Investigation of the effects of attenuation correction on the compatibility of two single photon emission computed tomography systems with the use of segmentation through registration

M Lampaskis\textsuperscript{1,2}, K Killilea\textsuperscript{1}, P Metherall\textsuperscript{1}, A Harris\textsuperscript{1} and D Barber\textsuperscript{1}

1 Department of Medical Physics and Clinical Engineering, University of Sheffield, United Kingdom
2 Department of Mechanical and Manufacturing Engineering, University of Cyprus, Cyprus

E-mail: lampaskis.marios@ucy.ac.cy

Abstract. The aim of this work was to compare images acquired from two Single Photon Emission Computed Tomography (SPECT), performing attenuation correction using different systems, to evaluate the level at which images from these systems can be used on patients to assess myocardial perfusion. The two systems are the Siemens E-cam with profile attenuation correction and the General Electric Hawkeye system. This study was performed using an anthropomorphic torso phantom. The motivation was to examine if attenuation corrected images from these systems are comparable when assessing the myocardial function of patients, with different conditions regarding background (adjacent tissues) activity and the presence or not of defects on the cardiac wall. To perform the analysis of the acquired images specialized software were used to extract information relating to the activity distribution within the cardiac insert (simulated myocardium). This was based on standardized myocardial segmentation used clinically, by the application of image registration using an artificial reference model. The results show that adjacent tissue activity did not affect the ability to detect defects. Further, the application of attenuation correction may reduce the comparability of the two systems to a small degree.

1. Introduction
The aim of this work was to compare images acquired from two SPECT (which perform attenuation correction using different methods) systems and corrected for the effects of attenuation, to conclude the level at which images from these systems can be used on patients to assess myocardial function. The two systems are the Siemens E-cam with profile attenuation correction located at the Northern General Hospital and the General Electric Hawkeye system located at the Royal Hallamshire Hospital.

2. Materials and methods
2.1. Anthropomorphic torso phantom
The anthropomorphic torso phantom (Bright Technologies Ltd, Sheffield, UK) used to carry out the experiments. It is designed to mimic the properties of a human torso in terms of the attenuation of its
various components and their relative positions. Its size and shape are comparable to that of a normal adult male. The main components consist of: two lung inserts filled with Styrofoam, a liver insert which is isolated from other organs and can be filled with different levels of activity, a spine (in the form of a high-density Teflon bar) to simulate the attenuation and scatter that occurs due to the vertebrae, the cardiac insert (only left ventricle) with an array of different defect simulating inserts.

As mentioned above the different chambers of the phantom can be filled with water and suitable levels of activity to simulate the activity distribution that the user wants to test. This is done so as to assess possible scatter as well as attenuation effects/artifacts that may occur in an examination. All fillable chambers used (excluding the lungs) were filled with water. The lung inserts were filled with Styrofoam beads so as to better mimic the attenuation of the lung of a human subject. The cardiac insert was used with and without added defects. The defects used were fillable (full of water) and were placed in the anterior basal region and the inferior mid/apical region of the simulated cardiac wall of the left ventricle.

![Figure 1](image.png)

**Figure 1.** Pictures of (a) the torso phantom from an anterior view, (b) the cardiac insert mounted outside the torso, (c) close up when mounted inside the phantom, (d) the defects used to simulate perfusion abnormalities (scale is in cm).

### 2.2. General Electric Hawkeye SPECT/Low dose CT and Siemens E-cam profile system

The GE Hawkeye system is situated at the Royal Hallamshire hospital in the Medical Physics and Clinical Engineering Department. It incorporates two gamma camera heads and a low dose CT scanner. This arrangement allows for SPECT images to be acquired without moving the patient, obtaining an attenuation map. Additionally, the image of the scattered radiation is also acquired and can be used for scatter correction. Automatic body contouring (positioning of the camera detectors as close as possible to the imaged volume) is facilitated by moving the two gamma camera heads towards (or away) from the imaged volume to maximize the resolution of the collimator.

The Siemens E-cam system is situated at the Northern General Hospital in the Medical Physics Department. It incorporates two gamma camera heads. To obtain an attenuation map, it uses two arrays of Gadolinium 153 in conjunction with the camera heads. This arrangement allows for the attenuation map and the activity images to be acquired at the same time. This can only be done when the camera heads are in L-mode (i.e. at 90° to each other). Both emission and transmission data can be acquired simultaneously (reducing examination time). The most important limitation is that the attenuation map acquired can only be used for attenuation correction; it is not of a quality that can be used for anatomical information.

### 2.3. Data acquisition

The phantom was prepared appropriately (as discussed in 2.1) and then the activity (99mTc in saline) was added to the liver, thorax and cardiac regions. The first acquisition of the session was obtained. Next, additional activity was added to the liver and the last acquisition of the session was performed. Two sessions on each system where held (as shown in table 1), one with defects in the cardiac insert and one without. The phantom was “emptied” before each session.

### 2.4. Image reconstruction and reorientation

The Ordered Subset Expectation Maximization (OSEM) algorithm [1] algorithm used to reconstruct the acquired data. All data were processed with the same algorithm (OSEM) to avoid differences
based on the reconstruction method. In all cases the iterative reconstruction was stopped after three iterations.

The acquired images were reoriented along the long axis of the heart. This was done by an experienced operator, since possible errors at this process could have a large effect in further stages. The images normally are correct to less than 5° deviation from their true position.

| Acq. par. | Myocardium activity (MBq) | Liver activity (MBq) | Thorax activity (MBq) | Ideal Heart/Liver ratio | Defects               |
|-----------|---------------------------|----------------------|-----------------------|-------------------------|-----------------------|
| A         | 9-11                      | 50-70                | 30-50                 | 0.17                    | Anterior & Inferior   |
| B         | 9-11                      | 180-220              | 30-50                 | 0.05                    | Anterior & Inferior   |
| C         | 9-11                      | 50-70                | 30-50                 | 0.17                    | None                  |
| D         | 9-11                      | 180-220              | 30-50                 | 0.05                    | None                  |

2.5. Segmentation of the left ventricle

The images were registered to an artificial model that was produced, based on the known geometry of the cardiac insert, to allow extraction of the segment information for the acquired images [2]. A segment number, as shown in figure 2, was assigned to each part of the known-geometry model [3].

![Figure 2. Assignment of 17 myocardial segments to coronary regions.](image)

By segmenting the image, the activity at each part of the cardiac insert could be examined independently. The acquired images were segmented according to different coronary artery regions simulated by the cardiac insert. The average intensity over each segment was obtained and displayed on circumferential polar plots (figure 3), similar to the way commonly performed in clinical practice.

![Figure 3. Example of a circumferential polar plot (right) in accordance to the cardiac segmentation map (left), numbered as in figure 2.](image)
3. Results
In total, eight data sets were acquired (four from each system), using the image acquisition parameters shown in table 1. The acquired data where then reconstructed with and without attenuation correction. An example of the attenuation correction effects on a circumferential polar plot can be seen in figure 4. The parameters explored included variation levels of liver activity and the presence of defects in the anterior and inferior regions. By comparing the maximum change that occurred in the average segment intensity, the importance of each factor was evaluated. For example, by quadrupling the liver activity, only 5 - 10% change in any segment was noticed; the ability to detect defect was not affected.

![Circumferential polar plots](image)

**Figure 4.** Examples of circumferential polar plots produced (a) without and (b) with attenuation correction. The plot in (c) shows the difference of (a) and (b). Note the increased intensity in the septal region and the presence of defects in the mid anterior and mid inferior.

In figure 5, the effect of attenuation correction on circumferential plots from the two different methods can be observed. Even though the exhibited enhancement of the Siemens E-cam system (figure 5b) is noticeably greater than that of the General Electric Hawkeye system (figure 5a), it cannot be considered significant.

![Circumferential polar plots](image)

**Figure 5.** Example: the difference of circumferential polar plots produced with and without attenuation correction for (a) the General Electric Hawkeye SPECT/Low dose CT and (b) the Siemens E-cam Profile system.

4. Conclusion
The results obtained suggest that the application of attenuation correction may reduce the comparability of the two systems only to a small degree. Future work should focus on acquiring a largerer amount of data to explore the possibility of using a dynamic phantom where the myocardium and diaphragm motion is simulated.

References
[1] Bateman T M and Cullom S J 2005 *Seminars in Nuclear Medicine* 31 37-51
[2] Barber D C and Hose D R 2005 *Journal of Medical Engineering & Technology* 29 53-63
[3] Cerqueira M D et al 2002 *Circulation* 105 539-542