3D ultrasound reconstruction from freehand scans using an optical tracking system

In this study, we report on a 3D ultrasound (US) image reconstruction method from scans collected with a freehand 2D US probe and a tracking system affixed to the probe. The method supports the construction of a multimodality image registration platform for the development of quantitative ultrasound imaging (QUS) as a method for staging of breast cancer, **Fig 1 (A and B)**. The advantage of a freehand US probe is that it can be used to obtain arbitrary volumes in the breast since the motion of the probe is unconstrained. However, the 2D image is limited to a thin plane at an arbitrary angle in the volume of interest, **Fig 2 (A)**. The 3D US image reconstruction overcomes this limitation, allows radio-frequency data collection for QUS analysis and allows accurate comparison with other 3D imaging modalities.

**Fig 1.** (A) Example of a linear regression analysis to calculate a midband-fit that can be used to discriminate between cancerous and viable tissue in breast. (B) Values of midband fit within the tumor (9.9±5.1 dB) and within a region of viable tissue outside the tumour (4.8±4.5 dB) averaged across 32 patients with locally advanced breast cancer. (C) 2D US section trough a reconstructed US volume demonstrating the regions inside the tumour (yellow arrow) and outside the tumour (magenta arrow).

**Fig 2.** (A) Selection of 2D US freehand scans plotted in a 3D Cartesian grid (axes in mm) illustrating the relative positions and non-regular orientation of the 2D scan planes in the 3D image volume. (B) The reconstruction accuracy was evaluated by comparing the known volume of three inclusions scanned in a brachytherapy (CIRS, Model 045) and breast phantom (CSP Medical, Model 051) with the volume obtained by contouring the inclusions on the new 2D slices resulted from 3D US volume reconstruction, overall relative error of 5%.

**Conclusion.** A 3D US image reconstruction method from scans collected with a freehand 2D US probe and a tracking system affixed to the ultrasound probe has been developed and tested. This will allow registration of 3D US with other 3D imaging modalities used in the detection of breast cancer and will allow the development of QUS methods for staging of breast cancer.