Qualitative evaluation of Chang method of attenuation correction on heart SPECT by using custom made heart phantom

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ABSTRACT

SPECT detects γ- rays from administered radiopharmaceutical within the patient body. γ - rays pass through different tissues before reaching detectors and are attenuated. Attenuation can cause artifacts; therefore different methods are used to minimize attenuation effects. In our study efficacy of Chang method was evaluated for attenuation purpose, using a custom made heart phantom. Due to different tissues surrounding heart, attenuation is not uniform more over activity distribution around heart is also non-uniform. In Chang method distribution of radioactivity and attenuation due to the surrounding tissue is considered uniform. Our phantom is a piece of plastic producing similar SPECT image as left ventricle. A dual head, ADAC system was used in our study. Images were taken by 180° (limited angle) and 360° (total rotation). Images are compared with and without attenuation correction.

Our results indicate that Chang attenuation correction method is not capable of eliminating attenuation artifact completely in particular attenuation effects caused by breast.

Key words: *attenuation correction, artifact, color intensity, SPECT.*

Introduction

Radionuclide imaging is a method of observing and evaluating heart muscle perfusion, thickness, ischemia and infarction. Radioisotope dose not concentrate inside the desired target area alone, some other tissues and organs are also involved (1). γ- rays diffraction causes decrease in photon energy and change in their direction making their identification and therefore mechanical and electronic elimination possible (2).

To reduce unwanted radiation from undesirable area, certain protocols are used to eliminate these radiations up to a certain level (2, 3). In heart SPECT imaging, we are interested in patient dose (as low as possible) and information obtained (as high as possible).Different methods are advised to correct for Compton scattering (4,5):

1) ***Experimental method***: in this method, attenuation coefficient for different area are directly measured and appropriate corrections are made (2, 4).

2) ***Mathematical analysis method***: in this method, radioactive distribution and attenuating medium are considered uniform (3, 4, 6) and include three categories:

a) Pre- reconstruction, here attenuation correction is carried out before filtered back Projection, (Sorenson method),

b) Post-reconstruction, here attenuation correction is carried out after filtered back projection (Chang first order and iterative attenuation correction method).

In Sorenson and first order estimation of Chang attenuation correction which are routine clinical methods (4), thickness value of attenuating tissue is assumed to be known. In this method, slice image is reconstructed and FBP is carried out after ward and depth related mean correction coefficient is multiplied pixel by pixel. This method is useful for areas of uniform attenuation. Here in the first step each uncorrected pixel is multiplied by appropriate attenuation correction i.e;

$$X^{(a)}_i = X_i c_i \quad (1)$$

Here c_i is determined as follow :

$$c_i = 1 / [1/l (\Sigma^l_{j=1} e - \mu L_{ij})] \quad (2)$$

If L_{ij} is distance from pixel (i) to projection (j) then attenuation is uniform. This relation is valid for point source only (first approximation). In the Chang iterative method, primary projections are reconstructed by attenuation compensation using standard FBP and then correction is carried out by means of equations (1) and (2) and finally is added to the original image . This process could be carried out repeatedly as required. The nature of Chang hybrid algorithm is well known and analytical stage of FBP is combined with an algebraic matrix coefficient therefore achieving good precision and efficiency i.e.:

$$f_c(x,y) = f(x,y)\, e^{\mu l} \quad (3);$$

$$\hat{l} = \Sigma_{j=1}^{n} l_j (x,y) /n \quad (4)$$

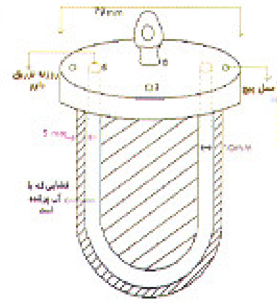
Here , $f_c(x,y)$ is corrected pixel attenuation, $f(x,y)$ pixel value at (x,y) location , μ linear attenuation coefficient of radionuclide in stopping medium and $l_j (x,y)$ is (x,y) pixel depth at the site of reconstructed tomographic image.

Materials and Methods

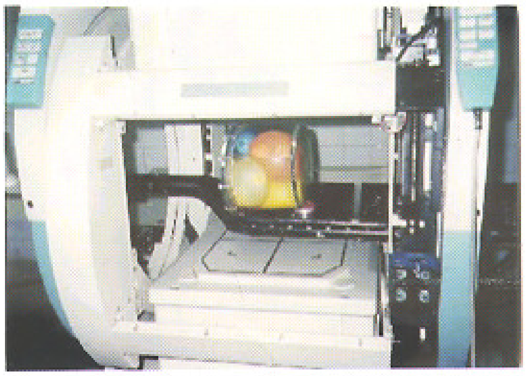
Study was carried out using dual head ADAC system at the nuclear medicine department, Shariati hospital with LEGP collimator. ^{99m}Tc-MIBI radiopharmaceutical was used as a 120 ml saline solution of 0.3-0.8 mCi activity inside the phantom. Heart phantom was a piece of plastic (polyethylene) (7) with few pieces of the same material to simulate cold lesion. Phantom size was chosen to match that of left ventricle. The whole assembly was immersed into a water container simulating body (tissue equivalent) having elliptical shape. Breast phantom was two semi spherical plastic containing two balloons filled with water (Fig 1).

Method: Phantom was first filled with ^{99m}Tc-MIBI (1) and was placed inside body phantom. To fix the heart phantom water filled balloons was placed inside body phantom in a way that it kept heart phantom in its proper position. Imaging was carried out with 180° and 360° rotation mood, with and without attenuation correction. Same procedures were performed with background and without background activity and with and without the breast phantom. Imaging was also performed with 45, 90 and 180 sector lesions and with annular lesions 1,1.5 and 2 centimeters diameter.

(a)



(b)



(c)

Fig 1. (a) Set of heart phantom and the breast phantom, (b) Heart phantom and (c) Position of phantom on the table of the ADAC camera.

Results

Image processing was carried out with and without attenuation correction each time after imaging was completed since correction is imposed on transverse view in Chang method (2). Two separate observations can be made for two different rotations in final image. In final image and for 360° rotation, colors will have more intensity if viewed separately. Images of two rotations at 180° and 360° if viewed simultaneously (one rest and another stress image) they will appear with the same color intensity because of normalization, but artifact show its presence and no appreciable change in contrast is noted.

Fig. 2a is obtained for sector lesion (4,5): $C_o=(1391 - 1727)/1727 = -0.19$ **(between two peaks)**

Fig. 2b, the same imaging condition with Chang correction: $C_o = (310 - 369) / 369 = -0.16$

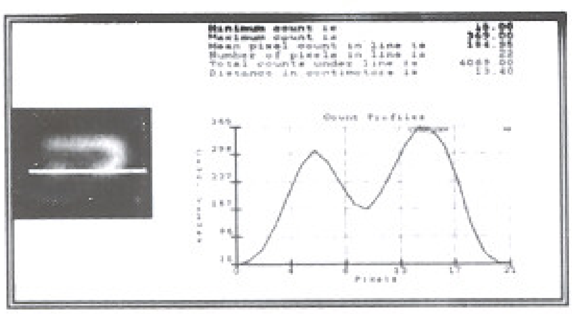


Fig. 2a

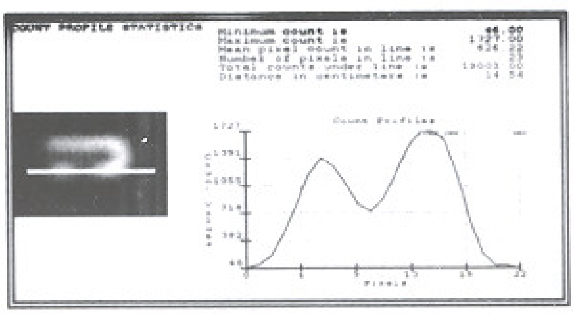


Fig. 2b

In figures 3c , 3d prefix AC indicates that attenuation correction has been imposed, and in fig. 3e instead of bulls eye illustration, projections have been selected to show phantom position by using serial kinetic performances.

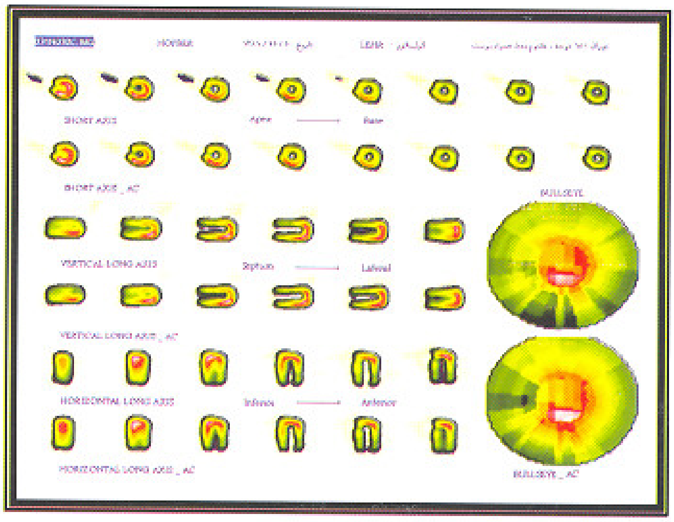


Fig. 3c

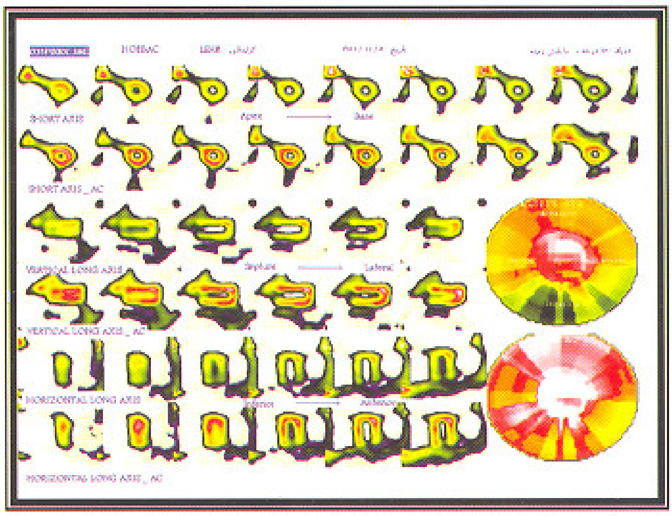


Fig. 3d

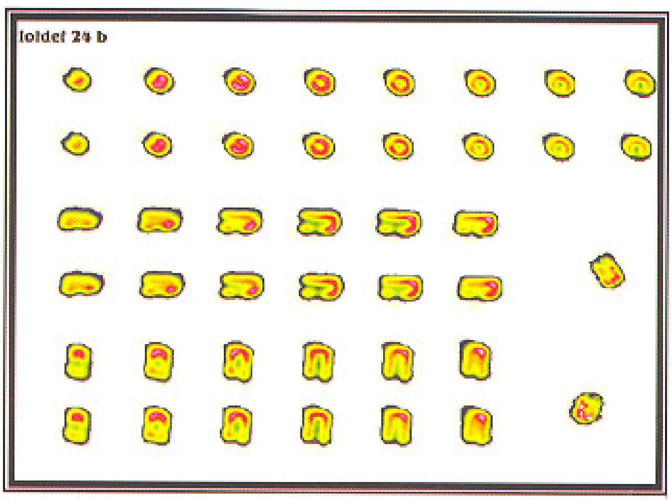


Fig. 3e

Conclusion

By viewing the processed images carried out by a series of contrast measurements and calculations, it shows that attenuation related to the different slice thickness, causes artifacts which are not present in normal images and Chang method of attenuation correction can not eliminate artifact in our set up. Even for attenuation due to background radiation, we only achieve more color intensed images, and in the presence of breast on our phantom, in 360° rotation not only improvement in image quality is not gained but image deteriorate actually takes place.

References

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