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Technical Notes

Investigation of an SFOV hybrid gamma camera for thyroid imaging

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ABSTRACT

The Hybrid Compact Gamma Camera (HCGC) is a small field of view (SFOV) portable hybrid gamma-optical camera intended for small organ imaging at the patient bedside. In this study, a thyroid phantom was used to determine the suitability of the HCGC for clinical thyroid imaging through comparison with large field of view (LFOV) system performance.

A direct comparison with LFOV contrast performance showed that the lower sensitivity of the HCGC had a detrimental effect on image quality. Despite this, the contrast of HCGC images exceeded those of the LFOV cameras for some image features particularly when a high-resolution pinhole collimator was used.

A clinical simulation showed that thyroid morphology was visible in a 5 min integrated image acquisition with an expected dependency on the activity within the thyroid. The first clinical use of the HCGC for imaging thyroid uptake of ^{123}I is also presented.

Measurements indicate that the HCGC has promising utility in thyroid imaging, particularly as its small size allows it to be brought into closer proximity with a patient. Future development of the energy response of the HCGC is expected to further improve image detectability.

Introduction

The number of small field of view (SFOV) gamma cameras in development or available to clinicians is increasing [1]. These cameras are often designed for specific tasks such as sentinel lymph node biopsy or for small organ imaging. The imaging performance of SFOV cameras may be characterised through test protocols (e.g. [2]) or through phantom simulations of specific clinical situations.

One small organ well-suited for SFOV gamma imaging is the thyroid, a superficial gland positioned in the neck. Thyroid physiology and morphology can both be investigated through gamma imaging, with clinicians looking for regions of unusually high or low radioisotope uptake. Thyroid imaging commonly uses ^{99m}Tc-pertechnetate (for morphology) or ^{123}I-sodium iodide (for true metabolic imaging) [3].

In this communication, a thyroid phantom was used to determine the suitability of an SFOV handheld gamma camera for clinical thyroid imaging through comparison with large field of view (LFOV) system performance. An example of the first clinical use for a patient undergoing thyroid imaging is also presented.

Materials and methods

SFOV camera

These studies used the Hybrid Compact Gamma Camera (HCGC), an SFOV camera designed and built at the University of Leicester [4]. The HCGC is based on a CsI:Tl scintillator coupled to an electron multiplying CCD. The HCGC uses a pinhole collimator and an additional optical component allows for simultaneous and coaligned optical imaging [5].

An earlier iteration of the HCGC has previously been fully characterised using adapted LFOV protocols [6]. The HCGC used in this report was adapted slightly for greater sensitivity and now uses a 1500 μm thick columnar CsI:Tl scintillator and a 0.5 mm or 1 mm diameter pinhole collimator. The sensitivity and FHWM spatial resolution of this system at an imaging distance of 100 mm are 9.8 mm and 0.5 cps/MBq respectively.

Each gamma photon detected by the HCGC produces a 'light splash' of scintillation photons on the CCD [4]. HCGC gamma images are reconstructed using an automatic scale space selection algorithm to fit each individual light splash [4]. Reconstructed images may then be viewed either in centre point mode – where pixel values indicate the calculated number of incoming gamma photons – or in cumulative mode – where pixel values indicate the calculated number of scintillation photons. The centre point mode is equivalent to that displayed by LFOV cameras and additional smoothing

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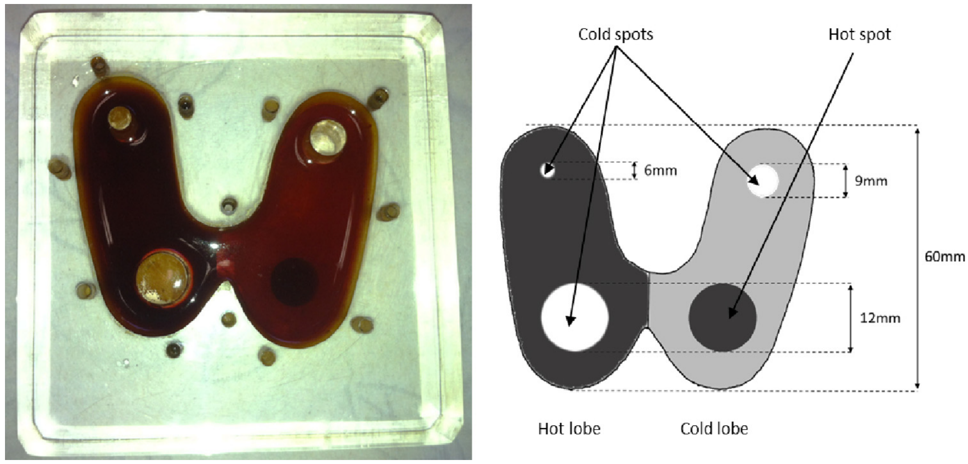

Figure 1. Photograph (left) and schematic (right) of the Picker thyroid phantom. White indicates cold spots, light grey half depth (9.2 mm) and dark grey is full depth (18.4 mm). The phantom was filled with a radionuclide solution, coloured for clarity, and was sealed with a 5 mm thick Perspex cap. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

may be applied to improve image quality. Cumulative mode is, in effect, a smoothed version of the centre point image where the width of the smoothing filter is variable – this presentation is the most similar to the raw data recorded.

Phantom specification

The Picker (Picker Nuclear, Part # 3602, Cleveland, OH) thyroid phantom (Fig. 1) is widely available in nuclear medicine departments and allows direct comparisons to be made with previously published studies. This phantom contains a number of structures which simulate features that may be seen in clinical images, including uneven uptake in each lobe of the thyroid and both hot (high activity) and cold (low activity) nodes.

The left 'hot' lobe of the phantom has a depth of 18.4 mm, the right cold lobe has a depth of 9.2 mm. Within these lobes are three cold nodes with diameters of 12 mm, 9 mm and 6 mm with no activity present. There is also a hot node, 12 mm in diameter, which has a depth of 18.4 mm in the cold lobe. The size of the entire phantom is approximately 60 mm × 60 mm, roughly 50% larger than a typical patient thyroid, with a fillable volume of 35 mL. The hot lobe contains approximately 65% of the fillable volume, the hot node 1% and the cold lobe (not including the hot node) 34%.

Quantifying the detectability of image features

A number of parameters can be used as measures of detectability. Contrast is defined as

$$C = \frac{|M_{ROI} - M_{background}|}{M_{background}} \tag{1}$$

where M is the mean counts per pixel in the specified region [7]. These measures can be applied either using known activity in the source (subject contrast) or the counts recorded in each pixel (image contrast).

Contrast to noise ratio (CNR) is defined as

$$\mathrm{CNR} = \frac{|M_{ROI} - M_{background}|}{\sigma_{background}} \tag{2}$$

where σ denotes a standard deviation [8]. This measure takes into account the effect of noise on detectability in addition to the contrast between ROI and background counts. To determine whether a feature is detectable, a threshold in CNR is used. Typically the CNR threshold used, as defined by Rose [9], is taken to be 3–5 [10] although this comes with a number of caveats as the Rose criterion is strongly dependent on the size of the image and the size of the lesion (or test element) being investigated. Exceeding the CNR threshold shows that the image feature is statistically likely to be real rather than due to random noise fluctuations; however it does not necessarily mean that this feature will appear visible to an operator.

ROI definition

To enable comparison with a previous study by Seret [11], ROIs were defined as follows: the ROI of interest for each node was centred on that node, with background ROIs positioned at the centre of each lobe. ROIs of the same physical size as used by Seret were achieved for the HCGC using diameters of 16, 11 and 8 pixels for the background, 12 mm nodes, and 9 mm node respectively.

Comparison to LFOV systems

Since LFOV gamma cameras are regularly used in clinical thyroid imaging, a comparison between the performance of these systems and the HCGC should give an indication of the HCGC's suitability for clinical imaging. Seret [11] performed a contrast study on 52 camera heads from commercially available conventional LFOV cameras using the Picker thyroid phantom. For this study, Seret's methodology was recreated to test the HCGC.

The Picker phantom was filled with 75 ± 5 MBq ^{99m}Tc solution and imaged from 100 mm. An image was acquired over 8 min – the approximate acquisition time used by Seret for each camera head. Due to the current energy resolution of the HCGC [6], an energy window of ±25% was used for the HCGC data collection. A uniformity correction was applied to all images [6]. Centre point images were used in this comparison.

Clinical simulation

A typical ^{99m}Tc thyroid scan will require administration to the patient of 185 MBq–370 MBq of activity, resulting in a typical uptake of 1%–5% in the thyroid [12] (note that administered activities will vary depending on location, e.g. 80 MBq is recommended in the UK [3]). This gives an expected thyroid activity ranging from 1.85 MBq