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Musculoskeletal ultrasound in childhood

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ABSTRACT

Ultrasonography is one of the first line imaging modalities for the evaluation of musculoskeletal disorders in children. This article provides an overview of the most important pathologic entities in which ultrasonography significantly contributes to the diagnostic workup.

1. Introduction

Ultrasonography (US) has emerged as an indispensable tool for primarily evaluating a variety of musculoskeletal disorders in children. It has certain advantages over other imaging modalities – it is a readily available, convenient and cost effective method. It is non-invasive and there is no need for sedation even in small children. US is particularly well suited for the examination of the immature skeleton with its large portion of cartilaginous, non-ossified structures as it can readily distinguish soft tissue from cartilage and from bone. The capability of real time imaging allows the dynamic assessment of musculoskeletal structures during joint movement and repetitive imaging in motion and at rest is possible. With US it is easy to compare the symptomatic to the contralateral side. The high sensitivity of US for fluid collections and joint effusions makes it an ideal tool for image guided puncture. By following structures and using Color Doppler sonography (CDS), vessels and nerves can be differentiated, and tissue vascularity can easily be assessed too.

There are some limitations for the use of US in musculoskeletal disease – US cannot penetrate bone and air, therefore certain regions of the body such as the deeper parts of the pelvis or bone marrow lesions cannot be assessed by US. The quality and consistency of an US examination rely on the expertise, creativity and patience of the examiner – this may be seen as a disadvantage or as a chance.

This article emphasizes the value of US in common developmental, infectious, inflammatory and traumatic conditions that affect the musculoskeletal system in children.

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2. Technical considerations

As most indications refer to structures, that lie relatively superficial, high frequency probes can be used to achieve optimal special resolution. Linear probes are preferable due to the lack of distortion. In small children hockey stick transducers allow the access of many regions, where conventional linear transducers would be too large. The use of a stand-off pad enables an optimal visualization of the area close to the body surface. In frightened children it may contribute to calm the situation. An alternative is the use of a water-bath, where the child puts the extremity in and the transducer can be held close without touching the skin thus avoiding pain or anxious distress in the child. If necessary, a child can even be examined comfortably in the arms of a parent.

In the sonographic evaluation of the musculoskeletal system the amplitude of the echo is highly dependent on the angle of insonation. Advances in ultrasound technologies have contributed to improvement of image quality. Compound imaging and beam-steering decreases many image artifacts inherent in conventional sonography and are especially helpful to avoid anisotropic artifacts in tendons and ligaments. Compound imaging also results in improved tissue-plane definition due to speckle noise reduction. Harmonic imaging aids in the differentiation of tissues, but also makes the borders between structures appear artificially thickened.

3. Developmental anomalies

Developmental dysplasia of the hip (DDH) is the most common indication for musculoskeletal US in children. It covers a spectrum of congenital abnormalities that ranges from immaturity and only instability to dislocation of the hip. Stabile positioning of the femoral head within the acetabulum is thought to propagate acetabular development allowing for remodeling of acetabular dysplasia over time, this is used as a conservative treatment approach. The maximum potential for effective treatment of DDH is in the first 3 months after birth.

US is an excellent tool to assess the anatomical details of the cartilaginous parts of the neonatal hip, and is much more informative than radiography in this age group. The accuracy and utility of US in examining neonatal and infant hips is high. A combined understanding of anatomy, pathology and sonography is required. Since hip US was first described by Graf in 1980 several methods for the assessment of morphology and stability of the neonatal hip have been developed [1]. The method proposed by Graf is widely used in central Europe. It assesses hip morphology, but also takes account of hip stability (2). A standard coronal view with the infant in the lateral position is acquired. The iliac bone has to be straight and the acetabular labrum as well as the lowest point of the acetabular part of the iliac bone has to be visible (Fig. 1a). Measurement of alpha and beta angels allows classification into four main and 9 sub-types (Fig. 1b). A stress test pushing the femur in a cranial and dorsal direction is added to assess hip stability [2]. The combined use of a stability test in conjunction with the assessment of the acetabular morphology using a standard coronary view defined by Graf and measurement of the alpha angle only was propagated by Rosendahl et al. [3]. Harcke et al. developed a dynamic US examination of the infant hip, which is widely used in the United States [4]. A four step scanning technique is used based on transverse and coronal planes in neutral and flexed position, at rest and during stress. Hips are classified as normal, lax under stress, subluxed or dislocated.

The femoral head coverage technique proposed by Morin and modified by Terjesen assesses the lateralization of the femoral head; it is used widely in France [5,6]. Femoral head coverage by the bony acetabular rim of less than 50% is considered abnormal.

Treatment is based on the reduction of a displaced hip (Fig. 1c) and stabilization of the femoral head within the acetabular fossa. Maintaining is achieved by several devices. With harnesses or splints US follow up is the method of choice until shadowing from the developing ossification center of the femoral head limits its usefulness. With the ossified femoral head radiography can be used to guide further treatment. MRI is helpful in those cases, where hip reduction cannot be achieved by clinical manipulation and for confirmation of femoral head position with spica casts in situ.

A reduction in the rate of patients requiring surgery for DDH was seen after the introduction of universal US screening in Austria and Germany [7,8], but the value of universal US screening for DDH is still under debate [9,10].

Recommendations for the sonographic evaluation of the neonatal hip were elaborated by the DDH Taskforce Group of the European Society of Pediatric Radiology. The latest update was issued in May 2011 [11].

The diagnosis of neonatal foot deformities is commonly based on clinical evaluation and radiography. As tarsal bones are largely cartilaginous and many even lack an ossification center US is a valuable means for estimating the severity of the deformity. US can visualize the cartilaginous parts of the neonatal foot und evaluate alignment. The examination is based on a series of measurements, such as the medial malleolus-navicular distance, the navicular alignment with the talar head, talar length and the calcaneo-cuboid distance [12,13].

The ability of US to visualize cartilage allows for further evaluation of limb deformities, where radiographs show only one bone at the forearm or lower leg. Aplasia or hypoplasia with solely

a

b

c

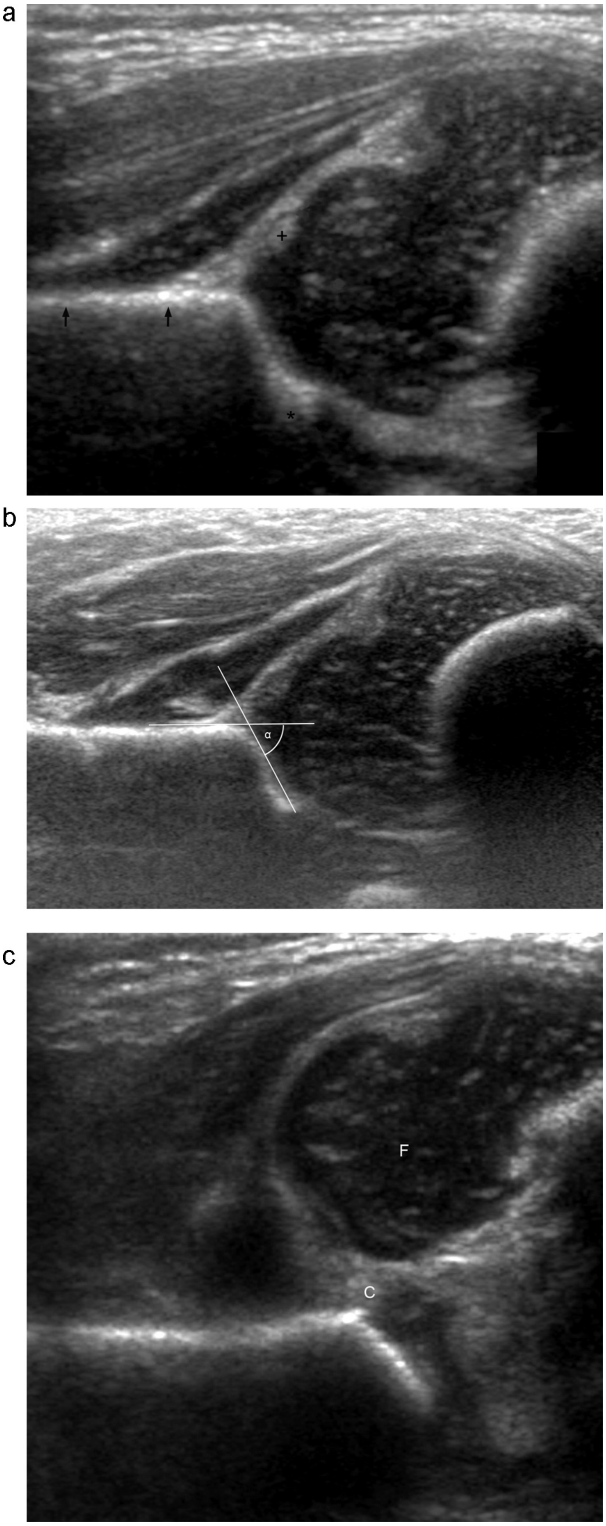

Fig. 1. Coronal US scan of the newborn hip (Graf's technique): (a) Normal hip: On a standard view showing the deepest point of the ilium within the acetabular fossa (*), the straight upper part of the ilium (arrows) and the cetabular labrum (+). (b) the alpha angle (α) is $>60^{\circ}$. (c) Dislocated hip: The fermoral head (F) is completely dislocated, the cartilage roof (C) is interposed.

cartilaginous Anlage of the radius or fibula can be differentiated (Fig. 2a and b).

Anterior chest wall deformities in children are a common cause of parental concern. They are often caused by an abnormal angulation of the cartilaginous rib which cannot be visualized