NEW DIAGNOSTIC IMAGING TECHNIQUE – SHEAR WAVES ELASTOGRAPHY

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SUMMARY

Shear wave elastography (SWE) is a new non-invasive diagnostic imaging technique, that maps the elastic properties of tissues. Nowadays this modality develops increasingly in medicine across its disciplines and opens a new era of high-quality ultrasound examination because it increases the specificity and thus improves diagnostic assurance. This method is similar to manual palpation, shows elastic properties of biological tissues and provides a kind of reconstruction of the internal structure of soft tissues based on measurement of the response of tissue compression. Various biological tissues have different elasticity and changes of these elastic properties often reflect pathological processes in the tissue and its abnormalities. This method is already used routinely on some foreign institutions in the detection and diagnosis of breast cancer and thyroid cancer, prostate cancer, in hepatology, cardiology, view the carotid arteries and lymphatic nodules. Finally examines its unquestioned benefit in ophthalmology. The output of elastography is an ultrasound image B-mode superimposed color-coded map. Shear waves elastography provides three major innovations: the quantitative aspect, the spatial resolution and the ability to run in real time.

Key words: ultrasound, elastography, Young's modulus, shear-wave, SonicTouch™, UltrafastTM display

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INTRODUCTION

Ultrasound examination is one of the most widespread diagnostic imaging methods across modern medicine, and thus occupies the top places in the examination algorithm. Ultrasonography is still developing as a method, which experienced rapid progress during the 20th century, and thanks to its non-invasiveness, relatively low acquisition price and thus excellent availability became the most frequently used diagnostic imaging method in a whole range of medical disciplines. The discovery of ultrasonic waves is attributed to the Italian biologist and physiologist Lazzaro Spallanzani, who in 1794 demonstrated the ability of bats to orient themselves in darkness using reverberations of high-frequency, inaudible sound (echolocation) (23). In 1880 the brothers Pierre and Jacques Curie discovered the phenomenon of piezoelectricity, which is the basis of today's ultrasound probes. The first publications on the possibility of use of ultrasound in medicine date back to the 1930s, and discuss the potential consequences of the effect of ultrasound on the human organism. Of primary significance for medicine was the study from the beginning of the 1940s by the American scientist F. A. Firestone, who was behind the birth of the ultrasound reverberation defectoscope, as methods of non-destructive demonstration of defects of material used in industry, working on the principle of the impulse reverberation method. The first ultrasonic diagnostic instrument developed in the 1950s on the basis of observations from the field of industrial defectoscopy used the historically oldest A-scan. They began to be applied primarily in ophthalmology and neurology (12, 17, 23). In 1942 the Viennese neurologist and psychiatrist K. T. Dussik published his observations on the possibility of the use of ultrasound in the diagnosis of brain tumours, and the first results of the use of high-frequency mechanical vibrations as a diagnostic tool (9, 10). This method was then introduced into medical practice by the doctors G. D. Ludwig and F. W. Struthers, who published the first work to mention ultrasonic reverberation from foreign bodies and gall stones in the human body (15). Towards the end of the 1950s the first diagnostic instruments using a two-dimensional B-scan were produced. Together with the reverberation method, a method based on the Doppler principle was progressively developed, serving for the detection of movement of tissues and measurement of the speed of blood flow. This principle was first described in 1842 by the Austrian physicist Christian Doppler (8). A kind of symbolic climax of this stage is the work of F. E. Barber et al., published in 1974, in which the duplex system is defined, combining the advantages of both ultrasound modules, i.e. two-dimensional B-scan and measurement of the Doppler signal from flowing blood (1). The core research and development of ultrasonic diagnostic instruments took place primarily in England, Australia , Germany and the USA, and from the 1970s onwards also in Japan. The use of ultrasound in ophthalmology was first referred to in 1956 by Hughes and Mundt, who among other factors demonstrate the exceptional diagnostic contribution of the A-scan in the case of intraocular tumours (18). The two-dimensional B-scan in real time and the immersion method of imaging were introduced in ophthalmology by Baum and Greenwood at the end of the 1950s (17, 23). In 1972 Bronson introduced the contact method of examination, which enabled wider use of the B-scan in ophthalmology. Imaging of the anterior segment of the eye begun in the 1990s with the introduction of the high-frequency ultrasonic biomicroscope, enabling in vivo observation of the structures

of the anterior ocular chamber (17, 23). In the Czech Republic the study of ultrasound has a long tradition. The first scientific study on the biological effects of ultrasound on vegetable material was published at the beginning of the 1940s by distinguished doctors and scientists from Brno (Herčík, Šprindrich, Hrdlička) (13). The technical and biological effects of ultrasound are dealt with in our literature by Šimonová-Čeřovská (21). The tradition of biophysical research into the effects of ultrasound was then followed on from by today's biophysical institute at the faculty of medicine at Masaryk University in Brno, in which the best results were achieved by a team headed by professor Hrazdira, who is a recognised expert in the study of the biological effects of ultrasound. In the field of ophthalmology it is also impossible to overlook professor Vanýsek, who in 1955 pointed to the possibility of detecting foreign intraocular bodies with the help of high-frequency ultrasound, and his close colleague and assistant Preisová, with whom he compiled a range of Czech and foreign publications (24, 25). The history of elastography dates back to the beginning of the 1980s, the name of the method was first used in 1991 by Ophir et al. (17, 23).

Ultrasound is a mechanical (acoustic) wave or vibration of particles of an environment around a static equilibrium position. This wave spreads within a flexible environment with a frequency higher than the upper limit of audibility of the human ear – i.e. frequencies higher than 20 kHz (kiloHertz), in which the realm of audible sound is within the range of 20 Hz – 20 kHz (Hz = 1 vibration/s). For diagnostic purposes frequencies of around 2-40 MHz (megaHertz) are used, and in ophthalmology 8-20 MHz. Ultrasonic vibrations are disseminated through tissues in the form of a predominantly longitudinal wave (in soft tissues and liquids), less frequently in the form of a transverse wave (e.g. in bones). The sources of ultrasonic vibrations are electrically generated piezoelectric transformers. The basis of ultrasonic examination is the principle of reverberation of ultrasonic waves on the interface of the environment with various acoustic resistance. Each environment is characterised by fundamental parameters such as the speed of dissemination of ultrasound (i.e. phase speed, dependent upon the frequency of ultrasonic waves), acoustic resistance, attenuation and reverberation. We calculate acoustic resistance of the environment as a product of the density of the environment and the phase speed of the dissemination of ultrasound. The quantity of acoustic energy which is reverberated on the acoustic interface is a function of the difference of the acoustic resistances of the tissues on this interface. The attenuation of the signal is dependent on the frequency and plays a role in selection of the frequency. The diagnostic information is subsequently obtained by the identification, processing and imaging of the reverberated signals from the tissue interfaces. We distinguish between two main types of ultrasound imaging. A-scan (Amplitude modulated – reverberations modulating the amplitude of deviations) refers to a one-dimensional, linear method of imaging in the direction of the transmitted ultrasonic waves. Impulses from the individual tissue interfaces are registered on the screen as vertical deviations, or “echoes”. The time basis indicates the time of passage of the impulse, the distance of the deviations corresponds to the ratio of the actual distances of the individual tissue interfaces and the place of reverberation, the amplitude corresponds to the quantity of reverberated energy. This represents the simplest type of ultrasound image used in ophthalmology, primarily for measurement of biometry. B-scan (Brightness = the identified reverberations modulate the brightness of the trace on the screen) is two-dimensional imaging, which can be divided into 3 types: The older type, referred to as “static B-scan” (image produced by very slow manual shift and inclination of the probe formed by one transformer), which did not identify the mobile structures or internal structure of the tissues or organs; M-scan (originally TM, also using A-scan to identify the mobile structures such as “floating echoes”); and dynamic B-scan, used exclusively at present, in which a progressive series of images of the examined area is created, including monitoring of movement. Dynamic imaging, thanks to the rapid recording of reverberations and the broad grey scale, provides fundamental information about the reflectivity of individual tissue structures (6, 12).

Elastography represents an imaging modality utilising the advantages of ultrasound in order to determine the difference in mechanical elasticity of tissues. This non-invasive diagnostic method is replacing traditional palpation examination, which is essential and used as standard in clinical physical examination of the patient. Palpation assists us in the diagnosis and screening of pathologies, and qualitatively determines the elasticity of tissue, but has its limitations because it is not always easy to perform due to the inaccessibility of lesions as a result of their deep position or their small size. Tissue ultrasonic elastography analyses the elasticity of tissues by generating low-frequency vibrations that create tension in the tissue, and this is subsequently analysed. Elastography examines the response of the tissue to the application of force (5, 16).

Shear-wave elastography (SWE) is a new ultrasonic concept that displays the elastic properties of tissues, increases the specificity of ultrasound examination and thereby improves diagnostic certainty. It is a method independent of the subjective abilities of the examiner and concerns a quantitative evaluation (in contrast with the qualitative evaluation upon palpation). The method is based on the automatic generation of transitional transverse waves (shear waves) and relies upon the fact that change of the mechanical properties of the tissue (above all change of elasticity) is frequently a reflection of pathological processes. The elasticity of tissue can be described most simply by Hooke's law, where the constant of proportionality is the physical quantity entitled Young's elasticity modulus (elasticity – E) stated in units of pressure (kiloPascal – kPa). Young's elasticity modulus is defined as the ratio between compression (= deformative strain, external homogeneous compression – S) and the generated tension (= deformation of the body – e): E = S/e [kPa]. The greater Young's elasticity modulus, the more rigid the tissue, and vice versa. Shear waves, or transverse waves, are mechanically generated following compression of the tissue. They are disseminated in the tissue in a tran-

sverse direction through the creation of a tangential sliding force between the individual layers of tissue at a speed of 1-10 m/s. They are therefore far slower than pressure ("bulk") waves, which are the basis of standard ultrasound imaging and are disseminated very rapidly (speed of approx. 1500 m/s) by gradual compression of the layers of the tissue. Shear waves are a response of the elastic resistance of the tissue to mechanical vibrations with low frequency (50-200 Hz). If we can measure the speed of dissemination (c) of the shear wave and at the same time we know that the density of the tissues (ϱ) is constant, we can directly express the elasticity of the tissue (E) according to the formula: E = 3 ϱc2. The presence of shear waves is therefore connected with the elasticity of the given environment. Liquid does not have elasticity, but in a solid and constant environment shear waves are well disseminated. The elasticity of tissues differs as a consequence of pathological processes, in such a manner that malignant deposits usually manifest greater rigidity (30-270 kPa) than benign deposits (1-70 kPa) or healthy tissue. In this the density of tissues (ϱ) in the human body is relatively constant, close to the density of water (1000 kg/m3). The elasticity values of certain human tissues were evaluated with the use of calibrated phantoms with different elasticity, or are a result of clinical trials (table 1).

Classification of elastography: Static (compression) elastography uses homogeneous compression of the surface of the body (compression performed by the examiner), which creates deformation of the tissue, which is made visible to us on the displayed level. Young's elasticity modulus cannot be used here, because we do not know the tension within the tissue. It does not provide quantitative information, it is highly dependent on the abilities of the examiner, and has poor repeatability. Dynamic elastography is the basis of magnetic resonance imaging (MRI) and uses continuous vibrations. Stationary waves induced in the body are analysed for an expression of elasticity. However, the displayed area is not in real time. Elastography based on shear wave uses transitional pulses, which generate transverse waves in the body. The elasticity of the tissue is expressed directly here by measurement of the speed of dissemination of the wave. It provides quantitative and local information on the elasticity of the tissue in real time (3, 5, 16).

Classification of elastography into four generations: The first generation ("manual strain-stress") uses the rhythmic pressure of the probe manually, in which compression and relaxation of the tissue is performed by the examiner by hand on the tissue of the patient. It determines the elasticity of the tissue on the basis of the difference of the ultrasound signal before and after compression, compares consecutive images (or their individual points – pixels), and in selected regions of interest (ROI) the mutual distances of these images are calculated. The subsequent colour coding displays qualitative information about elasticity. The more compressed areas of the tissue, i.e. more elastic are coloured blue, the less compressed – more rigid areas red. The method is dependent on the skill and experience of the examiner, is burdened by a quantity of artefacts, is not quantitative

Table 1 Elasticity values of selected human tissues

typ tkáně		E (kPa)	ϱ (kg/m³)
Breast tissue	Fat	18-24	1000 ± 8 % (water)
	Normal gland	28-66	
	Cyst	0-53	
	Fibrous tissue, fibroadenoma	96-244	
	Carcinoma	22-560	
Prostate	Normal anterior section	55-63	
	Normal posterior section	62-71	
	Benign hyperplasia	36-41	
	Carcinoma	96-241	
	Inflammatory deposit	20-27	
Thyroid gland	Parenchyma	5-40	
	Thyroiditis	15-55	
	Follicular carcinoma	6-59	
	Carcinoma	7-202	
Kidneys	Fibrosis	10-55	
Liver	Normal liver tissue	0,4-6,0	
	Cirrhosis	15-100	
Ligament		800	
Artery		700-3000	
Cartilage		790	
Dental enamel		20 000 000-84 000 000	

Zdroj: [15]

or well reproducible. The second generation is more sensitive. It utilises rhythmic compression of the tissue caused by the patient's own body (breath excursion, heart movement). The subsequent processing of the signal is the same as in the case of the 1st generation. However, evaluation of tissue elasticity is poorly reproducible. It is suitable for evaluation of formations on breasts, thyroid gland etc. The third generation uses the method of Acoustic Radiation Forced Impulse Elastography (ARFI). This concerns two methods of use. The first method of ARFI is Virtual Touch Tissue Imaging, again using a manual type of imaging. Deformation is generated automatically by a very powerful acoustic impulse of an electronic probe, not manually. ARFI is used primarily for examination of the liver and deeper located soft tissues. The result is a qualitative evaluation of relative elasticity of tissue in the ROI in a scale of grey (lighter areas = soft tissue, darker areas = more rigid tissue). The second method of ARFI is Virtual Touch Quantification – shear wave elastography, in which a strong acoustic impulse generates the dissemination of a transverse wave through the selected, very small ROI. The examiner initialises standard (lengthwise, axial) ultrasound measurement of the speed of the shear wave in m/s, the median value of which in m/s appears on the display. The value is quantitatively proportional to the average elasticity of the tissue in this ROI. In order to attain reproducibility of the result it is necessary to conduct approx. 10 subsequent measurements and to take an average thereof, it does not represent a dynamic mode but individual static measurements. No elasticity map is created.

The fourth generation, known as dynamic, real time Shear Wave Elastography (SWE) is patent protected with MultiWave sonographic-elastograph Aixplorer (SuperSonic Imagine, France). A standard broadband probe is the source of vibrations and generates pulses of acoustic pressure created by a focused ultrasonic ray, which are focused to various depths of the tissue at supersonic speed. Acoustic pressure ("acoustic vortex") induced in the ultrasonic beam stimulates the tissue situated underneath and acts upon the tissue in the direction of dissemination. However, the tissue provides resistance to this pressure (resurgent force), and this in turn induces mechanical waves and shear waves, which are disseminated transversely in the given tissue (fig. 1). This transverse wave, however, is very weak, and its attenuation is evident after dissemination of a few millimetres. SonicTouchTM technology eliminates this adverse phenomenon, since it works on the principle of an excitation phenomenon, thanks to progressive focusing of the ultrasonic beams to various depths of the tissue. It intensifies (coherently accumulates) the shear waves into the shape of a "Mach cone",

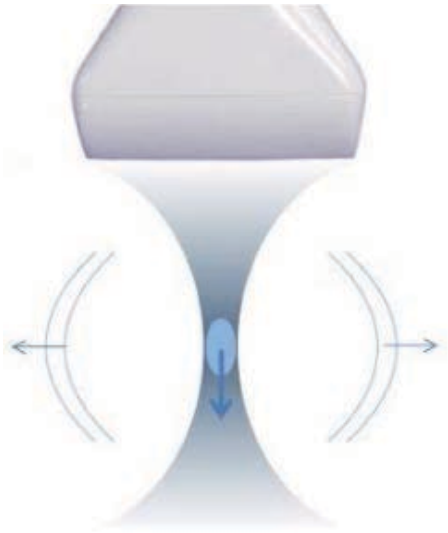

Fig. 1 Dissemination of shear waves Source: (15)

thus increasing the amplitude of the transverse waves and the distance of their dissemination, whilst simultaneously minimising the acoustic output to a safe level. More focus zones of the ray enable the generation of transverse waves at more depths. Shear waves are disseminated in tissues at speeds of 1-10 m/s (corresponding to elasticity of 1-300 kPa), from which it ensues that the pass through the level displayed by ultrasound and a width of 3-6 cm in 12-20 ms. However, within the time required for the creation of one image the shear waves would fade out and would not be identified by the system. As a result, image frequencies within the range of several thousand images per second are necessary for correct capturing of the shear waves with sufficient details. In the Aixplorer instrument these ultrafast imaging frequencies are termed UltrafastTM imaging, which in a single moment sends flat ultrasonic waves into the tissue for stimulation of the entire displayed level. The maximum imaging frequency is then influenced by the time within which the ultrasonic wave strikes the path from the probe to the tissue and back (e.g. for a typical breast image 4 cm deep the maximum attainable frequency is 20 kHz). This very high pulse repetition frequency (pulse repetition frequency – PRF) works in dependency on the depth and speed of ultrasound and depends on the type of tissue. Thanks to UltrafastTM imaging we are able to monitor in detail the dissemination of shear waves through the displayed level, which indicate small shifts of tissue, and these are recorded and quantified in a manner similar as in Doppler imaging. The speed of dissemination of

Table 2 Colour coding

Colour coding blue colour codes under standard conditions	Shear waves are disseminated	Solid tissue liquid with detritus
Black colour or shades of grey	No shear waves are disseminated	Liquid
	Very weak signal of shear waves	Very thin solid tissue
	Very rapid propagation of shear waves	Very hard (rigid) solid tissue

Source: (15)

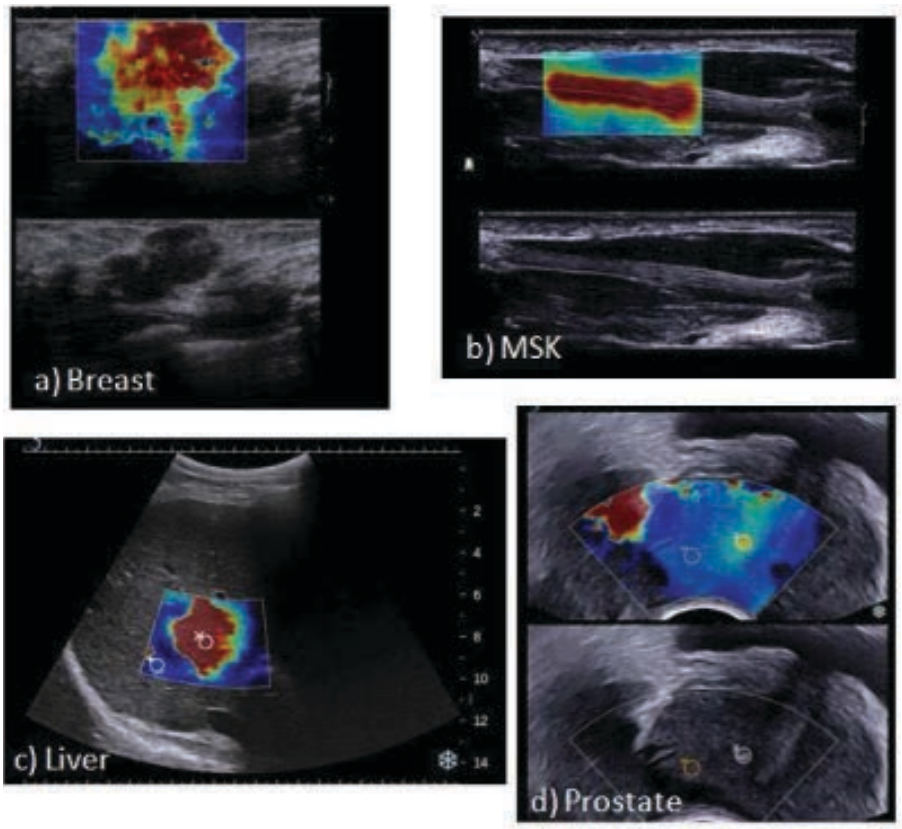

Fig. 2 SWE image of selected tissues
Source: (15)

shear waves is dependent upon the elasticity of the tissue. In the entire ROI it records shear waves, quantitatively displays the resulting map of speeds and the image of tissue elasticity in kPa, which is continually renewed in real time. The speed of data processing is very high (several Gbyte/s). The method is performed by the use of a conventional linear, convex or intracavitary probe (3, 4, 5, 16).

The output of the SWE is a B-mode ultrasound image covered with a colour coded map, in which a colour is attributed to each point of the tissue, coding its elastic properties. The resulting elasticity map displays the implemented shift of individual tissue structures according to their mechanical properties. Colour coding of the image (table 2) is on a scale of red to blue, in which more rigid tissues are shown in warmer shades (red, yellow) and softer tissues in colder colours (blue, purple). In the colour maps blue colour is the standard benchmark and is used to display soft solid tissue or viscous liquid in cysts. Red and yellow is used to illustrate hard tissue (malignant). Black spots of various shades of grey mean a loss of the shear wave signal and indicate clear liquid e.g. in a cyst (shear waves are not disseminated here) or rigid tissue (shear waves are very weak, are dampened or quickly propagated into the surrounded area). The resolution capability of the image is around 1 mm. Upon each measurement it is necessary to pause for around 3 seconds for the SWE image (fig. 2, 3) to stabilise, and only afterwards can we freeze and evaluate the image (3, 4, 5, 16).

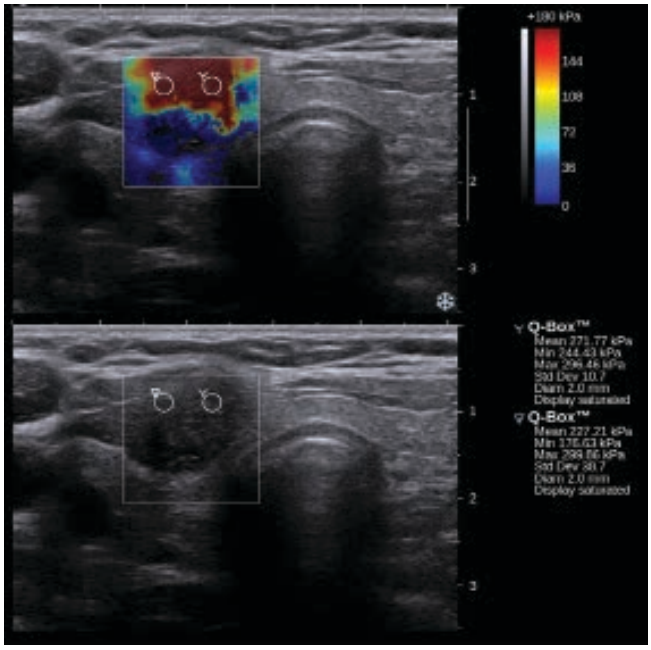

Fig. 3 SWE image – colour coding, elasticity values

DISCUSSION

Standards of elasticity values of human tissues, such as breast gland, liver, prostate or thyroid gland, are progressively being created across medical disciplines. Imaging of the superficial musculoskeletal system is being studied, as well as of the area of the rectum and, significant breakthroughs are also being made in other areas of medicine such as cardiology with SWE. The main studies from 2011 and 2012, which provided the basic data on human tissue elasticity and became groundbreaking are studies from hepatology (11), urology (2) and oncology of the breast (14).

In the area of breast treatment it is demonstrated by studies that SWE images are frequently better than a mere module

Table 3 Elasticity of thyroid gland

Elasticity of thyroid gland pathologies (kPa)		
	Study ECR 2011 (France)	Study endocrinol. 2010
Normal thyroid tissue	31±12	15.9±7.6
Benign thyroid tissue	34±17	36.0±30.0
Malignant thyroid tissue	114±61	150.0±95.0

Source: (20)

B-scan. SWE improves the identifiability of pathological lesions, which leads to better specificity of examination and a reduction of the number of unnecessary biopsies. From the studies that have been conducted we learn that upon deciding on the indication of a biopsy of a suspect deposit in breast tissue we are assisted by the "maximum measured elasticity value". If the value is lower than or equal to 80 kPa (Emax < 80 kPa) it is improbable that this concerns a malignant tumour, and we could consider a biopsy more prudently. By contrast, upon values of Emax > 160 kPa a biopsy should be performed earlier and the diagnostic procedure should correspond with the finding (14).

In hepatology SWE serves for monitoring the degree of cirrhosis of the liver, upon planning of patients waiting for a liver transplant also in assessing the condition of the transplanted organ. SWE provides real time quantitative mapping of elasticity of the liver together with real-time B-mode, and thereby improves the assessment of the stage of fibrosis (F0-F1, F2-F4). Upon differentiation of the stage of fibrosis we now know that degree F2 (significant fibrosis) has an elasticity value of up to 7.1 kPa, stage F3 (advanced fibrosis) up to 8.7 kPa and stage F4 (cirrhosis) 10.4 kPa, in which sensitivity and specificity of SWE examination is higher than 90% (11).

In the field of urology SWE holds the primary position in the early detection and excellent characterisation of prostate nodules. According to Barr's study conducted in 2013 on a total of 53 patients, in 11 patients SWE was used to detect malignant focuses, confirmed subsequently by biopsy. Thanks to this study the elasticity values from the inflamed areas were determined from benign hyperplasia to malignant deposits in the sense of carcinoma. SWE could thus become a first line screening method for prostate cancer (2).

In endocrinology (table 3) SWE helps determine a precise diagnosis in locating a nodule in the thyroid gland. We now know from the available studies that malignant nodes of the thyroid gland have greater rigidity than benign afflictions. This increase in rigidity in the case of a malignant nodule in comparison with a normal parenchyma or benign node is significant. Normal thyroid tissue has elasticity values of 31 ± 12 kPa, in which malignant nodules manifest a four to five fold increase in elasticity (table 3). Nevertheless, for the moment this concerns only a small group of patients, which opens up further possibilities for the use of SWE in clinical practice (20).

In today's ophthalmology international studies are currently under way, which in future could in certain cases replace imaging diagnostic methods which are financially costly and burdensome on the patient. SWE now appears to be a promising development in the diagnosis and assessment of changes in the extraocular muscles and tissue of the orbit in patients with endocrine orbitopathy (fig. 4) in comparison with the healthy population (fig. 5). The elastic properties of the outer extraocular muscles in patients with endocrine orbitopathy (EO) are altered e.g. thanks to fibrotic changes as a final consequence of the pathology. The tissue thus becomes more rigid (in the colour map it is shown in warm shades), which is documented by findings in the first examined patients. In the very modest clinical testing of this method to date, we can assume that change of elasticity of the outer ocular muscles is in correlation with the activity of this chronic pathology. Over a sufficiently large and representative group of patients with EO we will be able to determine the yield of the method and its classification into a diagnostic algorithm in the Czech Republic. We are also of the opinion that SWE may help in the diagnosis of intraocular and intraorbital tumours (fig. 6).

Data is available in the literature (7) from Greek authors who compare ultrasound images of horizontal extraocular muscles (m. rectus lateralis, m. rectus medialis) and their

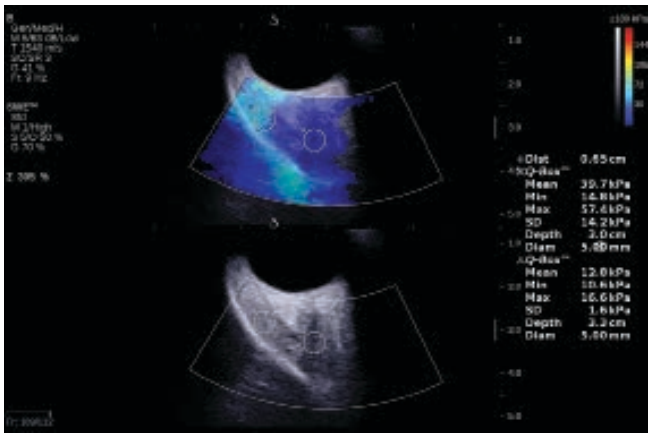

Fig. 4 SWE image of extraocular muscles in endocrine orbitopathy

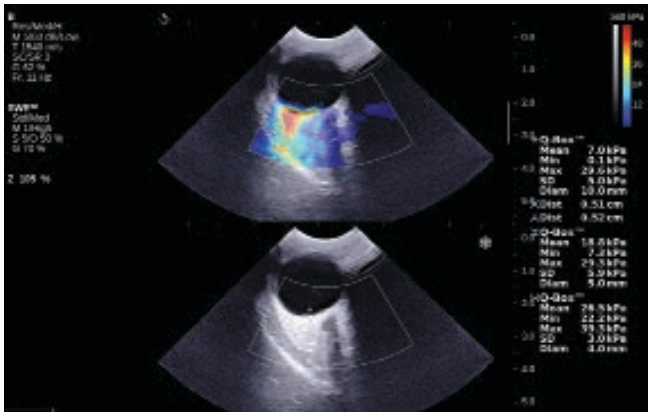

Fig. 5 SWE image of extraocular muscles in healthy individual

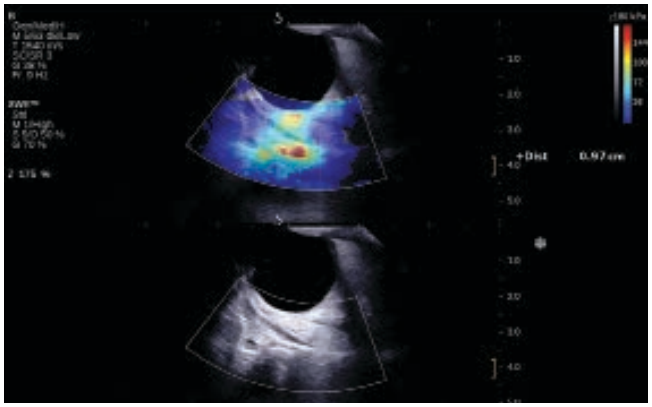

Fig. 6 SWE image of pseudo-tumour of orbit

different elasticity in primary position, and in adduction or abduction. A further possibility for how to use the excellent properties of SWE may appear to be the issue of differential diagnostics of myositis and other orbital afflictions (7).

A team of French scientists published a study (22) documenting changes of mechanical properties of the cornea following the stabilisation procedure corneal cross-linking (CXL). The study deals with the influence of the thickness and rigidity of the cornea on the measurement and correlation of intraocular pressure, and endeavours to comprehend ectatic pathologies of the cornea, such as e.g. keratoconus etc. In an ex vivo study on freshly enucleated pigs' eyes, it was determined with the aid of a conventional 15 MHz linear probe that the cornea has virtually homogeneous rigidity (elasticity) within an average of 190 ± 32 kPa. Following the stabilisation treatment CXL, elasticity of the cornea was significantly altered, Young's elasticity modulus increased in the anterior sections of the cornea – i.e. precisely where we perform the procedure – to average values of 890 ± 250 kPa (which indicates an increase of 460%). This technique could therefore have significant prospects in this issue (19, 22).

ShearWaveTM Elastography is the result of an examination of transverse waves and provides quantitative information about the elasticity of human tissues scanned in real time. SWE is capable of very precise localisation and display of the elasticity of small lesions with millimetre resolution. It provides reproducible display, independent of the examiner, thanks to fully automatic and effective generation of shear waves from an ultrasonic probe using the technology SonicTouchTM, without increasing acoustic output. The image is created through a combination of radial pressure induced in the tissue by an ultrasonic beam and ultrafast display of a sequence, capable of capturing the dissemination of the thus generated shear waves in real time. The SonicSoftwareTM platform enables the acquisition of ultrasound images on ultrafast recording frequencies (100 to 200 times faster than on conventional systems) in order to capture the dissemination of shear waves and measure the elasticity of tissues in kPa. SWE reduces the complexity and duration of examination, and offers the possibility of comparison and easy analysis of images. The clinical benefits of SWE include high reproducibility thanks to the acquisition of SWE maps, high reliability of measurement of the size and elasticity of lesions, and generally high sensitivity and specificity in comparison with conventional ultrasonographic examinations. SWE introduces new and as yet not entirely explored possibilities into clinical practice. A disadvantage of SWE is in particular the greater technological demand factor, and higher acquisition price of the equipment (3, 4, 5, 16).

CONCLUSION

Shear wave elastography is a new, non-invasive diagnostic display method, which maps the elastic properties of tissues and offers three main innovations: a quantitative aspect, spatial resolution and capability of display in real time. The output of the examination is a B-mode ultrasound image covered with a colour-coded map. In ophthalmology it is now appearing to be promising in the diagnosis and assessment of changes of the extraocular muscles and tissues of the orbit in patients with endocrine orbitopathy. The determination of the yield of the method and its classification within the diagnostic algorithm is for the meantime an issue and task of ongoing clinical trials..

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