Visualizing and Flow Velocity Estimation in Human Lymphatic Vessel Using Real-Time Photoacoustic Imaging

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Background

Photoacoustic (PA) imaging has been shown to be a promising tool for noninvasive blood vessels imaging. PA images of lymphatic system in mice with indocyanine green (ICG) injection have been showed in previous reports.

We visualized 3D structure of lymphatic vessels and blood vessels by PA still images and observed lymphatic pumping flow by PA movies of healthy volunteers.

We estimated the velocity and the frequency of reflux of lymphatic flow.

Method

PA images and PA movies were taken by PAI-05 system with a hemispherical detector array, which was made by Canon Inc. (Japan), Hitachi, Ltd. (Japan) and Japan Probe Co, Ltd. (Japan) [1]. We took PA still images to visualize three-dimensional structure of blood vessels and lymphatic vessels and PA movies to observe lymphatic flow. The FOV size was 270 mm x 180 mm in PA still images, and 20mm in diameter in PA movies. The frame rate of the PA movie was 10 Hz. After a subcutaneous injection of ICG (5 mg/mL) to the foot of healthy volunteers, PA imaging examination was performed in prone position. We chose two wavelengths (797 and 835 nm) for laser

emission to distinguish between blood vessels and lymphatic vessels including ICG.

We first imaged the entire foot with wide-field still images and then measured the targeted lymphatic vessels with PA movies.

The velocity and the reflux frequency of lymphatic flow were estimated from temporal changes in PA intensity at lymphatic vessels. The reflux frequency was calculated from interval times and the number of lymphatic flows. 20 lymphatic vessels from nine healthy volunteers were observed.

Results

Both in PA still images and movies, we could distinguish between blood vessels and lymphatic vessels by colors in human using ICG.

In the PA movies, it was clearly observed that the lymphatic pumping occurred intermittently with some intervals from 15 seconds to 4.5 minutes.

The average lymphatic flow velocity of 17 lymphatic vessels was 11.3 mm / sec, and the average of reflux frequency of 13 lymphatic vessels was 0.7 times / min.

Discussion

Our PA system is useful for more precise quantitative assessment of lymphatic function. Therefore, it has possibility for evaluation of lymphedema prognosis.

Reference

[1] K. Nagae, et al., F1000Research, 7:1813, 2018.