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Monte Carlo simulation of a Coded Aperture Imaging with Dedicated Gamma Camera System for scintimammography

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The incident of breast cancer is increasing and thus requires a powerful diagnostic technique for early detection. X-ray mammography (as screening and diagnostic tool) is claimed to be the golden standard in breast tumour imaging. However, mammographic findings are, non-specific in many cases, and adjunctive methods such as nuclear medicine techniques are needed. Planar scintimammography (SM) as an adjunct to mammography has been gaining significant attention. However, when undertaken with a conventional parallel-hole collimator has difficulty detecting tumours that are less than 1cm in diameter. In addition, such camera utilises a very small fraction of the total number of the emitted photons: this limit both the quality and the diagnostic value of the observed images, whereby spatial resolution and sensitivity trade off against each other. Moreover, imaging with standard gamma camera might cause problems gaining close proximity to the breast. As an alternative approach, we focus our attention on the applications of Modified Uniformly Redundant Arrays (MURAs) [1] Coded Aperture (CA) methods with dedicated high resolution gamma camera instrumentation without collimator for use in SM. Such CA pattern has an open area of up to 50%, thus making good use of the emitted photons, as well as exhibiting potentially significant sensitivity improvements. Thus, with enough photon statistics CA imaging might match the imaging objectives in SM: early detection of malignant disease.

The purpose of this study is to investigate and evaluate dedicated gamma camera breast tumour imaging with MURAs CA systems using a well established Monte Carlo simulation method. MCNPX code is used that has many capabilities and provide detailed physics simulation within the photon range encountered in nuclear medicine imaging. In addition, it does however model Compton scatter, X-ray fluorescence as well as photon penetration of the gamma camera collimator. We considered only 99mTc isotropic sources emitting 140 keV photons to perform a complete simulation. The simulation consists of tracing the path of gamma photons through tissue equivalent scattering material, through the CA and until detected in the scintillation crystal. We also simulate the statistical uncertainty in position read out and the statistical charge variation caused by photoelectron variation in the photomultiplier tube array. Thus, all the major physics aspects of the imaging system are considered. A full camera validation is currently under investigation.

The Monte Carlo Simulation model is based on a simple 3D block phantom containing breast and variable legion sizes (5, 10, 20 mm

diameter). The breast is schematized as a parallelepiped (of 6 x 6 x 6 cm3) a breast thickness of 6cm was chosen based on the assumption of light breast compression to emulate SM and to increases the lesion detectability. The lesions were always positioned at 3cm depth from the surface of the breast, as point-like sources (lesions represented as spheres) with or without background activity assigned to the surrounding media. The effectiveness and performance of CA SM will be evaluated by quantitative comparison of three fundamental parameters: breast tumour sensitivity, lesion detection (the contrast) and FWHM under a variety of clinical imaging situations. Although this work is primarily aimed at breast tumour imaging, other applications with similar levels of photon statistics may also benefit from such an approach e.g., small animal imaging and clinical paediatric imaging.

References

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