

ELASTOGRAPHY IN HEAD AND NECK REGION -A REVIEW

¹ Leelakshi

² Vathsala Naik

³ Smrithi Dv

⁴ Shrinyaka

¹ Postgraduate

² Professor and Head

³ Reader

⁴ Senior Lecturer

¹⁻⁴ Department of Oral Medicine and Radiology, Bangalore Institute of Dental sciences, Bangalore, Karnataka.

ABSTRACT: Sonographic elastography is a new technique for measurement of the tissue stiffness, and is currently under investigation for tissue characterization in several anatomic sites. In recent years, real-time Ultrasonography elastography (USE) modes have appeared on commercially available clinical ultrasound machines, stimulating an explosion of research into potential oncologic and non-oncologic clinical applications of USE. Preliminary evidence suggests that USE can differentiate benign and malignant conditions accurately in several different tissues. The principles underlying elastography are that tissue compression produces strain (displacement) within the tissue – which is lower in harder tissues than in softer tissues and that malignant tissues are generally harder than normal surrounding tissue. Therefore, elastography might yield clinical information useful in diagnosing cervical metastasis and improving prognosis in oral cancer .The purpose of this review is to highlight a promising new ultrasound technique, known as elastography, which measures the characteristics of tissue compliance.

KEY WORDS: Acoustic Radiation Force Impulse (ARFI), Elastography, Shear Wave Elastography (SWE), Strain elastography, Ultrasonography elastography(USE).

INTRODUCTION

Elasticity imaging quantifies and displays tissue stiffness properties non-invasively by measuring their displacement in response to mechanical stimulation.¹The word elastography, first coined by Ophir et al. in 1991, has become an umbrella term for any elasticity imaging technique. High-resolution sonography is a sensitive imaging test for the detection of superficial masses.¹In experienced hands, many lesions can be diagnosed using a combination of grayscale and power Doppler sonographic features. Sonographic elastography is one of the latest technologies that can be applied to conventional sonography for reconstructing tissue elasticity.^{1,2} As classification by technical methods, vibration energy is classified into manual compression, and acoustic compression, and imaging information is classified as strain imaging and shear wave imaging.

Several applications using sonographic elastography have been developed. This article therefore aims to review and highlight the applicaton of elastography in oral and maxillofacial fields, such as salivary glands, cervical lymph nodes, and masseter muscles.^{1,2,3}

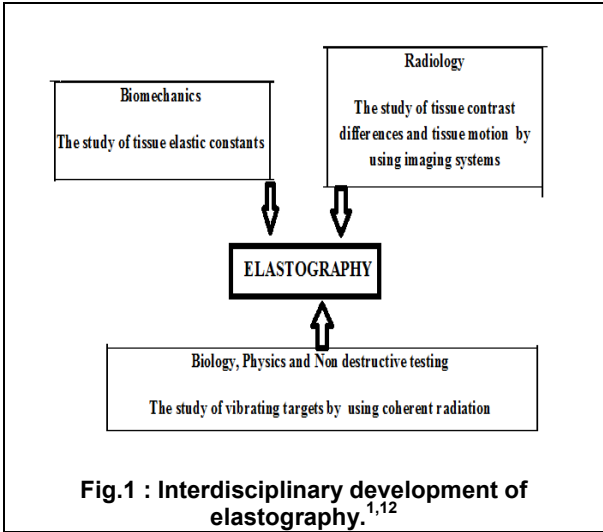
Principles

The main principles underlying elastographic technique is tissue compression. It produces strain (displacement) within the tissue and this strain is lower in harder tissues than in softer tissues.^{1,2,3} Therefore, by measuring tissue strain induced by compression, we can estimate tissue hardness.¹Tissue elasticity resulting from compression is

displayed as an image called an elastogram, on which hard areas are blue and soft areas are red. Because malignant tissue is generally harder than normal surrounding tissue, elastography might provide clinical information that permits observation of tissue stiffness, which would be a helpful addition to findings on palpation.⁴

Mechanics

Elastography allows assessment of the elastic properties of tissues, and the images obtained are compared before and after compression.^{1,5} Elasticity varies in different tissues (fat, collagen, etc.) and in the same tissue during different pathologic states (inflammatory, malignancy). Tissue stiffness tends to change (usually increase) with disease and can be imaged by measuring the tissue distortion under an applied stress. The resulting high contrast images can lead to early detection of disease processes.^{1,6} The data are then compared using a cross correlation technique to determine the amount of displacement each small region of tissue undergoes in response to the compression applied by the ultrasoundtransducer.^{1,7,8} The development of elasto- graphy has been the result of interdisciplinary research. Upon application of stress (or displacement), all points in the elastic medium experience a resulting level of longitudinal strain, although the greatest effect is observed in components along the axis of compression. If one or more of the tissue elements has a different stiffness parameter than the others, the level of strain in that element will be higher or lower, and a stiffer tissue



element will generally experience less strain than one that is less stiff. The longitudinal (axial and lateral) strains are estimated from the analysis of ultrasonic signals obtained from standard diagnostic ultrasound equipment.^{1,8,9} This is accomplished by acquiring a set of digitized radio-frequency echo lines from the tissue, compressing the tissue by a small amount with the ultrasonic transducer along the axis of ultrasonic radiation, and acquiring a second, post-compression, set of echo lines from the same region of interest.^{1,10,11}

The data from these two echo lines undergo processing, and an elastographic image (elastogram) ultimately appears on the monitor. There are two types of elastograms: grayscale and color. The hard and soft areas (ie, areas of high and low elasticity, respectively) appear in the gray-scale elastogram as dark and bright, respectively. In a color elastogram of a general device, increasing tissue hardness appears, in ascending order, as red, yellow, green, and blue. These colors represent the relative hardness of the tissues in the elastogram.^{1,11,12}

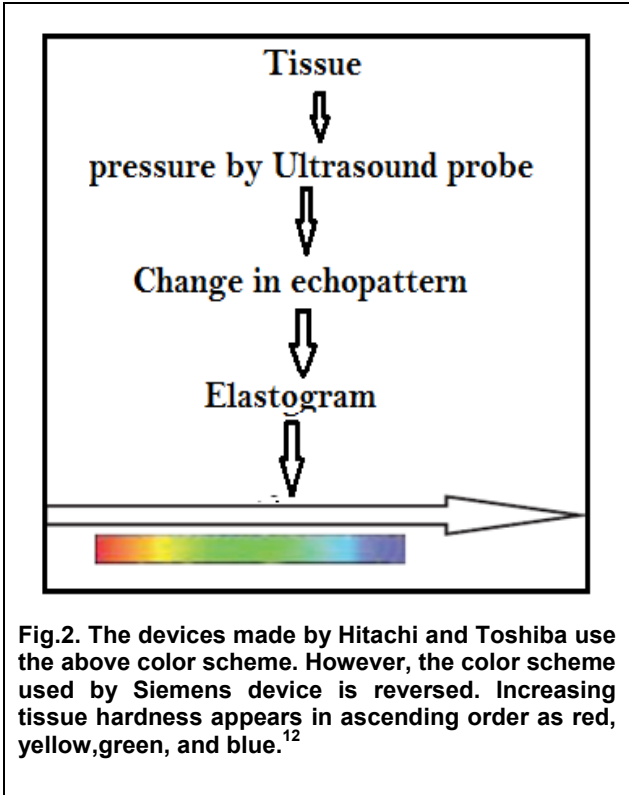
Classification of Elastography

- I. Methods of compression
 - a) Manual compression; ex-strain elastography
 - b) Acoustic radiation force impulse (ARFI); ex - Shear wave elastography
- II. Methods for imaging:
 - a) Strain imaging: ex-Strain elastography
 - b) ARFI Imaging(acoustic radiation force impulse imaging: ex- Shear wave imaging like Shear wave elastography

1. Strain elastography: Strain elastography depicts the stiffness of soft tissue by measurement of the tissue strain induced by manual compression.^{1,11,12} The various methods and names have been applied to measure tissue strain for each company or equipment. The strain data are converted into color-scale images and superimposed on B-mode images to easily recognize the relationship between the strain and lesion. The hard tissue shows low strain, and is displayed as blue-color in general; the soft tissue shows high strain, and is displayed as red-color.^{1,12} The qualitative evaluation is performed using elasticity score in differentiating benign and malignant masses on strain elastography. It is a 5 or 4-point visual scoring system based on the degree and uniformity of the color in the target mass. A higher score indicates a higher diagnostic confidence of malignancy.^{12,13} As a semi-quantitative method, the diagnostic approach of evaluating stiffness is proposed. Strain ratio is defined as a ratio of the strain in a target mass to that in a reference tissue on mainly Hitachi's machine. Elasticity ratio, which is defined as the ratio of the elasticity indices of two target tissues on GE Healthcare's machine, is also expressed numerically like the strain ratio. The elasticity index is a value expressed from 0 to 1.0 for softer than the average, and from 1.0 to 6.0 for stiffer than the average, assuming that the average strain in the displayed ROI is 1.0.^{1,12,13}

2. Shear wave elastography: Shear Wave Elastography (SWE) is based on the combination of a radiation force and an ultrafast imaging sequence, which capable of catching the propagation of the resulting shear waves in real time. The velocity information is converted to a color code, and displayed as a color map by superimposing it on the B-mode image.^{1,2,12} The propagation speed of shear waves is fast in hard tissue, and slow in soft tissue. The soft lesions are displayed as blue, and the hard lesions are displayed as yellow-red. The speed of propagation of the shear wave is proportional to the square root of the tissue's elastic modulus. Therefore, SWE allows expression of the shear wave velocity in m/s and estimation of Young's modulus in kPa. SWE is a highly reproducible technique without relying on the skill of the operator. SWE is excellent in the quantitative diagnosis of tissue elasticity.^{1,12,13}

3. Acoustic radiation force impulse imaging: Acoustic Radiation Force Impulse (ARFI) technology requires no external compression and exploits short-duration acoustic radiation forces to small volumes of tissue. When the focused ultrasound beam is transmitted with the probe, the tissue is displaced posteriorly. The tissue displacements are detected and imaged.^{1,12,13} A stiffer region of tissue exhibits smaller displacements than a softer region, and it is expressed as black. Shear waves are generated when the restorative force of the tissue propagates horizontally. ARFI technology allows not only qualitative visual evaluation, but also quantitative measurement of shear wave velocity in ROI. The stiffer the tissue is, the greater the shear wave velocity will be. This technique does not



need manual compression, and therefore, the reproducibility is good and there is little measurement error between examiners.^{1,14,15} Because the shear wave velocity of malignant lesions is higher than that of benign lesions, ARFI images is useful for differential diagnosis between benign and malignant lesions . Another

advantage is that the internal structure can be visualized well. ARFI technique is especially useful in diagnosing the complicated cyst accompanied by bleeding, protein-rich fluid, septum or calcification, because compression is given to each tissue . However, there is still little equipment with this technology, and the choice of probe is limited.^{1,12,14}

Application in head and neck region

Salivary glands: Sonography is the first-choice imaging in evaluation of salivary neoplasms. Several studies have reported features of the salivary tumors using sonographic elastography. Klintworth et al. qualitatively evaluated strain pattern distribution on strain elastography for parotid tumors, and documented that a pattern of heterogeneous reticular distribution was more frequent in malignant tumors than in benign tumors.^{1,14,15} The stiffness of the malignant tumors was higher than that of the benign neoplasms and that of pleomorphic adenoma was higher than that of Warthin tumors. However, the discriminatory performances for detection of malignancy are poor, because there is appreciable overlap between stiffness of pleomorphic adenomas and malignant neoplasms.^{1,12}

To differentiate benign from malignant Superficially lymph nodes

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.^{1,12} Inflammatory or reactive LNs, not containing metastatic deposits, have the same USE appearance as the soft tissues of the neck 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 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. Margin delineation was also better on elastograms, as the margins of metastatic LNs were more regular and distinct than those of benign LNs .^{1,12,15} 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. Yellow, green, and turquoise in color 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.^{1,12,16}

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, non representative, 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.^{1,12,13}

USE in assessing Masseter stiffness

A study conducted by Arijji to examine the stiffness of the masseter muscle using sonographic elastography. It was found that elastography is useful for assessing the masseter stiffness in various pathologies .^{1,12}

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.^{1,12,13}

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.^{1,12,16} 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.^{1,12,16}

References

1. Debdutta Das, Monika Gupta et al .Elastography: the next step Journal of Oral Science. 2011: 53: 137-141.

2. Peacock ZS, Pogrel MA, Schmidt BL (2008) Exploring the reasons for delay in treatment of oral cancer. J Am Dent Assoc 139, 1346-1352

3. Lingen MW, Kalmar JR, Karrison T, Speight PM Critical evaluation of diagnostic aids for the detection of oral cancer. Oral Oncol 2008 ; 44:10-22.

4. Shellenberger TD (2006) Sentinel lymph node biopsy in the staging of oral cancer. Oral Maxillofacial Surg Clin North Am 18, 547-563.

5. Alam F, Naito K, Horiguchi J, Fukuda H, Tachikake T, Ito K Accuracy of sonographic elastography in the differential diagnosis of enlarged cervical lymph nodes: comparison with conventional B-mode sonography. AJR Am J Roentgenol. 2008;191:604-610.

6. Parisi E, Glick M Cervical lymphadenopathy in the dental patient: a review of clinical approach. Quintessence Int 2005; 36:423-436.

7. Oeppen RS, Gibson D, Brennan PA . An update on the use of ultrasound imaging in oral and maxillofacial surgery. Br J Oral Maxillofac Surg 2010 ;48:412-418.

8. Breeze J, Williams MD, Howlett DC Ultrasound guided localisation during the excision of an impalpable branchial cyst. Br J Oral Maxillofac Surg. 2008; 46: 686-687.

9. Whittingham TA New and future developments in ultrasonic imaging. Br J Radiol. 1997 ;70, S119-132.

10. Ophir J, Céspedes I, Ponnekanti H, Yazdi Y, Li X Elastography: a quantitative method for imaging the elasticity of biological tissues. Ultrason Imaging .1991; 13:111-134.

11. Kunwar S.S. Bhatia, Yolanda Y.P. Lee et al Ultrasound elastography in the head and neck. Part I. Basic principles and practical aspects International Cancer Imaging Society. 2013;13(2), 253-259.

12. V Asha¹, Kim Upadhyay et al .Ultrasound Elastography – Implications in the Head and Neck Region .IJSS Case Reports & Reviews 2014;1(3):38-41.

13. Li Y, Snedeker JG. Elastography: Modality-specific approaches, clinical applications, and research horizons. Skeletal Radiol 2011;40:389-97.

14. Giovannini M. Endoscopic ultrasound (EUS) elastography. Medix Supplement. Special Issue: Clinical Applications of HITACHI Real-time Tissue Elastography; 2007; 32: 5.

15. Nakashima K, Shiina T, Sakurai M, Enokido K, Endo T, Tsunoda H, et al. JSUM ultrasound elastography practice guidelines: breast. J Med Ultrasoni. 2013; 40: 359-391.

16. Arijji Y, Gotoh A, Hiraiwa Y, Kise Y, Nakayama M, Nishiyama W, et al. Sonographic elastography for evaluation of masseter muscle hardness. Oral Radiol. 2013; 29: 64-69.

Corresponding Author

Dr. Leelakshi
Postgraduate
Department of Oral Medicine and Radiology,
Bangalore Institute of Dental sciences,
Bangalore, Karnataka.
email : Leelumh123@gmail.com