Reduced-dose [18F]-FDG PETCT scanning with current generation PETCT systems

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Positron emission tomography (PET) has made a valuable contribution to the staging of malignancy for well over a decade. This time period has seen a rapid evolution from 2D PET to 3D PET, to the current 3D extended axial field of view PET systems with integral multi-slice CT. This evolution has been accompanied by significant improvements in PET image quality and, by virtue of the CT component, accurate lesion localisation.

Over the same time period the number of recognised and evidence-based indications for the use of [18F]-FDG PETCT in oncology has increased and provisions have been made to ensure national availability of this modality. As knowledge has progressed, [18F]-FDG PETCT is increasingly recognised as having a valuable role to play in non-oncological indications for the use of [18F]-FDG PETCT is increasingly recognised as having a valuable role to play in non-oncological indications.

The Administration of Radioactive Substances Advisory Committee (ARSAC) national Diagnostic Reference Level (DRL) for PET tumour imaging with [18F]-FDG PET of 400MBq equates to a radiation dose to the patient of 8mSv from the [18F]-FDG alone. This DRL has remained unchanged since 1998 and was established during an era of far less sophisticated PET systems than the current state-of-the-art systems available from various manufacturers.

The increasing need for PETCT imaging is undoubtedly due to the respective contribution of true and random coincidences and their different dependence on activity both inside and outside the PET field of view. A common metric of image quality that can be calculated after taking into consideration the number of true, random and scattered coincidences is noise equivalent counts (NEC). NEC should give an indication of the SNR that is to be expected in the reconstructed image and can be considered to be approximately Poisson in behaviour, so that SNR correlates with the square-root of NEC. As such, a 20% gain or reduction in NEC would result in an approximate 10% gain or reduction of SNR in the reconstructed image.

For patients scanned one hour after administration of 400MBq [18F]-FDG, the relationship of NEC and activity can be considered approximately linear. PETCT systems from GE, Siemens and Philips offer functionality to acquire PET data in listmode, which can be reframed by taking a sub-sample of the acquired data usually achieved by reducing the bed time. As such, it is possible to produce images that closely simulate a reduction of administered activity by reconstructing images from a percentage of the acquired bed time. This allows users to explore the potential benefits of advanced image reconstruction on image quality for reduced-NEC data.

The nuclear medicine department at Central Manchester University Hospitals has a Siemens Biograph mCT system with an extended axial field of view and both TOF capability and PSF modelling options for image reconstruction. We have recently evaluated the use of TOF in reduction of the administered activity for oncology patients. Our standard procedure was to administer 350MBq [18F]-FDG, acquire images at one hour post-injection and reconstruct with a standard iterative algorithm without TOF. To validate the use of TOF, we reconstructed images with TOF using data from 60% of the acquired bed time, thus containing 60% of
the NEC. Image quality was quantified by SNR measured in the patients’ livers. Figure 1 shows that the SNR from the reduced-NEC images with TOF is close to that of the full-NEC data reconstructed without TOF.

Figure 2 shows a coronal PET image for a 48-year-old female, with a weight of 87kg and BMI of 30.5kg/m². It can be seen that lesion SUV$_{\text{max}}$ is maintained with TOF when using data from 60% acquired bed time compared with the full-time non-TOF. Visually, there is very little difference between the images.

The favourable outcomes of this work have led to a change in our practice, namely a 20% reduction of administered activity to 280MBq, and a 20% reduction in scanning time from 2.5 minutes to 2.0 minutes per bed position. The reduced activity results in a lower radiation exposure for patients and staff. The shorter image acquisition time allows either an increase in patient throughput or the flexibility to schedule more complex studies requiring whole body (vertex to feet) acquisition, dedicated local views or dual time point imaging.

As our centre is part of a regional cancer imaging network, it was important to maintain quantification for lesions to allow potential comparison with previous studies and the continued use of agreed threshold ranges of SUV$_{\text{max}}$ to assist in discrimination between benign and malignant lesions. In view of this, and in order to maintain quantification, the use of PSF modelling has not been adopted in this department.

Summary

The use of advanced reconstruction in FDG PETCT, especially TOF, allows for a reduction in radiation dose to both patients and staff. We would advocate that bodies such as ARSAC and the British Nuclear Medicine Society should recommend such techniques as a means of reducing the administered activity for patients undergoing PETCT investigations. Centres with current generation PETCT systems with TOF should look to establish local DRLs for administered FDG activity that are lower than the current national DRL. Findings from work undertaken in our department suggest that the use of TOF allows for a reduction of approximately 40% of acquired NEC while producing images of comparable quality to standard reconstructions. The reduction to NEC can be achieved by a combination of reduced activity and time if necessary.

The introduction of a standard reduced dose/reduced time protocol is, in our opinion, more straightforward than opting for a weight/BMI based dose reduction protocol which would result in varying doses and acquisition times from patient to patient. The use of PSF modelling may allow further dose reduction but a consensus on the adoption of PSF modelling is required from the PET community in view of the impact of this technology on quantification. The move to reducing doses requires involvement of medical physics experts and experienced clinicians to fully appreciate the impact of these reconstructions on the image quality and also quantification metrics such as SUV$_{\text{max}}$.

References

1. Royal College of Physicians and Royal College of Radiologists. Evidence-based indications for the use of PET-CT in the UK 2013.