Cancerous skin quantitative assessment based on morphological features using PS-FF-OCT system

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Abstract

Skin cancer is a leading cause for death. Worldwide around 80 percent of all skin cancers are due to Non-Melanoma Skin Cancers (NMSC), Basal Cell Carcinomas (BCC) and Squamous Cell Carcinomas (SCC). To characterize the breast cancerous tissue from normal one, three parameters were extracted i.e. mean, standard deviation and entropy. Quantitative information from optical coherence tomography images can be used for high resolution, label free, rapid skin diagnosis and also helpful to the clinicians.

Keywords: Breast tissues, Quantitative features and Optical Coherence Tomography

1. Introduction

In the worldwide generation diagnosed with the breast cancer is very common [1]. Survival of life directly depends upon the stage of cancer at the time of diagnosis. So, therefore, it is the need of early detection to cure the health of any kind of trouble [2]. Histology is basically used to provide microscopic tissue information but limited by staining process and long time to stain the tissue. On the other hand, OCT is an imaging technique which provides rapid high resolution images of tissue with improved diagnostic accuracy [3,4]. Over the last few years, various non-invasive optical imaging techniques have been employed for in vivo and ex vivo cancer tissue diagnosis such as reflectance confocal microscopy, spectral domain optical coherence tomography (SD-OCT), coherence-controlled holographic microscopy, digital holographic microscopy and spatial light interference microscopy [5–9]. Recently, FF-OCT has been employed for the diagnosis of tissue samples including breast, lung, skin and ovarian tissues [1-10]. Numerous methods of texture analysis have been established which include mathematical model based approach and transform based methods [11].

In the present study, we demonstrate the phase shifting full field OCT system (PS-FF-OCT) for finding the quantitative phase images of the normal and malignant breast tissues. Due to a good resolution of the system, it’s an ability to differ adipose tissue, fibrous stroma, breast lobules and ducts, as well as in situ and invasive carcinomas.
We generated here phase images of normal and malignant breast tissues using PS-FF-OCT system. Three parameters were extracted from normal and malignant human breast tissue images.

2. Experimental Details

Figure 1 shows the schematic diagram of PS-FF-OCT system [12]. White light from the source is collimated by a collimating lens and incident onto a beam splitter. Beam splitter send light towards Mirau interferometric objective lens (Model No 503210, 50X/0.55 DI, WD 3.4 Nikon, Japan). It follows common path and compact interferometric objective lens. The piezoelectric transducer (PZT) is linked to the Mirau interferometer, PZT is driven by the amplifier and the whole system is interfaced with a personal computer. The phase shifted interferograms are recorded by the camera and stored in the computer.

3. Methodology

The phase shifted white light interferograms are recorded by a colour CCD camera in the computer. The intensity distribution of an interferogram recorded by an area detector can be evaluated by equation no (1):

\[
I_n(x, y, z) = I_0(x, y)[1 + V\gamma(z)\cos\phi(x, y, z)]
\]

(1)

Where, \(n = 1,2,3,4,5\), \(I_0(x,y)\) is the background intensity, \(V\) is fringe contrast, and \(\gamma(z) = \exp\left[-2\pi\left(\frac{z - z_0}{l_c}\right)^2\right]\) the coherence envelope of low coherence light source with \(l_c = 0.44\ \lambda_0^2/\Delta\lambda\) being the coherence length, which is 1.6 µm
in the present case ($\lambda_0 = 560$ nm), $z$ is the vertical scanning position of piezo-electric transducer (PZT) scanner, $z_0$ is the peak position of coherence envelope, $\phi(x, y, z)$ is the phase, $n$ is the frame number.

In phase-shifting interferometry (PSI) a time-varying phase shift is introduced between the reference and the sample wavefronts and a time varying signal is produced at each measurement point in the interferogram. The phase is introduced by moving the reference mirror mechanically using PZT. A 5-step phase shifting algorithm is used to reconstruct the phase map given by equation no (2):

$$\phi (x, y) = \tan^{-1}\left[\frac{2(I_2(x, y)-I_4(x, y))}{I_1(x, y)-2I_3(x, y)+I_5(x, y)}\right]$$

(2)

From the phase images of the normal and malignant tissues, we can determine the morphological changes in terms of various parameters such as Spatial Mean Phase, Entropy and Spatial Standard Deviation, can be calculated by the equations (3), (4) and (5).

Spatial Mean Phase ($S_{\phi}$): describes the mean phase value of the tissue.

$$S_{\phi}(x, y) = \overline{\Delta \phi(x, y)}$$

(3)

where $x, y$ represents the no. of pixels of the phase image in horizontal and vertical direction

Entropy ($E$): describes the randomness of the tissue.

$$Entropy(x, y) = -\sum_{i=1}^{N} p(x_i, y_j) \log_2 p(x_i, y_j)$$

(4)

Spatial Standard Deviation ($S_{\text{std}}$): signifies the variations in the phase values of the tissue

$$S_{\text{std}}(x, y) = \sqrt{\frac{\sum (\Delta \phi(x, y) - \overline{\Delta \phi(x, y)})^2}{N}}$$

(5)

4. Results and Discussion

The morphological features of the normal and malignant human breast tissues were analysed from the PS-FF-OCT system. An algorithm for extracting the phase information is written in a MATLAB. The phase information is extracted with the help of equation no (2) as shown in figure 2 (b) malignant human breast tissue. The interference and phase image (radian) of malignant human breast tissue are shown in figure 2. Three features were extracted from phase images such as spatial mean phase, entropy and spatial standard deviation were calculated. It can be observed from the figure 2 that the malignant tissue has highly degraded and heterogeneous stroma.
Figure 2 (a) Interferometric image (b) phase image (radian) of malignant human breast tissue.

Table 1 shows the mean values of all the features were extracted from the normal and malignant human breast tissue. The malignant tissue has higher spatial mean phase value as compared with the normal one that attributes to aggravated necrosis and reduced collagen concentration. Furthermore the other features entropy and spatial standard deviation also gives the higher mean values in malignant breast tissues, which describes more heterogeneity and clustering associated with cancer growth.

<table>
<thead>
<tr>
<th>Features</th>
<th>Human Breast tissues</th>
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<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>Spatial Mean phase</td>
<td>0.106 (radian)</td>
</tr>
<tr>
<td>Entropy</td>
<td>2.96</td>
</tr>
<tr>
<td>Spatial Standard Deviation</td>
<td>0.147 (radian)</td>
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</tbody>
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5. Conclusions
In this study, PS-FF-OCT system was used to differentiate the malignant from the normal human breast tissues. Three features were extracted from the normal and malignant human breast tissue images. PS-FF-OCT system imaged large area of tissue in a non-destructive manner with high resolution, which will help the pathologist for the diagnosis. The sample doesn’t require any type of special preparation therefore PS-FF-OCT can be a potential
intraoperative tool for the margin assessment of the cancerous tissues. The system is compact, efficient, user-friendly and also gives high lateral and axial resolution, which makes system useful to clinical pathology labs.

References


