

Photoacoustic imaging of early gastric cancer diagnosis based on long focal area ultrasound transducer

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Abstract We illustrated a novel imaging method to diagnose gastric neoplasms via photoacoustic tomography (PAT). Depending on the structural characteristics of gastric cavity, we used column diffusion fiber to irradiate the stomach tissue through the esophagus, and the externally placed telecentric focus ultrasonic transducer detected photoacoustic signals from the gastric tissue. We reconstructed the distribution of light energy deposition of the simulated gastric tumor, and obtained the location and size information of gastric tumor.

1 Introduction

Over the past two decades, the mortality of gastric cancer showed a continuous downward trend. This decline was the result of advances in detection and treatment of early gastric cancer. Fighting against gastric cancer needs continuous clinical and basic research—enhancing detection technology and methods of treatment. In addition, creative detection technology is indispensable^[1].

An important sign of gastric cancer is oxygen overrun—high metabolism. Photoacoustic imaging technology can detect tissue oxygen metabolism. Photoacoustic imaging is an effective detection method for early gastric cancer because early gastric cancer has not spread that the diagnosis does not need contrast agent. Owing to the morphology and physiology pathological features of tumor, Photoacoustic imaging is used in early gastric cancer functional detection shows significant advantage than other advanced imaging methods which are used in various clinical applications. Therefore the photoacoustic imaging applies in early gastric cancer diagnosis, staging and nondestructive positioning shows that it is irreplaceable.

Photoacoustic imaging is based on the photoacoustic effects. Photoacoustic effects, discovered from solid by Bell in 1880^[2]. Photoacoustic effects were applied in spectroscopic studies to form photoacoustic spectroscopy in 1970s^{[3][4][5][6]}. In the 1980s, photoacoustic effects were applied in biological tissue imaging^{[7][8][9]}. PAT^[10] is a nondestructive and lossless method in biological photon imaging. PAT is based on the difference optical absorption of biological tissue and the ultrasound-mediated which combines high contrast ratio from pure optical imaging and high penetration depth from pure Ultrasonic imaging. In principle, the use of ultrasonic detectors instead of optical photon detection avoid the effect of optical



scattering, so it can provide high contrast and high resolution in biological tissue imaging. PAT provides an important means of detection in biomedical diseases^{[11][12]}, such as in physiological characteristics^{[13][14]}, pathological features^{[15][16]}, metabolic function^{[17][18]}. Photoacoustic imaging has wide application prospect in biomedical clinical diagnosis not only in vivo tissue structure but also in functional imaging.

2 PAT Principle and Setup

2.1 Principle

Figure.1 showed the schematic diagram of the PAT. A pulsed laser irradiates the tissue, light absorption tissue absorbs the light energy and expands thanks to photothermal effect that the ultrasound has generated. The external ultrasonic transducer receives the photoacoustic signal and stores the photoacoustic signal to the computer then analyzes the photoacoustic signal which carries the absorber information.

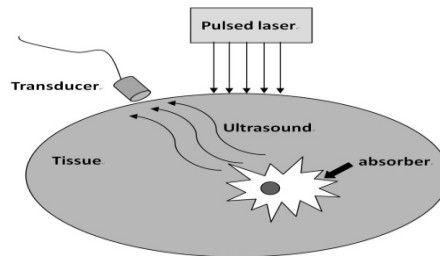


Figure.1 Schematic diagram of PAT.

Due to the different distance between absorber locations and transducer, the photoacoustic signals are received after different delay time. The position of absorber is determined by the product of time-resolved signals which detected by transducer and ultrasonic velocity. The size of the absorber can be calculated by using the distance between the anode and cathode of photoacoustic bipolar signal^[18]. The amplitude of photoacoustic signal reflects the light energy deposition of the absorber. The relationship between in situ photoacoustic pressure and photon energy deposition as follow:

$$P_0(x) = \Gamma \mu_a F(x)$$

Where Γ represents the Grignon coefficient (biological tissue is 0.25), μ_a means the absorption coefficient of the absorber, $F(x)$ is the light energy distribution at position x . The distribution of optical energy flow rate can be determined by the photoacoustic signals when the optical parameters are known. And then the absorption distribution in the tissue can be detected.

2.2 Experimental Setup

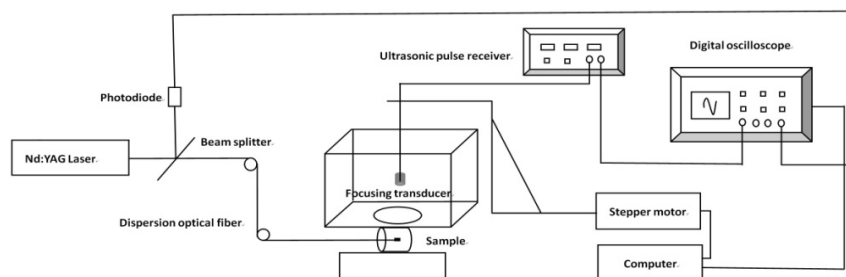


Figure.2 Experimental setup

The experimental setup was shown in Figure 2. The Q-switched Nd: YAG pulsed laser (Sutelite I-10, Continuum) was used to generate 532nm laser with 6ns pulse width and 10Hz repetition frequency. The short pulse laser was coupled to the customized multimode columnar dispersion fiber by optical coupler. According to the anatomical characteristics and the positional characteristics of stomach in the human body, the pulsed light was imported into the filling gastric cavity through the esophagus by fiber, and then irradiated the gastric tumor to produce photoacoustic signal. The signal was collected in the form of spatial scanning by the telephoto focus ultrasonic transducer which was placed in the left abdomen of the human body to achieve the detection of gastric cancer tissue.

3 Data Analysis

Figure 3 (b) and Figure 3 (c) showed the typically longitudinal photoacoustic pressure curve and the two-dimensional photoacoustic image which was obtained by scanning 5,000 times along the Y direction for figure 3 (a). It could be directly observed the location of simulated tumor in figure3(c), and the result showed that photoacoustic imaging has great potential value in non-destructive detecting for gastric tumor.

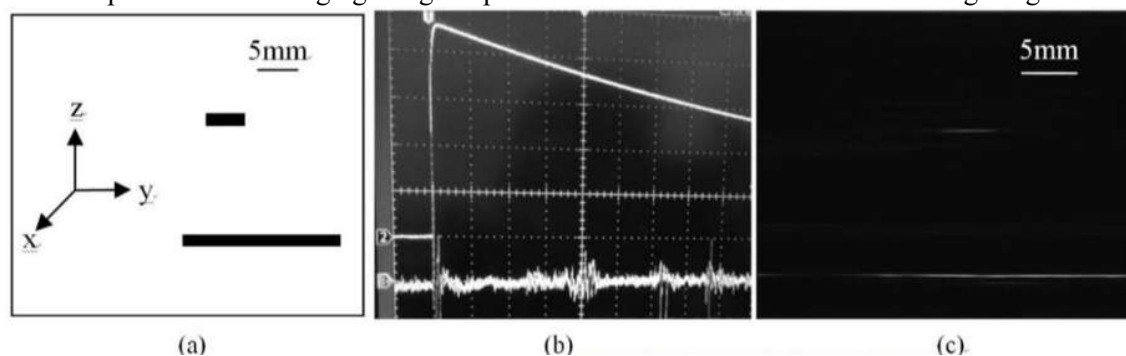


Figure.3 Simulated photoacoustic imaging of gastric tumor.

4 Summary and Outlook

The application range of emerging non-destructive biological tissue imaging technology photoacoustic imaging has been expanding very fast, however, there are few researches about the monitoring and diagnosis of gastric cancer. Owing to rich of blood vessels, the cancerous tissue is an excellent source of fresh blood. The blood has a strong absorption on the 532nm wavelength green light, there is a significant difference between normal tissue. Accordingly, photoacoustic imaging is very suitable for the detection of gastric cancer with the highly sensitive of difference in tissue optical absorption.

This paper took advantage of the ability of PAT, which combines the advantage of optical imaging and acoustic imaging, to reconstruct the light energy deposition distribution of gastric cancer, and obtained the size and location information. However, because of the acoustic signal reflection and mechanical vibration, the system will appear artifacts and errors. Thus more effort is needed to diminish the system error and improve the quality of photoacoustic image further.

Acknowledgment

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