# EFSUMB Course Book, 2nd Edition

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# Bone fracture ultrasound

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## Introduction

Fracture sonography is an object of research since 1975 (1). There are numerous studies about the feasability of ultrasound in fracture diagnosis which point out the potential of this method (2, 3), but do not compare sensitivity and specifity with radiologic imaging. Therefore the clinical usage of the method was recently limited to highly specialized examiners.

Since 2006 a structured research with comparison to x-ray allowed the definition of indications, safeness and the development of clinical standards which can easily be adopted to any clinical circumstances (4).

## Remarks to technique and indication

### Technique

#### *Ultrasound technique*

For fracture sonography regular ultrasound devices with 4-12 MHz linear transducers are used. No special equipment is needed. The opportunity for electronic angle measurement is advantageous but not mandatory.

Due to the high impedance difference between bone and soft tissues, a total reflection of ultrasound waves occurs at the cortical surface. This results in an excellent visualization of the corticales while deeper structures like cancellous bone cannot be examined.

#### *Visualization*

Sonography reveals alterations of the bone surface. The advantages in comparison to x-rays are the opportunity of multiple angles and planes with no overlying and the visualization of soft tissues like joint effusion, haematoma and blood vessels; the disadvantage is that deeper structures and intraarticular fractures cannot be adaequately diagnosed.

Cartilage is not well visualized by ultrasound, while soft tissues like muscle, fat and blood vessels can be examined easily. These have no relevant impact on the fracture diagnosis, because any severe soft tissue damage deserves x-ray evaluation of the bone.

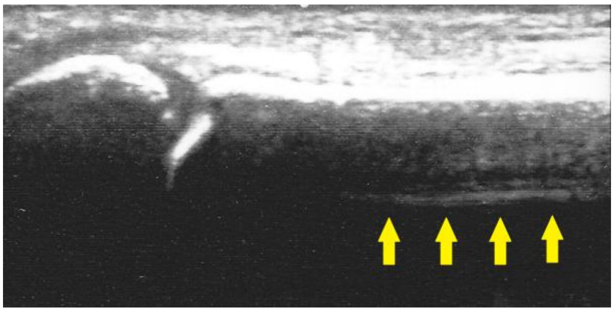
Sonographic measurement of bone deformities is precise with a mean difference of 2° (4, 5); only extreme deformities which are clinically apparent and doubtless deserve surgical repositioning, cannot be assessed well (6).

However, the gold standard of x-ray is in doubt (7). Studies showed that minor fractures which are not radiologically diagnosed can be seen in the ultrasound examination (5, 8). If a fracture is clearly seen in the x-ray images, the assessment is based on 2 planes which are not always in correct projection (9); ultrasound allows the assessment with multiple planes so that the complete deformity can be visualized (9).

Most linear transducers show a section of 4-6 cm length, longer structures can be documented sequentially. This may be necessary in case of a bowing fracture or a shaft fracture.

Bone tissue is displayed as a sharp line with full ultrasound wave reflection. Echoes behind the corticalis are artificial [Figure 1].

**Figure 1 The tissue behind the cortical bonne cannot be pictured. The echoes in this projection are artificial (*)**

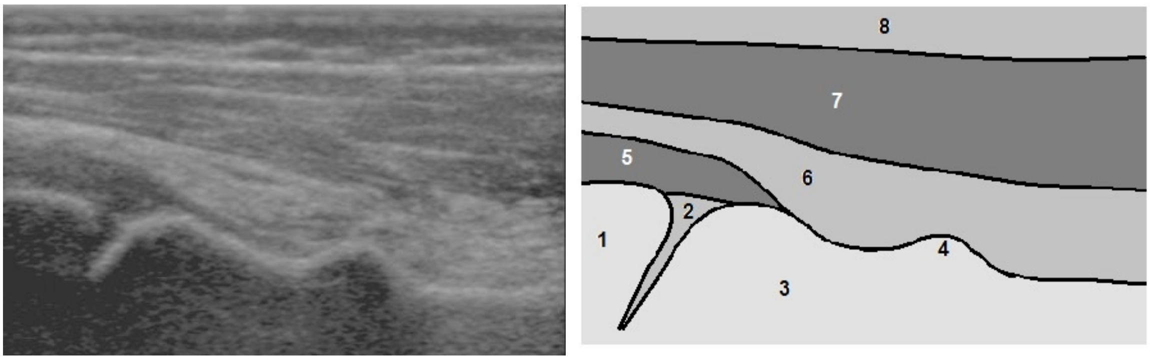


Muscle tissue, fat and nerves are well visualized and show the typical echoes similar to other locations. Haematomas and muscle tears can also be diagnosed.

The joint capsule of the wrist appears as a sharp line covering the dark joint cavum.

The epiphyseal plate is not pictured itself but can be assessed by the position of meta- and epiphysis. Cartilage is not well visualized [Figure 2].

**Figure 2 While bone and soft tissue is well visualized, cartilage and the epiphyseal plate are not echogenic structures; 1=epiphysis, 2=epiphyseal plate, 3=metaphysis, 4=fracture bump, 5=joint capsule, 6=deep fat, 7=muscle, 8=cutis and subcutaneous fat (*)**




## Application fields

### *Patient age*

Sonographic fracture diagnosis is feasable for patients from 0-12 years. In this population nearly all fractures cause cortical alterations and intraarticular fractures are rare. Also the thin soft tissue cover of the extremities is advantageous.
Due to the high sensitivity of growing tissue to radiation, these patients profit from the ultrasound diagnosis in a particular way.
An additional advantage is the high correction potential of these patients, which makes the ultrasound-guided treatment safe.

### *Fracture localisation*

Ultrasound cannot be ubiquitarily utilized. In respect of the special implications of every fracture entity focussed research is necessary for every location. Ultrasound is only advantagous if a) radiation exposure can be avoided or b) diagnosis quality is improved.
Actually 3 localizations where fracture sonography is feasible have been identified by prospective studies with direct comparison with x-ray imaging (10-13):

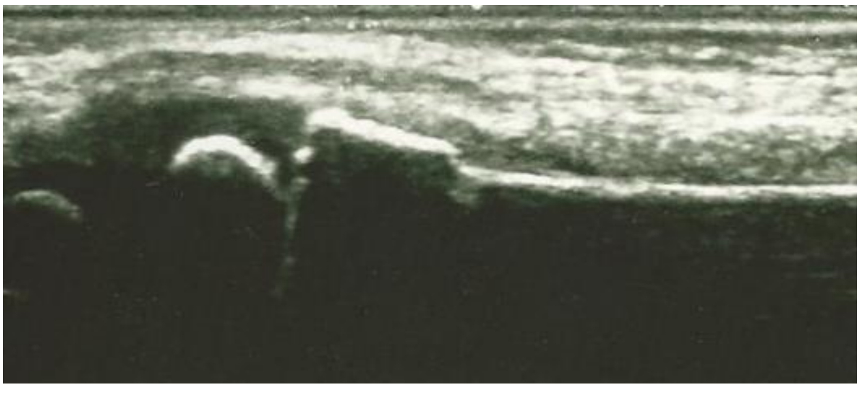
1. wrist fractures; in this location diagnosis and treatment is completely ultrasound-based. X-ray imaging is limited to special indications. The high frequency of these fractures results in a relevant reduction of radiation exposure for the patient population.
2. elbow fractures; in this location ultrasound serves as a screening method to rule out an intraarticular lesion. If a fracture is suspected (30% of the cases), x-ray diagnosis in 2 planes is mandatory, otherwise x-ray is dispensable.
3. proximal humerus fractures; in this location ultrasound can rule out a fracture and avoid radiation exposure. In case of a fracture, sonography allows a better visualization of the deformity in comparison to x-ray imaging.

**Documentation basics**

For the reason that the print documentation of ultrasound examination does not allow the identification of exact localisation and view, there are high requirements for the documentation. Beside the patient identification the exact bone, the plane and the side of the body have to be noted. This process can be simplified by using the diagnostic standard procedures mentioned below.

In fracture sonography only axial planes (parallel to the bone axis) are applicable, transverse planes rarely yield benefit. The documentation should picture the epiphysis as well as the metaphysis and shaft over the whole extend of the image from left to right [Figure 3].

**Figure 3 The standard for documentation is the picturing of the epiphysis. To guarantee an axial view, the bone should be pictured from the left to the right image border. (*)**



## Wrist fracture

### Basics / Anatomy

The distal epiphysis of radius and ulna contributes 80% to the length growth of the lower arm and therefore has a high potential for spontaneous correction of deformities.
The distal forearm fracture is the most frequent fracture in childhood and in 90% of the cases is treated conservatively.
In the examination the wrist joint with epiphysis and epiphyseal plate, the metaphysis and the shaft are visualized. Cutis and subcutis, muscle and deep fat can be seen as well as the blood vessels.
Fracture diagnosis and treatment control are completely ultrasound based. The fractures are well visualized and intraarticular fractures are extremely rare.

### Patient preparation

After exposure of the extremity the examination is performed in a relaxed supine or sitting position (e.g. sitting besides the parents). For the reason that the wrist can be surrounded with the transducer, only minimal positioning is necessary and the patient is allowed to maintain the spontaneous relieving posture [Figure 4].
Open fractures, severe soft-tissue lesions and high-grade deformities are contraindications for ultrasound diagnosis. If clinical examination reveals an indication for an operation, sonography should be skipped and x-ray imaging is preferable.

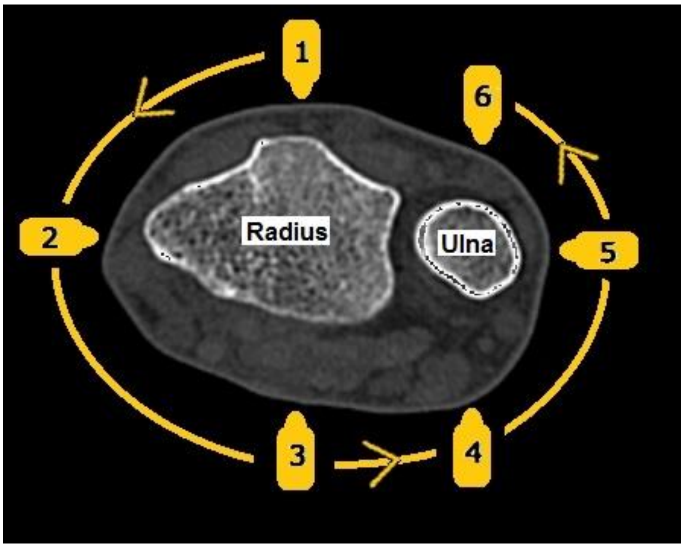
**Figure 4 The patient may lie or sit in a relaxed position and maintain the relieving posture. The wrist can be surrounded with the transducer. (*)**

**Examination / planes**

The first step is the injury anamnesis and clinical assessment. Even in young children this allows, in most cases, a differentiation between distal forearm and carpal lesions. This is important because carpal fractures are not suitable subjects for either ultrasound diagnosis or of x-ray imaging. In case of a suspected carpal lesion an MRI is indicated.

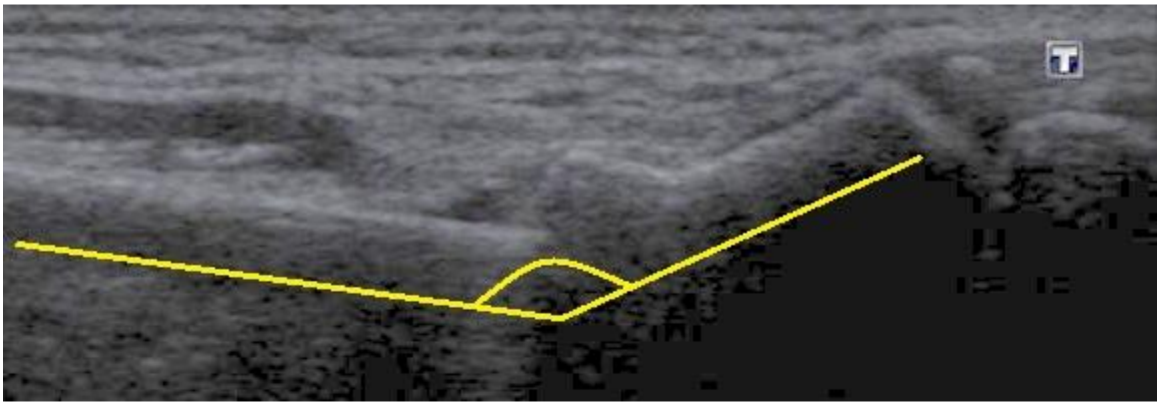
The wrist is examined in 6 planes [Figure 5]. As the wrist is normally held in pronated position the examination starts radial-dorsal and visualizes the whole radius, followed by the ulna. If necessary, 45° planes may be added.

**Figure 5 The wrist is examined in 6 planes, 3 for each bone. (*)**




Any deformity has to be measured in 3 planes in order to avoid underestimation [Figure 6].

**Figure 6 A deformity has to be assessed in 3 planes. Otherwise there is the risk of underestimation. (*)**



## Documentation

All 6 planes are documented electronically or with print images. If a deformity is detected, the apex should be localized in the image center in order to improve the measurement. In the axial planes the greatest angulation corresponds to the real deformity.

## Pathologies

There are four main morphologic fracture signs which can appear solely or in combination with each other:

1. Bump [Figure 7].
2. Angulation [Figure 8].
3. Offset [Figure 9].
4. Fracture Gap [Figure 10].

**Figure 7 A bumb deformity of the cortical bone at the metaphysis (*)**

**Figure 8 An angulation with a localized apex in the cortical bone (*)**

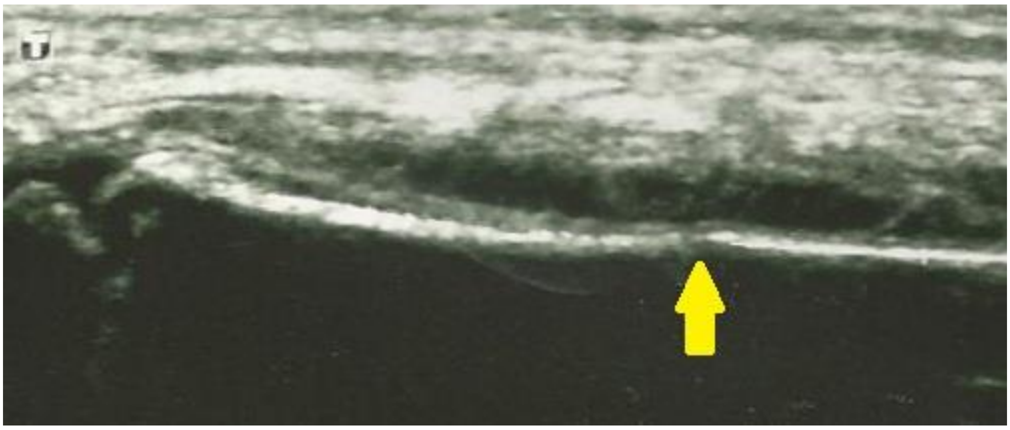


**Figure 9 Offset of cortical bone (*)**

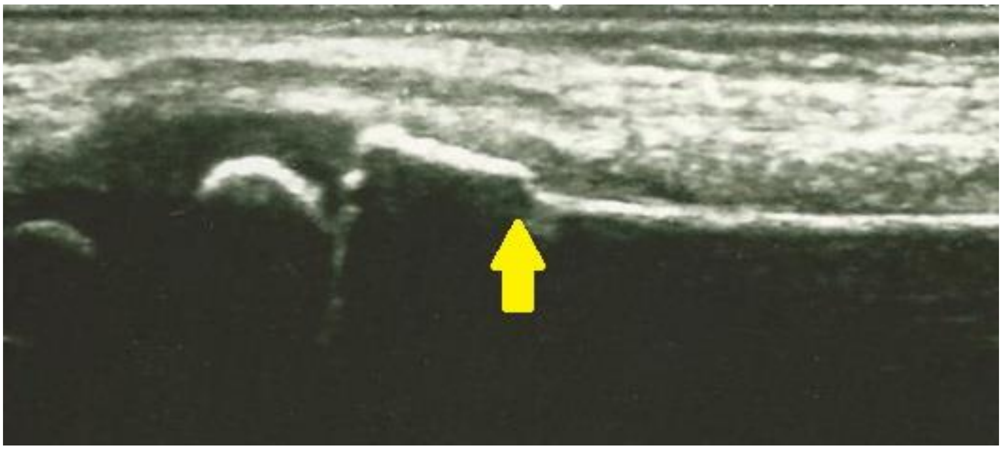
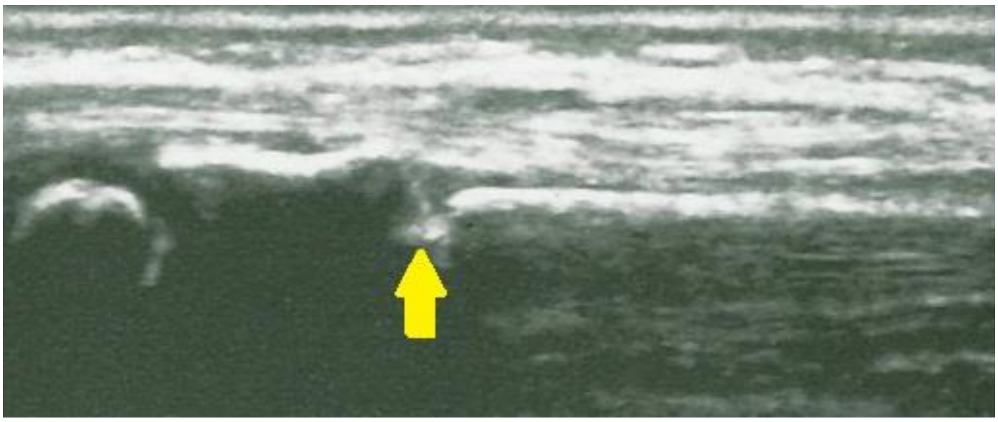


**Figure 10 Fracture gap with loss of cortical reflex (*)**



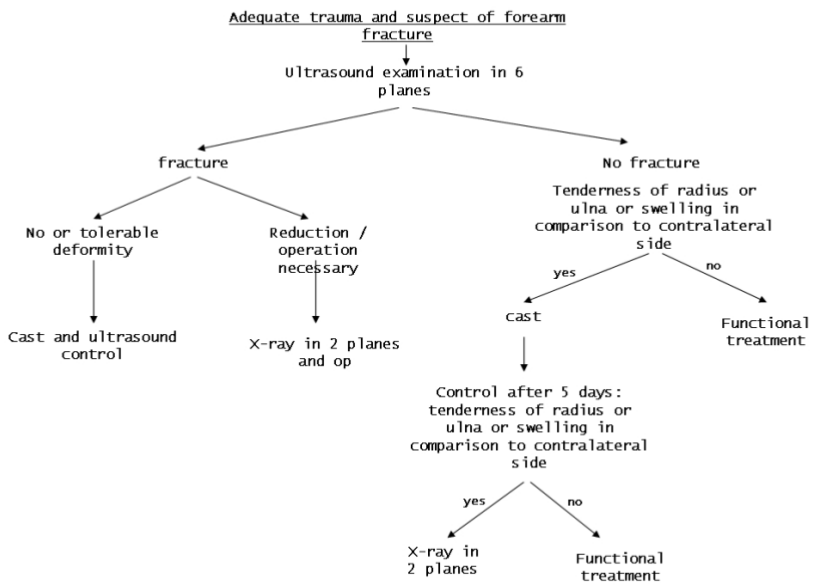
**Therapeutic implications**

If a fracture is diagnosed the deformity is assessed and the treatment respects the guidelines for traumatology in children. If no fracture is seen, a cast may be applied in case of severe pain. When pain persists in a clinical control after 5 days, a x-ray is taken in 2 planes, as well as in any case of doubt (10).

**Wrist SAFE**

Fracture sonography of the wrist of children up to 12 years has proven a sensitivity of 94-96% and a specifity of 97-99% in comparison with x-ray imaging (4, 5, 14) .

**Figure 11: Wrist SAFE (*)**



### Pitfalls

Fractures have a very high potential of spontaneous correction which makes the diagnosis and treatment safe.
Fractures of the carpal bones are not adaequately visualized, but can be ruled out by their clinical appearance. If there is a suspicion of a carpal fracture, an MRI is necessary, because x-ray imaging does not allow a safe diagnosis due to the presence of cartilage tissue in the growing bone.
An epiphysiolysis in anatomical alignment may be missed as well as in x-ray imaging. In these cases a comparison with the contralateral side or an MRI is useful. X-ray does not show more information than ultrasound.

## Elbow fracture

There are multiple types of elbow fractures (supracondylar, condylar, olecranon, radial head) which all cause effusion of the elbow joint, which therefore is a sensitive predictor for elbow fractures with a sensitivity of 97,3% and a specificity of 90,5% (15-17).
For the reason that the elbow-associated fractures have a limited potential of spontaenous correction an exact diagnosis is mandatory. Nevertheless 70% of clinical suspects of a fracture end up with a contusion diagnosis and the radiation exposure can be avoided with ultrasound screening.
The rationale of the fracture sonography in elbow fractures is to detect a joint effusion (SOFA (+) = **So**nographic **Fa**t-pad detected, SOFA (-) = no **So**nographic **Fa**t-pad). Ultrasound allows this with a sensitivity of 100% and a specificity of 93,5% (15, 18, 19). In case of SOFA (+) a radiological diagnosis in 2 planes is mandatory to achieve an exact assessment of deformity and fracture type.

### Patient preparation

After exposure of the extremity the examination is performed in a relaxed sitting position (e.g. sitting besides the parents). Only minimal positioning is necessary and the spontaneous relieving posture of the patient can be maintained [Figure 12].

Open fractures, severe soft-tissue lesions and high-grade deformities are contraindications for ultrasound diagnosis. If clinical examination reveals an indication for an operation, sonography should be skipped and x-ray imaging is preferable.

**Figure 12 The patient in a relaxed sitting position (*)**

**Examination / planes**

SOFA is detected in a single dorsal axial view which visualizes the fossa olecrani, the elbow is flexed 70-90°. In any case of doubt the contralateral side may be examined.
There is the opportunity to take up to 8 views of the distal humerus and an additional 3 of the olecranon and 2 of the radial head in order to visualize fractures and deformities (20, 21), but up to now a secure utilization is proved only for the SOFA sign. Future studies have to reveal the potential of the additional views.

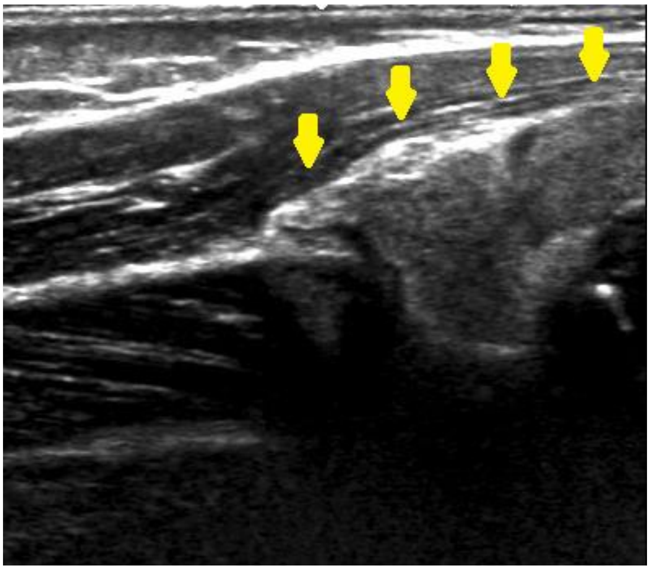
## Documentation

The documentation includes the dorsal longitudinal view and, if necessary, the same view of the contralateral body side.

## Pathologies

The dorsal capsule spreads from the distal humerus in a sharp angle. The dorsal fat pad sign impresses as a bump with blunt junction of the capsule to the bone and an echogenic joint effusion. [Figure 13]

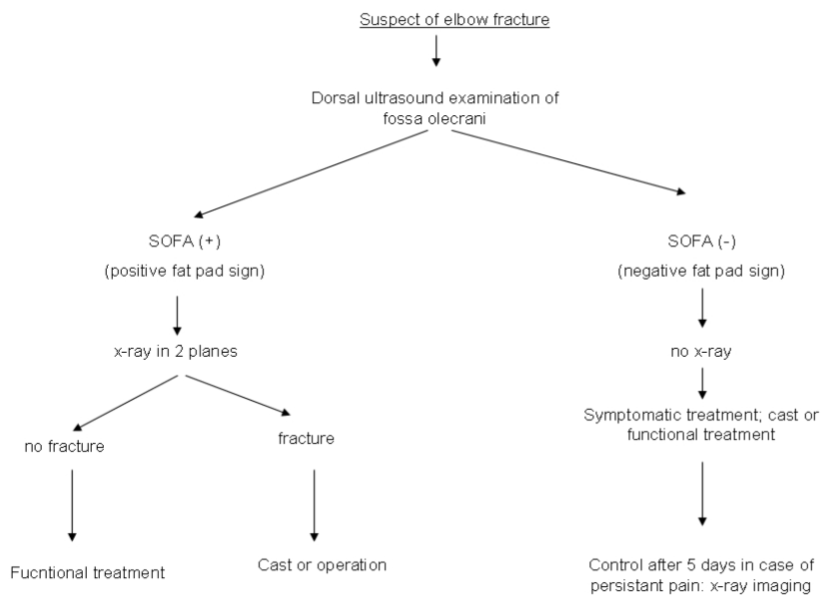
**Figure 13 The joint effusion is pictured as an echogenic bump of the joint capsule in the fossa olecrani. (*)**



## Elbow SAFE

The elbow SAFE sensitivity for elbow fractures is 97,9%, the specificity 95% (13) [Figure 14].

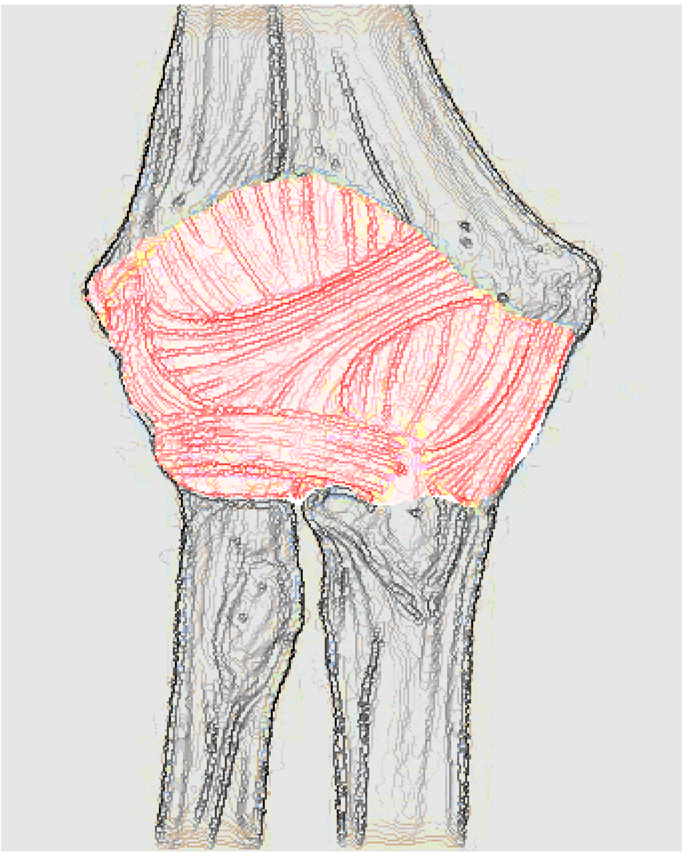
**Figure 14 Elbow SAFE (*)**




**Pitfalls**

Certain fractures of the ulnar / medial epicondyle may be extraarticular [Figure 15], therefore cause no joint effusion and may be missed with this method. If the clinical examination reveals a relevant tenderness of the medial epicondyle, x-rays in 2 planes are recommended.

**Figure 15 Joint capsule of the elbow joint (*)**



## Proximal Humerus fracture

Fractures of the proximal humerus have a very high potential of spontaneous correction due to the high growth potential of the epiphysis.

Sonography of the proximal humerus can rule out a fracture. If a cortical lesion is detected, the deformity is assessed and documented. For the reason that a tumor or a cyst may be the underlying pathology and these are not adequately visualized, in every fracture a single x-ray image is taken in one plane (22).

### Patient preparation

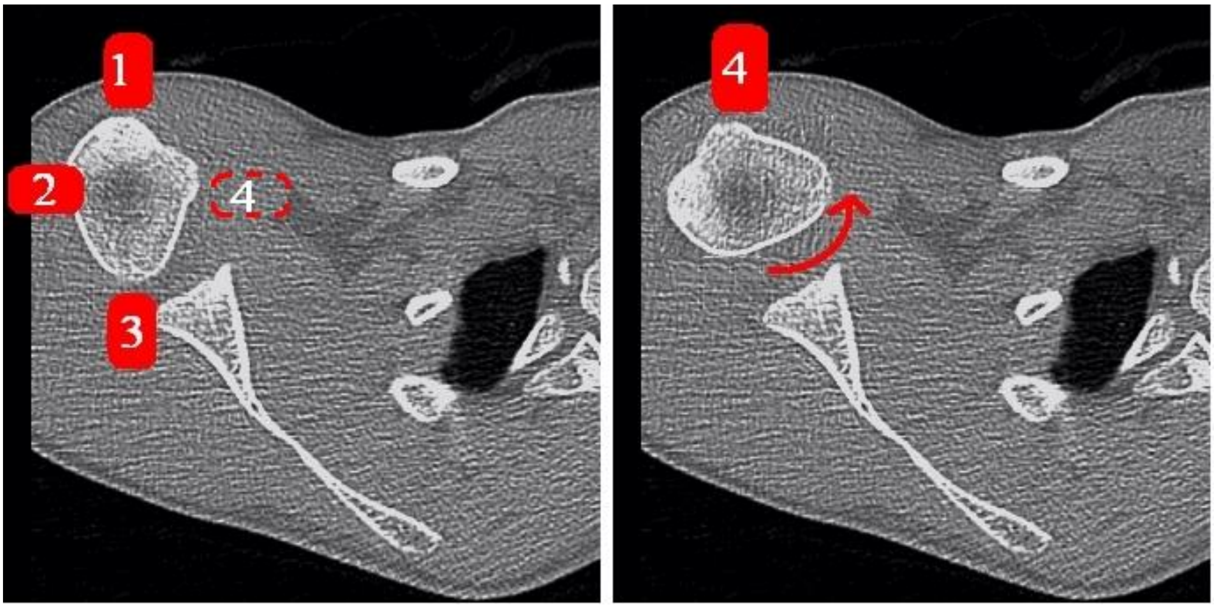
After exposure of the extremity the examination is performed in a relaxed sitting position (e.g. sitting besides the parents). For the reason that the proximal humerus can be surrounded with the transducer, only minimal positioning is necessary and the spontaneous relieving posture of the patient can be maintained.

Open fractures, severe soft-tissue lesions and high-grade deformities are contraindications for ultrasound diagnosis. If clinical examination reveals an indication for an operation, sonography should be skipped and x-ray imaging is preferable.

**Examination / planes**

In the initial clinical examination the fracture localization has to be differentiated from the more common clavicle fracture and lesions of the scapula and the humerus shaft.The proximal humerus is examined in 4 planes; 3 of these can be obtained in relieving posture. Then the arm should be rotated in neutral position to expose the fourth plane [Figure 16].

**Figure 16 3 planes are obtained in the relieving posture, then the arm is gently rotated in neutral position which exposes the 4th plane. (*)**



## Documentation

All 4 planes are documented. If a deformity is revealed, the greatest deformity should be documented. In case of a fracture a single x-ray of the shoulder is taken.

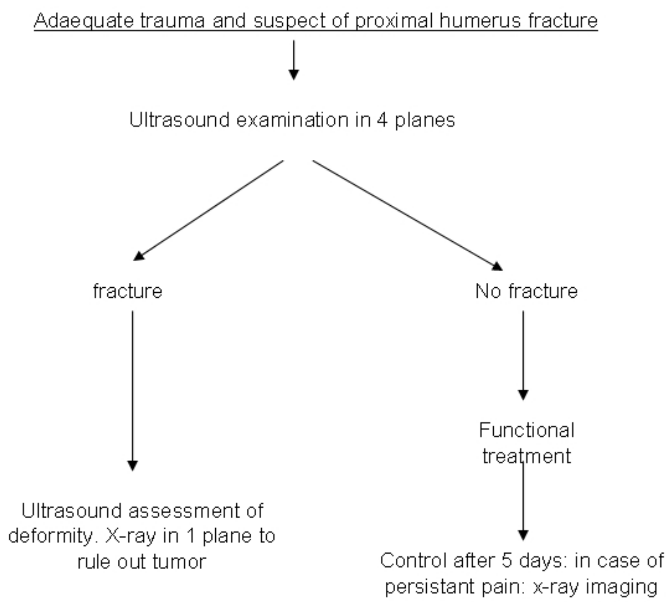
## Pathologies

The fracture signs are similar to that of the wrist. Intracortical pathologies must be diagnosed by x-ray or MRI.

## Shoulder SAFE

The sonographic evaluation of the deformity in proximal humerus fractures is more precise than the x-ray assessment and has a sensitivity of 94% and a specificity of 100% (22) [Figure 17].

**Figure 17 Shoulder SAFE (*)**



**Pitfalls**

Humerus shaft fractures and fractures of the clavicle or the scapula may be missed in the case of a brief clinical examination.

Fractures have a very high potential of spontaneous correction which makes the diagnosis and treatment safe.

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