Ultrasound Elastography – Implications in the Head and Neck Region

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Ultrasound elastography (USE) is a method to assess the mechanical properties of tissue, by applying stress and detecting tissue displacement using ultrasound.1 It is based on the principle that malignant tissues are harder than the nonmalignant tissues. While histopathology is a gold standard, USE is a noninvasive method for differentiating benign and malignant lesions in multiple organs. Ultrasonography is used widely as diagnostic means because it is cost-effective, easy to use, and provides information of high resolution. However, no single ultrasound criterion has sufficient diagnostic accuracy and has limited sensitivity or specificity. The aim of this review is to provide an overview on the uses of USE in the head and neck region.

Keywords: Lymph nodes, Salivary glands, Thyroid

INTRODUCTION

Elastography is a recent imaging modality used for the evaluation of tissue stiffness of superficial organs. It is a sensitive imaging test for the detection of thyroid nodules, cervical lymph node (LN) nodules, salivary masses, assessing stiffness of the masseter muscle, and other superficial neck masses. Tissue elasticity measurement is useful for the diagnosis and differentiation of tumors, which are stiffer than normal surrounding tissues. Ultrasound elastography (USE)/sonoelastography allow the qualitative visual or quantitative measurements of the mechanical properties of tissue.1-7 It is also widely recognized that conventional ultrasonography (US) has limited accuracy for malignancy in these sites. USE is useful for providing imaging of tumors and enhancing tumor-node-metastasis staging, provides guidance for fine-needle aspiration (FNA) and biopsies in cases where several LNs appear suspicious and which LN should be punctured to obtain sufficient tissue for histologic assessment is not always clear. There are several USE techniques used in clinical practice; strain (compression) USE is the most commonly used technique which can be used to assess difference in hardness between diseased tissue and normal tissue.3

PRINCIPLES OF USE

The underlying principle of elastography is that when the tissue is compressed, it produces strain or displacement within the tissue. The produced strain or displacement is lower in harder tissues than that in softer tissues. Malignant tissues are generally harder than the normal surrounding tissue (Figure 1).8 The distance of tissue movement after application of pressure is measured in elastography. A standard ultrasound imaging equipment and specialized software is used. Soft tissue deforms more as compared to hard tissue; this difference in deformity is seen as the difference in ultrasound signals, which is represented on the video screen by a color map, called an elastogram,3 the hard areas appear blue and soft areas appear red (Figure 2).

MECHANICS

Elastography is used to measure the elastic properties of tissues, and the images which are obtained are compared before and after compression. Elasticity differs in different tissues (fat, collagen, muscle etc.,) and in the same tissue during pathologic states (inflammatory, malignancy).

When the stress is applied, all points in the medium experience a resulting level of longitudinal strain, although the greatest effect is observed along the axis of compression.3

The longitudinal (axial and lateral) strains are estimated from the analysis of ultrasonic signals which are obtained from standard diagnostic ultrasound equipment. A set of digitized radio-frequency echo lines from the tissue is acquired by compressing the tissue by a small amount with the ultrasonic transducer along the axis of ultrasonic radiation, and then a second set of post-compression echo lines is obtained from the same region of interest (ROI).
The data from these two echo lines are processed, and an elastographic image (elastogram) appears on the monitor.3

There are two types of elastograms: Gray-scale and color. The hard and soft areas appear in the gray-scale elastogram as dark and bright areas, respectively. In a color elastogram increasing tissue hardness appears in ascending order as red, yellow, green, and blue (Figure 2). These colors represent the relative hardness of the tissues in the elastogram.3

**TECHNIQUE**

As with traditional color Doppler imaging, USE is performed with conventional ultrasound probes and does not require additional instrumentation either for measuring pressure or producing vibrations. The tissue elasticity distribution is performed in real time, and the results are represented in color which is superimposed over the conventional B-mode image,2 the relative stiffness of the structures within the scan plane, inside an ROI can be visualized. Therefore, the scan area should not only encompass the target lesion but also surrounding normal reference soft tissues. The upper limit of the ROI should always be placed as close to the transducer as possible. The ROI should exceed the target boundaries at least 5 mm on each side, to encompass both the target lesion and the surrounding, reference tissue, at the same depth with the lesion. During the compression, the transducer should be perpendicular to the skin surface.1

**To differentiate benign from malignant superficial LNs**

The most important prognostic factor in patients with head and neck cancer is LN status. Neck LNs are well-positioned for the elastographic examination. They are easily accessible and can be efficiently compressed against underlying anatomic structures with the use of an ultrasound probe.3 Inflammatory or reactive LNs, not containing metastatic deposits, have the same USE appearance as the soft tissues of the neck4,5 and are scarcely visible as distinct entities on USE images. They do not contain blue areas, or blue areas occupy <45% of the node surface. Benign nodes are mostly yellow, green, and turquoise in color (Figure 3).

Malignant LNs, due to their increased stiffness appear as blue areas. Blue areas depicting rigid, hard tissue occupy more than 45% of the LN area. Red, yellow, and green are not encountered in malignant deposit areas, where stiff tissue is depicted only in turquoise and blue.4 Margin delineation was also better on elastograms, as the margins of metastatic LNs were more regular and distinct than those of benign LNs (Figure 4). This finding may reflect the differences of elasticity properties between malignant LNs and surrounding tissue or a desmoplastic reaction that creates a stiff rim around malignant LNs.5
USE had sensitivity of 93.8% and specificity of 89.5% in the differentiating benign and malignant cervical LNs. Results of a study of 141 peripheral neck LNs which were evaluated using strain elastography showed a sensitivity, specificity, and accuracy of 85%, 98%, and 92%, respectively; while the best gray scale criterion achieved 75% sensitivity, 81% specificity, and 79% accuracy.

USE in evaluation of salivary gland lesions
Several types of salivary pathology have typical sonographic appearances although there is considerable overlap. Margin irregularity is the main sonographic feature of malignancy but has limited sensitivity and specificity. Dumitriu et al. evaluated 74 salivary tumors (18 malignancies) using qualitative USE and documented higher strain indices in malignant neoplasms compared with benign tumors. A study by Wierzbicka et al. found that Warthin tumors were elastic (blue, green, small parts shaded yellow) and pleomorphic adenomas were predominantly elastic (green, yellow, less than half shaded). The mean stiffness value in 10 malignant tumors was 146.6 kPa and in 33 benign lesions, it was 88.7 kPa.

USE in evaluation of thyroid nodules
Thyroid nodules are extremely common, and only a small proportion is malignant. Even for nodules undergoing US-guided fine-needle aspiration cytology, the sensitivity for malignancy may be suboptimal because the specimens may be inadequate, nonrepresentative, or indeterminate in the case of follicular lesions. A meta-analysis of eight USE studies performed between 2005 and 2009 (639 thyroid nodules, 24% malignancies) calculated a pooled sensitivity and specificity of 92% and 90%, respectively.

USE in assessing masseter stiffness
A study conducted by Ariji to examine the stiffness of the masseter muscle using sonographic elastography and to investigate its relationship with the most comfortable massage pressure in the healthy volunteers found that the masseter stiffness index can be one index for determining the massage pressure.

LIMITATIONS OF USE
The main pitfall of elastography is the inability to control the extent of tissue compression by the ultrasound. Transducer, images obtained during the application of strong pressure can lead to misdiagnosis. This fault can be overcome using acoustic radiation force impulse imaging, which uses radiation impulses to induce localized displacement of tissues and the induced displacement of the tissues is then monitored.

There are elasticity changes at the borders of the elastogram attributed to inhomogeneous application of pressure, and so overlapping images should be acquired to overcome this problem. There are also limitations and difficulties related to the anatomy of the area examined.

USE is especially problematic in cases of superficial protuberant masses and in areas with prominent adjacent bony structures, where it is difficult to apply uniform compression over the entire ROI.

Tuberculous nodes, with scarring, calcification, or necrosis may display hard areas or a mixture of colors. Little is still known about the USE appearance of relapsing or chronic lymphadenitis. Focal deposits within an LN may produce a small, hard area, occupying <45% of the node surface (Figure 5). Some malignancies, especially lymphomas, produce “softer” appearing nodes, with less blue. Necrotic nodes with liquefaction will display an evocative blue-green-red pattern.

CONCLUSION
USE with its high sensitivity and specificity is a helpful improvement in US for the assessment of superficial head and neck malignancies, in which biopsies should
be performed. A lot of research is still needed to fully understand the varied appearance of diseases and to standardize its application. Due to the encouraging results of USE in head and neck region, it is possible that it will become a part of the routine diagnostic sonographic procedure in the near future.

REFERENCES


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