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Online supplementary text

General recommended procedures

MSUS modes

MSUS includes two principal modes, B-mode (or grey-scale) and either colour or power Doppler which is the superimposition of Doppler information on the B-mode image. B-mode provides us with morphological information registered as shades of grey between the extremes of black (no reflection of emitted ultrasonic waves) to white (full reflection) created by the reflective properties of tissue interfaces within and on the surfaces of the anatomic structures and tissues being imaged. Doppler mode, either colour Doppler or power Doppler, detects the movement of blood cells within vessels. Doppler examination is an important part of the rheumatologic MSUS examination in that it is able to detect areas of increased blood flow (neovascularization or vasodilation) characteristic of the inflammation encountered in many RMD. Colour Doppler and power Doppler can both be used to detect small vessels with slower flow rates located within normal or pathological tissues whereas colour Doppler is utilized to evaluate flow characteristics (including flow direction) in large vessels (67,68). B-mode MSUS should be performed with high-resolution linear transducers (i.e. probes) with frequencies between 6-14 MHz for deep/intermediate areas to 15-22 MHz for superficial areas. Probes with a large footprint are optimal for large joints/structures while small footprint probes are appropriate for superficial small joints/structures (e.g. hands and feet). Tissue harmonic imaging, spatial compound imaging, extended field of view (i.e. panoramic) and virtual convex imaging are some of the software capabilities that may be useful in MSUS.

Technical aspects of US scanning

<u>Probe positioning and sweeping</u>

When scanning a joint, the probe should be aligned in the long axis of the joint in order to visualize both bony components. Ideally, the bone surfaces should be continuous across the screen from left to right. It is critical to orient the probe perpendicularly to the bony cortical surface (the so-called “bony acoustic landmark”) so that the cortical margin appears bright, sharp and hyperechoic. This enables the visualization of minimal bone changes including small erosions or fractures while avoiding artefacts from the bone profile or overlying tissues. In addition, this also enhances the appearance of the soft tissues over the bone including cartilage and capsular structures by maximizing the intensity of ultrasonic wave transmission altered by their interfaces.

A dynamic scanning technique, using slight movements of the probe from side-to-side (toggling or sliding), back-to-front (tilting or rocking) or rotation (around central axis of probe) is highly desirable in order to allow the best visualization of the structure(s) of interest. It is also important to be able to move the underlying structure to ascertain normal mobility (for example, in suspected impingement such as in “triggering”), to stress the structure to reveal subtle changes in its architecture (e.g. small tears) or patency, to facilitate the movement of fluid within capsular structures and to straighten linear structures such as tendons, nerves and ligaments to optimize the visualization and eliminate anisotropy, Anisotropy refers to the hypoechoic (or anechoic) appearance of a normally hyperechoic structure when the insonation angle of the US beam is not exactly perpendicular to it. In tendons, this sensitivity to the insonation angle is due to the orientation of intratendinous specular reflectors revealing the most dramatic changes with slight angulations of the probe, and other tissues with relatively regular structure (nerve, ligament) showing less dramatic changes. Anisotropy must be eliminated to assure that no pathologic changes are present in these tissues. It should be pointed out that anisotropy may sometimes be useful identifying tissues and distinguishing them from one another owing to their varying sensitivity to beam angle which is directly related to the degree of structural regularity. To avoid anisotropy and the common pitfalls that accompany it, it is necessary not only to straighten these tissues as much as possible but also to continuously adjust the probe to maintain the beam perpendicular to the tendon fibres especially in insertional regions such as the entheses owing to the curving that the inserting tissue undergoes just prior to the bonding site.

The "cartilage interface" sign is a fine hyperechoic line seen directly above the cartilage which represents the acoustic reflection occurring between the cartilage surface and the overlying intra-articular fluid as a result of differences in acoustic impedance. It is seen when the probe is exactly 90º to the surface of the cartilage. Its identification is important because it can identify the boundary of the cartilage when there is overlying fluid.

<u>Structure axis</u>

Non-spherical structures have a long or longitudinal axis and a short or transverse axis. Axis of the probe corresponds to visualized axis of the structure of interest.

When the long axis of the structure of interest corresponds to the cranial-caudal orientation of the human anatomic position, the most proximal aspect of the structure is usually placed on the left-hand side of the screen. However, other options are acceptable as long as a consistent probe orientation is maintained (e.g. visualization on the left side of the screen what is shown by the edge of the probe that is held by the thumb of the operator). Short axis orientation on the screen is at the preference of the examiner. For the short axis, our preference is to align the structure of interest on the screen as if the observer is looking at the patient (ie from the front or behind).

Rotational movement is performed around the central axis of probe over the centre of the structure of interest to visualise the structure in both axes. For those structures that morphologically have no well-defined long and short axis, the orientation of the probe is referred to the adjacent structures, e.g. annular pulley to the finger flexor tendons or articular cartilage to the adjacent epiphysis.

<u>Probe pressure</u>

Probe compression plays a critical role in the MSUS examination. Compression can be helpful in distinguishing a compressible liquid collection (e.g. effusion) from a non-compressible solid (e.g. synovial proliferation) even though their echogenicity may be similar. Little or no compression is important when performing Doppler examination to avoid vascular compression and cessation of flow in small vessels. It can also be used to distinguish venous from arterial vessels and confirm their patency. Thus, probe pressure should be variable, minimal or none for detection of flow by Doppler mode or small amounts of fluid and can be increased for deep structures to minimize distance between probe and structure in order to enhance penetration with higher frequency where detection of flow is unreliable.

<u>Gel</u>

A generous amount of gel should be used for superficial structures especially when little or no pressure is indicated. The identification of a gel film over the skin surface on an image can suggest to the observer that minimal pressure was applied.

Machine settings

MSUS is highly dependent on the training level of operators and also machine-dependent. It requires a thorough knowledge of the adjustable parameters along with their consistent application to maintain reasonable sensitivity and avoid artefacts. As the Doppler image is superimposed over a B-mode image, it is important to optimize the grey-scale image before initiating Doppler examination. The machine setting for B-mode and Doppler mode [e.g. focal zone, frequency, gain, dynamic range, depth for B-mode; focal zone, colour box, frequency, gain, pulse repetition frequency (PRF), persistence, wall filter, colour priority for Doppler mode] should be properly adjusted prior to and during the examination to optimize the US images acquisition process.

A patient perspective

MSUS is a valuable tool in the diagnosis and management of rheumatic disease. Also from a patient point of view MSUS is a relative well tolerated imaging technique. Although obtaining an optimal image is the most important part of the scanning process, ideally this is performed with the least pain or discomfort to the patient. Online Supplementary Table I shows recommended procedures intended to contribute to this.

Online Supplementary Table 1. Recommended procedures from a patient perspective

1) Let the scanning take place in a room with an appropriate temperature 2) Place the scanned region as well as the rest of the body in as natural position as possible. Avoid or limit hyperextension/flexion, internal/external rotation and supination/pronation. Even the smallest bit can cause pain or discomfort 3) Make sure the body is in a relaxed position as much as possible. Provide adequate support utilizing the examination table, pillows or towels 4) Where there is an alternative position, allow the patient to choose. Present the alternative choice from the start to prevent a painful or uncomfortable position, as the patient is likely to adjust because he or she understands the purpose and necessity of the examination. 5) Move the scanned region slowly and let the patient move slowly 6) In case of a prolonged or painful examination, let the patient pause or move their scanned region. 7) In other cases be efficient with time. 8) When possible, involve and educate the patient with information, viewing the screen, etc. This can provide distraction to the patient and possibly improve their tolerance. 9) If an uncomfortable or painful position cannot be avoided, a caring attitude is of great value. 10) When appropriate, use humor. A positive mind can substantially improve tolerance

HP perspective

Online Supplementary Table 2 displays suggestions to improve the health service experience both from the patient and sonographer perspective.

Online Supplementary Table 2. Recommended procedures from HP perspective

1) A room spacious enough to contain the US machine, the examination bed (not against a wall), the sonographer's chair plus a chair for the patient, an optional extra-chair could be used for the patients belongings or an accompanying person and/or translator, and a place to hang patient's cloths and coat. 2) Placement of the US machine and sonographer's seat to facilitate scanning with the dominant hand. 3) Accessibility for wheelchairs. 4) Appropriate illumination (i.e. adjustable lighting), with thick curtains to darken the room plus indirect small light for the US examination.

5) Readily accessible equipment such as gel, towels, dustbin, gloves (including latex free ones), etc.
6) Access to a wireless phone near the US machine.
7) Appropriate information systems and processes to help recording the session without burden to the sonographer.
8) Use of auxiliary devices for a comfortable positioning of the patient: wedges, pillows, cushions of different sizes.
9) Time allocated for appropriate explanation of the procedure, its objective and results to the patient.