COMPUTER ASSISTED CANCER DIAGNOSIS SYSTEM USING PET/CT DELAYED SCAN IMAGE

Rui Zhang, Takako Sato and Hiroshi Arisawa
Graduate School of Yokohama Nat. Univ., 79-7, Tokiwadai, Hodogayaku, Yokohama, 240-8501,Japan

Keywords: PET/CT, Whole-body delayed scan, CAD, CADS, Tumor detection, SUV, DTA.

Abstract: In this paper, a new method for CADS (computer assisted diagnosis system) is proposed: whole-body PET/CT delayed scan. Whole-body PET/CT imaging is quite useful for detecting cancerous regions, however sometimes too many "suspicious areas" due to ambiguous signs within 3D images. We propose a method in which two images i.e. original images and whole-body delayed scan images are compared and the true positive regions are identified. For the purpose of detection, a matching algorithm for comparing each region on both two images has been developed. It contributes not only to improve accuracy of a diagnosis but to reduce "false positive" regions. We compare this new method with the routine one and show its supporting technologies and advantages. In the end we indicate our research emphasis.

1 BACKGROUND

Since computer-aided diagnosis (CAD) was first researched by the laboratory of Kurt Rossmann during the 1980's, the research on CAD systems has been increasing, which constituted a sturdy foundation for the basis of CAD systems. One application for these systems is aiding radiologist with growing burden of making effective and efficient diagnoses from increasing amounts of imaging data. For that end, a large number of research on computer assisted diagnosis system (CADS) has been proposed (Jiang et al, 2001) (Toriwaki, 2000) (Tsai and Lee, 2001) (Cheng, Akiyama, Wang, Itoh, 1998) (Ukai, 2000).

The diagnostic method for cancer detection using the PET/CT images is a core technology in CADS; it has shown its superiority in the clinical management of cancer. During cancer inspection by PET/CT scan, drugs called FDG (fluorodeoxyglucose) are injected into patient. After 1 hour, gamma rays emitted from the patient are photographed by the nuclear imaging system. Because much more FDG is taken into a cancer cell than a normal cell, as a result, we observed the concentration of FDG absorbed by the tissues and organs to distinguish between normal and abnormal areas.

To further improve the accuracy of the diagnosis, a second scan, known as PET delayed scan is performed. A half hour after the PET/CT scan a PET delayed scan is performed at specific areas where potential tumor was shown in the original whole-body scan. By comparing the original image with the delayed scan image, a more accurate diagnosis is achieved. If the value of SUV (standard uptake value) of a certain part in the delayed scan image is higher than the corresponding part's SUV in the whole-body scan, this part is likely to be a malignant pattern which indicates a true positive. Otherwise this part is likely to be a benign pattern which means it is a true negative. PET delayed scan is not very prevalent in the diagnosis for tumor detection. Only a few hospitals use it for about 10% of their patients.

Still PET delayed scan is one of the promising technologies for the medical image processing system. But this technology is only applied to specific parts of the body but not to the entire body. So we propose a new method of cancer diagnosis: Whole-body PET/CT delayed scan with CADS.

2 PROCEDURE OF NEW METHOD OF WHOLE-BODY PET/CT DELAYED SCAN

A large number of data and experiments testify the usefulness of dual time imaging in tumor detection (Matthies et al, 2002) (Zhuang et al, 2001).

Zhang R., Sato T. and Arisawa H..
COMPUTER ASSISTED CANCER DIAGNOSIS SYSTEM USING PET/CT DELAYED SCAN IMAGE .
DOI: 10.5220/0003287203990404
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2011), pages 399-404
ISBN: 978-989-8425-34-8

Part-body delayed scan could distinguish between malignant and inflammatory lesions by comparing SUVs of corresponding sites in two images thereby reducing the false positive results. FDG is absorbed adequately by the tumor during the half hour after the first scan so that cancerous areas are diagnosed more easily, which means delayed scan could decrease false negative results. However, the disadvantage of dual time imaging for part of the body is also obvious. The cancerous cells have the characteristic of normal metastasis. The site where a tumor is may be not found if this site shows a false positive result in the first scan and is excluded from the delayed scan. So we propose the new method of PET/CT whole-body delayed scan.

Figure 1 is the description of radiologist's routine method of PET/CT scan. Figure 2 describes the diagnostic process of a delayed scan which is utilized but not so prevalently nowadays, and Figure 3 shows the procedures of tumor detection using a whole-body PET/CT delayed scan in the future.

In figure 1, patients accept the whole-body PET/CT scan only once, and then radiologist makes the final diagnosis by the PET/CT image. For the figure 2 and 3, there are three differences between these two figures: firstly, it is obvious that the delayed scan of figure 3 is taken over the whole body while the other is only the suspicious area; secondly, recently, only 10% of patients could be subject to a second PET scan on the suspicious parts; we hope in the future this new cancer diagnosis method of whole-body PET/CT delayed scan could be used for all the patients after the first PET scan. Thirdly, the computer assisted diagnosis system (CADS) in figure 3 is utilized.

In figure 3, most diagnoses and comparisons are made by the CADS, not by the doctor. The whole-body delayed scan process produces the double workload of reading images for radiologists because the area of the second image increases to the whole body. That is the main reason why whole-body delayed imaging has not been used in clinical medicine. The CADS will solve this problem by reducing false positive results significantly and having the task of comparing the original images with the delayed images done by a computer. The doctor only does the final diagnose which is simplified by the CADS. So the CADS constitutes the principal advantage and precondition for the deploying of whole-body delayed scan. Now Arisawa laboratory in Japan is devoted to the study of the CADS.

The CADS is a system which imitates diagnosis of radiologist. The most important part of the CADS is a diagnosis algorithm which could interpret a doctor's methodology during PET/CT scan diagnosis and uses the proper PET/CT terminology to describe the program's action so that it would simulate the performance of the radiologist. This system is designed so that a doctor can monitor the process of diagnosis from the local to the whole body level, to evaluate diagnosis's validity and to recommend improvement.

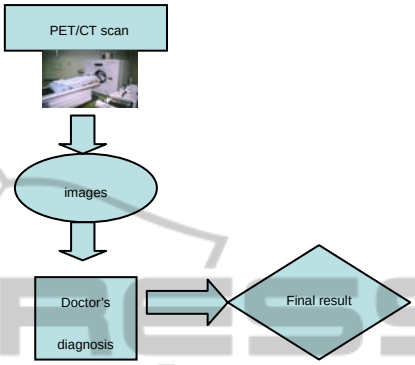

Figure 1: Routine method of PET/CT scan.

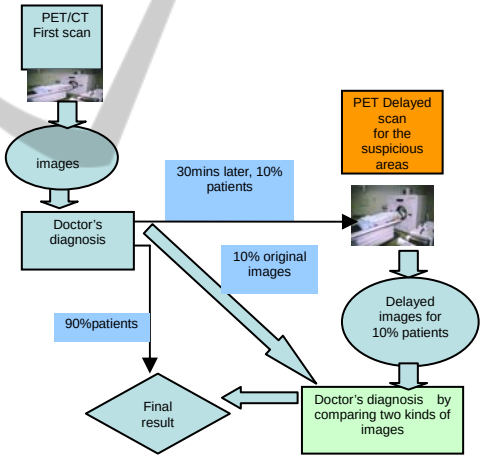

Figure 2: Diagnostic process of delayed scan which is utilized but not so prevalently nowadays.

3 SUPPORTING TECHNOLOGIES

The realization of this new method needs many technologies. Now we introduce supporting technologies which we are devoted to research.

3.1 Multi-organ Identification and Cancer Diagnosis

Obtaining an organ's shape and position is crucial

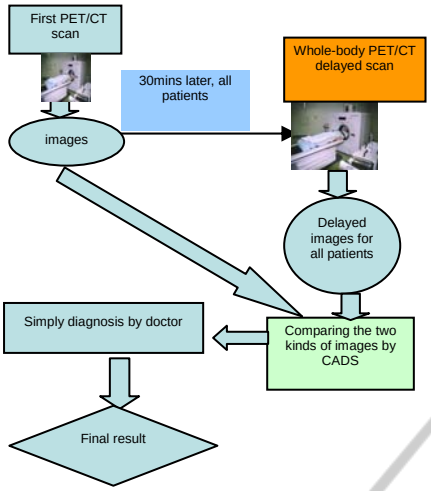

Figure 3: Procedure of tumor detection with the new method of PET/CT scan for the whole body in the future.

step before tumor detection. Some researchers think that the first processing step of a CAD system in the future should understand the normal structure of the human body by the processing of input images (Kobatake, 2009). The outline image of an organ from a PET/CT scan is very useful to confirm the location of the accumulation of cancer. In general, PET images readily allow identification of certain organs like the brain due to high metabolism, while CT images are most suitable for extracting the areas of the lungs and the skeleton due to their distinctly differences in density compared to soft tissue (Wen, Leung, Eberl, Feng, Bai, 2008). But this issue is the difficult point in the research of cancer diagnosis all along.

Multi-organ cancer diagnosis is the future of computer assisted diagnosis system. There are different criterions for tumor detection in different organs. Existing works are mostly focusing on specific organs such as lung and breast (Takeo, Shimura, Imamura, Shimizu, Kobatake, 2005). Research about other organs such as liver, gallbladder and so on are in the primary stage.

3.2 Dynamic Threshold Adjustment

Setting appropriate threshold values such as SUVs in PET/CT images contributes to not only identify the organs and acquire the figures of organs exactly but also finding tumors and extract the shape of cancer. Even in one organ, dynamic threshold values are needed to obtain the organ's boundary and ensure the location of cancerous cells. DTA (dynamic threshold adjustment) method (Arisawa, 2009) is proposed for this situation. DTA is useful for extracting the outline of an organ and position of a tumor, it could elevate the precision of diagnosis and it is an important focus for further research

In cancer detection, DTA method can notice fine differences of threshold values of abnormality. That is, in the preliminary stage, detecting whole "critical" areas (c-areas) which have sharp increasing of SUV locally, then calculating the average value (c-value) of the c-area. This c-area should be extended if some spots have a higher SUV than c-value around the original c-area. Finally, for all the extended c-area refiltering will be done depending on the organ-specific value. The remaining c-areas are considered "abnormal" accumulations (Arisawa, 2009).

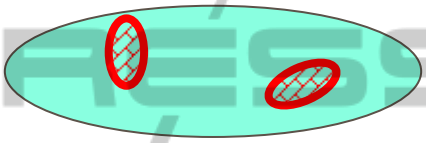

Figure 4: Target areas for tumour detection.

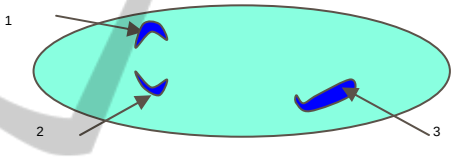

Figure 5: Extracting the areas which have sharp increasing of SUV locally, and then calculate the average value of c-area (c-value of area No1 is 3.0; c-value of No 2 is 2.8; c-value of No 3 is 4.0).

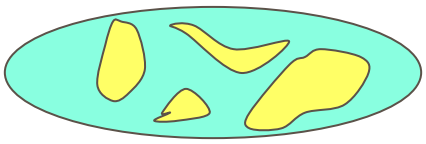

Figure 6: Obtaining the suspicious areas based on the c-value of No.1 area.

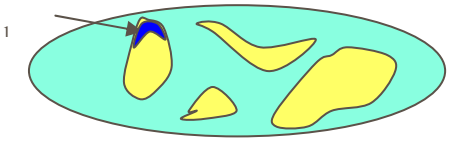

Figure 7: Preserving the areas which overlap with No.1 area.

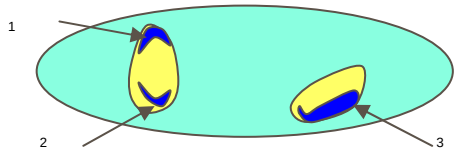

Figure 8: Applying the same operation on the No.2 and No.3 areas.

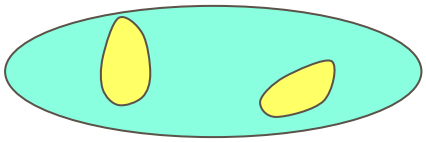

Figure 9: Result of tumour candidates by the DTA method.

3.3 Position Adjustment of Images

Position adjustment between previous PET/CT image and delayed scan PET/CT image is an important step to ensure whether the areas have cancer or not. There is a wait of about 30 minutes between first PET/CT scan and the delayed scan, the two images subject to many differences caused by changes in a patient's laying positions and persistent absorption of FDG by organs during the 30 minute interval. For example, the position of the body in both images is changed; the areas of FDG accumulation in both pictures are altered. Research involving position adjustment of images includes two aspects: (1) image adjustment, and (2) accumulation area adjustment (HONG, Sato, Arisawa, 2008).

(1)Image adjustment includes rescaling of size and barycenter between two images and so on. We rescale the size of delayed image by the method of Linear Interpolation.

In normal condition, the patient's barycenters of original image and second image are different.

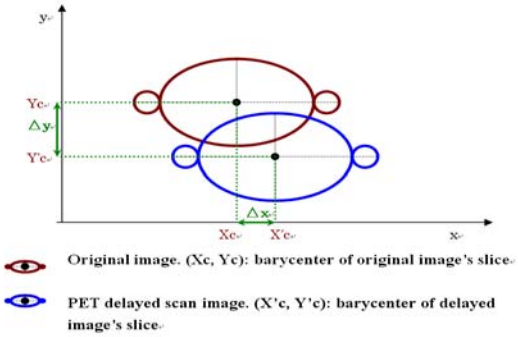

Figure 10: The difference between barycenters of two images.

The computing formula of patient's barycenter of original image:

$$(Xc, Yc) = \left(\frac{\sum_{i=1}^{SumOfPixels} x_i}{\text{Sum of pixels}}, \frac{\sum_{i=1}^{SumOfPixels} y_i}{\text{Sum of pixels}}\right) \quad (1)$$

The computing formula of patient's barycenter of delayed image:

$$(X'c, Y'c) = \left(\frac{\sum_{i=1}^{SumOfPixels} x'_i}{\text{Sum of pixels}}, \frac{\sum_{i=1}^{SumOfPixels} y'_i}{\text{Sum of pixels}}\right), \quad (2)$$

The differentials between patient's barycenters of two images:

$$\Delta x = X'c - Xc \quad (3)$$

$$\Delta y = Y'c - Yc \quad (4)$$

So we can rescale the delayed image by the formulas of relationship between the original image's point (x, y) and delayed image's point (x', y') :

$$x' = x + \Delta x \quad (5)$$

$$y' = y + \Delta y \quad (6)$$

(2) Accumulation area adjustment is to make accumulation mapping for two images. There are four possibilities for accumulations' changes by comparing the original image and delayed image: (a) the SUV of delayed image becomes higher than the SUV of original image(in figure, SUV = 6.7→7.9); (b) Two accumulations combine together; (c) One accumulation separates to two parts; (d) The position of accumulation in image is changed.

For the accumulation of (a), this part indicates true positive and accumulation of (d), we could conclude it is false positive result because the cancer's accumulation could not transfer. Accumulation (b) and (c), we should do further analysis to make sure whether there is cancer or not.

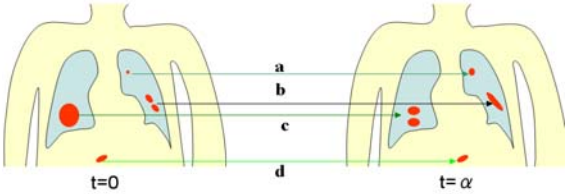

Figure 11: The changes between original image's accumulations and delayed image's accumulations.

3.4 Comparing the SUVs of Two Images

During the interval of 30 minutes between first scan and delayed scan, normal cells will release the FDG so that SUV of normal region decreases; meanwhile cancer cell continue to absorb the FDG in that 30 minutes so that its SUV increases. Therefore, comparing the SUVs of the first scan image with the ones of the delayed scan image is a research subject for this new method. Generally speaking, lesions such as in the lung area with decreased or stable SUVs over time are likely to have a benign etiology. In contrast, lesions with increased SUVs over time are likely to be caused by malignancy (Matthies et al, 2006). At present there are no identified standards for whole-body tumor detection by comparing SUVs of two images, which is one of our research objectives.

4 EXPERIMENTAL RESULT

Using the above procedure, we have already implemented a preliminary experiment. The result shows that a delayed scan with CADS reduces the false positive results, which mean a more precise diagnosis is achieved.

		Routine scan	Delayed scan by CADS	Diagnosis by doctor
Case 1	Abnormal areas	4	1	1
	Suspicious areas	10	0	0
	Normal accumulation	1	14	14
Case 2	Abnormal areas	23	0	0
	Suspicious areas	11	0	0
	Normal accumulation	0	34	34

Figure 12: Experimental result by 3 different methods.

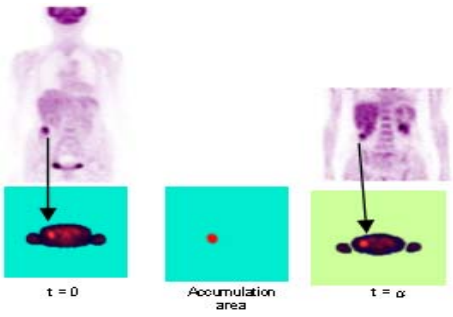

Figure 13: PET image of case 1.

5 ADVANTAGES

5.1 Accomplishment of More Comprehensive Diagnosis

More comprehensive diagnosis could be achieved by the whole-body PET /CT delayed scan. Now PET delayed scan of specific parts of the body allows a doctor to make omissions of cancerous area during the diagnosis process. Unlike other diseases, cancer is not necessarily only limited to one primary organ, but also may involve local and distant metastases to the lymphatic system and other organs (Knoepp and Ravenel, 2006). So PET /CT delayed scan for the whole body diagnosed is a potentially promising method for the tumor detection.

5.2 Achieving More Accurate Diagnosis

The CADS makes the result of tumor detection more reliable and precise. Mistakes maybe made by the radiologist's diagnoses because of doctor's negligence for the tiny accumulation of high SUV. But in CADS, there are standard SUVs which are determined by computer to distinguish tumor areas and normal areas. The CADS has a higher sensitivity for the SUVs so as to make more accurate diagnosis.

5.3 Decreasing the Burden of Radiologist

Nowadays, a great number of diagnoses by doctors are needed in tumor detection. Adding CADS processing to doctors' diagnoses by the whole-body PET/CT delayed scans will simplify the diagnosis for radiologists, especially for the doctors in the countries where PET/CT imaging for tumor detection is a regular health test for the patients.

6 CONCLUSIONS

The new method of PET/CT delayed scan for the whole body has been briefly introduced. We hope delayed scan in the future could apply to all the patients, not only 10% patient, and achieve whole-body PET/CT delayed scan instead of part-body PET delayed scan. For the realization of this new method, computer algorithms are extremely important to make the diagnosis active and automated. Whole-body PET/CT delayed scan should be one of the trends in computer assisted diagnosis system. In the future, our research will

focus on position adjustment of images in many situations such as patient's arms putting down beside body during the first scan in order to capture the arms but holding them up over the head during the second scan in order to reduce noises, which has a big influence in PET/CT imaging for the breast area.

ACKNOWLEDGEMENTS

We express our appreciation to Dr. Ryogo Minamimoto of National Center for Global Health and Medicine, Professor Tomio Inoue of the Yokohama City University Graduate School of Medical Studies and Dr. Seishi Jinnouchi of Atsuchi Neurosurgical Hospital PET Center.

REFERENCES

Jiang, H., Masutoh, N., Nishimura, O., Okumura, T., Yamamoto, S., Iisaku, S., Matsumoto, T., Tateno, Y., Iinuma T., Matsumoto, M., 2000. Computer-Aided Diagnosis System of Lung Cancer Screening by X-Ray CT, *IEICE TRANS.(D-II)， J83-D-II (1), 333-341.*

Toriwaki, J., 2000. Trends and Future Problems in Computer Aided Diagnosis of X-ray Images, *IEICE TRANS.(D-II), J83-D-II (1), 3-26.*

Tsai, D., Lee, Y., 2001. Fuzzy Reasoning Based Computer-Aided Diagnosis for Automated Discrimination of Myocardial Heart Disease from Ultrasonic Images, *IEICE TRANS.(A)，j84-A(12)， 1431-1438.*

Cheng, X., Akiyama, I., Wang, Y., Itoh, K., 1998. Breast Tumor Diagnosis System Using Three Dimensional Ultrasonic Echography，*IEICE TRANS.(D-II)，J81-D-II (1), 1402-1410.*

Ukai, Y., Niki, N., Satoh, H., Watanabe, S., 2000. Computer Assisted Diagnosis System for Coronary Calcifications Based on Helical CT Images，*IEICE TRANS.(D-II)，J83-D-II (1), 342-350.*

Matthies, A., Hickeson, M., Cuchiara, A., et al.2002,Dual time point 18F-FDG PET for the evaluation of pulmonary noudles. *J. Nucl. Med., 43;871-875.*

Zhuang, H., Pourdehnad, M., Lambright, E. S., et al.2001. Dual time point 18F-FDG PET imaging for differentiating malignant from inflammatory processes. *J. Nucl. Med., 42(9);1412-1417.*

Takeo H., Shimura K., Imamura T., Shimizu A., Kobatake H., 2005, Detection System of Clustered Microcalcifications on CR Mammogram (Biological Engineering), IEICE transactions on information and systems, E88-D(11), 2591-2602

Hidefumi Kobatake, 2009.Trends in Research on CAD in Japan, T*he Institute of Electronics,Information and Communication Engineers—IECE Technical Report 217~218.*

Lingfeng Wen, Wilson Leung, Stefan Eberl, Dagan Feng, Jing Bai, 2008, A preliminary study on the knowledge-based delineation of anatomical structures for whole body PET-CT Studies, *Proceedings of the 5th International Conference on Information Technology and Application in Biomedicine*

Hiroshi Arisawa, 2009 . Improvement of Automated Cancer Detection System Using PET-CT Images, *RNSA pp.921*

Hoang Thuy Hong, Takako Sato, Hiroshi Arisawa, 2008 Improvement of Cancer Detecting Ability in PET Automated Diagnosis System by Using Delayed Scan Images, *Paper Volume of the 7th Information Technology Forum of Information ProcessingAacademy,pp.453-454, Sep.*

U. W. Knoepp and J. G. Ravenel, "CT and PET imaging in non-small cell lung cancer," *Critical Reviews in Oncology Hematology, vol. 58, pp. 15-30, 2006.*