Operator motion effects of a small field of view hybrid gamma camera: to hold or not to hold, that is the question?

A H Ng\textsuperscript{1,2}, S L Bugby\textsuperscript{3}, J E Lees\textsuperscript{3}, P S Morgan\textsuperscript{1,4} and A C Perkins\textsuperscript{1,4}

\textsuperscript{1}Radiological Sciences, School of Medicine, University of Nottingham, Nottingham, NG7 2UH, UK
\textsuperscript{2}National Cancer Institute, Ministry of Health Malaysia, No. 4, Jalan P7, Precinct 7, 62250, Putrajaya, Malaysia
\textsuperscript{3}Space Research Centre, Michael Atiyah Building, University of Leicester, Leicester LE1 7RH, UK
\textsuperscript{4}Medical Physics and Clinical Engineering, Nottingham University Hospitals NHS Trust, Nottingham, NG7 2UH, UK

E-mail: hao06051982@yahoo.co.uk

Abstract. Recording gamma images using a hand held small field of view (SFOV) hybrid gamma camera requires a few minutes to complete an acquisition. Operator motion during image acquisition may deteriorate image quality and hence affect diagnostic accuracy. The purpose of this study was to assess the magnitude of movement caused by the operator when holding a camera weighing approximately 1kg. Six participants were invited to take part and each was provided with a full explanation of the study. A SFOV hybrid gamma camera was used to acquire gamma images of a radioactive point source containing approximately 15 MBq of $^{99m}$Tc-percheltechnate placed at source-to-collimator distance (SCD) of 7 cm. Each participant was requested to hold the camera for 3 minutes at their convenience during image acquisition in a clinical setting. A control image was acquired with the camera head mounted on a fixed articulated arm. The scintigraphic images obtained were post-processed and saved as DICOM images prior to assessment using bespoke software (MOCO) to determine the magnitude of motion by tracking the centre of mass (COM) of the hot spot. From this study the centre of mass (COM) was found to move away from the initial point by $4.34 \pm 2.43$ mm and $7.18 \pm 3.34$ mm in x and y directions respectively. Subjective assessment of the images acquired with the camera held by an operator showed blurring of details when compared to the control image. The mean COM displacement for the first 30 seconds of the image acquisition was less than 5 mm; however it exceeded 5 mm after one minute of acquisition. This study suggests that the image acquisition time of the SFOV gamma camera should preferably be within a minute when the camera is hand held during use.

1. Introduction
A small field of view (SFOV) hybrid gamma camera was developed and characterised by the Universities of Leicester and Nottingham [1-3]. The device is a combined optical and gamma camera system intended for intraoperative and bedside hybrid imaging. The compact nature of the camera system allows the device to be hand held when in use, hence increasing access to procedures which are inaccessible when using other larger size gamma cameras. However, when held by hand the voluntary and involuntary movement of the operator may cause deterioration of image quality and subsequently
affect diagnostic accuracy. The severity of motion may potentially be affected by the design of the camera head (e.g. weight and size), the duration of holding the camera head, tremor amplitude of individual operator, involuntary motion, such as sneezing, or other external factors.

These effects could be a real problem since typical static planar nuclear medicine imaging requires relatively long acquisition times of approximately 1 to 5 minutes. This has been recognised in SPECT-CT and PET-CT whole body imaging where the long acquisition times of the PET and SPECT images may result in movement artefacts in the reconstructed images when viewed together with the CT images [4-6]. To our knowledge no data previously exist on the duration that operators may hold such a camera without movement. To our knowledge this is the first experimental work to be carried out to assess the magnitude of operator movement and motion effects when acquiring images with the SFOV hybrid gamma camera.

2. Methods

2.1. Study design
Six potential experienced users (3 nuclear medicine technologists and 3 medical physicists (from the nuclear medicine service at Nottingham University Hospitals) were invited to take part in the camera movement study. The camera was set up in the clinical research room in Medical Physics and Clinical Engineering, Queen’s Medical Centre, Nottingham, UK. A point source containing approximately 15 MBq of $^{99m}$Tc-pertechnetate in a 3 mm diameter 9 mm deep well of a miniature Williams phantom [7] was positioned at a source to collimator distance (SCD) of 7 cm in front of the detector. Each operator was requested to hold the camera for 3 minutes at a time and in a position that was convenient for image acquisition (Figure 1). The image acquisition was repeated with the camera head mounted on an articulated arm in a fixed position and this data was used as a control for comparison purposes.

In addition, qualitative assessment was carried out to examine the image quality of gamma images of the mini Williams phantom filled with 8 MBq of $^{99m}$Tc-pertechnetate in four wells. The camera was positioned at SCD of 4 cm in front of the camera head, either held by an operator or mounted on the camera holder on a fixed articulated arm. The time of each image acquisition was 3 minutes. The resulting images were post-processed and visually assessed. Line profiles were plotted horizontally across the hot spots.

2.2. Image analysis and software
Each scintigraphic image produced by the camera was processed and saved as a multi-framed (2 seconds per frame) DICOM image. The image was then assessed using in house software named MOCO [8]. The software was developed to determine the magnitude of motion by tracking any changes in the position of centre of mass (COM) of the image hot spot. The MOCO software was originally developed to correct organ motion in planar gamma camera acquisitions by tracking the
COM of detected gamma photons, and as a consequence could be used to produce coordinates of the motion of the COM of the activity over time. During the data processing, the software determined the COM of counts in the first frame of the image and set this as the reference COM (x- and y-coordinates). The COM of each subsequent frame was then determined (xn- and yn- coordinates) and the magnitude of the displacement (distance on the respective x- and y-axes) between the COM in each frame and the reference COM was calculated. This information was saved in a text file for further analysis. All data was transformed into an absolute value for the calculation of the displacement in mm.

3. Results
All participants were able to complete the image acquisition by holding the camera for 3 minutes. Fig. 2 shows plots of the COM displacement in x- and y-axes against the acquisition time. With the camera mounted on the camera holder a discrete bright spot was seen on the control images. In general the gamma images acquired with the camera held by an operator showed blurring of details when compared to the control image. For the operator motion study, the images from five subjects were included in the data analysis while one (User 5) had to be excluded due to the movement of the camera completely out of the FOV during the acquisition. User 2, 4 and 6 held the camera with both hands while User 1 and 3 held the camera with either their right or left hand. The summary results are tabulated in Table 1. The mean magnitude of movements from the reference COM for users was 4.34 ± 2.43 mm and 7.18 ± 3.34 mm in x and y directions respectively.

Table 1. Summary of the COM displacement (mm) in x- and y- axes.

| User | Displacement (mm) | Max | Min | Mean ± SD |
|------|-------------------|-----|-----|-----------|
|      |                   | x   | y   |           |
| 1    | 14.72             | 23.11| 0.01| 0.39      |
| 2    | 7.24              | 11.53| 0.01| 0.03      |
| 3    | 9.03              | 6.44 | 0.10| 0.22      |
| 4    | 5.37              | 12.81| 0.15| 0.75      |
| 6    | 13.75             | 10.62| 0.03| 0.02      |
| Mean | 10.02             | 12.90| 0.06| 0.28      |
| Control | 1.89              | 2.09 | 0.00| 0.03      |

Based on the quantitative assessment of the images, the magnitude of displacement for the first 30 seconds of the image acquisition was less than 5 mm; however it exceeded 5 mm after one minute of acquisition. This suggests that the image acquisition time should preferably be within a minute when the camera is hand held during use. Fig. 3 shows the mean COM displacement over the acquisition time.

From a visual assessment of the gamma images of the mini Williams Phantom filled with 99mTc solution, the image acquired with the camera head held by the operator showed blurring of the details of the phantom compared to the image acquired with the camera held by the fixed camera holder. The pixel intensity profiles of both images were generated as shown in Figure 4.
Figure 2. COM displacement plotting over image acquisition time for all users. Blue and red lines show the magnitude of displacement at x- and y-axis respectively and green line shows the average displacement for the control image.
**Figure 3.** Magnitude of the COM average displacement over the acquisition time (n=75).

**Figure 4.** (Left) Line profiles of the gamma images of the mini Williams phantom filled with $^{99m}$Tc solution in the wells, acquired by the camera held by the camera holder (top right image) or by the operator (bottom right image).

### 4. Conclusion
This experimental work has provided new and essential information to bridge the gap between laboratory testing and clinical use. It has provided baseline data on user hand held operation and examined the imaging consequences of operator motion effects. This study suggests that the image acquisition time of the SFOV hybrid gamma camera should preferably be within a minute when the camera is hand held during use. Use of mechanical holder or articulated arm would be beneficial for longer acquisition times to steady the user’s hand motion.

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