17a-D4-3

Time-resolved diffuse optical tomography and its application to clinical studies

Yukio Ueda
Central Research Laboratory, Hamamatsu Photonics K.K.
E-mail: ueda@crl.hpk.co.jp

1. Introduction

We have been developing time-resolved diffuse optical tomography (time-resolved DOT) composed of a multi-channel time-resolved spectroscopy system. DOT is highly anticipated to make it possible to capture images of breast tumors and brain activity in three-dimensions by using near-infrared light [1].

Breast cancer is a major health problem worldwide. It is estimated that one in eighteen Japanese women and one in eight American women will develop breast cancer at some point during their lifetime. However, early detection and diagnosis of this disease significantly reduce the mortality rate and also the need for more extensive surgery. Use of DOT especially for breast cancer diagnosis, so-called optical mammography, is not expected to provide precise anatomical information but could provide evidence of angiogenesis, metabolic activity and oxygen consumption in the tumor [2, 3].

Moreover, the possibility of measuring human brain activity was reported in 1993 [4]. This functional near-infrared spectroscopy (fNIR) has been long-awaited in the field of three-dimensional tomographic imaging [5]. Herein, we report the applications for time-resolved DOT.

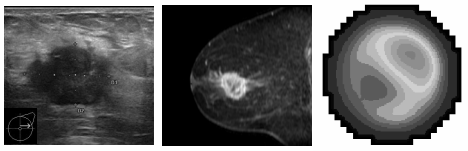
2. Methods

Our optical mammography (Prototype-2) uses the time-correlated single photon counting (TCSPC) method for measuring the target with high temporal resolution [6].

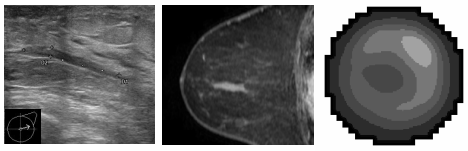
It consists of the light source, detector units, controller (PC) and examination bed. The light source was a mode-locked Ti: Sapphire laser (MaiTai, Spectra-Physics Lasers Inc., USA) useable at three wavelengths (765 nm, 800 nm, 835 nm). The detector unit consisted of the photo detector unit (PDU) and the signal processing circuit (SPC). The PDU consisted of a photomultiplier tube (PMT, H7422-50MOD, Hamamatsu Photonics K.K., Japan). The quantum efficiency (QE) of the PMT was approximately 15% (800nm), and transit time spread (TTS) < 250 ps. The SPC consisted of constant fraction discriminators (CFD), time-to-amplitude converters (TAC), A/D converters and a histogram memory. The examination bed consisted of the bed and the gantry. Scattered light was collected by optical fibers placed on the surface of the gantry. An ultrasound probe was placed internally at the bottom of the gantry. We visualize a breast surface for detecting the nipple position as a landmark. To reconstruct a 3D image of the breast, we employed a method using a time-resolved photon path distribution based on the assumption that scattering and absorption are independent of each other [7, 8].

3. Results

Figure 1 shows the results before and after chemotherapy. The patient is a 63-year-old woman with invasive ductal carcinoma which has a diameter of 30 x 26 x 26 mm in the upper outer quadrant area of the left breast. The tumor showed a marked decrease in size after chemotherapy and was barely visible on subsequent ultrasound and MRI scans. The maximum total hemoglobin (tHb) concentration in the tumor area was remarkably decreased, by 43 %.



(a) Before chemotherapy



(b) After chemotherapy

Fig. 1. Ultrasound, MRI and optical mammography before (a) and after (b) chemotherapy. Left, Ultrasound image; Center, Contrast enhanced T1-weighted MR image; Right, Optical mammography image (tHb)

4. Conclusions

Our optical mammography was shown to have excellent reproducibility in three-dimensions and this system also enables tHb images of the breast before and after chemotherapy to be compared. Therefore, our optical mammography system has potential for evaluating the effectiveness of neoadjuvant chemotherapy.

Acknowledgements

The development of optical mammography was supported by SENTAN, JST.

References

[1] T. Durduran et al. Rep. Prog. Phys. **73** (2010) 076701.
[2] B. J. Tromberg et al. Med. Phys., **35** (2008) 2443.
[3] Y. Ueda et al. Technol. Cancer Res. Treat. **10** (2011) 393.
[4] for example; F. Okada et al. Brain Research **601** (1993) 337.
[5] Y. Ueda et al. Jpn. J. Appl. Phys., **44** (2005) L1203.
[6] M. Oda et al. J. Jpn. Coll. Angiol. **49** (2009) 131.
[7] Y. Tsuchiya Phys. Med. Biol. **46** (2001) 2067.
[8] Y. Tsuchiya J. Opt. Soc. Am. A **19** (2002) 1383.