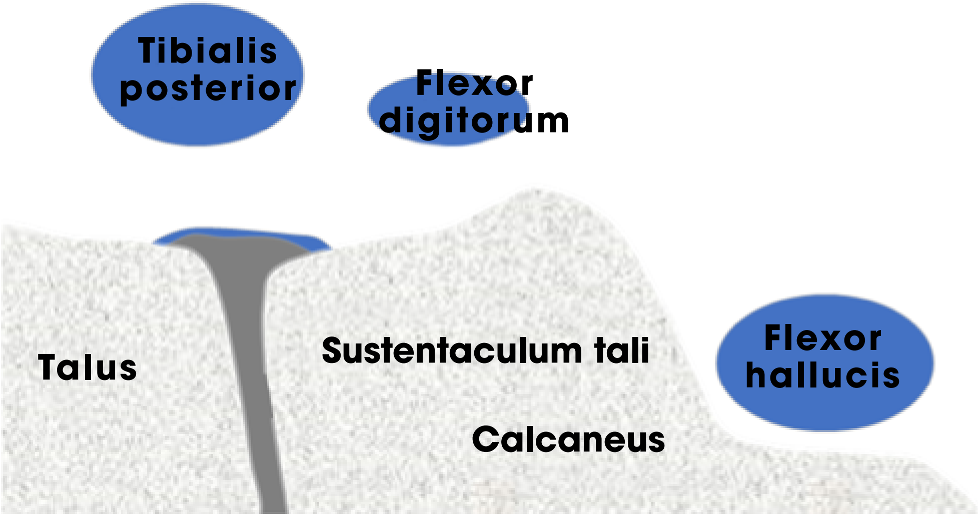




Extensor tenosynovitis

Scanning the ankle - subtalar medial

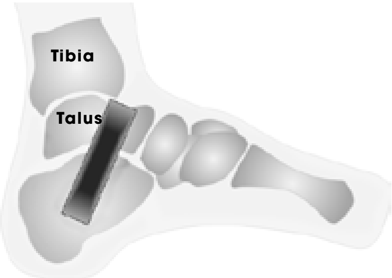


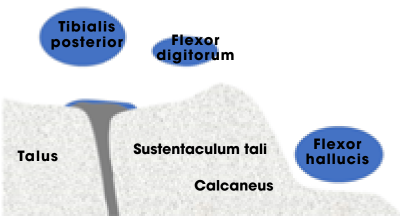


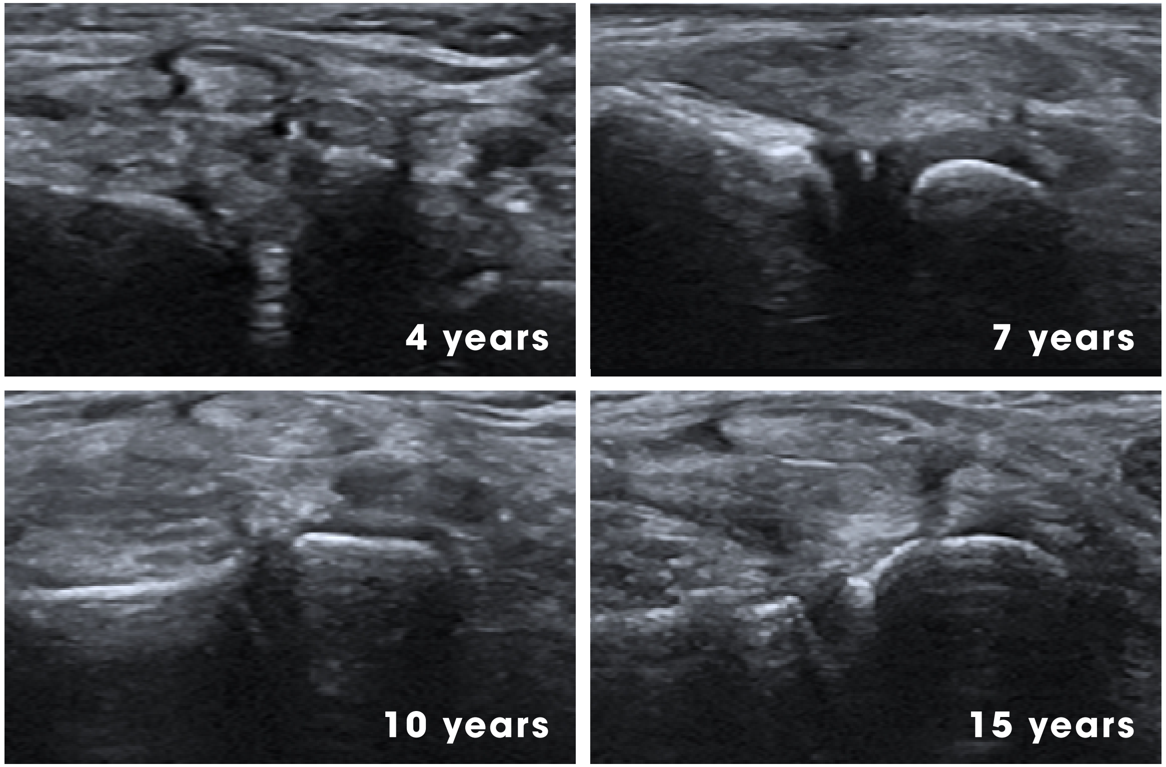
TIP / Use the prominent sustentaculum tali as anatomic landmark

Scanning the ankle - subtalar medial

HEALTHY PATHOLOGY



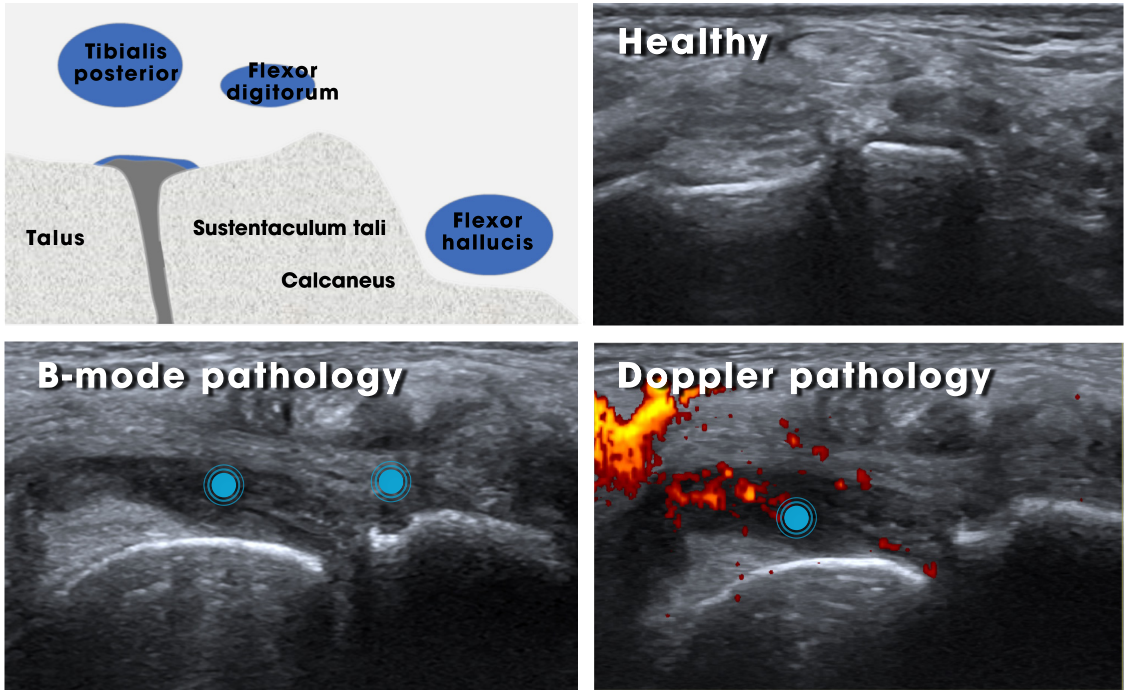




TIP / Use the prominent sustentaculum tali as anatomic landmark

Scanning the ankle - subtalar medial

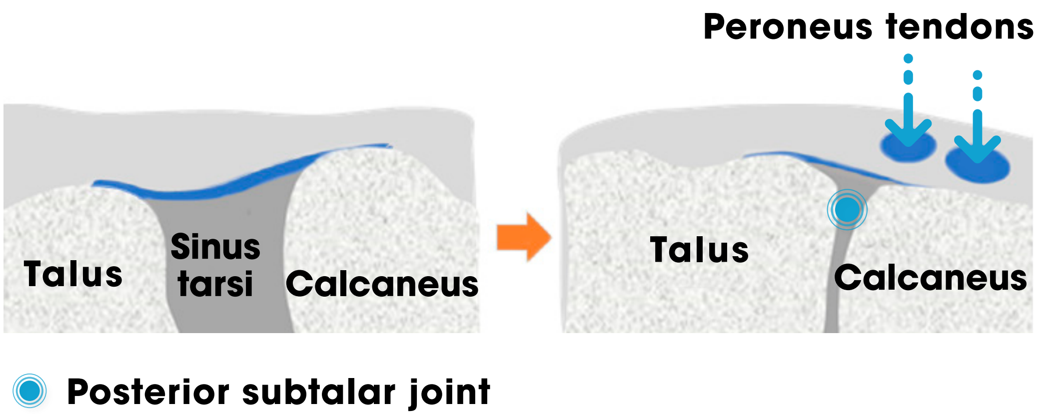
HEALTHY PATHOLOGY

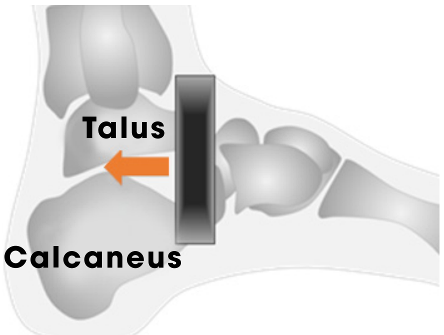


Subtalar synovitis

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



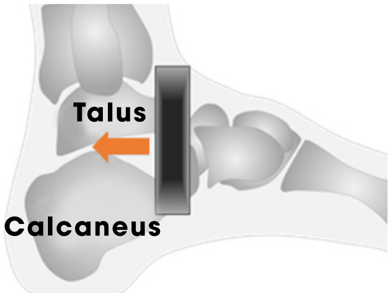


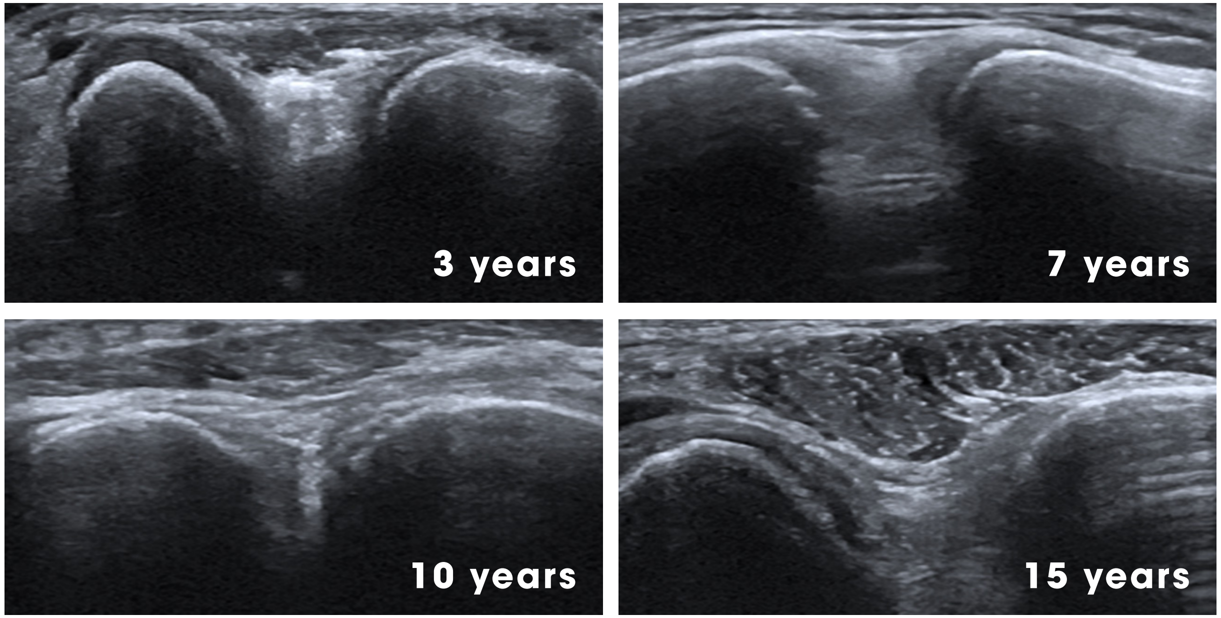
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

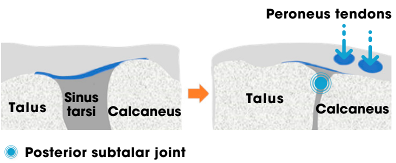
TIP / Position the probe at a 90 degrees angle to the sole of the foot and then slide it posterior in this position to explore the entire extent of the sinus tarsi and the posterior subtalar joint

Scanning the ankle - subtalar lateral

HEALTHY | PATHOLOGY



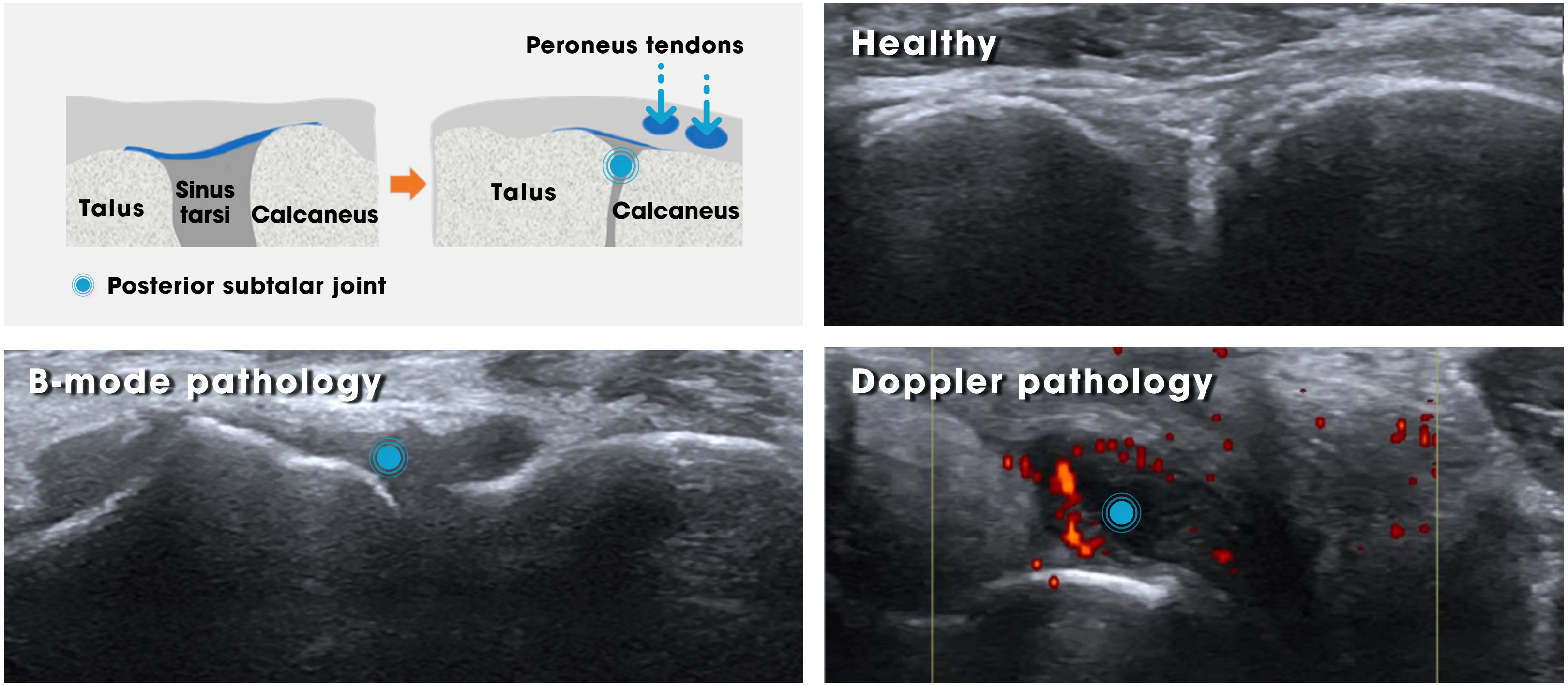




SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the ankle - subtalar lateral

HEALTHY PATHOLOGY

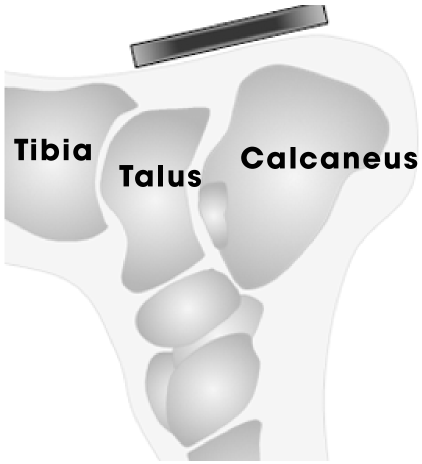


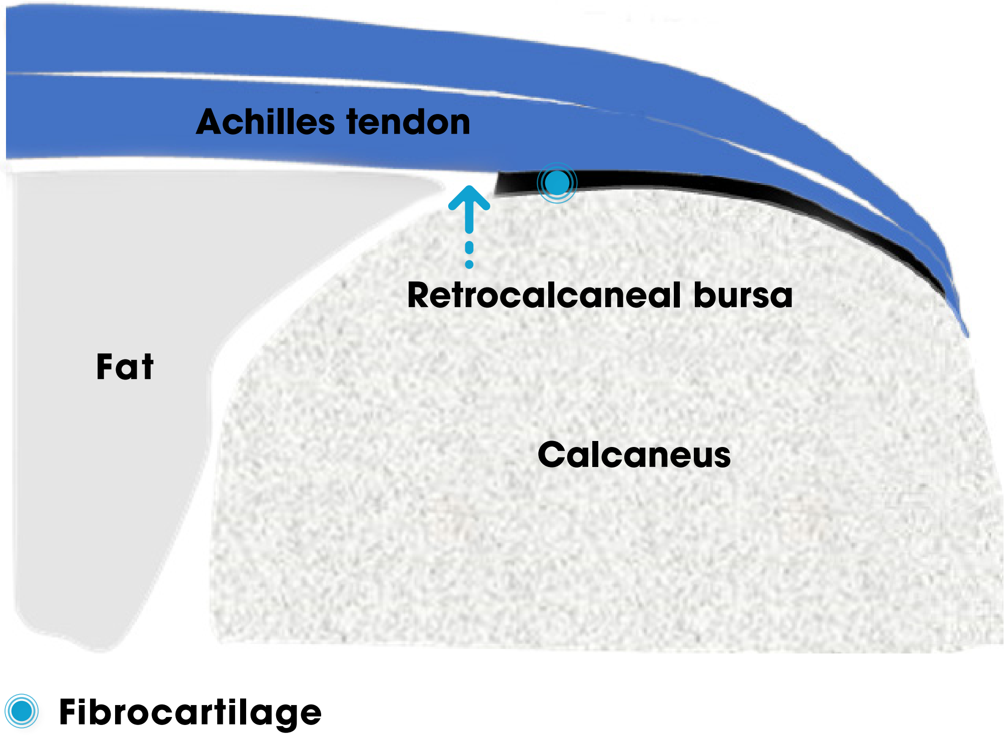
Subtalar synovitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Dynamic examination helps to detect smaller effusions

Scanning the ankle - posterior superficial

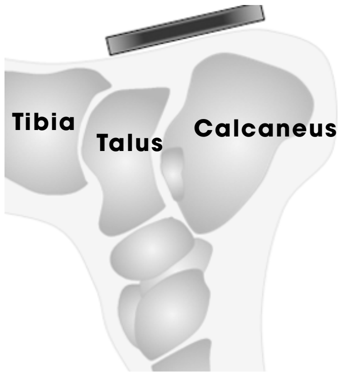


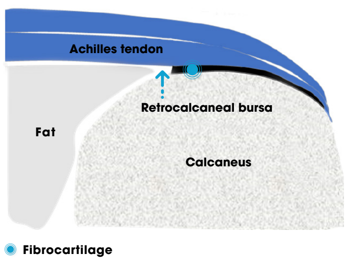


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

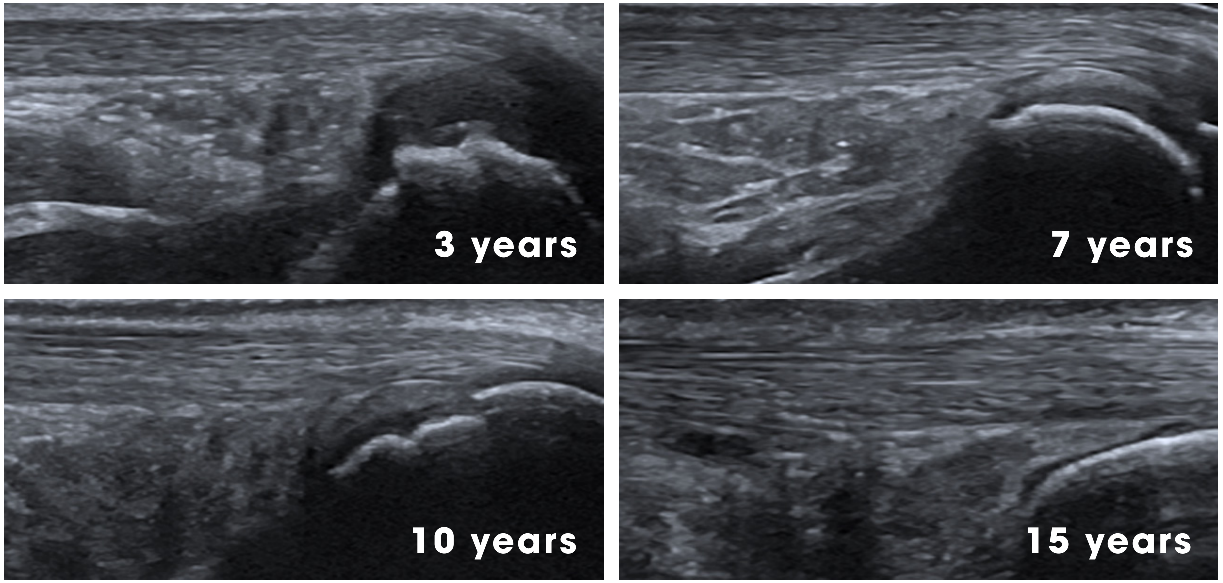
TIP / Younger children may show physiological bony irregularities of the calcaneal bone

Scanning the ankle - posterior superficial





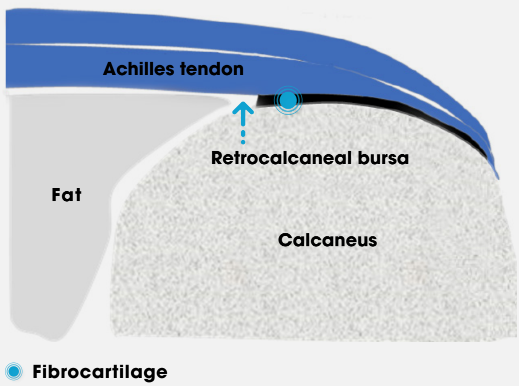
HEALTHY PATHOLOGY

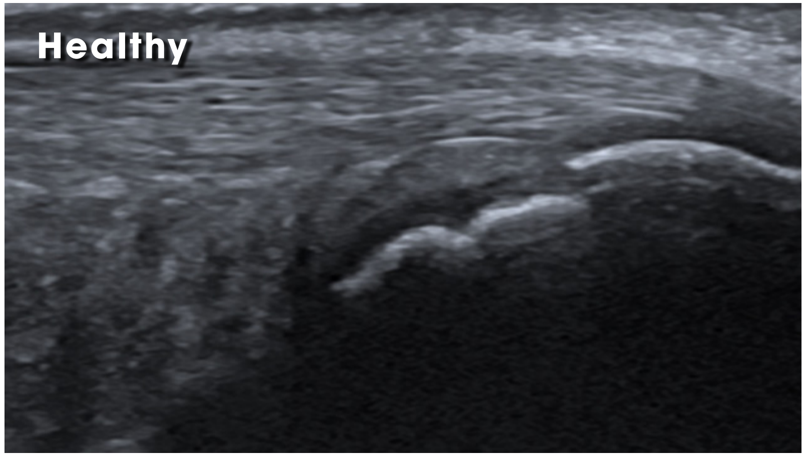


TIP / Younger children may show physiological bony irregularities of the calcaneal bone

Scanning the ankle - posterior superficial

HEALTHY PATHOLOGY



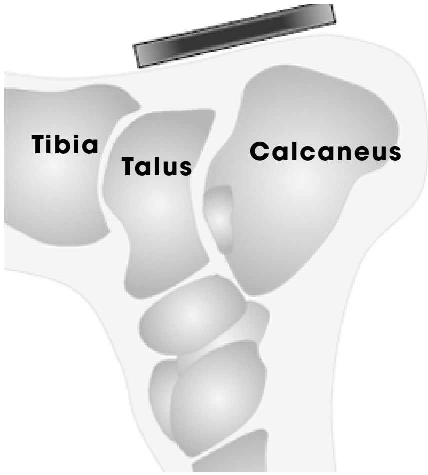


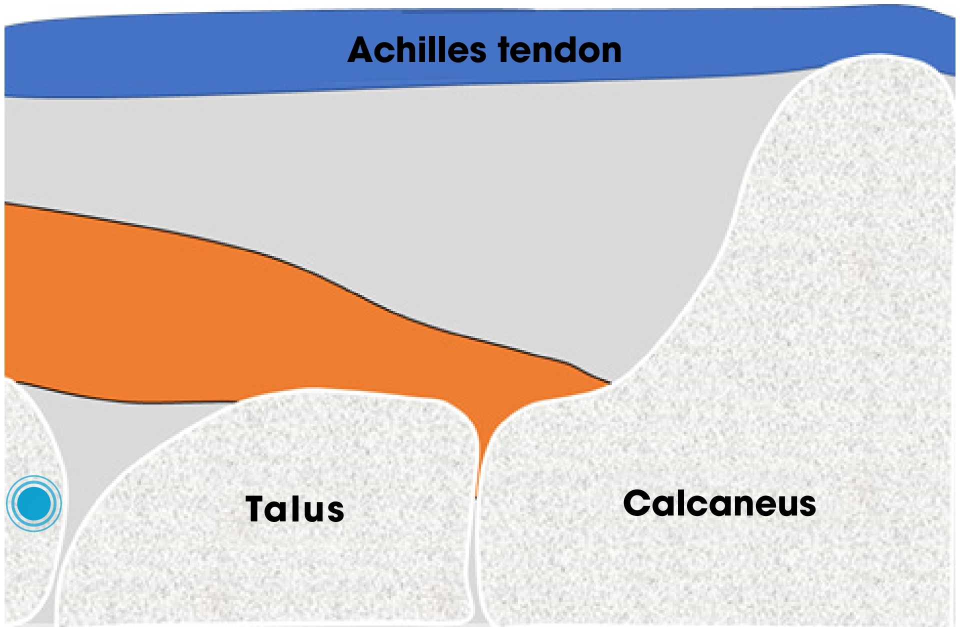
Retrocalcaneal bursitis

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

Scanning the ankle - posterior deep





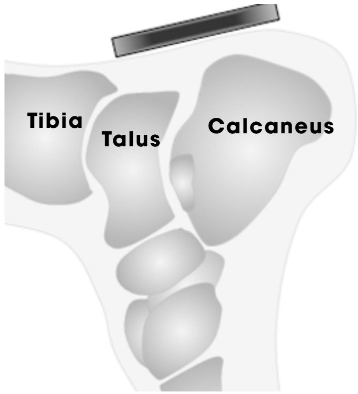
Tibia

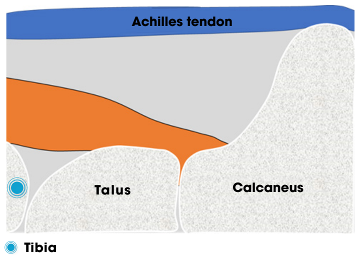
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

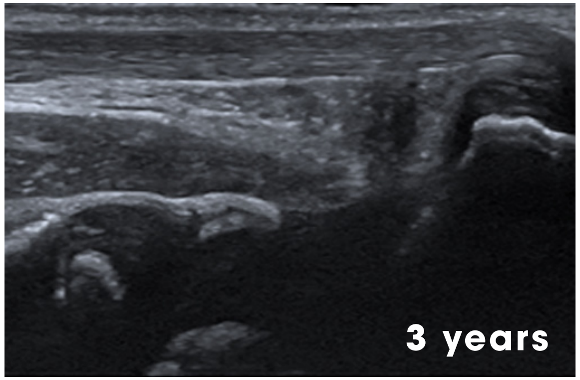
TIP / Younger children may show physiological bony irregularities of the calcaneal bone

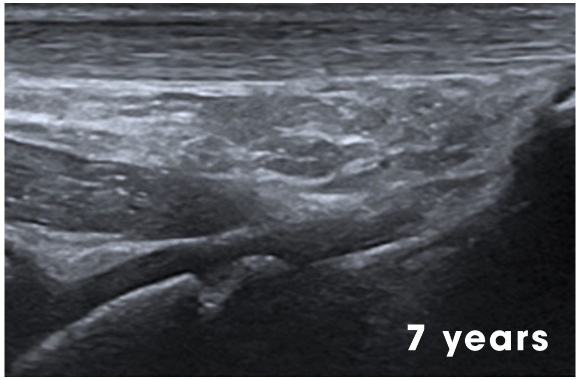
Scanning the ankle - posterior deep

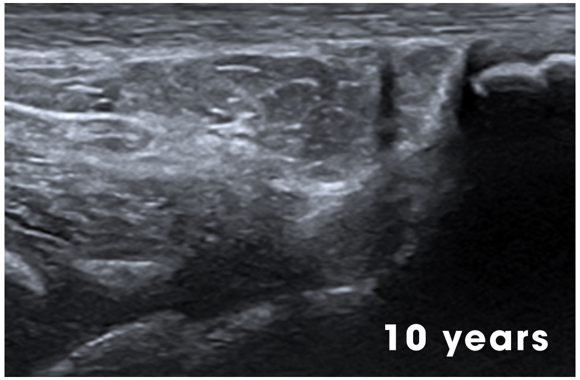
HEALTHY PATHOLOGY







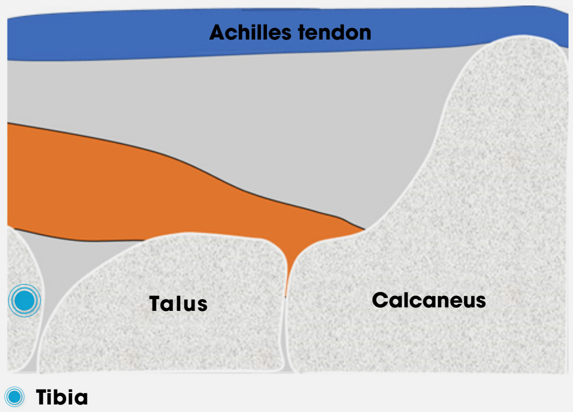


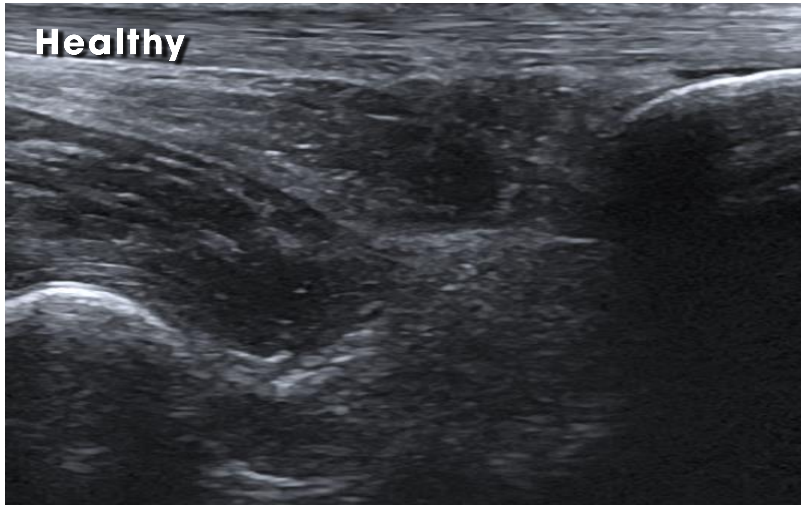


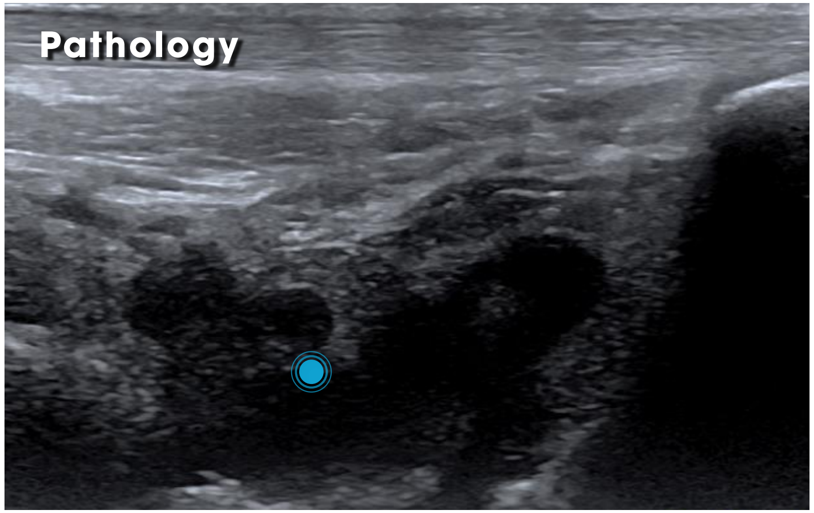
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Reduce frequency to visualize the posterior tibiotalar joint and the posterior subtalar joint

Scanning the ankle - posterior deep





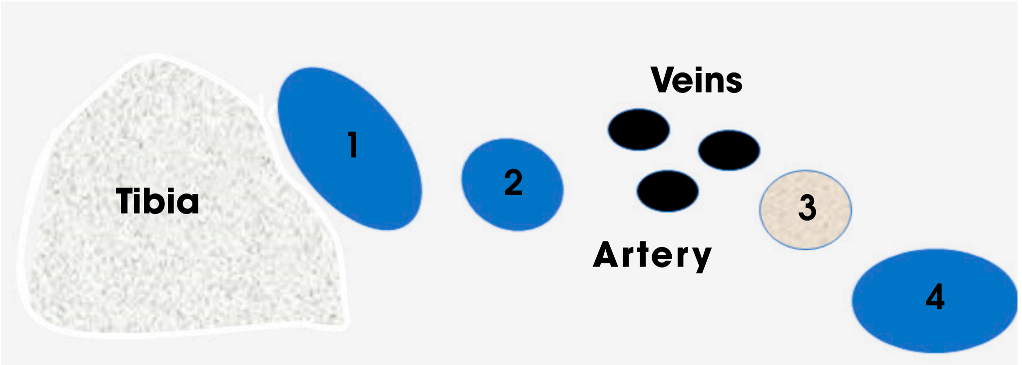


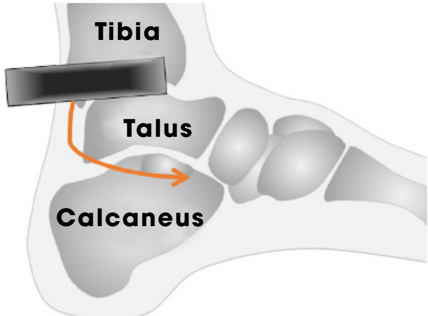
Effusion and synovial proliferation

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / Synovitis of the posterior tibiotalar joint or subtalar joint may lead to effusion in this area

Scanning the ankle - tendons medial





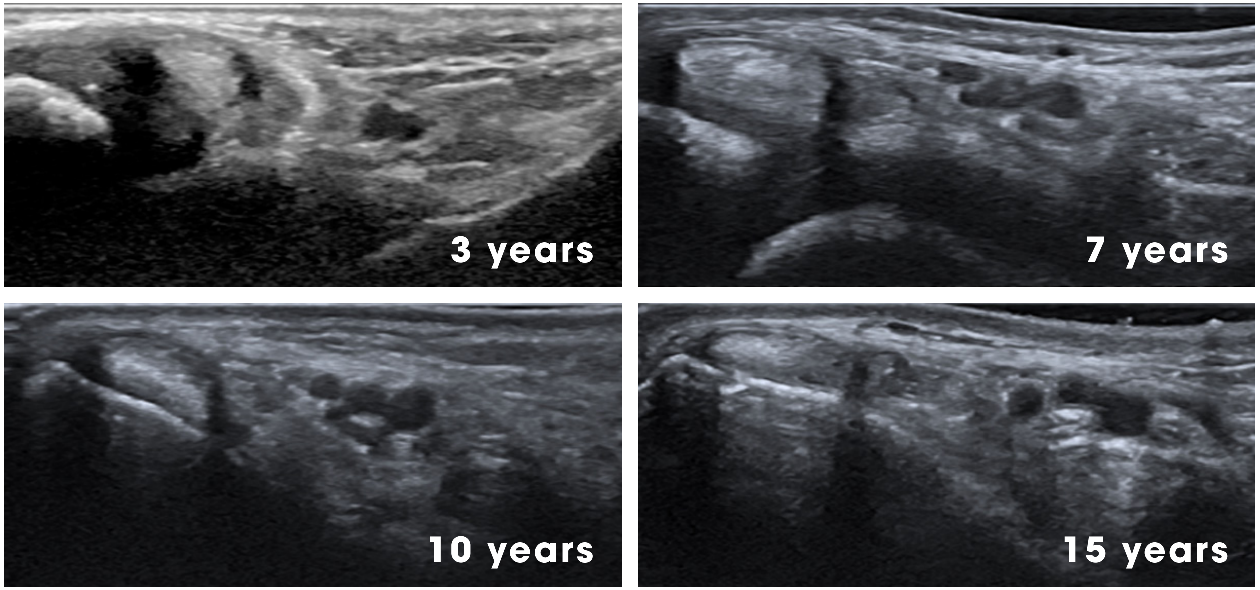
1 = Tibialis posterior tendon
2 = Flexor digitorum tendon
3 = Tibialis posterior nerve
4 = Flexor hallucis longus tendon

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

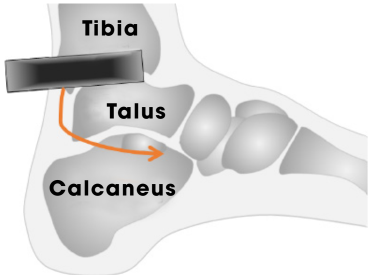
TIP / Use the neurovascular channel as anatomic landmark

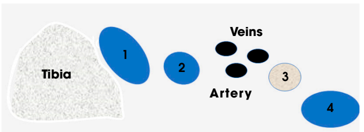
Scanning the ankle - tendons medial

HEALTHY PATHOLOGY



SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

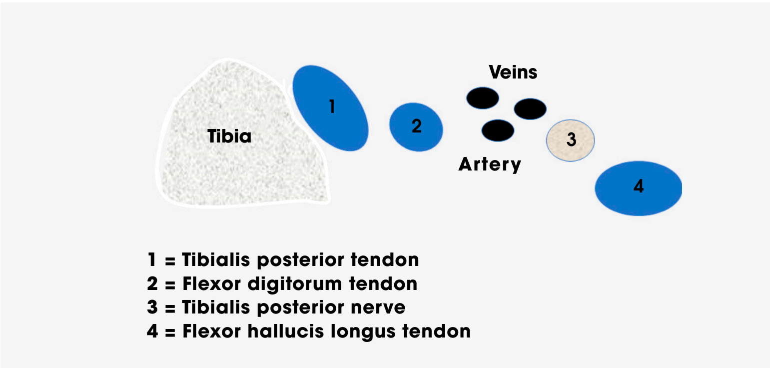


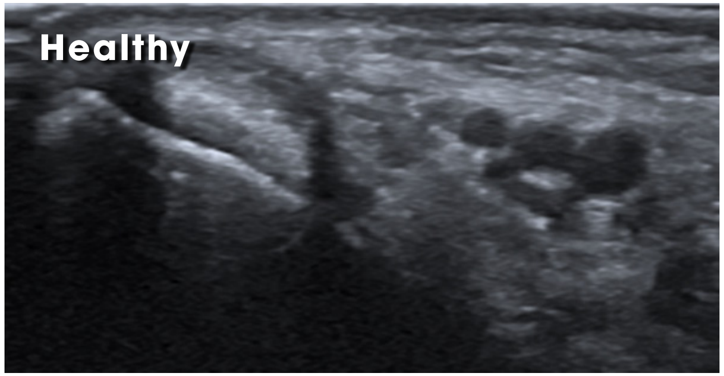


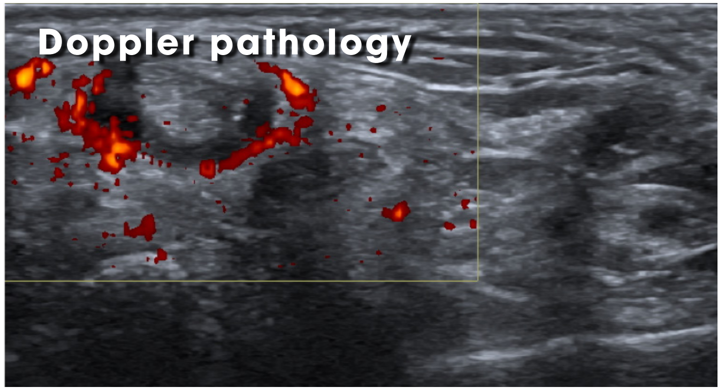
1 = Tibialis posterior tendon
2 = Flexor digitorum tendon
3 = Tibialis posterior nerve
4 = Flexor hallucis longus tendon

TIP / Use the neurovascular channel as anatomic landmark

Scanning the ankle - tendons medial

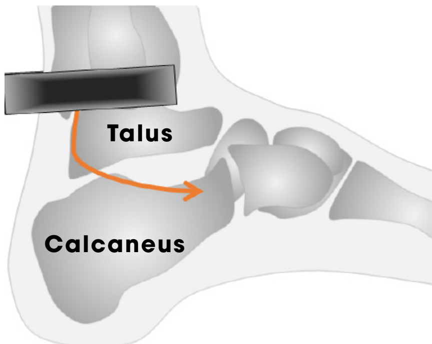


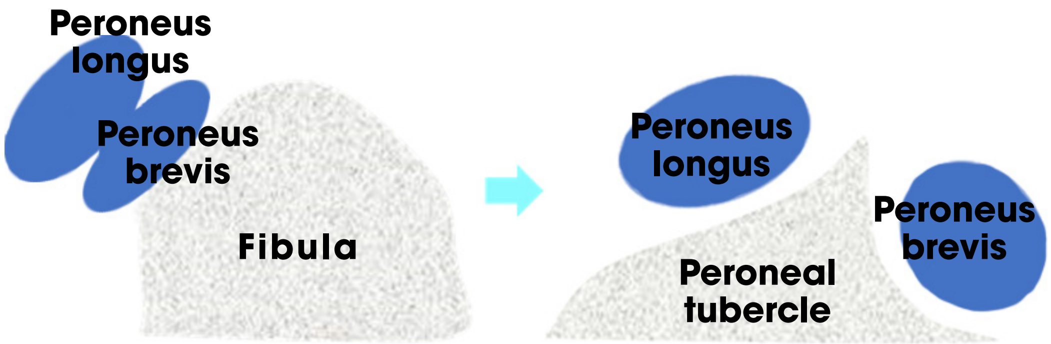




Tenosynovitis of the tibialis posterior tendon

Scanning the ankle - tendons lateral

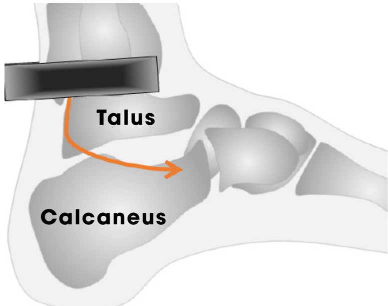


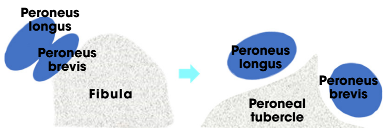


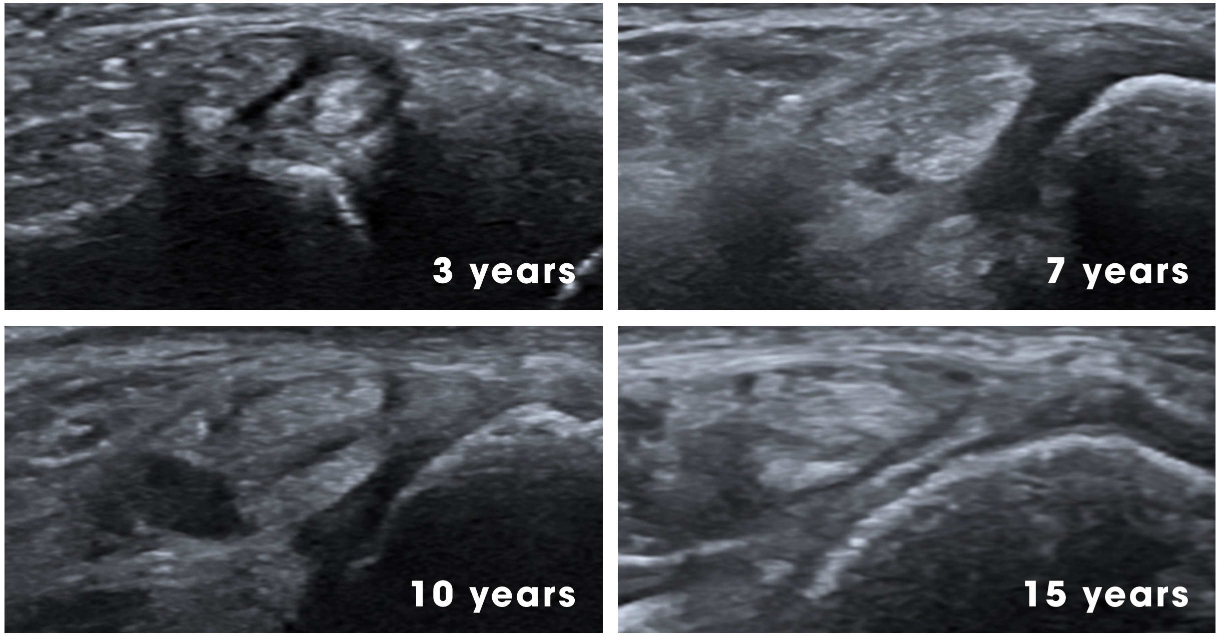
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

TIP / The peroneus brevis tendon runs closer to the bone

Scanning the ankle - tendons lateral



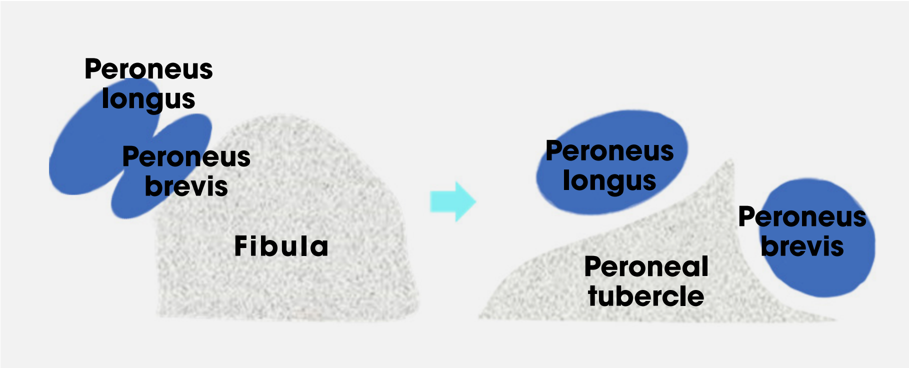


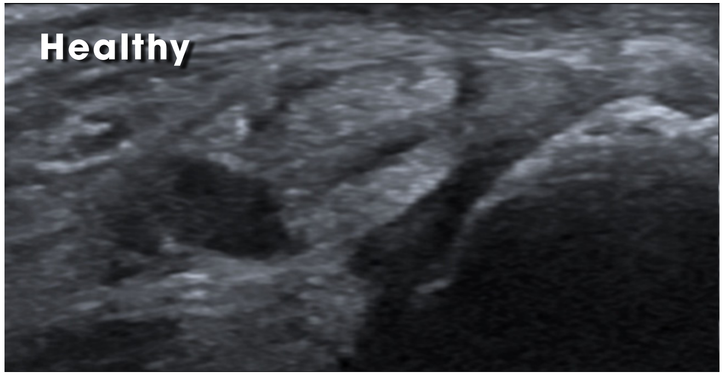


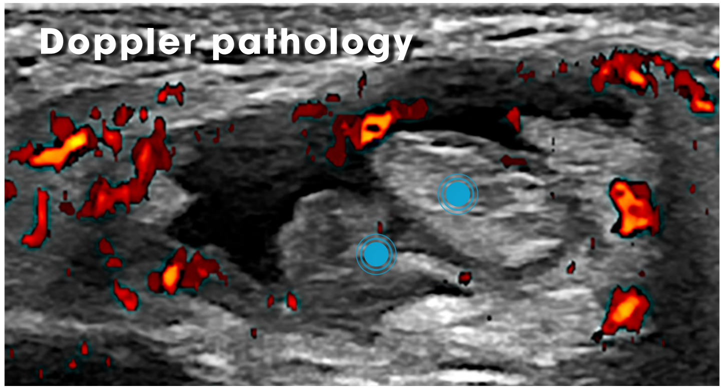
TIP / The peroneus brevis tendon runs closer to the bone

Scanning the ankle - tendons lateral

HEALTHY PATHOLOGY



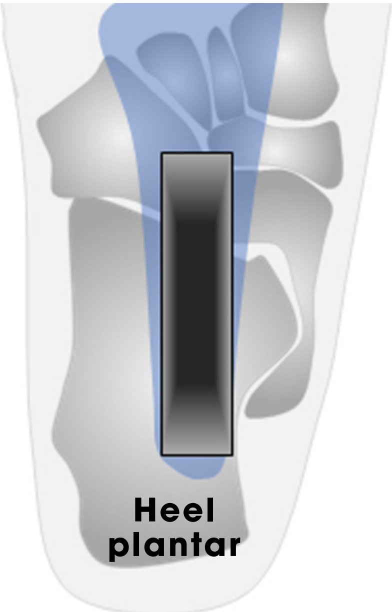


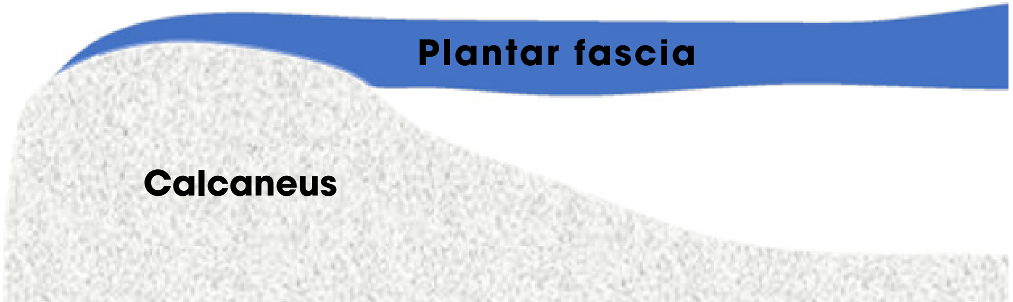


Tenosynovitis of the peroneus tendon compartment

Peroneus tendons

Scanning the ankle - plantar fascia

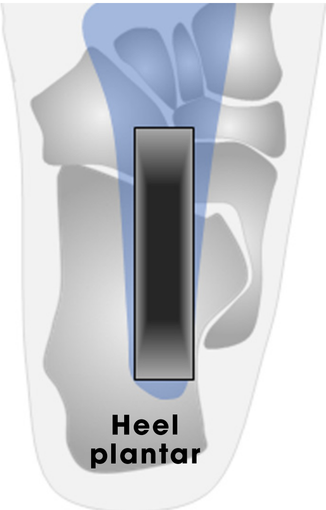




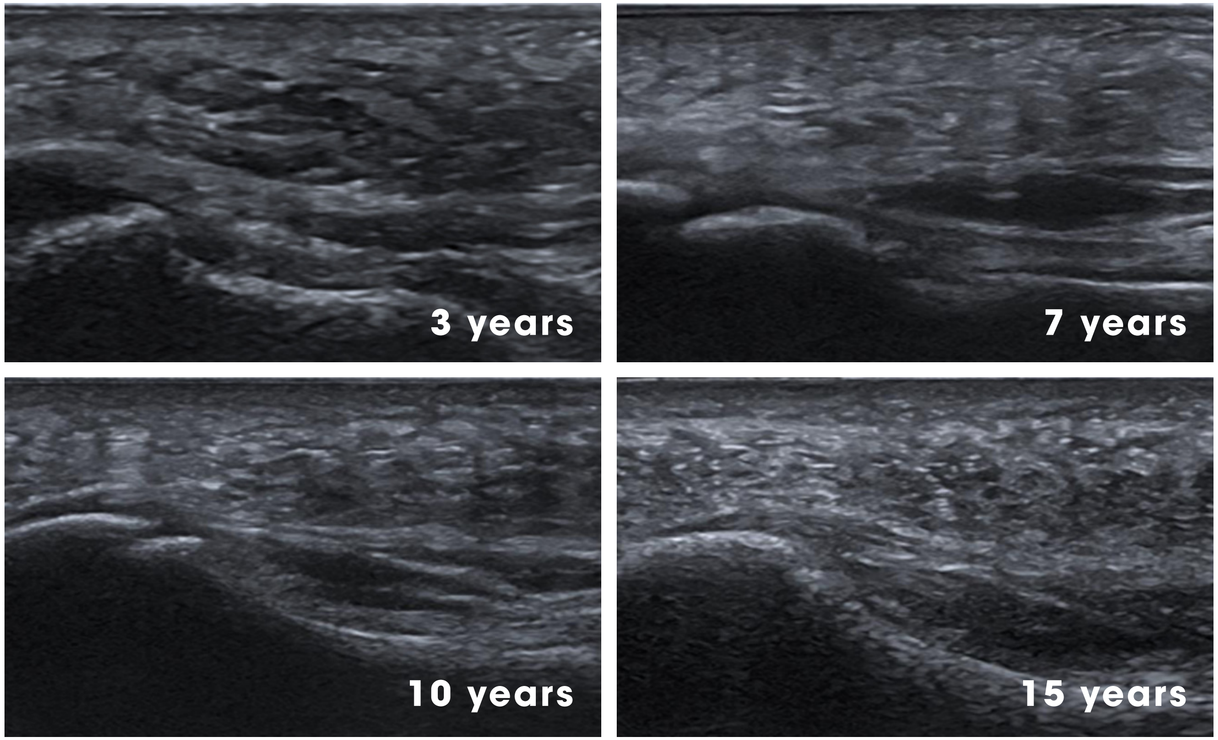
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

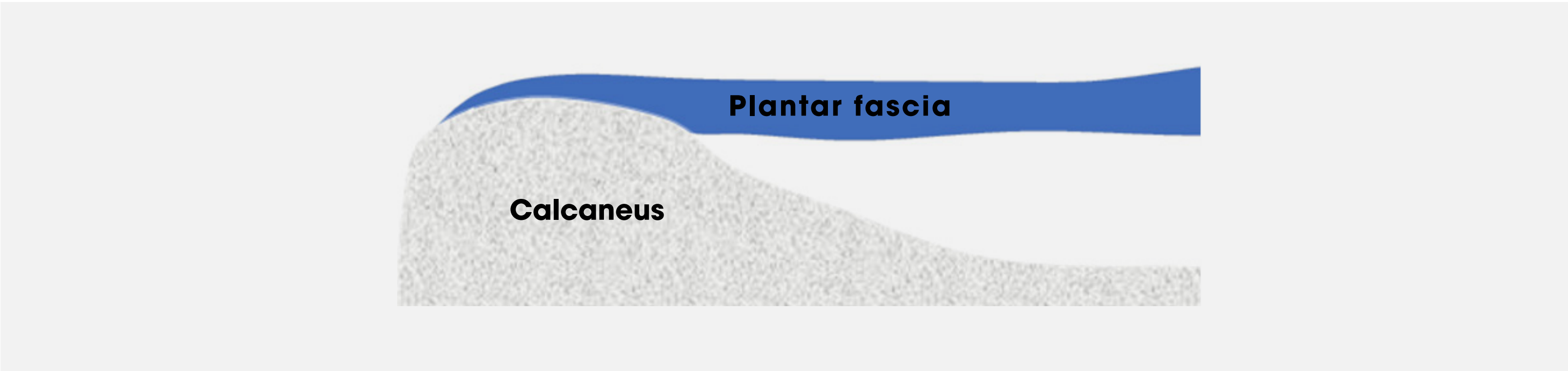


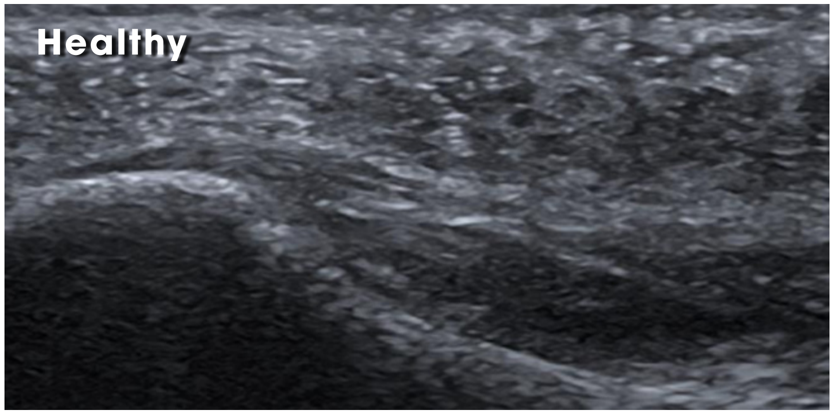
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

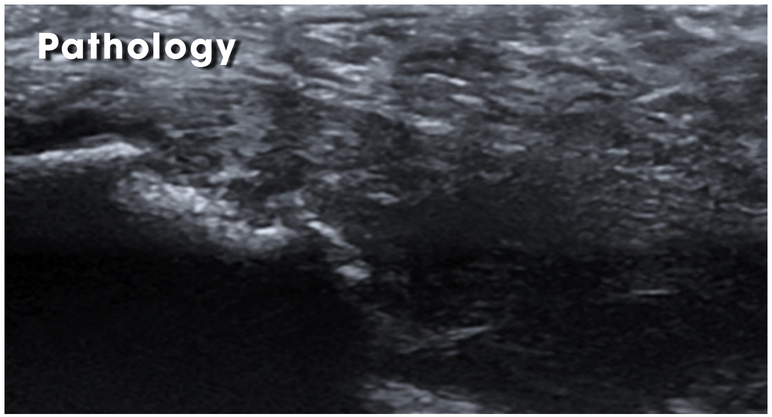
TIP / Note that the main bundle of the plantar fascia inserts a bit medially on the calcaneus and the probe needs to be positioned accordingly

Scanning the ankle - plantar fascia

HEALTHY PATHOLOGY



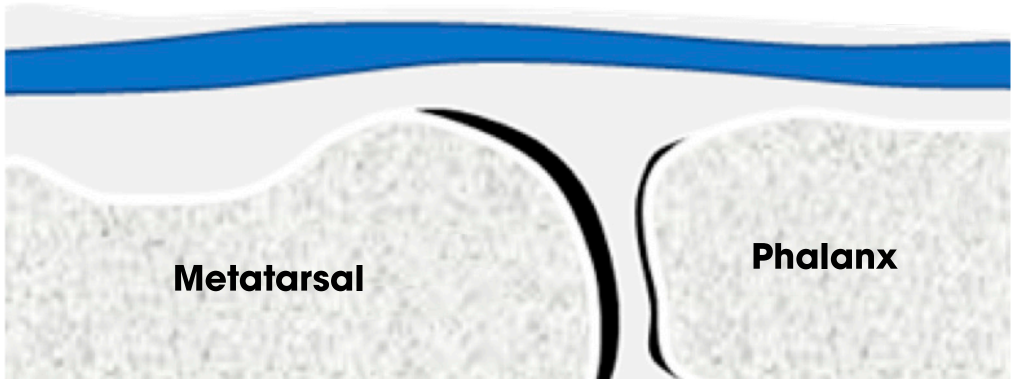


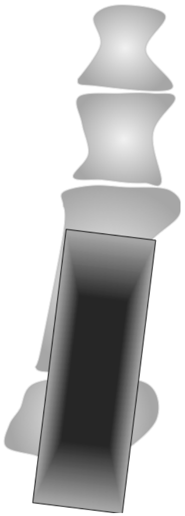


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

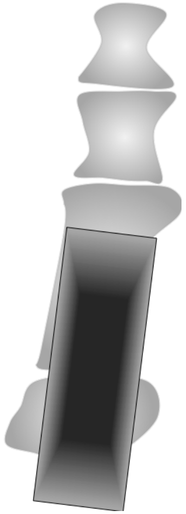
TIP / Some patients may demonstrate bone irregularities at the insertion of the plantar fascia in case of fasciitis. Use low frequencies to see all structures. Doppler might be very difficult to detect

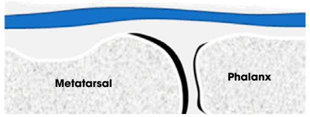
Scanning the toes - MTP



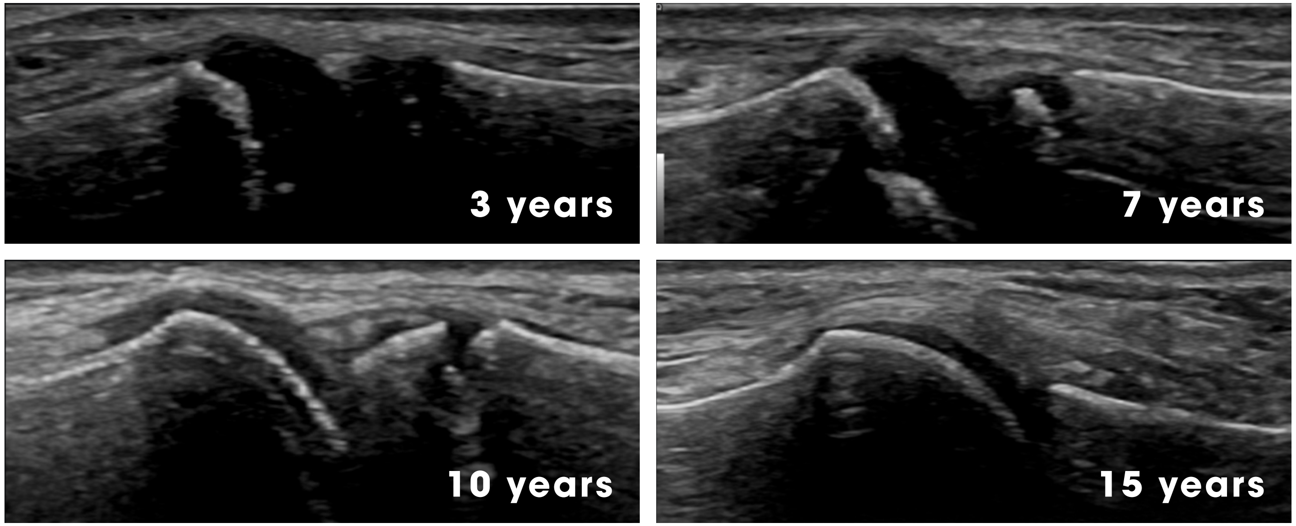


Scanning the toes - MTP





HEALTHY PATHOLOGY

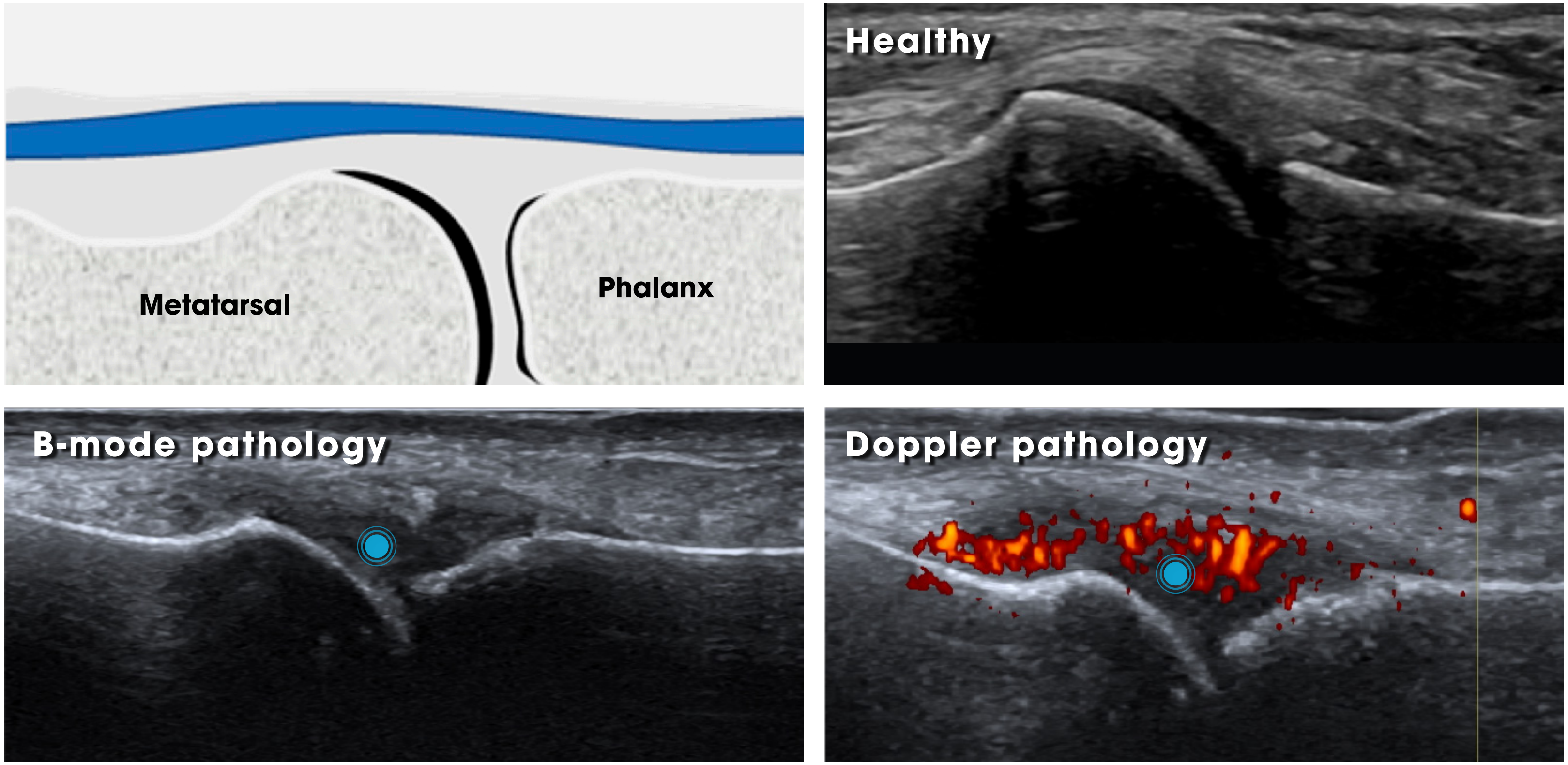


SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

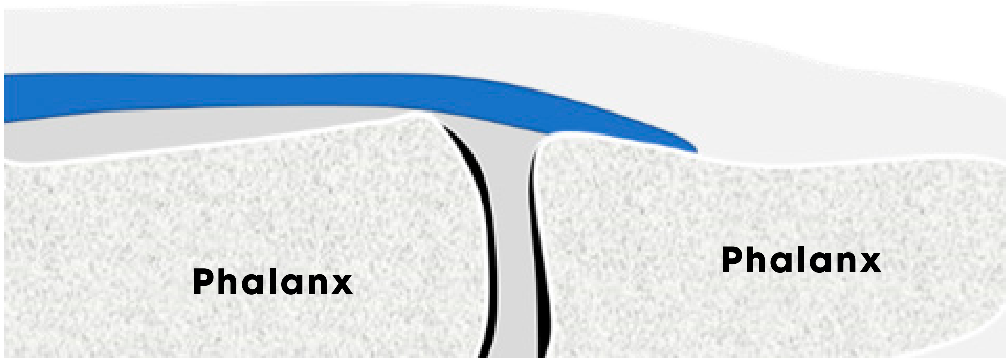
Scanning the toes - MTP

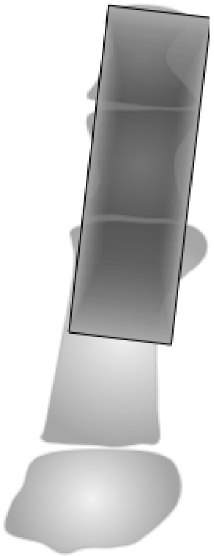
HEALTHY PATHOLOGY



Synovial fluid, proliferation and increased Doppler signals

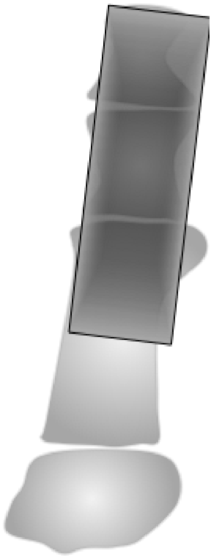
Scanning the toes - IP

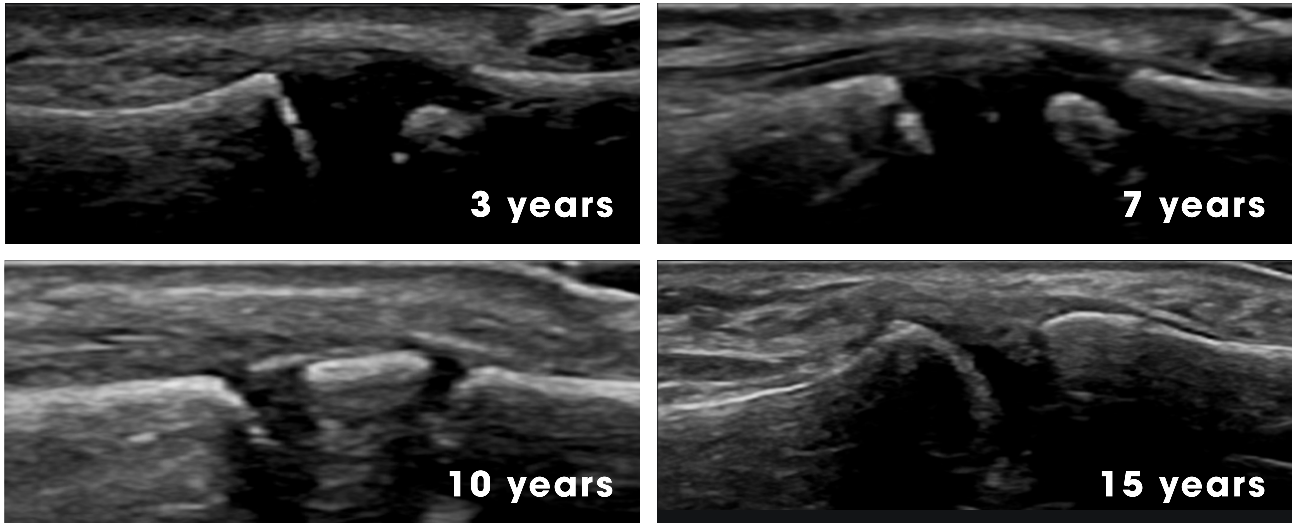


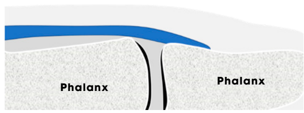


Scanning the toes - IP

HEALTHY PATHOLOGY



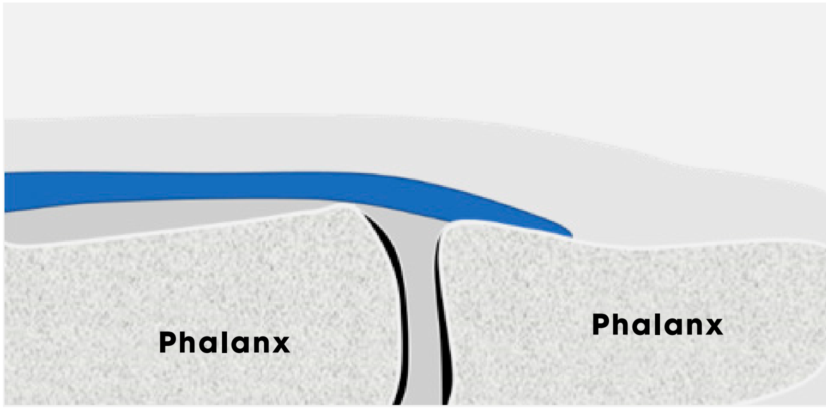


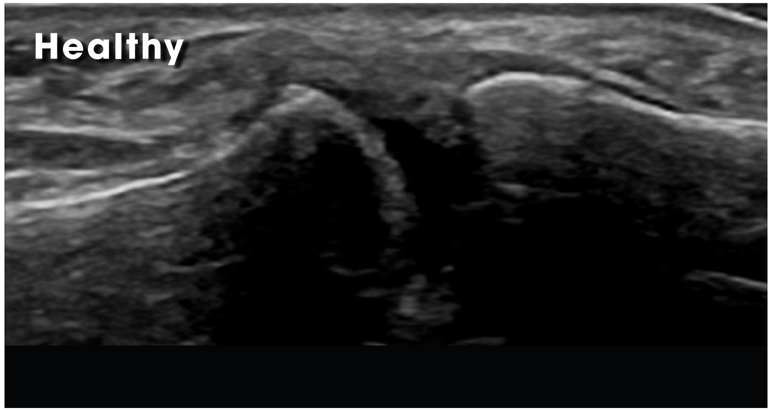


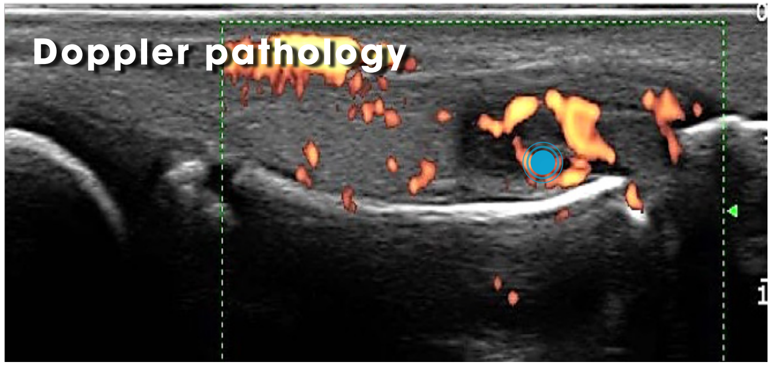
SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

Scanning the toes - IP

HEALTHY PATHOLOGY





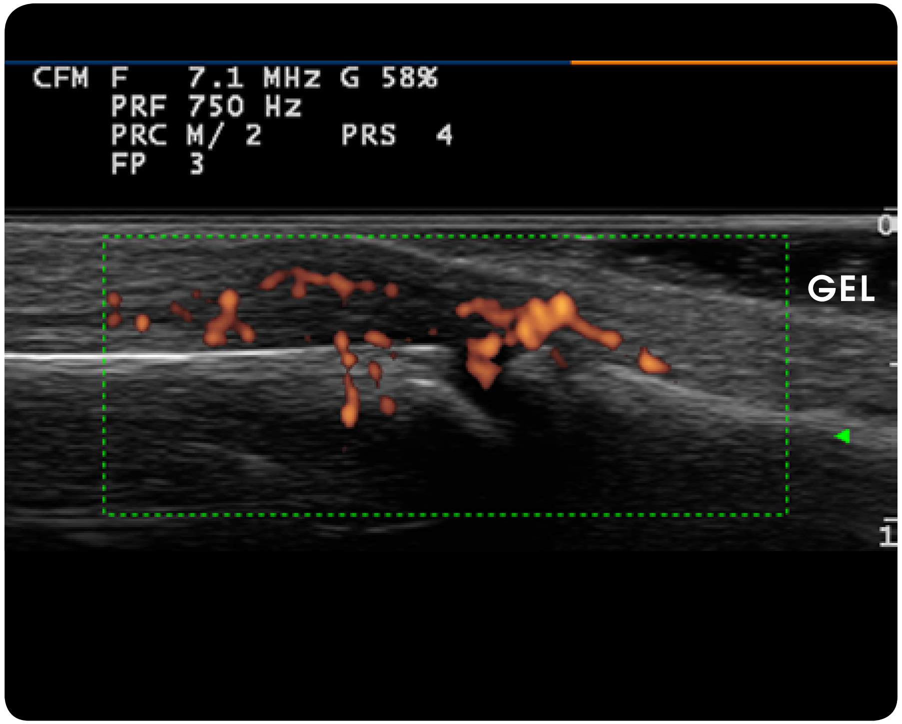


Synovial fluid, proliferation and increased doppler signals

SHOULDER
ELBOW
WRIST
FINGER
HIP
KNEE
ANKLE/FOOT

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

1. Möller I et al. Ann Rheum Dis 2017;76:1974–1979; 2. Torp-Pedersen ST, Terslev L. Ann Rheum Dis 2008;67:143–149

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

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

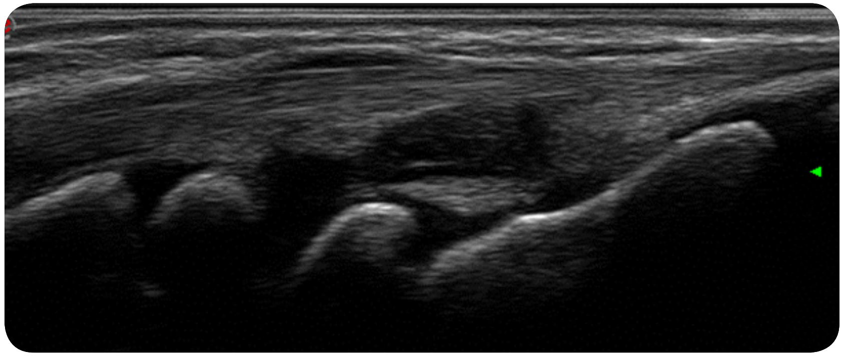
Wrist joint recesses and tendons

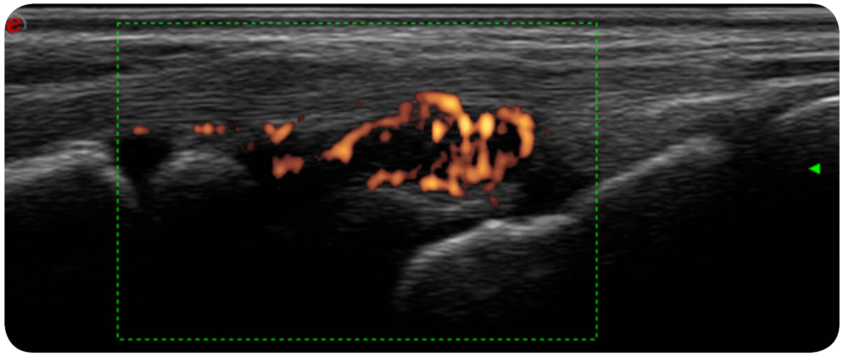
Machine X
High-frequency linear array probe (10 to 18 MHz)

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

Signature





Include representative images of the pathological findings.

Iagnocco A et al. Rheumatology (Oxford) 2014; 53:367–373

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MSUS Report

Genoa, mm/dd/yyyy

Date of examination

Mario Rossi
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

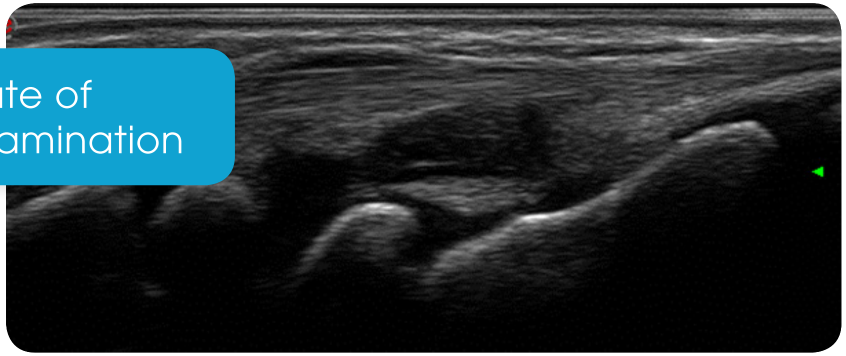
Wrist joint recesses and tendons

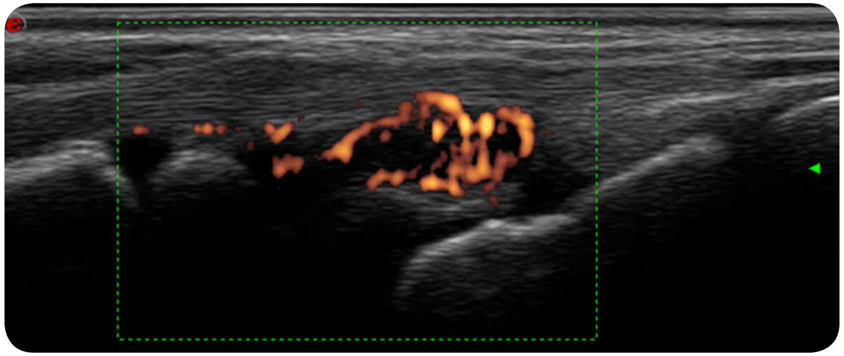
Machine X
High-frequency linear array probe (10 to 18 MHz)

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

Signature





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MSUS Report

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

Patient's full name and age

Wrist swelling lasti… …d 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

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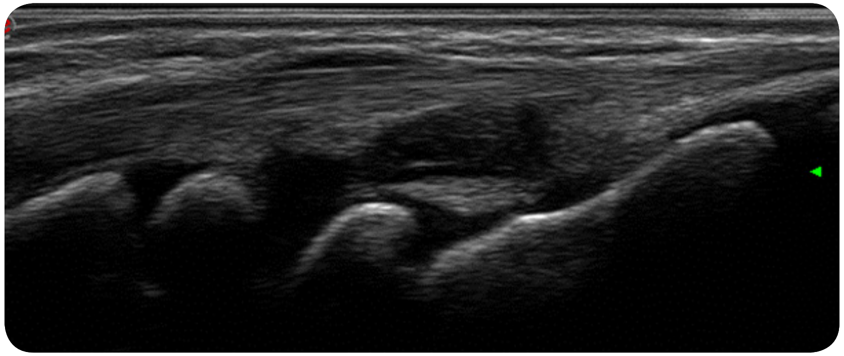

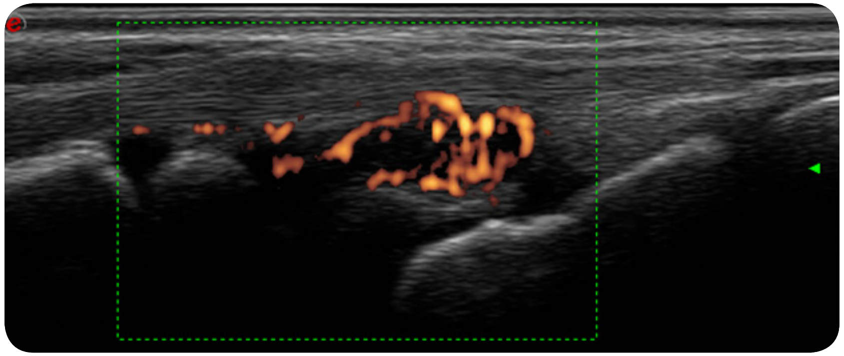

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MSUS Report

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

Indication for the US examination

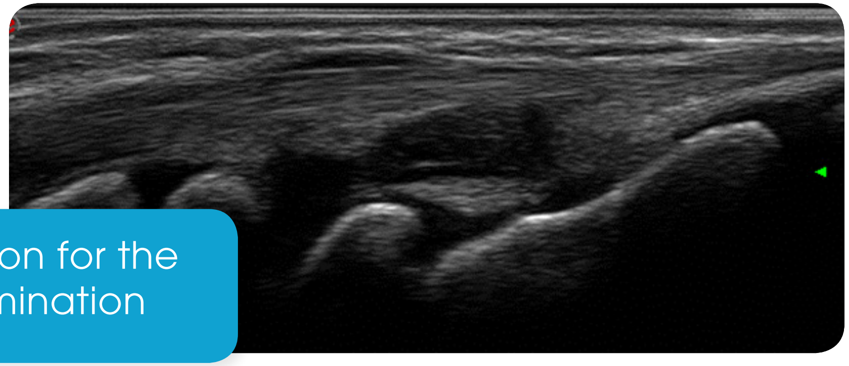
Wrist joint recesses and tendons

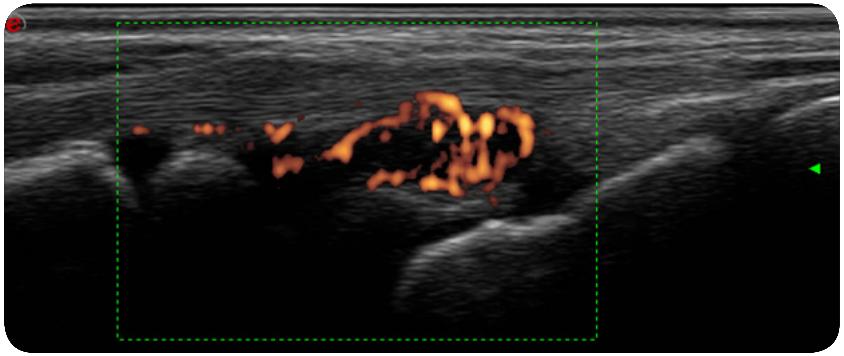
Machine X
High-frequency linear array probe (10 to 18 MHz)

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

Signature





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MSUS Report

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

Wrist joint recesses and tendons

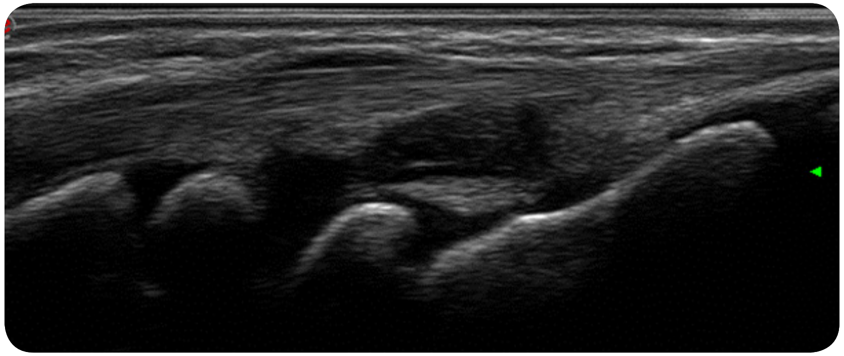
List of the regions examined

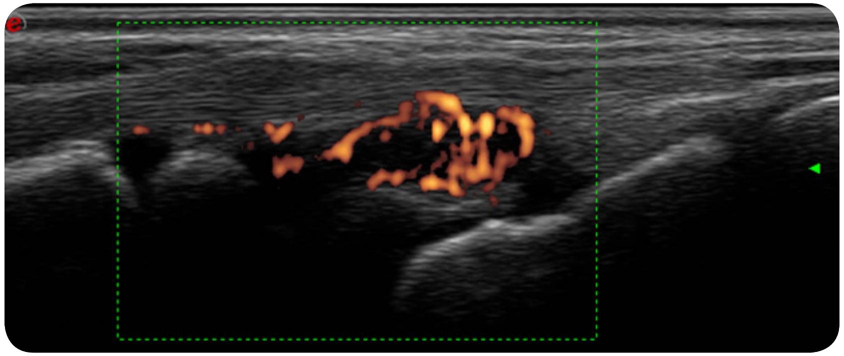
Machine X
High-frequency linear array probe (10 to 18 MHz)

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

Signature





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MSUS Report

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

Wrist joint recesses and tendons

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

Type of equipment

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

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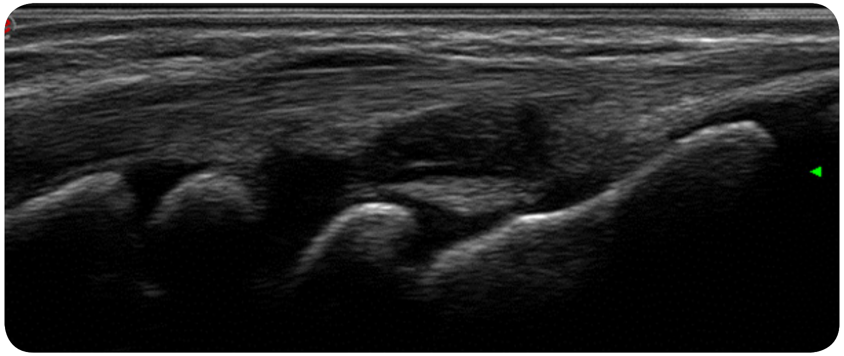

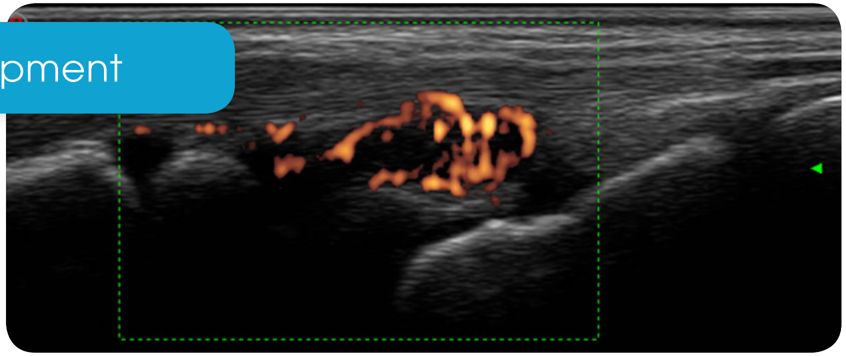

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MSUS Report

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

Wrist swelling lasting 2 months. Suspected tenosynovitis

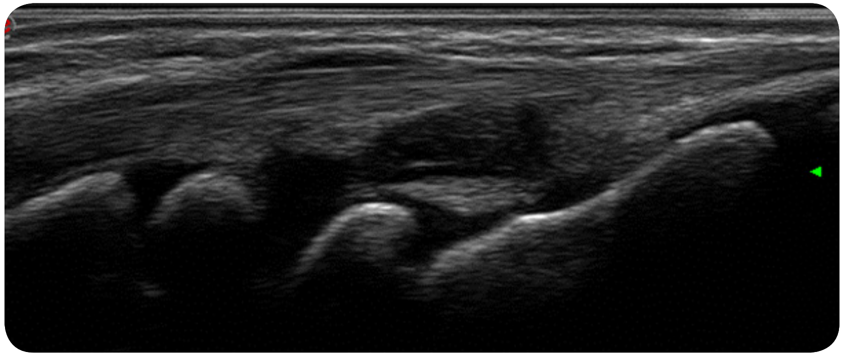
Wrist joint recesses and tendons

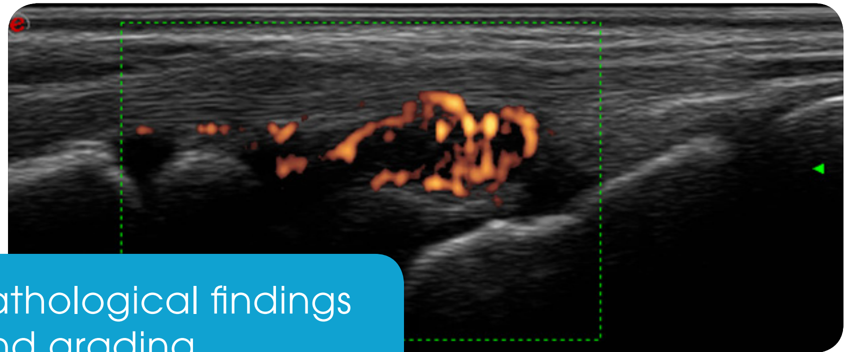
Machine X
High-frequency linear array probe (10 to 18 MHz)

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

Signature





Pathological findings and grading

Include representative images of the pathological findings.

Iagnocco A et al. Rheumatology (Oxford) 2014; 53:367–373

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

Genoa, mm/dd/yyyy

Mario Rossi
mm/dd/yyyy

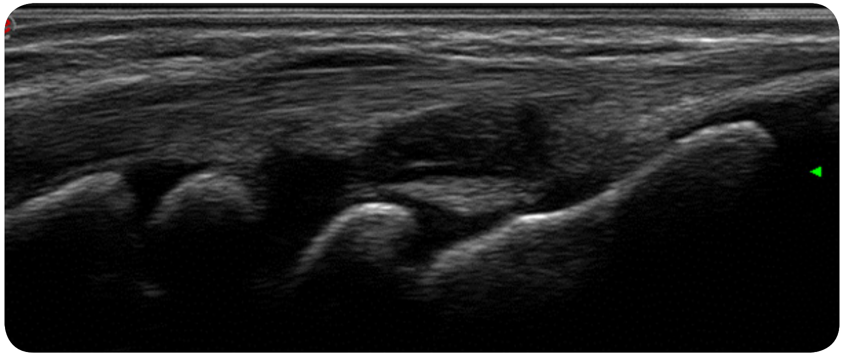
Wrist swelling lasting 2 months. Suspected tenosynovitis

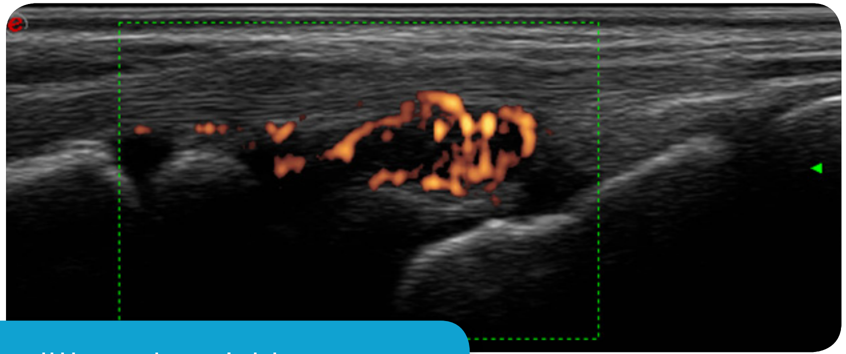
Wrist joint recesses and tendons

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





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

tive images of
ndings.

Iagnocco A et al. Rheumatology (Oxford) 2014; 53:367–373

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

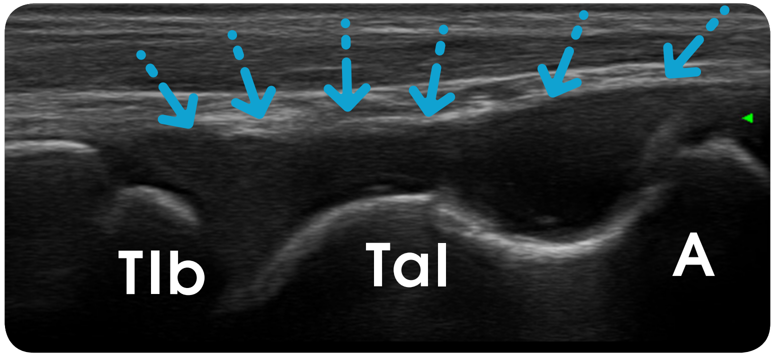
Qualitative approach (based on the description of changes in synovial hypertrophy, joint effusion, and Doppler signals)

2

Quantitative approach (measurements, pixel count, etc.)

3

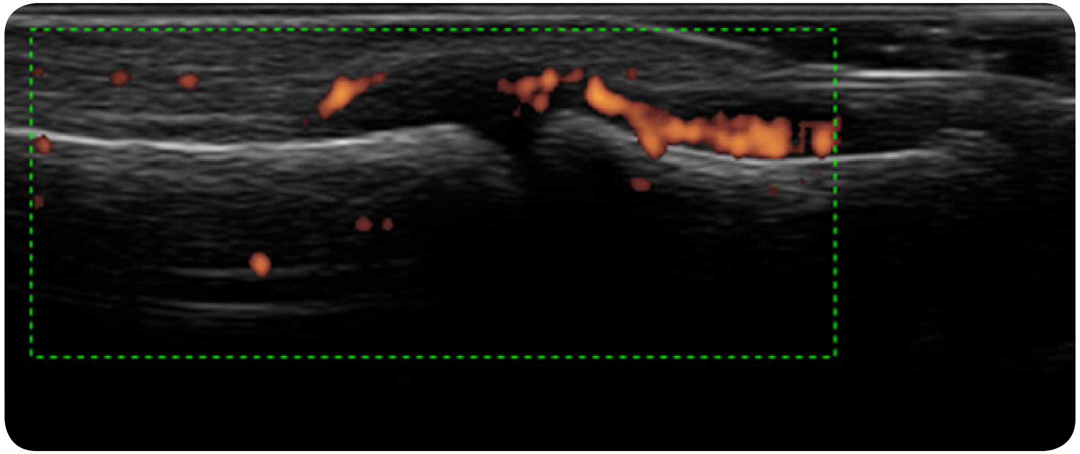
Semiquantitative scores (4-point grade: 0: absent, 1: mild, 2: medium, and 3: severe)



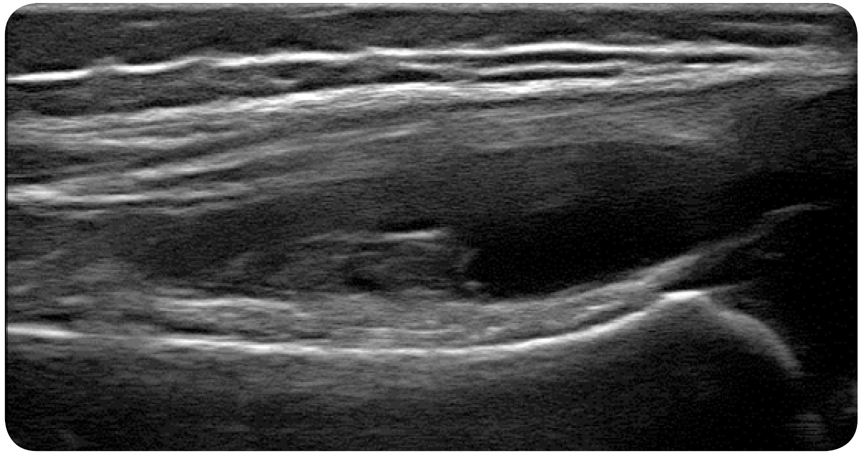
Tibiotalar joint in a patient with JIA and ankle involvement. US images have been collected before (A) and after (B) treatment

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[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

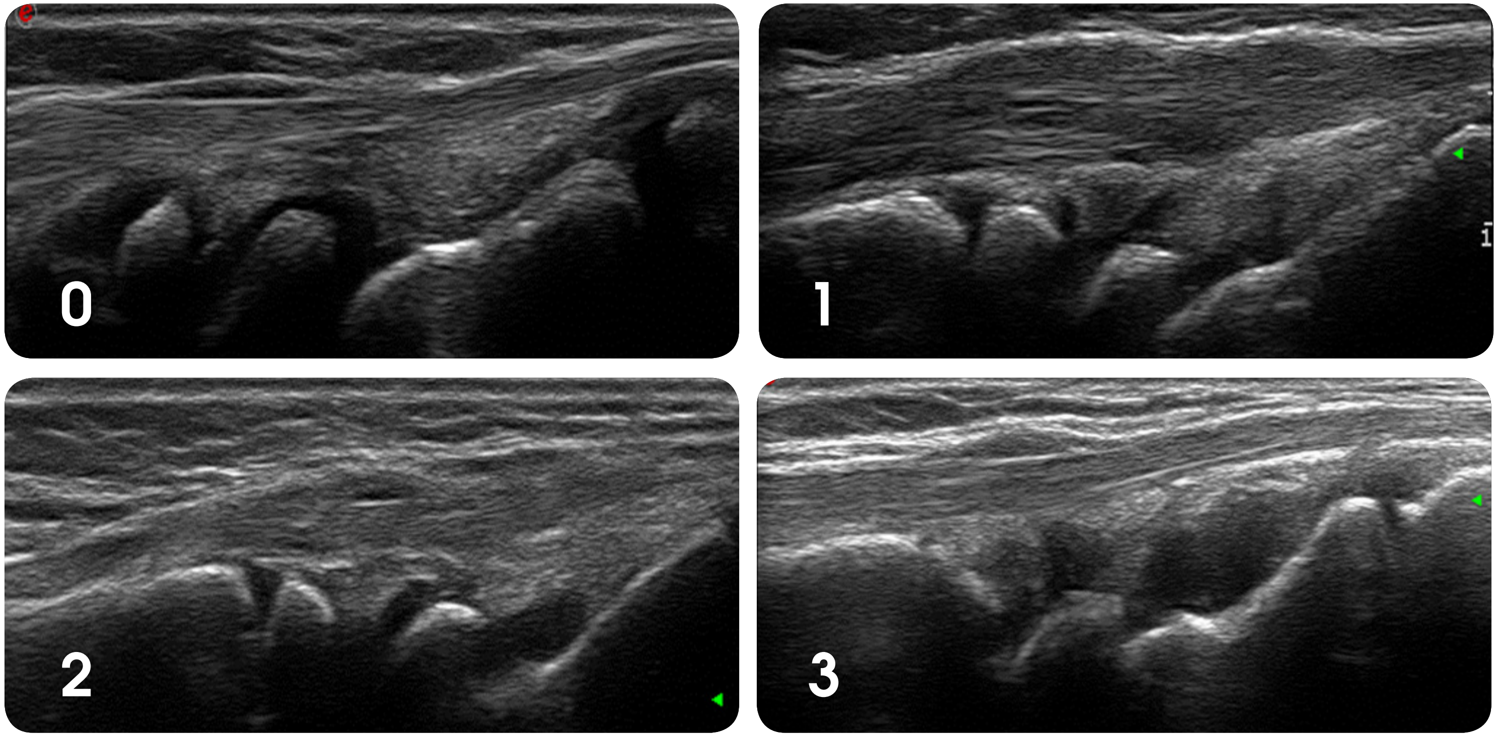
1. Vojinovic J et al. Ann Rheum Dis 2017;76(Suppl 2):1015; 2. Szkudlarek M et al. Arthritis Rheum 2003;48:955–962; 3. Hartung W et al. Arthritis Care Res (Hoboken) 2012;64:675–682

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



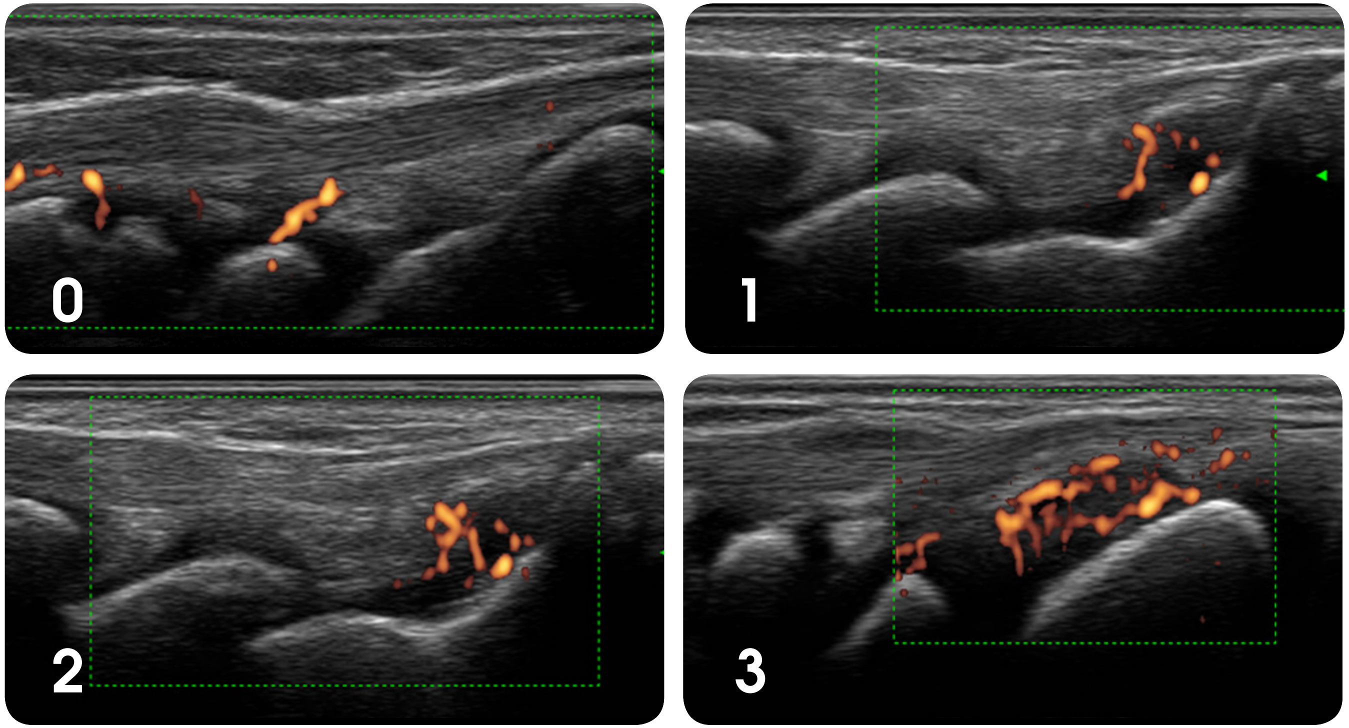
TIP / Score assignment should be based on a comprehensive evaluation of the whole joint recess aiming to establish the precise extent of the pathological findings

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



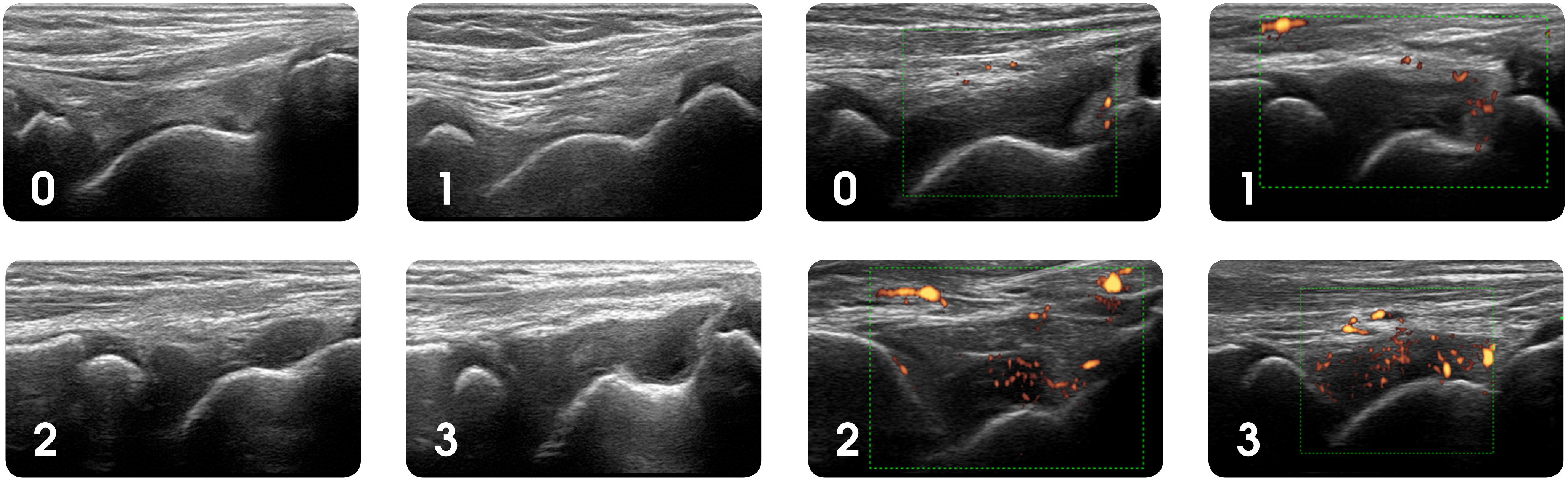
TIPS /

- 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

B mode

Power Doppler US

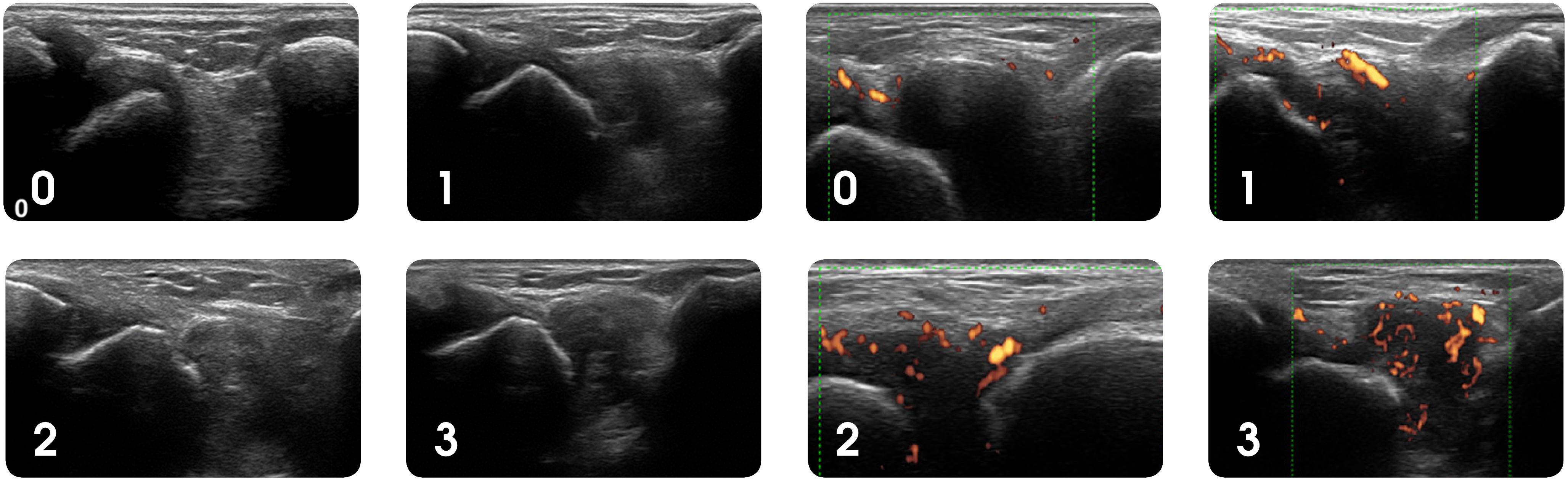


Longitudinal anterior scan of the ankle. B mode and power Doppler US of the tibiotalar joint showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe synovitis

Grading

B mode

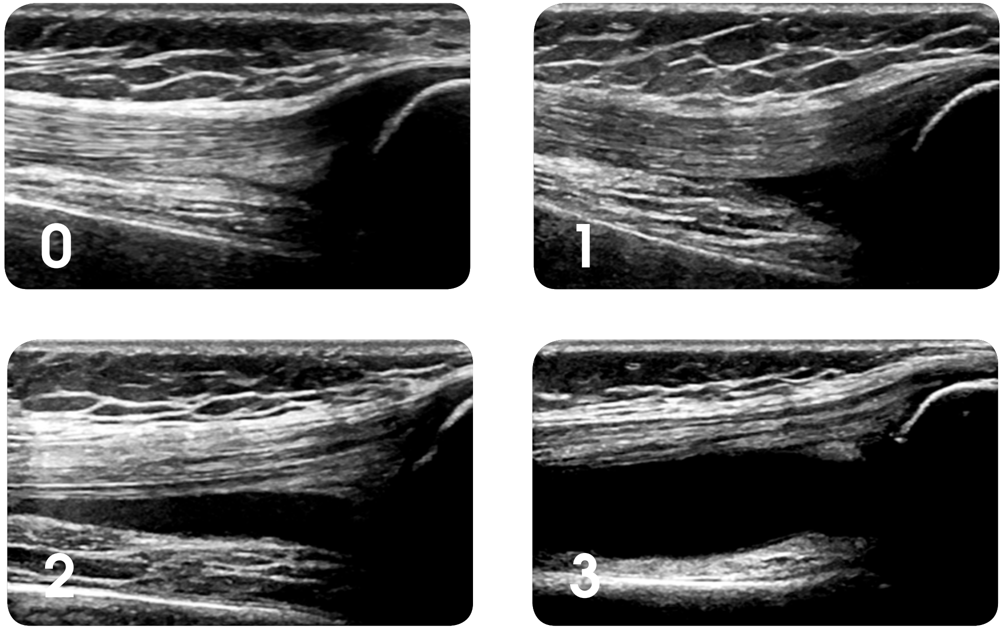
Power Doppler US



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

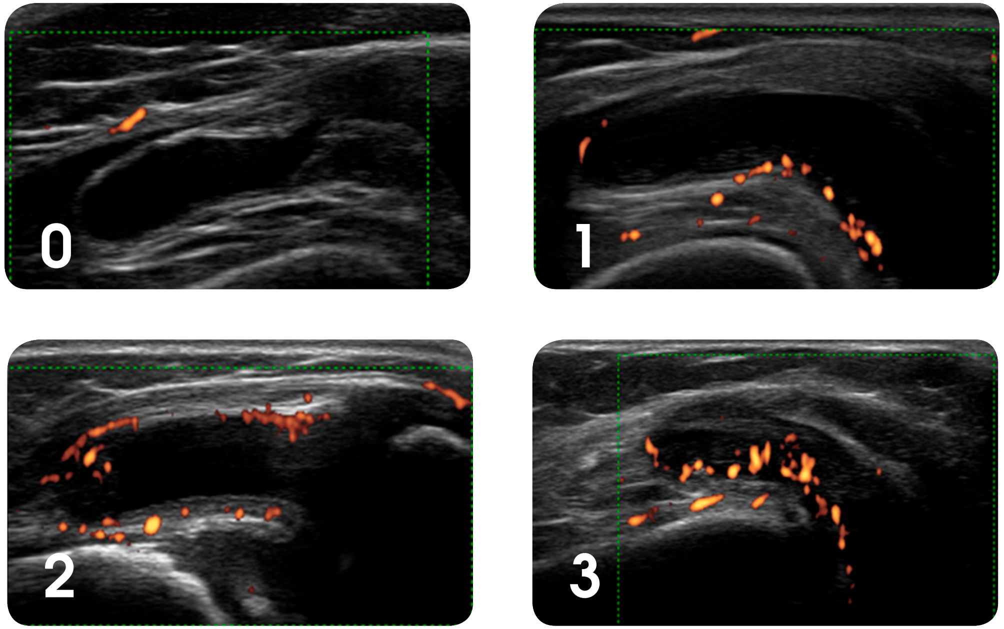
Grading

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

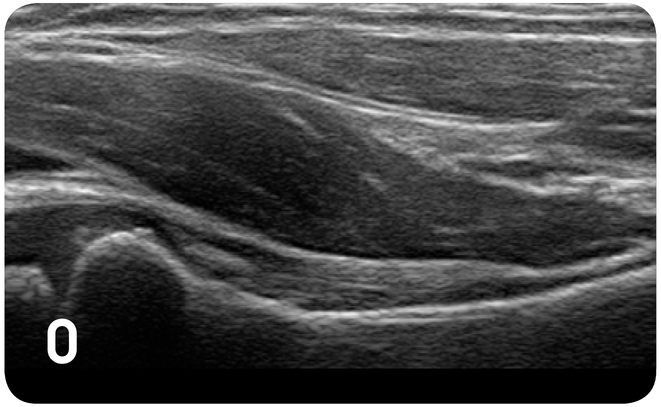


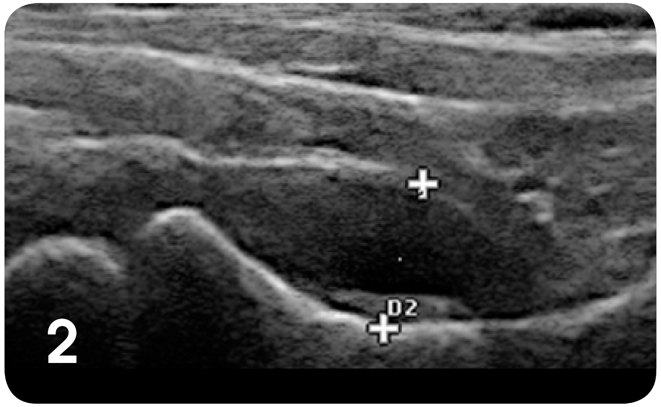
Transverse lateral parapetallar scan of the knee in power Doppler showing different grades of severity of synovitis: 0: absent, 1: mild, 2: moderate, and 3: severe

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[1]
- 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[1]
- 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[1-2]
- A difference of more than 2 mm between the two hips is an important additional criterion for the sonographic diagnosis of hip joint effusion[1]

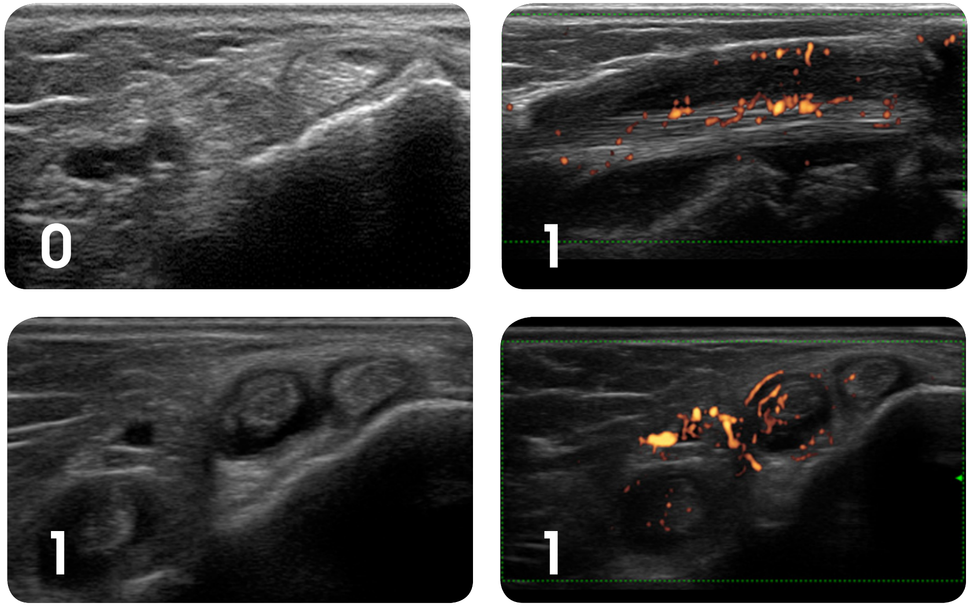




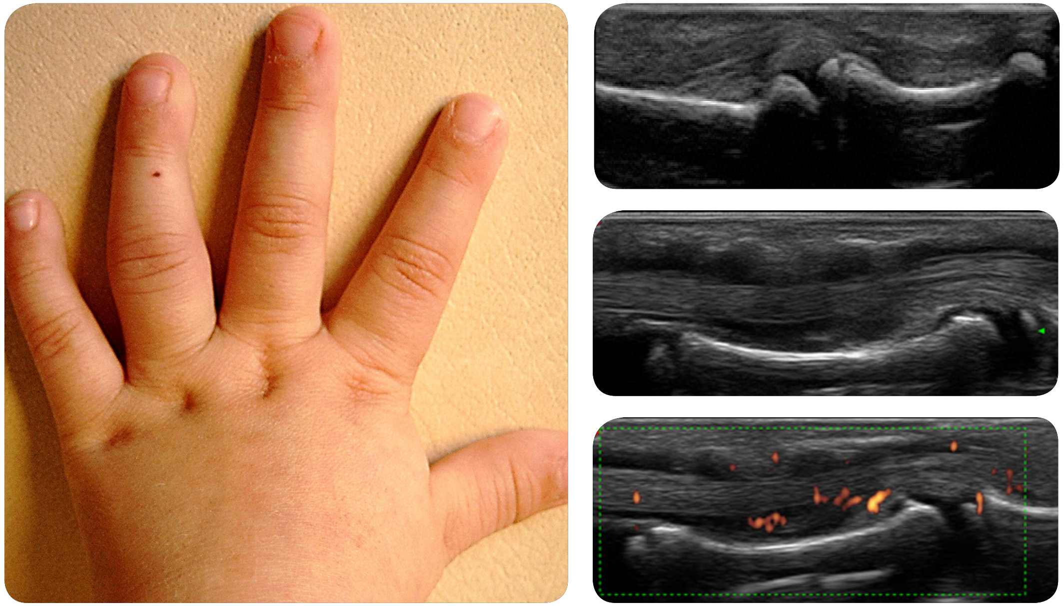
1. Rohrschneider WK et al. Pediatr Radiol 1996;26:629–634; 2. Żuber Z et al. Pediatr Rheumatol Online J 2017;15:8

Grading

Ankle flexor tendons



Flexor digitorum tendons

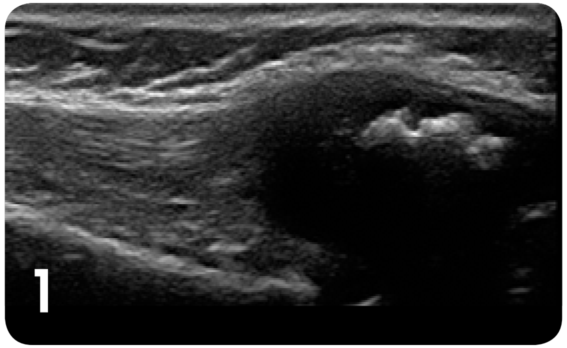


- MSUS allows accurate detection of tenosynovitis
- The most common US components of tendon involvement are hypoechoic or anechoic synovial sheath widening or thickening, hypoechoic or anechoic tendon sheath effusion, tendon thickness and peritendinous ± intratendinous PD or CD Doppler signal
- Since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

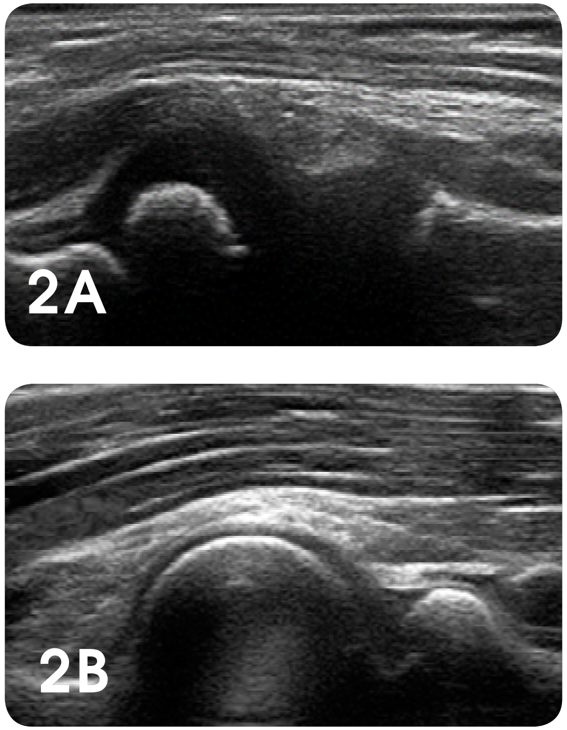
Ting TV et al. Arthritis Care Res (Hoboken) 2018 (Epub);doi: 10.1002/acr.23746

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



Longitudinal anterior suprapatellar scan of the knee obtained from a 4-year-old boy showing physiological irregularities of the bone profile of the patella

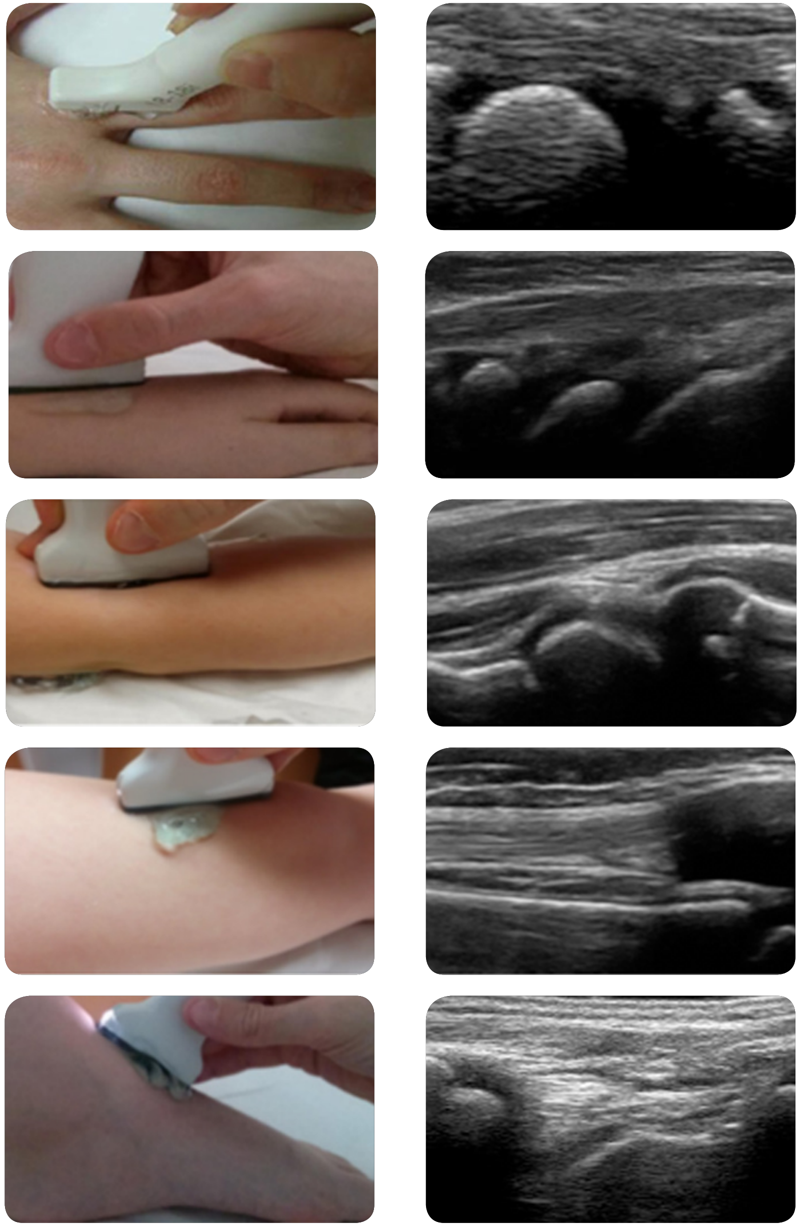


Anterior humeroradial longitudinal scans obtained from 3-year-old (A) and 16 year-old (B) healthy girls, showing decreasing thickness of cartilage with age

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

1. Colebatch-Bourn AN et al. Ann Rheum Dis 2015;74:1946–1957; 2. Rebollo-Polo M et al. Arthritis Care Res (Hoboken) 2011;63:1013–1019; 3. Collado P et al. Clin Exp Rheumatol 2014;32:597–603

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

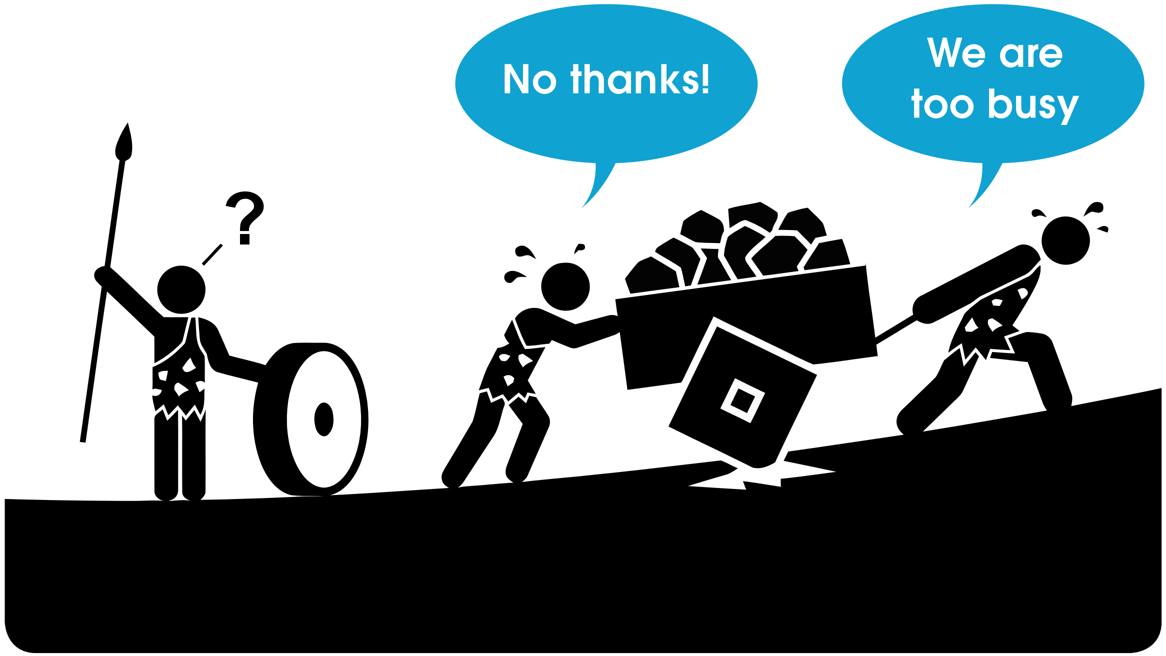
Baseline ultrasound can be a predictor of flare in JIA in remission

- 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)

de Lucia O et al. Ann Rheum Dis 2018;77:1426–1431

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

Consolaro A et al Clin Exp Rheumatol 2012;30:S157-62

Ped-MUS™

CRUS|SURC
Canadian Rheumatology Ultrasound Society
Société pour l'ultrasonographie en Rheumatologie au Canada

PANLAR

GKJR
Gesellschaft für Kinder- und Jugend-rheumatologie

I-Pure
Italian Pediatric Ultrasound in RhEumatology