Chapter 1
Introduction

A patient with a rheumatological inflammatory disorder usually presents with symptoms or signs including pain, stiffness, fatigue, weakness, or joint swelling. In rheumatology, history taking and physical examination are the fundamentals of the diagnostic process in which information from signs and symptoms has to be weighed in terms of positive and negative predictive values. Although exact data are lacking, it is estimated that by means of history and physical examination, a correct tentative diagnosis is made in 80–90% of patients at presentation. In the miscellaneous 10 to 20%, further diagnostic steps, i.e., laboratory tests and imaging techniques, are required for establishing a diagnosis. Ultrasound has proven to be more sensitive than clinical examination to detect synovitis in patients with early rheumatoid arthritis; furthermore, it has been shown to have superior sensitivity compared to conventional radiographs for picking up small erosions in finger joints.

The sensitivity for synovitis and erosions is reported to be comparable with that of MRI in some studies but inferior in others, due to the fact that ultrasound sensitivity is related to the site and the accessibility of the joint. Ultrasound is also able to detect minute fluid collections in joints, entheseal abnormalities like calcifications and enthesophytes, as well as tendon sheath inflammation and thickening of finger pulleys and tendons in psoriatic arthritis. By means of its power Doppler feature, ultrasound can pick up signals of dilated small blood vessels at various anatomical sites including entheses, tendon sheaths and joint synovia. Color Doppler combined with grayscale ultrasound may detect the oedema of arterial walls like that of the temporal artery in temporal arteritis. Grayscale ultrasound may already give a preliminary impression of joint synovitis, but positive power Doppler signals will definitely confirm the active inflammation of the joint. Abnormal structure of the salivary glands related to Sjögren's syndrome can be detected as well as abnormal muscle anatomy encountered in myositis. The proof of the pudding, however, is in the eating. Thus, the legitimate question to reflect on is, does ultrasound make a difference to daily patient care? And if so, can we measure its impact on patient care? For instance, can ultrasound be used to diagnose early (undifferentiated) arthritis and can it help to predict a development into chronic arthritis or self-limiting arthritis?

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Data indicate that ultrasound assessment may have a significant impact on clinical decision making, particularly in rheumatologic evaluation for diagnosis.

The evidence for other indications, including disease activity monitoring and aiding in prognosis, is less compelling. Ultrasound monitoring of inflammation did not result in improved outcomes, such as low disease activity/remission or less radiographic progression compared to conventional monitoring with DAS-28 ESR in patients with rheumatoid arthritis.

A very useful feature of ultrasound is guiding the needle pathway for injecting difficult joints and aspirating fluid from specific sites. Furthermore, based on its high resolution, ultrasound is the imaging technique of choice for diagnosing tendon disorders and peripheral nerve lesions. An additional advantage of ultrasound is that the patient does not need extensive preparation, which makes the procedure time-efficient. The only clinical requirements are good equipment and about 15 minutes of time.

Care must be taken to avoid errors in interpreting images. Therefore, knowledge of the pitfalls of the technique is an essential part of the clinician's training. One of the pitfalls are artifacts due to incorrect positioning of the probe. Insight into ultrasound findings in rheumatic disease requires familiarity with the anatomy and pathology of the structures involved. Widely regarded as the expert in rheumatic diseases, it is key that the rheumatologist also masters the cross-sectional anatomy of the musculoskeletal system. Rheumatologist-ultrasonographers have to bear in mind that cross-sectional anatomy is quite different from the classical anatomy lessons back at medical school. Hence, getting used to cross-sectional thinking implies a considerable investment of time for training and practice.

Despite these limitations, including the long and steep learning curve for the operator and the small field of view, musculoskeletal ultrasound obviously bears the potential to significantly improve daily patient care in rheumatology practice.

1.1 Historical Perspective

A number of pioneers, including scientists, engineers and clinicians, have contributed to the development of diagnostic ultrasonography.

During the early 1940s, the Austrian neurologist-psychiatrist Karl Theodore Dussik was probably the first physician to use ultrasound for diagnostic purposes. Although John Wild published a landmark study of breast nodules reporting a diagnostic accuracy of 90%, the Glasgow obstetrician Ian Donald was responsible for the ultrasound boom in medical diagnosis (Fig. 1.1). In 1956, in partnership with a young engineer, Tom Brown, Donald developed the first two-dimensional, direct contact scanner in 1956, which he first demonstrated at a clinico-pathological conference at the University department of Midwifery in Glasgow. Many physicians in the audience were totally opposed to the idea of relying on a machine instead of their hands when examining an unborn baby, until there and then, a Glasgow professor of Internal Medicine happened to make a diagnosis of malignant ascites in a female patient.

Fig. 1.1 The Glasgow obstetrician Ian Donald with the first automatic ultrasound scanner designed by Tom Brown (1960)

On examining the patient himself with the ultrasound machine, professor Donald informed the audience that the finding looked more like an ovarian cyst. Definite clinical interest was aroused when this diagnosis was confirmed in the operating theatre.

At the same time, another milestone was set at the University of Lund in Sweden, when Inge Edler, one of the most prominent cardiologists of his time, together with the scientist Carl Hertz, introduced M-mode (M for motion) registration. M-mode is a method that uses a single ultrasound beam aimed in a fixed direction through the heart. It marked a breakthrough into the understanding of cardiac disease.

Edler and Hertz applied a transducer to the human chest in the 3rd and 4th intercostal space at the left sternal edge and reported echo motion synchronous with the heartbeat. Many years later in 1969, the Dutch engineer Nicolaas Klaas Bom (Fig. 1.2) improved the early reflectoscope of Edler and Hertz with the introduction of the first linear array transducer at the department of Cardiology of Erasmus University in Rotterdam. Realizing that a moving object is easier to observe than a still object, Bom mounted twenty crystal elements on his prototype, which were switched on sequentially, so producing twenty echo lines. Featuring real-time images of a moving heart for the first time in history, the device produced a spontaneous applause at the European cardiology congress of 1972. By the 1970s, following its successful use in imaging horse tendons in veterinary practice, ultrasound imaging of the musculoskeletal system began to interest radiologists and orthopedic surgeons. Seltzer published the first study on the rotator cuff of rhesus monkeys before and after fluid instillation and Graf reported on the acetabular rim of infants in order to detect congenital hips dysplasia.

Fig. 1.2 Dutch engineer Nicolaas Bom and the prototype of the first linear array ultrasound probe

However, visualization of smaller joints was still a hazardous endeavour as resolution of images remained poor. Hence, three important technological advances have made inroads regarding the use of ultrasound in rheumatology. Firstly, the advent of high-resolution probes permitted the evaluation of smaller and superficial structures, such as finger tendons, small joints, nerves and pulleys. These “footprint probes” emitted waves with frequencies of 10–20 MHz and more, and came with an axial resolution of 0.1 mm. With these frequencies, reliably assessing the articular capsule or the hyaline cartilage of small joints like the MCP, PIP or MTP joints became feasible. Broadband probes which include a range of frequencies (e.g., 5–10 MHz, 8–14 MHz, 6–24 MHz) were becoming increasingly popular because of the ease in examining superficial and deep structures at the same time.

Secondly, progress in data processing by the computer enormously advanced the technologic scope of ultrasound. An example is the spatial compounding techniques in which the transducer beam is electronically steered to acquire overlapping scans from different angles and produce images with superior spatial resolution. A relatively novel development is the acquisition of volume data sets and the rendering technology for reconstructing 3-dimensional images from 3 planes. Three-dimensional ultrasound is potentially able to reduce the operator dependency of the technique.

Thirdly, the development of the color and power Doppler technique has enabled assessment of soft tissue hyperemia. Power Doppler mode detects low-velocity blood flow at the microvascular level, for instance of synovium or malignant masses. Since inflammation coincides with increased perfusion, power Doppler ultrasound helps to differentiate inflammatory synovitis from degenerative lesions, active from inactive synovitis, and assists in monitoring the response to therapy. Color Doppler ultrasound is used to examine larger vessels for the detection of stenoses and vessel wall abnormalities. In rheumatology, the technique is particularly applied for the study of vasculitis, including temporal arteritis.

Development of ultrasound in rheumatology will not halt at this point. The research agenda prompts grayscale ultrasound and power Doppler to be validated, not only in inflammatory joint disease, but also in other rheumatological disorders including osteoarthritis, vasculitis, myopathies and salivary gland disease. Comparisons with golden standards, including MRI, synovial biopsy, and arthroscopy, as well as reliability studies testing the intra- and interobserver reliability on inflammation in various joints, continue to be carried out in order to validate the technique and thus strengthening and corroborating the role of ultrasound in rheumatology.