Contribution ID: **75** Type: **Oral**

Feasibility studies of a novel ultra-low dose stationary tomographic molecular breast imaging system utilising 3D position of interaction CZT detectors

Thursday, June 29, 2023 10:00 AM (20 minutes)

Mammography is widely used as a screening procedure for breast cancer. However, its cancer detection sensitivity is limited in patients with dense breast tissue [1]. Molecular breast imaging (MBI) using a pair of planar detector arrays has been shown to have high sensitivity even in dense breast tissue [2]. Nonetheless, long imaging time and radiation dose, that is higher than mammography, impede the widespread adoption of MBI in clinical practice. Several tomographic MBI systems have been proposed in the past [3-4], including systems with rotating head or multi-pinhole (MPH) collimation. A prototype of a novel ultra-low-dose MBI system offering tomographic imaging with stationary detectors is currently under development by Kromek. It is based on the use of dual opposing CZT detector arrays and densely packed MPH collimators leading to significant multiplexing (MX) in the acquired projections. Proprietary de-multiplexing image reconstruction algorithms were developed to reduce the adverse effects of the multiplexing artefacts using the high-resolution 3D position capabilities of CZT detectors. The goal is to achieve at least the same sensitivity for lesion detection as planar MBI, but with the effective patient dose similar to mammography. This new concept for the MBI camera and first imaging results from a proof-of-principle prototype were presented in 2021 [5-7]. The performance of the prototype was evaluated further and the results, along with further development of the image reconstruction algorithms, provided a basis for designing and building an upgraded feasibility prototype. The new prototype is currently under evaluation including spectral and phantom measurements.

The new feasibility prototype was built with an upgraded version of the previously used D-Matrix gamma imager technology. It is comprised of a 2x2 detector array of 5 mm thick CZT detectors with Depth-of-Interaction (DOI) capability and an MPH collimator with 49 pinholes. The spectral performance of the new prototype was characterised using collimated Am-241 and Co-57 sources (see Fig.1), with uncorrected FWHM of 3.94% and 2.82% respectively. The DOI is calculated using the anode over cathode ratio. The DOI resolution (FWHM) was measured with a 0.5 mm pencil beam collimator. It slightly varies between 0.93 and 1.02 mm depending on the depth.

The detector performance is also studied with a detector simulations model based on COMSOL Multiphysics and GEANT4. The model is a further development of the work presented at iWORID 2017 [8]. The simulations have been improved with the addition of Coulomb repulsion and a pulse shaping model based on the analytical representation of a pulse shaping circuit outlined in [9] and charge pulses produced by the COMSOL model. The goal of the detector simulation model is to provide realistic detector data as an input for the image reconstruction development and optimisation.

The imaging performance of the new prototype was characterised using a number of "activity-painted"[5] phantoms. The new image reconstruction and de-noising algorithms were optimised to maximise the contrast-to-noise ratio (CNR) and reduce the fluctuations of the correlated background noise associated with MPH image reconstruction. The collimator parameters studied were the pinhole size, opening angle, and separation distance. Non-local noise filtering and a relaxation scheme were applied to the results. The optimal system, achieving the CNR of ˜15, was obtained with collimator hole size of 1.75 mm, opening angle of 90⍰ and inter-aperture spacing of 10 mm. An example of the reconstructed 3D image comprised of a 6 mm "lesion"on a uniform background obtained with Tc-99m is shown in Fig.2.

The latest experimental and simulation results indicate that we can achieve the goal of the dose reduction to the mammography level and a strong reduction in the measurement time from current 40 min / 4 views to ˜20-25 min. Those achievements remove the main regulatory roadblocks defined by American College of Ra-

diology [10] which have prevented the acceptance of MBI as a screening modality for detecting breast cancer. In addition, the combination of the dose and time reduction makes our Ultra-Low-Dose Tomographic MBI technology more competitive with other modalities that are currently being evaluated for screening patients with dense breast tissue.

[1] Rhodes DJ et al. AJR, 204 (2015), 241-51.
[2] Hruska CB. AJR, 208 (2017), 275-83.
[3] van Roosmalen J et al. Phys Med Biol, 61 (2016), 5508-28.
[4] Brzymialkiewicz CN et al. IEEE Trans Med Imag, 24(7) (2005), 868-77.
[5] A. Cherlin et al. Proc. Virtual IEEE NSS RTSD MIC (2021).
[6] B. Hutton et al. Proc. Virtual IEEE NSS MIC (2021).
[7] K. Erlandsson et al. Proc. Virtual IEEE NSS MIC (2021).
[8] A. Cherlin, iWORID (2017).
[9] A. Makeev et al. Proc. of SPIE, Vol. 9412, 94124V-1.
[10] Debra L. Monticciolo et al. J Am Coll Radiol 15 (2018), 408-414.

The authors acknowledge funding from the Innovate UK grant (104296) and NIHR University College London Hospitals Biomedical Research Centre.

Primary author: Dr CHERLIN, Alexander (Kromek plc)

Co-authors: Mr WIRTH, Andras (Kromek plc); Dr ERLANDSSON, Kjell (Institute of Nuclear Medicine, UCL); BAISTOW, Ian (Kromek plc); Prof. THIELEMANS, Kris (Institute of Nuclear Medicine, UCL); Prof. HUTTON, Brian F (Institute of Nuclear Medicine, UCL)

Presenter: Dr CHERLIN, Alexander (Kromek plc)

Session Classification: Applications

Track Classification: Applications