COMPENSATION FOR PATIENT MOTION IN NUCLEAR MEDICINE RENAL STUDIES BY FAST CORRELATION IMAGE REGISTRATION

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ABSTRACT

A computer method has been developed to compensate for patient motion which degrades nuclear medicine renal dynamic studies. The method is based on a fast correlation algorithm which accomplishes decoupling of the registration variables translation, rotation and scaling, and converts rotations into cyclic shifts using polar transformations of the images in the Fourier domain. The method has been implemented into a fully automated program which compensates for translational and rotational differences between images acquired while the patient was immobile and images acquired after the occurrence of motion. Preliminary results indicate the usefulness of the program as a clinical tool for salvaging renal scintigraphic studies with patient motion, thus preventing erroneous interpretations or repeat of the examinations.

INTRODUCTION

Patient motion is a serious problem in nuclear medicine dynamic renal imaging (renal scintigraphy). A dynamic renal scintigraphic study is acquired by a gamma camera and stored on the computer as a set of sequential planar images (frames), each of 30 sec duration for a total of 22 minutes. The duration of the study makes it very difficult for the adult patient to remain immobile because of discomfort, back pain, and, occasionally the need to micturate; children are restricted but, even then, may substantially move. Although visual appreciation of sequential images may not be severely affected by patient motion, quantitative analysis is seriously impaired. As with most nuclear medicine studies, renal function and disease are quantitated by computer analysis which generates time-activity curves (renograms), representing the transit of the radioactivity (radiopharmaceutical) through the kidney(s). To obtain renograms from the sequential images by a semi-automated computer approach it is necessary to assign regions of interest, i.e. kidney(s) and/or parts thereof, and calculate the radioactive counts within the boundaries assigned in the entire set of acquired sequential images. Each region of interest (ROI) should include the same anatomical site throughout the entire set of images. Patient motion during the acquisition period results in random changes of the anatomical site which is selected on the first or another representative image of the set (Figure 1). The resulting renogram is erratic and does not represent the expected function of the selected organ (Figure 2). Furthermore, the effects of motion are not always easily recognizable and thus may result in erroneous interpretations. Conversely, when motion is appreciated, the entire study may be discarded and a repeat may be decided with all its negative consequences. Therefore, it is understandable that salvaging such studies through methods which compensate for patient motion by registration of the entire image sets would help the patient and the health care professionals.

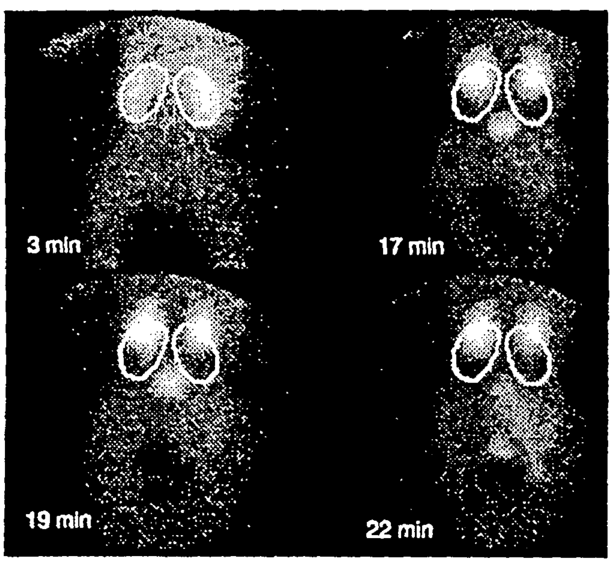
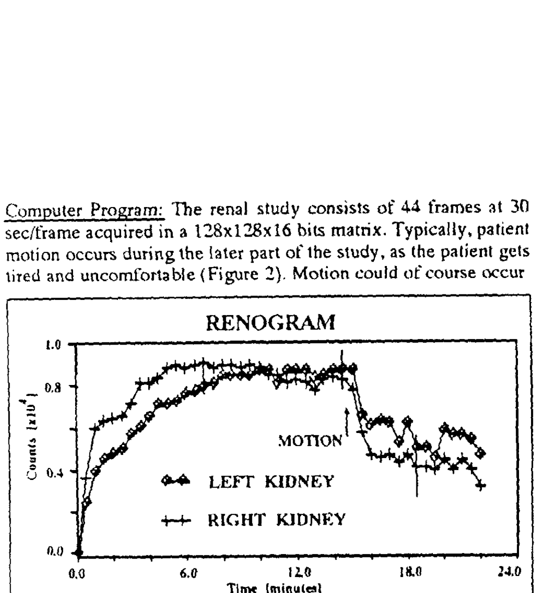


Fig.1: *Renal scintigraphic images with superimposed ROIs, showing the effect of patient motion. The ROIs have been selected in the first image of the shown sequence (3min), and are applied to the following images without change of their position.*

MATERIALS AND METHODS

Image Registration Method: Registration of images is achieved by finding the maximum cross-correlation coefficient in an appropriately transformed domain. Details of this method and its application to multi-modality (PET, MRI) images [2,3] and high resolution retinal images [4] have already been published. In short, it is assumed that the transformation between any two consecutive (in time) images in the dynamic renal study can be well approximated by a combination of translation and rotation. The determination of the shift parameters and the rotation angle is accomplished in two steps: In the first step, the Fourier magnitude of each image is used to decouple rotation from translation by effectively centering the information content of each image. Next, the Fourier magnitude images are transformed into polar coordinate representation, r and Θ, which converts rotation into a cyclic shift along the Θ-coordinate. The two-dimensional cross-correlation function (cyclic in Θ, linear in r) is calculated for the two polar Fourier magnitude images. The position of the maximum determined along the zero r shift profile of the cross-correlation function specifies the optimum rotation angle between the images. In the second step, one of the original images is rotated appropriately, and is cross-correlated with the other original image. The maximum of this cross-correlation function specifies the optimum translation parameters.

Computer Program: The renal study consists of 44 frames at 30 sec/frame acquired in a 128x128x16 bits matrix. Typically, patient motion occurs during the later part of the study, as the patient gets tired and uncomfortable (Figure 2). Motion could of course occur



	TOTAL COUNTS	MAX COUNTS	20-MIN COUNTS	PEAK TIME	PK TO T 1/2	20-MIN % OF MAX
LEFT KIDNEY	2.998 E5	8681.	5259.	14.5	>7.51	60.5
RIGHT KIDNEY	3.018 E5	8985.	4154.	7.0	>10.7	46.2

Fig.2: *Erratic renogram, showing a substantial drop in counts as the effect of patient motion after the 15th minute.*

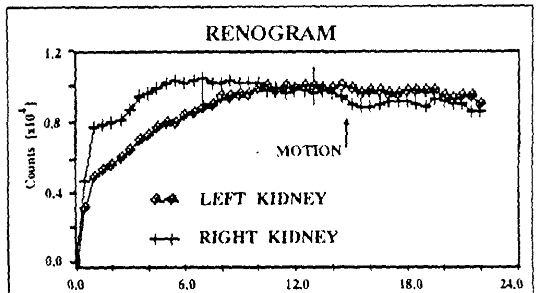
at any other time during the study as well. The motion can be detected visually by displaying the sequential images as a dynamic series in cinematic ("cine") mode, or by placing ROIs around the kidney(s) on the early frames and applying them to subsequent frames through the end of the study. There are two approaches to selecting a reference frame for registration: In the first approach, every frame acquired after patient movement is registered with the last frame acquired before patient movement (reference frame). Subsequently, the calculated translational and rotational differences are compensated for, and the transformed images are appended to the images without motion. The new image set is then used for ROI placement and renogram generation. In the second approach, the fact that the image content (amount of activity inside the kidneys), changes as the study progresses is taken into consideration in the following way: Each frame with motion is registered with the previous image in the dynamic series and the relative translation and rotation parameters are calculated. The registration proceeds backwards in time in a chain fashion, until no rotation and translation changes are found (or they may be smaller than a maximum allowable limit) between neighboring frames. At that time, the overall translational and rotational differences of each frame with motion are computed with respect to the frame without motion and the appropriate transformations take place. The corrected series is thus available for ROI placement and renogram generation.

RESULTS

The method was evaluated with ten clinical cases that demonstrated motion and it was found to perform equally well for native as well as transplanted kidneys. Figure 3 shows the motion-corrected renogram for the patient whose motion characteristics are illustrated in Figures 1 and 2. The sudden decrease in counts seen in Fig.2 after 15 minutes as a consequence of motion and the mismatch of the ROIs disappear. The method presented in this paper yielded objective results in all cases using the single reference frame approach, even though higher cross-correlation coefficients were derived from the moving reference frame approach.

CONCLUSION

The described method of compensation for patient motion in renal scintigraphic studies using fast correlation algorithms for image



	TOTAL COUNTS	MAX COUNTS	20-MIN COUNTS	PEAK TIME	PK TO T 1/2	20-MIN % OF MAX
LEFT KIDNEY	3.862 E5	9987	9562.	13.0	>9.01	95.7
RIGHT KIDNEY	4.088 E5	10309.	9075.	7.0	>15.0	88.0

Fig.3: *Corrected renogram, obtained from the same image study as in Figure 2, but after compensation of patient motion. The renogram shows no more unphysiological decline at the time of the patient motion which is indicated by the arrow.*

registration provides objective results in clinical cases with patient movements during data acquisition. It is a useful clinical tool because it can save studies which would otherwise need to be repeated, thus eliminating additional costs in labor, time and materials. The performance of the method suggests that the registration algorithms may be applied in other planar acquisitions for correction of patient motion, such as liver transplant quantitation, and with appropriate modifications it could also be applied to tomographic studies, such as cardiac SPECT.

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