Abstract
Sonoelastography is a novel technique that uses ultrasound waves to assess the elasticity of tissues noninvasively. It provides an ultrasound-based method to detect and display the relative stiffness of tissue. The main principle of sonoelastography is the measurement of tissue distortion in response to external compression. Changes in elasticity and tissues deformation elicited by compression are measured, processed and then shown in real-time presentation with color-coded elastograms. Most of the elastography applications are well known and have been described in detail in adults, e.g. evaluation of liver fibrosis or thyroid nodules. Similarly, most of sonoelastographic studies are based on groups of adults. The purpose of this review article is to bring this technology closer to pediatric clinicians and to summarize some of its current clinical applications that are being pursued. In this part we take into consideration utility of elastography in evaluation pathologies of musculoskeletal system, lymphatic nodes, thyroid, kidneys in pediatric patients and also elastography of placenta (Adv Clin Exp Med 2015, 24, 4, 725–730).

Key words: sonoelastography, muscles, thyroid.
Lymphatic Nodes

Lymphadenopathy is one of the commonest clinical problems in children. In most cases it is caused by benign conditions such as inflammation, although enlarged lymph nodes might be also the first sign of the malignant diseases, including Hodgkin disease, acute leukemia or non-Hodgkin lymphoma. [7]

The majority of the clinical studies on the utility of elastography in superficial lymph nodes assessment is related to adult patients and very often concerns metastatic nodules. Furukawa et al. used RTE to establish its usefulness in the diagnosis of cervical lymph nodes metastasis and monitoring the treatment results in adult patients with head and neck cancer. The elasticity of the examined lymph nodes was estimated qualitatively and classified into 4 patterns: in pattern 1, 80% or more of the cross-sectional area of the lymph node was revealed as red or green, i.e. soft; in pattern 2, 50% or more and less than 80% was showed in red or green; in pattern 3, 50% or more and less than 80% was shown in blue and in pattern 4, 80% or more was revealed in blue, i.e. hard. Research outcomes allowed the authors to claim that RTE might be a useful technique in lymph node metastasis detection in patients with head and neck malignancies [8]. Zhang et al. carried out the study on a value of...
the RTE in distinguishing benign and malignant superficial lymph nodes. A total of 112 adult patients (82 with lymphadenopathy and 30 healthy volunteers) with 155 lymph nodes were examined with B-mode ultrasonography, power Doppler US and RTE. Most of them were histopathologically diagnosed by FNAC and some of them had the diagnosis confirmed by clinical data considered together with follow-up findings. The elasticity of the lymph nodes was measured semi-quantitatively and determined as a stiffness value. The elastographic outcome was referred to the findings by Furukawa et al. [8] and classified into 4 patterns. In both researches most of malignant lymph nodes were rated as patterns 3 and 4, whereas most of the benign ones as pattern 1 and 2. In conclusion, the authors assumed that RTE could potentially serve as a valuable technique for evaluating the nature of the superficial lymph nodes in clinical practice [9]. There are also studies on quantitative assessments of the lymph nodes elasticity using shear-wave ultrasound elastography (SWE). One of them, performed by Bhatia et al., included 46 patients with cervical lymphadenopathy – 55 lymph nodes were examined by conventional US, underwent US-guided FNAC and were followed by real-time SWE. Outcomes of elasticity measurement were displayed on color-coded elastograms and correlated with cytology findings. This study showed that although SWE is technically feasible for cervical lymph nodes examination, it seems to be unsuitable screening tool for neck nodal malignancies. However, it could serve as an ancillary technique in identifying the most likely malignant nodes with indication to FNAC [10]. The other study carried out by Choi et al. was focused on patients with head and neck carcinoma. Authors compared the diagnostic performance of SWE and grey-scale ultrasound to distinguish metastatic from benign lymph nodes. Histopathological examinations of surgical specimens served as a reference standard. This study included 15 patients (total number of 67 lymph nodes were examined) with pathologically confirmed diagnosis of head and neck malignancy. All of those patients underwent surgery and received final diagnosis based on surgical specimen examination. This study showed higher sensitivity, specificity and accuracy of SWE than grey-scale ultrasound in differentiation between benign and malignant cervical lymph nodes, which suggests that SWE can be a valuable technique in reaching the decision about the necessity to perform an invasive biopsy [11]. Although all presented research, including different types of elastography, were performed in groups of adult patients, their results let us suppose that it can be also a useful tool in the examination of children, especially important for the differentiation of benign and malignant lymphadenopathy. Up to now there are some symposium abstracts which seems to confirm the usefulness and advantages of this method in children lymph nodes examination [12] (Fig. 1). However, further multicenter trials focused on children need to be performed.

**Thyroid**

The prevalence of thyroid nodules in children has been estimated to range from 0.9% to 5.1% [13, 14, 59, 60]. However, even 25% of these nodules are malignant [13, 15]. Fine-needle aspiration cytology (FNAC) is the main tool to define the character of the nodule due to its high accuracy and...
reproducibility [16]. However, FNAC is characterized by a grey diagnostic area – Thy3 in the British Thyroid Association guidelines [17, 18]. The consequence of this fact is that about 80% of patients with Thy3 undergo unnecessary thyroidec- tomy [16, 17]. A meta-analysis published in 2010 could be an example of a study suggesting the usefulness of elastography in the dilemma mentioned above. It showed that qualitative real-time ultrasound elastography had a sensitivity of 92%, specificity of 95% in differentiating malignant from benign nodules and it could reduce the rate of unnecessary surgical interventions after FNAC [19]. However, later research did not confirm the usefulness of strain elastography in the pre-surgical selection of nodules and their authors suggest the need for a quantitative or semi-quantitative elastography [20, 21]. Such research was made by Cantisani et al. Authors reported high sensitivity, specificity, negative and positive predictive values of semi-quantitative elastography in the differential diagnosis of thyroid nodules with indeterminate cytology [16]. However, probably the largest study in the last years gave unsatisfactory results. Bhatia et al. compared SWE results with US guided FNAC also to assess discriminatory capability of SWE. Authors reported a sensitivity of 76.9% and specificity of 71.1% by using the cut-off value of 34.5 kPa, which was the threshold of highest accuracy [22]. That study showed SWE is probably more operator-dependent than it was considered to be. Despite this, results of Corrias et al. in their review suggest a follow-up in negative for malignancies elastography in case a suspicions of FNAC in children [23].

Kidneys

Very interesting preliminary results were presented by Bruno et al. Twenty-eight children (age range 9–16 years) with primary or secondary vesicoureteral reflux (≥ grade III) underwent scintigraphy and ultrasound with ARFI. ARFI examination was also performed on 16 age–matched healthy controls. After scintigraphy, the kidneys had been divided into three groups: normal, affected, contralateral. Kidneys of controls were described as “healthy”. The mean ARFI values obtained in the “affected” kidneys (5.70 ± 1.71 m/s) were significantly higher than those measured in both “contralateral” (4.09 ± 0.97, p < 0.0001) and “healthy” kidneys (3.13 ± 0.09, p < 0.0001). Authors noticed decreasing ARFI values from kidneys with secondary vesicoureteral reflux to kidneys with primary reflux, than to unaffected kidneys contralateral to reflux and then finally to normal kidneys [24]. These preliminary results are very encouraging and show the possibility to include elastography in renal diagnostic imaging protocols. A study by Lee et al., where age-related normal ARFI values for kidneys, liver and spleen were measured, was mentioned above [25].

Placenta

Tissue re-building is a process that need some time; therefore, there is a small possibility that elastography will take a leading place in neonatal diagnostic imaging. However, there are some cases when it could be useful. Sugitani et al. from Fukuoka analyzed ex vivo, after delivery, velocity of shear wave propagation in placentas by using ARFI technique. The study group included 115 patients divided in 3 subgroups: normal, fetal grow restriction (FGR) and pregnancy-induced hypertension (PIH). Results revealed a significant difference in shear wave velocity between FGR and normal group – higher in FGR group (1.94 ± 0.74 vs. ± 1.31 0.35, p < 0.05), and no significant difference between normal and PIH group. Moreover, authors noticed a correlation between increased velocity and decreased birth weight Z-score [26].

Despite that the authors did not observe any histological damage to the placental tissue after ARFI examination and some researches confirm that temperature increase caused by pulse burst might still be within the safe limits determined by Food and Drug Administration [26–28], safety of ARFI or other similar techniques on pregnant should be carefully investigated.

Conclusion

Pediatric elastography studies are visibly less numerous, often less structured and more equivocal than those based on adults. In the last years, however, more and more research based on children was published and it seems that tendency will last. Some pediatric pathological conditions are either rarely or not seen at all in older patients and, therefore, are at risk of being inadequately diagnosed with the use of conventional methods. It is very likely that sonoelastography will fill the gap and help to clear many diagnosing doubts as relatively accurate, non-traumatic and non-expensive method. However, it is rather not possible to say that elastography is commonly acclaimed as a basic diagnostic tool in pediatrics groups of patients. To summarize, sonoelastography still requires many well-designed studies to confirm its value in pediatric diseases. Hopefully, actually available research is rather encouraging. Probably in next couple of years this method will be more and more popular and therefore widely accepted.
References


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