Palpation is an important element of medical diagnosis. As early as 2,400 years ago, Hippocrates, known as the Father of Western Medicine, asserted that the elasticity of the body’s internal organs could be used to judge a person’s state of health. During China’s Spring-Autumn Period (771-476 BC), the famed doctor Bian Que proposed the concept of "qie zhen," which means using the hands to feel the pulse and perform palpation on the abdomen as a means of diagnosis. Although presented in somewhat different terms, the approaches of Hippocrates and Bian Que are equally effective in practice. Nevertheless, palpation cannot quantify organ characteristics. Reflecting the need to quantify elasticity, medical imaging has given rise to a new discipline, i.e., elasticity imaging.

The basic principle of elasticity imaging is that an organism’s endogenous stress (or stress applied by imaging instruments) can cause a response (strain) in the organism’s tissues and measurement of the degree of response can be used to assess the elasticity of tissues (where the elastic modulus = stress/strain). Sources of stress include externally applied static compression, dynamic vibration, and acoustic radiation force (ARF), as well as endogenous stresses such as heart beat, pulse, vascular blood flow, and breathing. Methods used to measure the response to such stresses include magnetic resonance imaging, ultrasound, radiation, and optical imaging.

There are approximately 10 elasticity imaging methods that have been developed at various universities and research institutes to apply stress and measure strain. In particular, ARF-based elasticity imaging has swiftly developed during the past decade. This approach measures the response to stress applied in the form of ultrasonic waves. To date, many suppliers of ultrasonic equipment have incorporated elasticity imaging functions in their commercial ultrasound products. This form of elasticity imaging has been applied to the diagnosis of diseases of the breast, liver, prostate, thyroid gland, and muscular tissue by measuring tissue elasticity. In addition, ARF-based elasticity imaging can appraise the effectiveness of local ablation therapy.

What is ARF? When sound waves are transmitted through a medium, the absorption of the waves’ energy by the medium will result in attenuation and part of the absorbed energy will be converted to momentum. The medium will undergo displacement due to this momentum and the degree of displacement can be measured using Doppler ultrasound. Like the "hitting an ox through telekinesis" skill in martial arts novels, this method allows objects to be probed remotely, which is why some scholars have termed it "virtual palpation." Apart from using sound waves to induce axial displacement of a medium, ultrasound can also generate shear waves in a direction perpendicular to the direction of sound wave propagation. By detecting the speed at which shear waves propagate, this method can also be used to infer the elasticity of the medium.

The principle of ARF was first proposed by the British physicist Lord Rayleigh in the early 20th century. By the mid-1990s, the Russian scientist Dr. Armen Sarvazyan was using ARF to derive the theoretical basis for assessment of the elasticity of living tissues and invented shear wave elasticity imaging (SWEI) [1]. Dr. Kathryn Nightingale of Duke University subsequently invented acoustic radiation
force impulse (ARFI) imaging technique in 2001 [2]. This technique uses the principle of ARF to produce images based on the elasticity of different tissues. The Acuson S2000® ultrasound machine, introduced by Siemens in 2008, incorporated ARFI imaging technology (which bears the trade name of Virtual Touch® Imaging) and is the first commercial device to use ARF to perform elasticity imaging.

ARFI imaging provides images of selected areas of the body where the intensity of the gray scale image corresponds to the degree of displacement. However, this method provides only qualitative information. Dr. Nightingale and her collaborators used SWEI to further develop a quantitative method for assessing the coefficient of elasticity of the liver, and this technology has been incorporated into the Acuson S2000® ultrasound machine under the trade name, Virtual Touch™ tissue quantification.

In 2009, the German researcher Dr. Mireen Friedrich-Rust, published the first clinical study employing Virtual Touch™ Quantification technology in the journal Radiology [3]. She proved that this technology could accurately assess the degree of liver fibrosis in patients with chronic hepatitis. To date, over 100 original papers and four meta-analyses have been published on relevant topics and all have confirmed that Virtual Touch™ Quantification is a practical means of assessing liver fibrosis.

The principle of ARF has also been utilized in developing supersonic shear imaging (SSI) technology. SSI was first reported in 2004 by French Scientist, Dr. Jeremy Bercoff, who together with his colleagues developed an ultrasound device with an ultra-high frame rate (more than 5,000 frames per second) that provided quantitative elasticity imaging in real-time. The French ultrasound vendor, SuperSonic Imagine, whose founders include Drs. Sarvazyan and Bercoff, incorporated SSI technology in its Aixplorer® ultrasound machine which was introduced in 2008. Various original papers describing the application of this technique to the diagnosis of liver fibrosis, breast and soft tissue disease have been published in subsequent years. Other ultrasound machine manufacturers, including Philips and Toshiba, have incorporated ARF-based elasticity imaging techniques in their high-end machines to quantify tissue elasticity.

The aforementioned imaging technology applications are still subject to certain restrictions, however. For instance, ARF has limited range and cannot provide high-quality images that reveal the elasticity of deep tissues. As a result, the effectiveness of such techniques may suffer in certain cases, such as in obese patients or in patients who cannot hold their breath. In addition, there is still no method to standardize the quantitative values provided by the different elasticity imaging technologies and discrepancies may exist in tissue elasticity values for the same subject when measured using different equipments. Due to the limitations of space, this article cannot describe, in detail, the differences in the imaging principles employed by SWEI, ARFI, and SSI. For further details, please read the review article by Doherty et al [4] and consult the references.

References