

## Dual-headed Coincidence PET vs. Dedicated PET/CT in the Evaluation of Thoracic Malignancies

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**Abstract.** *The aim of this study was to evaluate the usefulness of coincidence PET imaging as compared with dedicated PET/CT in cancer staging. Patients and Methods: Sixteen patients with thoracic malignancies referred to a PET/CT examination accepted to repeat the acquisition with a coincidence PET system. One experienced nuclear medicine physician compiled a report from the PET/CT examinations and the coincidence PET images. The reports were compared and evaluated according to the degree of agreement: no agreement, unsatisfactory, acceptable or satisfying agreement. Results: Satisfying or acceptable agreement between the PET/CT and the coincidence PET examination was found in 14 out of 16 patients (88%). The main issue for the examining physician was to anatomically locate the FDG uptake in the mediastinum in the coincidence PET images. Conclusion: The data from this small study imply that the staging results obtained with coincidence PET are in most cases concordant with those obtained with dedicated PET/CT.*

The most commonly used tools in cancer diagnostics today are various x-ray techniques, including chest x-ray, computed tomography (CT) and positron-emission tomography (PET). CT is the most commonly used method in evaluating the anatomical stage, but this technique does not discriminate lesions that are benign from those that have a malignant potential. The ability to visualise metabolic activity with PET by using the glucose analogue <sup>18</sup>F-fluorodeoxyglucose (<sup>18</sup>F-FDG) as a radioactive marker has improved cancer imaging significantly during the

past decades (1). Since malignant cells have an up-regulated metabolism and thus have an enhancement in the uptake of glucose, it is possible to use the PET technique (<sup>18</sup>F-FDG) in discriminating benign from malignant lesions. This method has further been improved through the combination of PET imaging with computed tomography (CT) scan imaging as an integrated examination (PET/CT). Accurate registration of the anatomical and functional qualities of cancerous lesions has put PET/CT in a pivotal role in the diagnosis, staging, prognosis, treatment planning, treatment evaluation and recurrence detection. Malignancies in which PET/CT has an important role in staging include lung cancer (2), lymphoma (3), breast cancer (4), malignant melanoma (5), esophageal cancer (6), head and neck cancer (7) and colorectal cancer (8).

However, one significant drawback with the PET/CT systems is their high cost and, as a result, less expensive alternatives have been sought. Trials have been carried out in order to reproduce the staging capability of PET/CT by using a dual-headed gamma camera to image the photons emitted by <sup>18</sup>F-FDG with the addition of a coincidence detection mode (9-12). The addition of coincidence circuitry to a dual-headed gamma camera is relatively inexpensive compared to the cost of a dedicated PET scanner. This means that if the results obtained with coincidence PET prove to be equivalent to those obtained with dedicated PET/CT, its lower cost would probably make it more widely used, especially in clinics with a limited budget.

In this study, we have investigated whether differences between coincidence PET imaging and PET/CT have any implications for the radiological results in clinical practice. Are the methods comparable, or are there factors pointing in certain directions for either method?

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### Patients and Methods

*Patients.* Over a period of 10 months patients referred for a PET/CT examination were asked if they consented to repeat the acquisition with a coincidence PET system. Altogether, 16 patients accepted the proposal, nine female and seven male. Their ages ranged from 20

Table I. Comparison between reports from PET/CT images and the coincidence PET images.

Patient no.	Not agreeable	Unsatisfactory agreement	Acceptable agreement	Satisfactory agreement	Comments
1				x	Normal
2				x	
3		x			Missed Ln node
4				x	Lung cancer
5			x		Ln node in cPET??
6				x	
7				x	
8				x	Ln abdomen
9				x	
10				x	
11			x		Difficult anatomic localisation
12			x		Difficult anatomic localisation
13				x	Normal
14		x			Difficult anatomic localisation
15			x		Difficult anatomic localisation
16			x		Difficult anatomic localisation

to 84 years, with a mean of 56 years. The diseases were nine lymphomas, five lung carcinomas, one metastasized breast cancer and one malignant melanoma.

They all followed the normal procedure for PET/CT examination with 4 h fasting before the F-18 FDG injection. Exclusion criterion was  $\beta$ -glucose > 8.0 mmol/l. An individual dose of 3.0 MBq/kg F-18 FDG was administered intravenously in a dark and quiet room. The patients were instructed to rest 1 h post injection.

**PET/CT imaging.** PET/CT scans were performed using a mobile Discovery ST system (GE Healthcare/Alliance Medical BV) in 2D mode. Acquisition time was 20 minutes with a scan range from skull to pelvis including a high dose CT. The images were reconstructed at the Discovery workstation and transferred to the Nuclear Medicine Department for fusion (PET and CT) and visualisation.

**Coincidence PET imaging.** After the PET/CT examination the patient was transported to the Nuclear Medicine Department and the coincidence PET camera (5/8" NaI(Tl), E.Cam+; Siemens). The acquisition time was 45 minutes per bed position (40 cm) and the imaging started approximately 2 h post injection. One or two bed positions were performed for each patient dependent on the disease. Reconstruction was done at the E.Soft workstation (Siemens) and coincidence PET images were fused together with the CT images from the former mobile PET/CT acquisition.

**Reporting.** One experienced nuclear medicine physician compiled a report from the PET/CT examination within one to three days after the acquisition. More than four weeks later, the physician repeated the visual interpretation but from the coincidence PET images. The report was compared and evaluated according to the extent of agreement: no agreement, unsatisfactory, acceptable or satisfactory agreement.

## Results

In Table I, the results from the comparison between reports from the first review of the PET/CT and the coincidence PET examinations are displayed. Satisfactory agreement was

found in 9 out of 16 patients (56%), acceptable agreement in 5/16 (31%) and unsatisfactory agreement in 2/16 (13%) patients. No study was found to be "not agreeable" in this limited material. The main problem for the physician was the anatomic localisation of the FDG uptake.

An example from one of the investigated studies is shown in Figure 1. The different image quality is clearly seen between the PET/CT and the coincidence PET images. The uptake of FDG in lymph nodes is clearly seen in both examinations on the neck (A, B) but the uptake in the mediastinum is not visible in the coincidence PET image (D). In the coincidence PET study, only one bed position (40 cm) is shown (neck-thorax region).

## Discussion

The PET technique, which is based on determining the distribution of positron-emitting radionuclides, is unique in its ability to perform imaging events taking place at the cellular level, such as of blood flow or metabolic processes. This feature makes it different from conventional imaging methods, including radiography, ultrasonography (US), CT and magnetic resonance imaging (MRI). PET using <sup>18</sup>F-FDG is today widely used for the detection of primary tumours and metastases, prognostic evaluation, planning and monitoring of tumour therapy, as well as to detect recurrent tumour growth before it becomes clinically evident (13). Imaging devices able to detect the annihilation radiation but unable to detect single-photon-emitting radionuclides are known as dedicated PET scanners. These systems are fairly expensive and as an alternative, gamma cameras equipped with high-energy collimators have been used to image the photons emitted by <sup>18</sup>F-FDG. This technique, known as single photon-emission computed tomography (SPECT), has

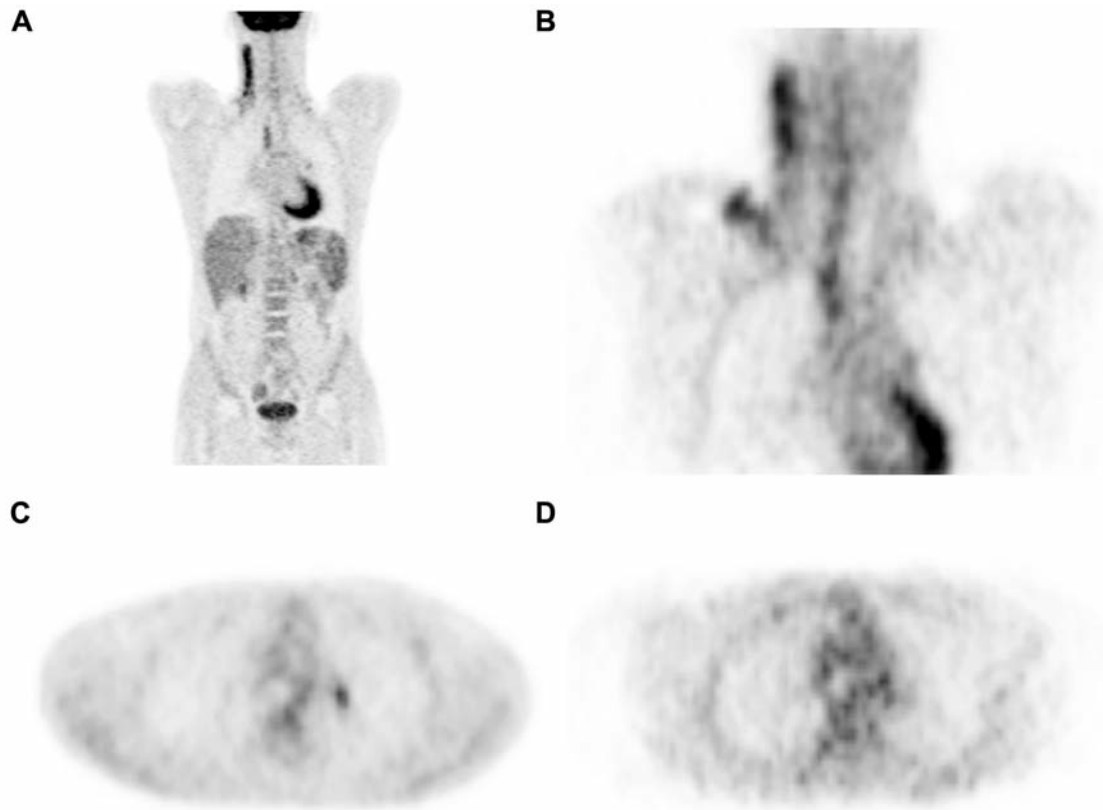


Figure 1. Coronal (A, B) and transverse (C, D) images from PET/CT (A, C) and coincidence PET (B, D) on the same patient.

a lower cost but this comes at the price of poorer spatial resolution (14). The addition of a coincidence detection mode to a standard dual-head detector system so that it can identify two simultaneous annihilation photons has enabled both single-photon and annihilation coincidence detection. Since the addition of coincidence circuitry to a standard SPECT camera is relatively inexpensive, this method makes it possible to add a PET capability to a Nuclear Medicine Department without needing to invest a large amount of money in a dedicated PET scanner. However, coincidence PET does have several limitations. Camera-based systems are less sensitive than dedicated PET scanners in detecting annihilation radiation, which makes the image quality and contrast resolution poorer (15, 16). Furthermore, since only a limited angle of detection is covered by the photon detectors, the camera has to rotate around the patient. In this study, the mean time for the reports were 30 and 60 minutes for the PET/CT and the coincidence PET, respectively, and due to this acquisition time, movement artefacts may occur. In addition, coincidence PET does not allow three-dimensional dynamic imaging (13). Considering the known differences between coincidence and dedicated PET, it is of major interest to investigate whether these methods yield comparable results in clinical practice. In this case, it would

be reasonable to believe that coincidence PET would become more widely used as an alternative to dedicated PET.

In thoracic malignancies, PET can be used for investigating the metabolic activity of the primary lesion to distinguish a malignant from a benign process as well as for mediastinal lymph node staging. In the present study, the quality of the coincidence PET images was reasonably comparable with PET/CT as long as the investigation with  $^{18}\text{F}$ -FDG was limited to the neck and thorax. In our series, 14/16 (87%) of the reports showed satisfying or acceptable agreement between the two methods, whereas only 2/16 showed unsatisfactory agreement. This is in agreement with a similar comparison study by Shreve *et al.* comparing coincidence and dedicated PET where the latter method was used as the standard of reference (9). Of the nodules or masses depicted at dedicated PET, 13 (93%) of 14 intrapulmonary nodules were correctly identified on the coincidence PET images. However, the corresponding value for intra-abdominal nodules was only 6 out of 26 (23%).

In a study of 27 patients with pulmonary nodules, Weber *et al.* compared the cancer detection ability and staging accuracy of dual-headed coincidence PET with that of dedicated PET/CT with histopathological diagnosis as reference (10). Both imaging modalities were able to

correctly identify all 27 pulmonary lesions. However, while dedicated PET was able to detect all 11 histopathologically proven lymph node metastases, coincidence PET was only able to detect 8 of these (73%). All false-negative lymph nodes in the coincidence PET studies had a diameter of  $\leq 2.0$  cm. In a similar study, coincidence PET with and without attenuation correction and dedicated PET was compared in the evaluation of mediastinal lymph nodes in 40 patients (11). With histopathological diagnosis as reference, the diagnostic accuracy for coincidence PET with or without attenuation correction was 80 and 74%, respectively, as compared with 82% for dedicated PET. Zhang *et al.* conducted a study in which 26 lesions in 13 patients with suspected lung cancer were analysed with both dedicated PET and coincidence PET on the same day (17). Of the 26 lesions, coincidence PET and dedicated PET was able to detect 21 lesions (80.8%) and 23 lesions (88.0%), respectively. However, when taking only lesions  $\leq 2.0$  cm in diameter in consideration, the sensitivity of coincidence PET fell to 37.5%, which was significantly poorer than for dedicated PET (62.5%).

Taken together, the reports from previous studies as well as the results from present study indicate that the detection rate of pulmonary and cervical lesions is comparable for coincidence PET and dedicated PET for lesions with a diameter of at least 2 cm, whereas dedicated PET is superior in the evaluation of smaller, mediastinal and intra-abdominal lesions. It seems that the sensitivity of coincidence imaging for small lymph node metastases is limited by low contrast. The main image quality problem is noise in the images, which causes an even larger problem in the abdomen. The limited scanned region (one bed position) together with the relative long acquisition time (possible patient movement) introduces problems in the fusion between coincidence PET and CT images. Another problem with coincidence PET investigations is the rather long visual interpreting time for the physician. However, dual-head coincidence detection may be a sound alternative to dedicated PET at clinics with a limited budget or where the volume of  $^{18}\text{F}$ -FDG studies is relatively low. With the introduction of attenuation-corrected coincidence PET, which improves lesion contrast and signal-to-noise ratios, the overall results may improve. We are aware of the fact that the very similar results for coincidence PET and dedicated PET are based on a small number of unselected patients. Thus, further research on larger cohorts of patients is advocated to fully elucidate the role of coincidence PET in clinical practice.

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