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“Sports Ultrasound”, advantages, indications and limitations in upper and lower limbs musculoskeletal disorders. Review article

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ABSTRACT

Ultrasonography (US) is a safe and noninvasive imaging modality that is gaining popularity in different medical and surgical fields. Its introduction in musculoskeletal and sports medicine has taken this advanced subspecialty to a higher level. It has the advantage over other imaging techniques with regards to ease of use, availability, comfort and cost. Not to mention, in terms of safety profile, patients are not exposed to radiations, like in x-rays, and it can be performed on patients with metal or pacemaker implants, which are contraindicated in MRI. Standard diagnostic sonography doesn't have any known harmful effects on humans. In this article we will discuss the role of ultrasound in sports medicine, highlighting the diagnostic and interventional indications, uses and limitations.

1. Introduction

The story of the development of ultrasound (US) applications in medicine starts with the history of measuring distance under water using sound waves back in 1826. The term **SONAR** refers to **Sound Navigation and Ranging**. Ultrasound scanners can be regarded as a form of 'medical' Sonar. It was in 1948 that extensive studies on ultrasonic medical imaging were starting to be undertaken in the United States and Japan [1]. Earliest report of US use in the musculoskeletal system dates back to 1972 when Baker's cyst was differentiated from thrombophlebitis [108]. Then in 1978 US was utilized to demonstrate synovitis and evaluate the result of treatment in rheumatoid arthritis [109].

Ultrasonography (US) use is a non-invasive imaging procedure. At odds with X-rays and computerized tomography (CT) scan, it doesn't expose the patient to ionizing radiation, and unlike magnetic resonance imaging (MRI), it's considered safe even in patients with cardiac pacemakers and metal implants and in those with claustrophobia. Overall, standard diagnostic ultrasonography doesn't have contraindications.

Application of US in medical and surgical fields covers many subjects starting from gynecology and obstetrics, urology, general surgery, vascular and orthopedics surgery. Its appeal in orthopedic surgery was due to its low cost, non-invasiveness and easy availability in clinics or as portable devices. Add to it, the high resolution images and real-time

assessment give the magnificent diagnostic benefits to orthopedic ultrasound, hence often referred to as the “orthopedic surgeon's stethoscope” [2,3]. Having a wide range of use within sports medicine that are not just restricted to orthopedics, the American Medical Society for Sports Medicine recently proposed changing the name of ultrasound used within medicine from “Musculoskeletal US” to “Sports Ultrasound” (SPORTS US) as a more accurate delineation of the broad and unique application of ultrasound in this sub-specialty [4,5].

Conventional ultrasound shows the images in thin, flat slices of the body. Developments in ultrasound machinery include three-dimensional (3-D) ultrasound that displays the sound wave data into 3-D images.

2. Discussion

2.1. Indications and general consideration

The indications of US use in sports medicine have increased substantially in the last few years. Yet, if used correctly, it can lead to significant reductions in healthcare cost. Parker et al. [6] estimated that replacing MRI with ultrasound for the evaluation of specific shoulder pathology would save the United States \$6.9 billion in health care costs between 2006 and 2020. Moreover, Middleton et al [7] established that for assessment of shoulder problems patients opted for diagnostic

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US rather than MRI. The Institute for Healthcare Improvement has established an Initiative referred to as the Triple Aim [8], the objectives of which are to improve the patient's experience of care (including quality and satisfaction), Improve population health, and lower healthcare costs. Ultrasound has all of the elements required to meet this triple aim.

The images produced by US are exquisite. It is able to delineate anatomy of structures in relation to their echo textures. In other words, images are created based on physical changes in composition while, with MRI, images are provided based on chemical changes in the structures. They yield higher resolution images of superficial soft tissue anatomy than any other modality including MRI [3,5]. This helps in earlier detection of pathologies, causing tiny calcifications in soft tissue, tendon tears or reparative hypertrophic changes on bone surfaces, than with x-rays, CT or MRI [9,10].

Moreover, and most importantly, ultrasonography is a hands-on and interactive examination where you can interact with the patient while imaging [11]. Additionally, we can't undervalue the significance of the dynamic real time diagnostic capability of the sports US in assessment of joints, tendons movements and stability, ligamentous injury, nerve compression, structural abnormalities, infection and detection of fracture nonunion [11,12].

Apart from its diagnostic utility, US imaging is ideal for guiding most musculoskeletal interventional procedures [13–17]. Real-time ability to intervene and check the response is beneficial for therapeutic techniques, like aspiration of a joint or cyst, and guiding biopsy of soft tissue masses [18–22]. Repeatability is another feature as well, helping in monitoring the disease progression (e.g. in partial tendon tears) and response to treatment. Worth mentioning is the ability to compare targeted findings with those of the contralateral side. Summary of SPORTS US advantages in Table 1.

Despite its several advantages, its user dependency and thus the lengthy training period might appear as a relative limitation/challenge against its wide use in sports medicine. Operators should be familiar with the limitations of US examination which are summarized in Table 2. US produce a high resolution picture of a small area under examination. When patient presents with a diffuse shoulder pain, then it's wise to consider MRI or CT scan studies. The limited penetration of US into deeper structures presents difficulty in assessing deep body regions, morbidly obese patients and areas deep to bone, e.g. sub acromial space or inferior border of clavicle [23].

2.2. Basic technical consideration

At the time of examination, comprehensive knowledge of anatomy is required. Likewise accurate selection of US machine, settings and a sound review of the US machine manual. Probe selection can be crucial for optimum visualization. In summary (Fig. 1), lower-frequency curvilinear probes (3–5 MHz) target deeper structures, like knee and hip joints [24,25], they allow deeper US penetration which come at the cost

Table 1
Advantages of SPORTS US.

Non invasive
No radiation exposure
Portable (availability)
Relatively inexpensive
Safe in patients with pacemaker and metal implants
No claustrophobia
Higher resolution images of superficial soft tissue anatomy than MRI
No known contraindications
Real time assessment
Dynamic examination
Can interact with the patient while imaging
Rapid contralateral limb examination for comparison
Repeatability to monitor disease progression or treatment
Guide procedures (injections, aspiration, biopsy)

Table 2
Disadvantages and limitations of SPORTS US.

Technique	Limited field view Incomplete evaluation of bones and joints Limited penetration
Operator	Experience dependent Lengthy training period Dearth of certification development



Fig. 1. Commonly used ultrasound transducers in musculoskeletal ultrasound. Left, High-frequency (15-7 MHz), small-footprint, linear array transducer, also called a “hockey stick” transducer. Center, High-frequency (17-5 MHz) linear array transducer. Right, Low-to medium-frequency (5-2 MHz) curvilinear array transducer. Both linear transducers are used for superficial imaging, whereas the curvilinear transducer's lower frequency facilitates examination of deeper regions such as the hip (Philips iU22 Ultrasound Machine; Philips Medical Systems, Bothell, WA).

of poorer resolution [26]. At the other side, higher-frequency linear probes (7–15 MHz), lack the depth penetration of lower-frequency probes, but provides marvelous resolution and images, hence it is used for injecting superficial structures [27,28]. High frequency, hockey stick transducers have a smaller footprint and permit better contact between small irregular surfaces, improving probe contact and visualization, hence ideal in guiding injections around the foot and hand [29].

2.3. Shoulder

Shoulder disorders are extremely common. One in three people experiences shoulder pain at some stage of his/her life [30]. It is the most common musculoskeletal symptom after cervical and lumbar pain [31]. 30% and 70% of such shoulder pain arises from pathology of the rotator cuff [32,33]. Rotator cuff tears are the most common non-traumatic upper limb cause of disability in people over 50 years. Given the popularity and the availability of high resolution transducers, US is at the forefront as a diagnostic tool in many patient with shoulder pain [34,35].

Recent studies utilizing arthroscopy or MRI for validation of ultrasound have demonstrated sensitivities of 58–100% and specificities of 78–100% for full-thickness tears [36,37]. In certain cases, the lower values reflected investigator bias or poor-quality equipment. Studies using current machines and skilled operators report a high overall accuracy of 96%, a sensitivity of 100%, and a specificity of 85% [38]. In experienced hands ultrasound can identify the presence and extent of partial-thickness and even full-thickness rotator cuff tears with an accuracy similar to MRI [39–44].

Some operators prefer to face the patient and others favor standing behind when scanning over the patient's shoulder [45,46]. Structures orientation in (Fig. 2).

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