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Principal Component Analysis of Scintimammographic Images

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Abstract

The recent development of new gamma imagers based on scintillation array with high spatial resolution, has strongly improved the possibility of detecting sub-centimeter cancer in Scintimammography. However, Compton scattering contamination remains the main drawback since it limits the sensitivity of tumor detection. Principal component image analysis (PCA), recently introduced in scintimammographic imaging, is a data reduction technique able to represent the radiation emitted from chest, breast healthy and damaged tissues as separated images. From these images a Scintimammography can be obtained where the Compton contamination is "removed". In the present paper we compared the PCA reconstructed images with the conventional scintimammographic images resulting from the photopeak (Ph) energy window. Data coming from a clinical trial were used. For both kinds of images the tumor presence was quantified by evaluating the *t*-student statistics for independent sample as a measure of the signal-to-noise ratio (SNR). Since the absence of Compton scattering, the PCA reconstructed images shows a better noise suppression and allows a more reliable diagnostics in comparison with the images obtained by the photopeak energy window, reducing the trend in producing false positive.

KEYWORDS: Scintimammography, Principal Component Analysis, SNR, *t*-student.

1. Introduction

Scintimammography is a nuclear medicine technique that uses Tc99m Sestamibi (140 keV energy emission) to discriminate breast malignant lesions from the surrounding normal tissue. Single Photon Emission Mammography (SPEM), utilizing a dedicated detector based on PSPMTs coupled to scintillating array, has strongly improved the sensitivity of this technique in finding tumors sized less than 1 cm. This result follows from the combined intrinsic spatial resolution of detector, positioning close to the tumor and the breast compression [1]. Compton scattering contamination is the main drawback in Scintimammography, since it limits the sensitivity of tumor detection. Indeed, scattering from extra mammary source due to the high Tc99m taken up from heart and liver can significantly affect the detection of a posterior located cancer. The method currently used in nuclear medicine to remove Compton noise from the image is the energy window. To enhance the tumor detection in the presence of high Compton contamination, a numerical method utilizing the Principal Component Analysis (PCA) has been recently introduced [2]. Principal component image analysis is a "spectral imaging" technique used to gain information by the simultaneous analysis of images measured for different wavelength or energy radiation distribution [3]. Scintimammographic images obtained by using the total pulse height distribution of the detector may be considered as a stack of images – a multivariate image – each of them corresponding to different energy ranges of the spectrum. Principal component image analysis algorithm allows us to compress the information present in all the images and separate breast regions containing the chest emitted radiation and the tumor ratio as independent images [3,4]. In the present paper preliminary results of the principal component image analysis performed on clinical trial is presented. To evaluate the efficiency of PC based scintimammography the *t*-student statistic was introduced to evaluate of signal-to-noise ratio (SNR).

2. Principal Component Image Analysis

The goal of principal component image analysis, also known as Multivariate Image Analysis (MIA), is to extract significant information from an image data set while reducing the dimensionality of the data [3,5]. Figure 1A makes evident that the spectrum resulting from the scintimammographic imager can be considered as a set of images. Extending the conventional approach based on the 'photopeak' energy window [1], the total pulse height distribution was described by six energy windows called w_1 to w_6. To this respect, the output of the imager can be considered as a stack of images each of them viewing the same field-of-view; i.e., a multivariate image [3,4]. PCA divides information into orthogonal components by transforming multivariate images into a number of principal component (also called scores) images that carry information related to these orthogonal components. The first principal component account for as much of the variability as possible, and each succeeding components ac-

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count for as much of the remaining variability as possible. The primary components represent the set of components that are required to reproduce the original data set within the experimental error. The remaining principal components, each describing a low variance, represent the noise. The idea behind PCA is presented in Figure 1B. The objective is to identify images which pixels are globally correlated or anti-correlated. For each original image w_k, this information can be displayed as *loadings* coefficients; whereas the pixels that are responsible for the correlation can be displayed as *Principal Component* (*scores*) images. Score image may be easier to interpret than the variable images.

3. Equipment and Method

Images utilized for the analysis was collected by a high resolution gamma camera dedicated to the scintimammography. The detector consists on: a photodetector, based on 4x4 array of one inch PSPMTs Hamamatsu H8520-C12 closely packed, a 10×10 cm2 NaI(Tl) scintillation array (1.8×1.8×6mm3 pixel) and a General Purpose collimator. The detector overall dimension are 112×120×75.3mm3. Each PSPMT is connected to a weighted summing circuit, and the output signal is first amplified and then converted to digital values. We performed an initial clinical experience on a few patients with breast cancer. The patients were submitted to scintimammography in cranio-caudal projection, 30 min after a single administration of 740 MBq (20 mCi) of 99mTc Sestamibi.

4. Results and Discussion

As recently shown [2], principal component image analysis is a data reduction technique that transform the multivariate image resulting from the windowed of pulse height distribution (Figure 1) in a series of scores images, each of them collecting a specific component of γ-rays reaching the detector. MIA of a scintimammography showing a large tumor near the chest is displayed in Figure 2. Pixel in scores PC1 and PC2 depict the Compton scattering from the chest and the radiation emitted from healthy tissues [2], respectively. Score image PC3 to PC5 detail the region containing the tumor, and in the last PC the PSPMT configuration is evident [6,7]. By using score images showing the tumor and the corresponding loadings; i.e., the algorithm detailed in Figure 1B, a scintimammographic image can be obtained, where the damaged tissue has a better visibility than in the image obtained by the photopeak selection. This is evident in Figure 3 where the scintimammography resulting from MIA and from the conventional approach are shown. Both the images in Figure 3 are characterized by the presence of a tumor grater than 1 cm size positioned near (Figure 3A) and distant (Figure 3B) from the chest, and were chosen

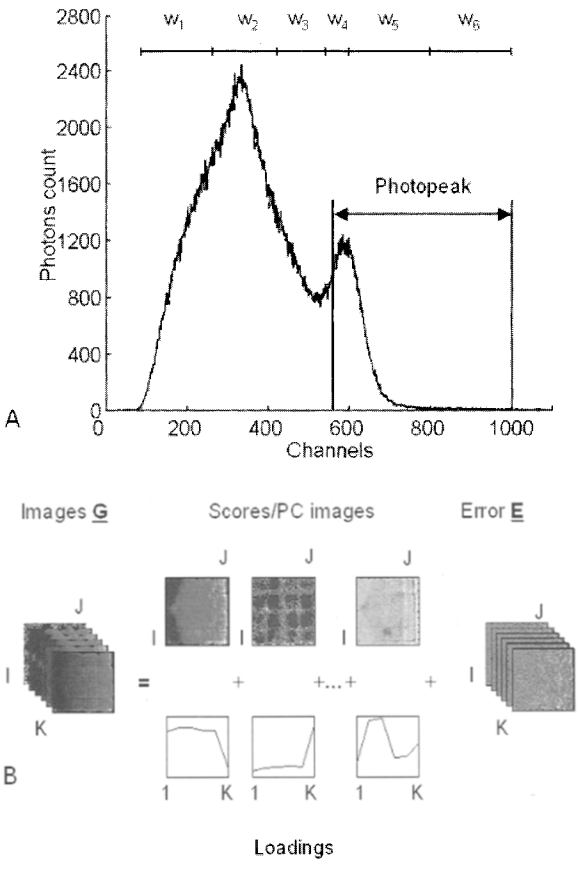

Fig. 1. A) Imager pulse height distribution with the photopeak and energy windows. B) Image Principal Component Analysis algorithm. The series of K images G is decomposed via PCA into K principal components images (scores images) and loadings associated with each of them. The A components represent significant variation within the original K variables, whereas (K-A) represent noise in the original variables and are included into error images E.

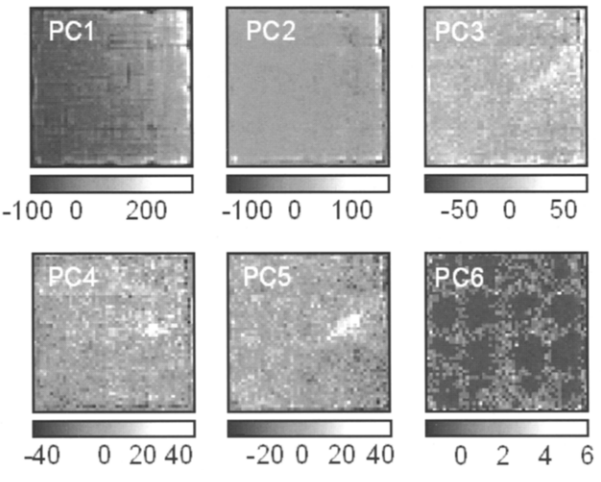

Fig. 2. Scores images calculated for the case study showing a tumor near the chest (see text). Scores PC1 and PC2 collect the 93% of variability in original images; Scores containing the tumor give reason of about the 6% of total variability.

as a case study to test the efficiency of PC image analysis. To quantify differences between PC and conventional scintimammography regions-of-interest (ROI) selected at increasing distance from the

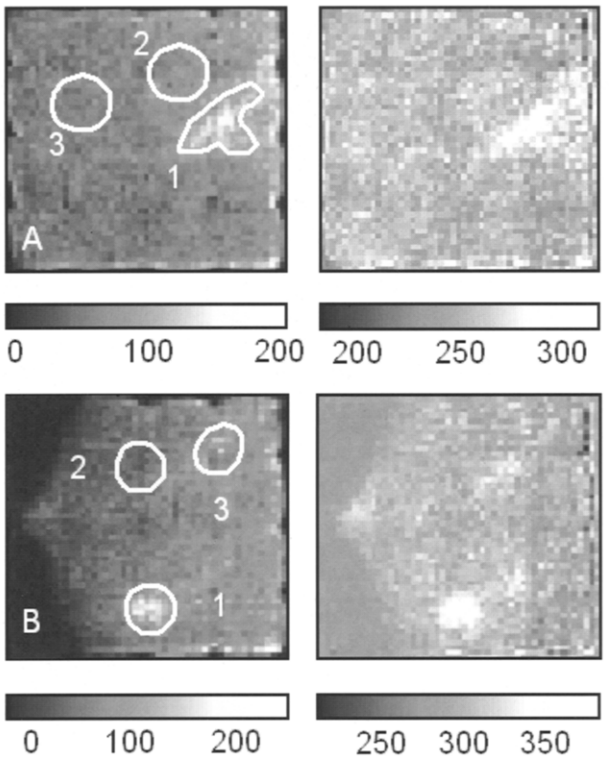

FIG. 3. Scintimammographic image obtained by the Photopeak energy window (left) and by Principal Component Image analysis (right). Scintimammography in Fig. 3 shown a tumor greater than 1 cm size positioned near (A), and distant from the chest.

chest was selected and the *t*-student statistics for independent sample was calculated. Where $\overline{X}$, s and n indicate the

$$t = \left(\overline{X}_i - \overline{X}_j\right) \Big/ \sqrt{\frac{s_i^2}{n_i} + \frac{s_j^2}{n_j}}$$

mean, the standard deviation and the total number of photons in selected ROIs. Figure 3, where ROI 1 delimits the tumor, whereas ROI 2 and ROI 3 indicate background regions at increasing distance from chest. For conventional scintimammography the *t*-student statistic is equivalent to the signal-to-noise ratio (SNR) [1]; indeed, comparing ROI 1 and a background ROI the difference between mean detected photons, $\overline{X}_1 - \overline{X}_j$, estimate the signal and the difference between standard errors s_i / n_i estimate the noise. In addition, it is worth nothing by the *t*-student statistics we can quantify the difference between background ROIS, as well. As expected, results in Table 1 indicate that SNR values computed for tumor located near chest, Figure 3A, strongly depend on Compton scattering contamination. The conventional Photopeak scintimammography gives higher SNR values depending on the distance of background ROIS from the chest. The same is not true for PC-reconstructed scintimammography where the SNR confirms the tumor presence with a weak dependence by the ROIS choice. For tumor located away from chest, Figure 3B, the SNR are very similar for both the Photopeak- and the PC-reconstructed

TABLE 1. Absolute values of t-student statistic calculated for Photopeak and Principal Components images. Selected ROIS are shown in left column of FIG. 3.

Tumor position	ROIS	Photopeak	Principal Components
Near the chest	1 vs 2	16.7	10.3
	1 vs 3	26.8	14.2
	2 vs 3	8.5	1.7
Distant from chest	1 vs 2	14.7	13.9
	1 vs 3	5.6	9.1
	2 vs 3	10.9	4.2

images. The comparison between the background ROI 2 and ROI 3 still confirms the dependence from Compton scattering. The high *t*-student values computed in Photopeak scintimammography are not validated in PC-reconstructed images. Indeed, in the case study of Figure 3A (tumor near the chest) the value $t = 1.6$ indicates that ROI 2 and ROI 3 have quite the same concentration of radiotracer. In other words, in terms of SNR the comparison ROI 2 vs ROI 3 evaluated for the Photopeak scintimammography should be classified as "false positive". On the contrary for the case study in Figure 3B, the comparison between ROI 2 and ROI 3 give a high value, $t = 4.2$, still for PC-reconstructed images and since in this reconstruction the influence of Compton scattering has been strongly reduced, the high *t*-student values must be carefully considered.

5. CONCLUSION

The preliminary results shown in the present paper indicate that the scintimammographic images resulting from Principal Component image analysis allows a more reliable diagnostics in comparison with the conventional Photopeak scintimammography. In fact, the case study here presented shows that the presence of Compton scattering strongly affect the SNR evaluation and give rise to a misleading interpretation of ROIS showing a high pixel density. In other words, it appears evident that the scintimammographic technique here introduced reduces the trend of the conventional Photopeak based scintimammography in producing false positive.

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