SKIN CANCER DIAGNOSIS USING TORSIONAL WAVE ELASTOGRAPHY: A NEW APPROACH

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ABSTRACT

A new technique based on propagation of shear elastic waves into the skin tissue, called Torsional Wave Elastography (TWE) for diagnosis of skin cancer and characterization of skin mechanical properties is presented. Non-invasive diagnostic methods are desirable to avoid invasive procedures and potential complications. The technique evaluates three biomarkers: elasticity, viscosity, and anisotropy. A TWE device able to generate shear elastic waves at 0.4-1 kHz was developed providing information about the mechanical properties of the tissue. TWE tests were conducted on patients and the results were evaluated by considering Histopathology as the gold standard.

Palabras Clave— skin cancer, Torsional wave elastography, non-invasive diagnosis, shear wave elastography

1. INTRODUCTION

Skin cancer, characterized by the abnormal growth of skin cells, is one of the top 20 most common cancers globally, categorized into two main types: melanoma and non-melanoma cancers. In recent years, there has been a noticeable rise in the occurrence of various skin cancer types globally, with nearly 200,000 cases of melanoma and more than 3 million non-melanoma cancers reported in the United States alone in 2022 [1].

The diagnosis of skin cancer primarily relies on conventional methods, which are inherently seen as invasive diagnostic methods. These methods are primarily based on visual inspection of the lesion by the dermatologist and regional biopsy to characterize the type of pathology that occurred on skin. Furthermore, skin is regarded as one of the body's organs for which its mechanical characteristics have not been completely understood. To this end, several techniques, such as Optical Coherence Elastography (OCE), transient elastography methods (HF-TE), Sono elastography, Shear wave Elastography, and Indentation, have been explored to uncover the biomechanical properties of the skin. A shared element among all these methods is the assumption that there are alterations in the stiffness of the tumor when compared to the surrounding tissue.

In OCE, the assessment of skin tissue stiffness involves measuring the surface wave created through an external excitation method and monitoring the propagated wave using an OCT beam [2]. On the other hand, in HF-TE, an externally generated mechanical wave is tracked using a high-frequency ultrasonic probe [3]. In Shear wave elastography, the tissue is exposed to acoustic radiation force, and its displacement is studied using the same transducer. While all these methods are categorized as quantitative elastography techniques with the capacity to characterize the mechanical properties of soft tissue, there are limitations in their clinical application. Most of these methods rely on an external wave source and track the propagated wave into the tissue using commercially available devices. Furthermore, only a small number of studies have involved participants with suspicious skin lesions. When using shear wave-based techniques, characterizing the mechanical properties of the skin, which comprises three different layers with a total thickness of less than 5 millimeters, is challenging and often not feasible due to the requirement for a high-frequency device with high

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resolution to track the wave in the desired layer. Another drawback in techniques based on the propagation of shear waves is the challenge of effectively separating longitudinal waves from shear waves when tracking them within the tissue [4].

To mitigate the limitations associated with evaluating the mechanical properties of skin, a new technique based on propagation of torsional waves is proposed. Torsional waves are shear elastic waves propagating radially into the soft tissue and in a curled geometry in depth [4]. This technique will evaluate the mechanical properties of soft tissue by considering (1) elasticity, (2) viscosity, (3) anisotropy and (4) non-linearity. The focus of this paper is on the extraction of the elasticity of the pathological tissue and comparison of the acquired results with the result of the histopathology tests for validation of robustness of torsional wave elastography in diagnosis of skin cancer.

2. TORSIONAL WAVE ELASTOGRAPHY

Torsional wave elastography (TWE) is a new dynamic elastography technique based on propagation of shear elastic waves into the soft tissue and extraction of the elasticity of the tissue. In this technique, the challenges associated with the attenuation of the emitted shear wave within the medium are mitigated due to the radial propagation behavior of the torsional wave in soft tissue [5]. This advantage over shear waves facilitates the development of a novel non-invasive diagnostic technique. Furthermore, TWE possesses the capability to assess the biomechanical characteristics of soft tissue through the emission of low-frequency shear elastic waves spanning from 50 Hz to 2 kHz.

3. PERFORMNCE ANALYSIS OF TWE

3.1. Device

A new TWE device based on the previous concept of torsional wave elastography device for evaluation of cervical elasticity [6] was designed and fabricated for diagnosis of skin diseases such as Basal Cell Carcinoma (BCC), Squamous Cell Carcinoma (SCC) and Melanoma. The device is composed of an emitter able to generate shear elastic waves at 50 Hz to 2kHz and a receiver to sense the propagated wave into the tissue.

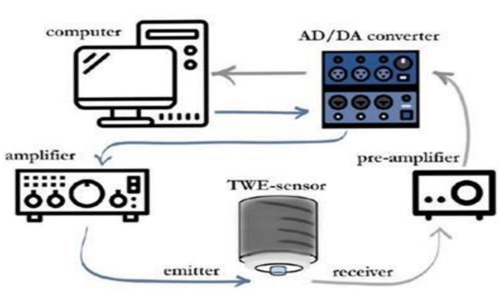

Figure 1. TWE device components

3.2. Validation

To establish the validity of the new device, two sets of hydrogel phantoms with different concentrations of gelatin 10 % and 15% were fabricated and tested using a torsional wave emitter which propagated the wave in burst as 1-cycle sinusoidal frequency of 1kHz and amplitude of 500mV [7], and Verasonics research system L22-14vX transducer with center frequency of 18 MHz as the receiver. The acquired shear wave speed from both phantoms were recorded to compare the results with the tests done on the same phantoms using the TWE device (table1).

Table 1. Comparison of the shear wave velocity acquired using Verasonics research system and the TWE device.

Ultrafast Imaging $({}^{m}/_{s})$	**TWE** $({}^{m}/_{s})$
3.831±0.225	3.931±0.325
4.395±0.089	4.379±0.343

4. IN-VIVO EXPERIMENTS

4.1. Participants

Patients with skin lesions suspicious of any type of cancer were primarily diagnosed by the dermatologists at the Hospital Universitario clinico San cecilio, Spain. After the preliminary diagnosis, patients were referred to the radiology department for the pre-surgical TWE test.

Participants were enrolled for TWE test after meeting the eligibility criteria. Patients with the following conditions were excluded from the tests.

- Pregnancy in females.
- Presence of pathological tissue associated with open wound.
- Medical history of cutaneous, rheumatoid, immunological, or metabolic diseases.
- Prior history of radiation therapy or chemotherapy.
- Previous excision of the lesion with subsequent recurrence.
- Refusal to participate in the tests.

4.2. Testing procedure

TWE tests were conducted after obtaining informed consent from the participants and receiving ethical approval. The skin is regarded as significantly anisotropic, with a broad spectrum of Young's modulus values that vary based on the alignment of Langer's lines [8]. To evaluate the stiffness of the pathological tissue, the lesion was tested by measuring the shear wave velocity in a clockwise manner. This method of testing enables the possibility of detecting the distribution of the cancerous cells in the tissue. Moreover, to be able to understand the changes in the stiffness of the pathological tissue, the healthy tissue in the proximity of the pathological tissue or on the symmetrical side of the body was tested by putting the hand-held probe in directions transverse and parallel to the fiber alignment.

4.3. TWE results

Obtained results from tests conducted on 1 patient in frequencies 400 Hz to 1 kHz are shown in Figure 2. The preliminary acquired results are considered as the velocity of the shear wave in the tissue vs the frequency of the generated wave. With this approach the changes in the stiffness of the tissue will be evaluated based on the changes in the frequency of the generated wave.

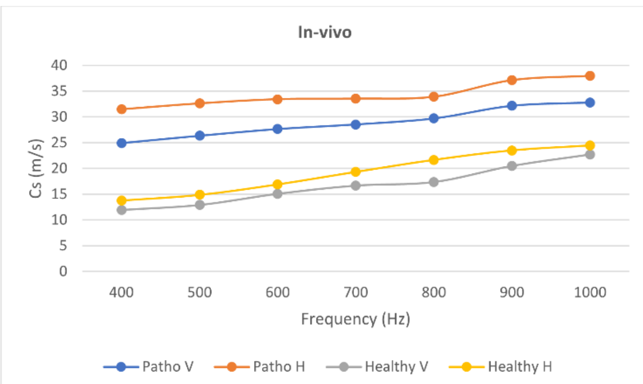

Figure 2. TWE measurement on a patient with Basal Cell Carcinoma.

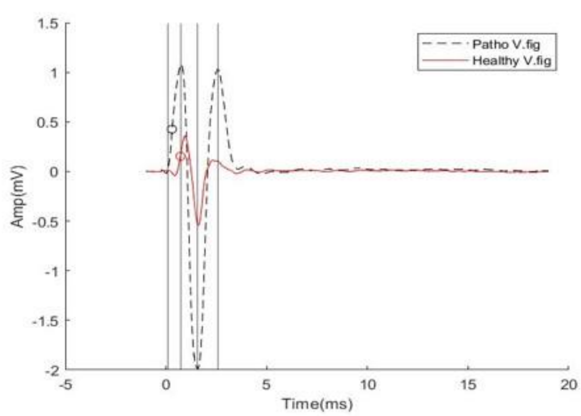

Figure 3. Signal acquired from TWE test.

4.4. Calculation of stiffness ratio

Stiffness ratio is calculated based on the velocity of the shear wave in the pathological tissue and healthy tissue to understand the severity of the disease. (Table 2) provides as overview of the results of the TWE tests conducted on 5 participants diagnosed with different types of skin cancer. These results were evaluated by histopathology reports after the excision of the lesion.

Table 2. Shear wave velocity and stiffness ratio acquired from TWE tests.

# patient	Patho (m/s)	Healthy (m/s)	Stiffness ratio
1	25.59	4.91	5.2
2	16.40	6.21	2.6
3	9.74	4.33	2.2
4	17.94	4.31	4.2
5	27.81	19.39	1.4

5. COCLUSION

A non-invasive low frequency elastography technique based on generation of shear elastic waves was proposed and investigated for the diagnosis of skin cancer. Estimation of shear elasticity is based on measurement of the shear wave speed in the tissue allowing the extraction of the mechanical properties of pathologies. This technique was tested on patients suffering from various types of skin cancers. The shear wave velocity of the skin changed with the presence of the pathological tissue. Moreover, this technique enables the possibility of characterization of the behavior of soft tissue exposed to different frequencies in a single measurement.
Correlation of the TWE results with the histopathology reports demonstrates that this method could be a useful tool for diagnosing skin pathologies. The detection of most cancers in minor organs, such as the mouth and glands, may be facilitated by comprehending the changes in the mechanical characteristics of skin tissue. Torsional wave elastography is a contemporary and user-friendly instrument that offers expanded possibilities for many applications, hence providing several benefits to individuals across diverse domains.

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