35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

A Study on the Artifacts Generated by Dental Materials in PET/CT Image

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Abstract*—PET/CT system reduces the scanning time and provides an anatomical image because it realizes a CT-based attenuation corrected image without using an isotope, such as 68Ge or 137Cs, in the attenuation correcting method due to the recent technological development. On the other hand, artifacts are generated in a CT image by dental materials, which affect the attenuation corrected PET image. Against this backdrop, this study performed a clinical experiment and a phantom experiment. The clinical experiment targeted 40 patients without oral disease, including 20 patients who had metal prosthesis in their tooth and 20 patients who had a dental implant in tooth. In the phantom experiment, a dental cast was used for a PET/CT scan after the metal prosthesis and the dental implant was inserted in the original dental phantom to make a dental cast. According to the study results, when the patients had metal prosthesis, standard uptake value (SUV) decreased by approximately 19.6% in the dark streak artifact region and increased by approximately 90.1% in the bright streak artifact region, compared with the artifact free region. In the phantom with metal prosthesis, the SUV decreased by approximately 18.1% in the dark streak artifact region and increased by 18.0% in the bright streak artifact region, compared to the artifact free region. When the patients with dental implant, the SUV decreased by approximately 19.1% in the dark streak artifact region and increased by 96.6% in the bright streak artifact region, compared with the artifact free region. In the phantom with dental implant, the SUV decreased by approximately 14.4% in the dark streak artifact region and increased by 7.0% in the bright streak artifact region, compared to the artifact free region. Therefore, by considering these results, we can improve the diagnostic accuracy in oral and maxillofacial cancer.

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I. Introduction

In oncology recently, PET imaging has been replaced quickly by PET/CT imaging due to the fusion of CT technology. PET/CT system reduces the scanning time, because it realizes a CT-based attenuation corrected image without using an isotope, such as 68Ge or 137Cs, in the attenuation correcting method due to the recent technological development. Such advances in PET imaging equipment has reduced the scanning time for a whole-body PET image by 30-40%, which has increased the number of patients who take these examinations significantly, compared to an existing PET scan. Furthermore, the acquisition of a CT image provides in-phase information on PET and CT images, which ensures the acquisition of a precise anatomical and functional image simultaneously. Despite these advantages, there are some shortcomings in a CT-based PET/CT attenuation correction. One of them is the possible effect on a PET/CT attenuation correction due to artifacts that appear in the CT image in a PET/CT scan [1]. In a CT-based attenuation corrected image, the difference in the attenuation of X-rays is expressed in an image that results in an attenuation corrected PET image. In a CT image, beam-hardening artifacts might affect the image due to the nature of X-rays. In a PET/CT image, a beam-hardened CT image is used for an attenuation correction, which may affect the PET image. This phenomenon is illustrated when an artificial pacemaker, metal dental materials and artificial joint used in orthopedics generate artifacts due to X-ray beam-hardening in the CT image, which affect the PET image [2]. In particular, it is difficult to take a precise reading of a head and neck image in a PET/CT scan due to artifacts generated by metal dental materials in the mouth. From this background, this study examined the effects of artifacts due to dental materials on a PET/CT image.

II. Materials and Methods

A. Experiment method

The phantom experiment method was to insert a dental cast into a NEMA PET Phantom™ (NU2-1994) (Fig. 1). The dental cast was implanted with a dental implant or metal prosthesis before being placed into the phantom. The phantom was filled with water and injected with 3.7 kBq/g ^{18}F-FDG (Fig. 2). CT scan was carried out to before obtaining a PET emission image for 2 minutes in a 1 bed position.

The patient experiment involved a retrospective examination of 40 patients (range of age: average 38 ± 7.89 years) with no disease in the mouth among patients who underwent a PET/CT scan in this hospital from January to November 2010. The patients fasted for at least 8 hours before the examination. The blood sugar before the examination was

6.69 mmol/l (120 mg/dl) or less for all of them. Before injecting the radioactive isotopes, the patients were instructed to drink approximately 500-1000 ml water while taking a rest for approximately 15 minutes. Subsequently, they underwent an intravenous injection of 18F-FDG in approximately 5.6 MBq/kg (0.11 mCi/kg). After the injection, they were advised not to move to prevent an increase in uptake by muscle and advised to take a rest for 60 minutes in the supine position. Before the examination, the patients were asked to urinate to an empty bladder. The patients then underwent an examination from the skull base to the midpoint of the femoral region in the supine position. CT without the use of contrast medium (non-contrast CT) was taken for approximately 1 minute before taking the PET emission images in 5-7 bed positions. The total imaging time was approximately 10-14 minutes (2 minutes/bed position).

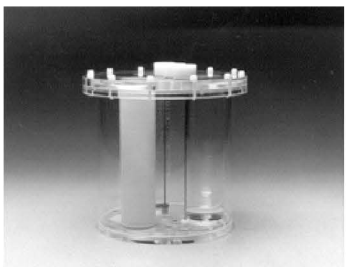

Figure 1. NEMA PET Phantom™ (NU2-1994)

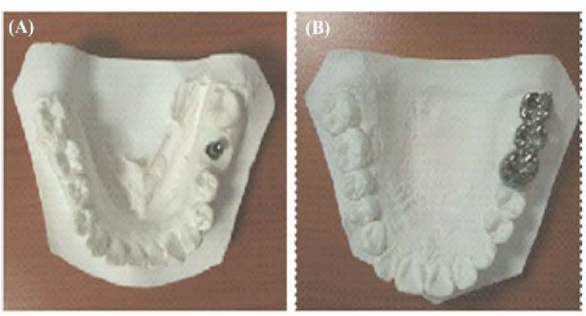

Figure 2. The dental arch cast with dental implant (A), metal prostheses (B).

B. Image acquisition method

PET/CT Discovery 600 (GE Healthcare, Milwaukee, WI, USA) scanner was used for imaging in three dimensional, whereas BGO(bismuth germanate) was used as a crystal. The intrinsic resolution was a full width at half maximum (FWHM) of 4.29 mm, whereas the display field of view (DFOV) was 500 mm. The 3D reconstruction method used was the OSEM, which was repeated 16 times in subset reconstruction and twice in the iterative reconstruction. The CT consisted of 16 slices and the image was reconstructed under the following conditions: 120 kVp and 10 mAs, pitch of 1.15, table speed of 27 mm/s, and slice thickness of 2.5 mm.

C. Image analysis method

The clinical experiment targeted 20 patients with a metal prosthesis and 20 patients with a dental implant. The regions of interest (ROIs) in a diameter of 16 mm were set as three regions that included artifact free region, dark streak artifact region and bright streak artifact region in the same cross sectional PET/CT image. The CT numbers in the CT image and standard uptake values (SUVs) in the PET image were examined. The measurement was conducted five times to calculate the average for analysis (Fig. 3). The phantom experiment was conducted in the same manner. A paired t-test was used for statistical analysis.

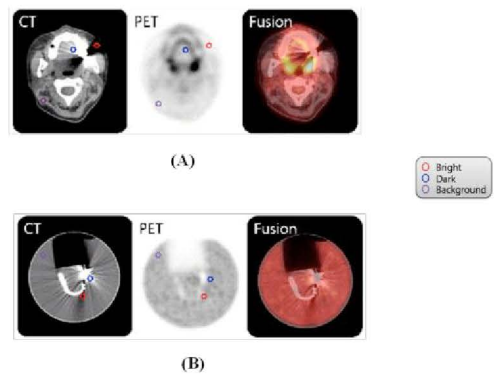

Figure 3. An analyzed CT and AC PET images. ROI of the patient with metal protheses (A), ROI of the phantom with dental implant (B)

III. Results

TABLE I. CT NUMBER AND SUV IN METAL PROSTHESIS

Metal Prosthesis					
Region		***Patient***		***Phantom***	
		CT(HU)	*PET(SUV)*	*CT(Number)*	*PET(SUV)*
Artifact free	Maximum	65.28 ± 11	0.79 ± 0.15	18.6 ± 10.1	1.18 ± 0.59
	Mean	46.21 ± 21	0.8 ± 0.15	6 ± 4.2	1.18 ± 0.47
Dark streak artifact	Maximum	-333.5 ± 135	0.76 ± 0.43	-241 ± 26	1 ± 0.34
	Mean	-463.07 ± 211	0.76 ± 0.43	-423 ± 98	1 ± 0.24
Bright streak artifact	Maximum	635 ± 221	1.54 ± 0.55	459 ± 64	1.6 ± 0.75
	Mean	515.57 ± 207	1.52 ± 0.56	252 ± 22	1.4 ± 0.54

In CT of the patients with a metal prosthesis, the CT number in the artifact free region was 65.28 ± 11 at the maximum and 46.21 ± 1 on average. In contrast, the CT number in dark streak artifact region was -333.5 ± 135 at the maximum and -463.07 ± 211 on average, and the CT number in the bright streak artifact region was 635±221 at the maximum and 515.57 ± 207 on average. The number in the bright and dark streak artifact region was approximately 1,102.01% and 1,866.77% higher than that in the artifact free region.

In PET scan, the SUV in the artifact free region was 0.79 ± 0.15 at the maximum and 0.8 ± 0.15 on average. The SUV in the dark streak artifact region was 0.76 ± 0.43 at the maximum and 0.76 ± 0.43 on average, and the SUV in the bright streak artifact region was 1.54 ± 0.55 at the maximum and 1.52 ± 0.56 on average. The SUV in the dark streak artifact region was 19.64% lower than that in the artifact free region ($p < 0.05$), whereas the SUV in the bright streak artifact region was 90.17% higher ($p > 0.05$) (Fig. 4).

In CT of the phantom with a metal prosthesis, the CT number in the artifact free region was 18.6 ± 10.1 at the maximum and 6 ± 4.2 on average. In contrast, the CT number in the dark streak artifact region was -241 ± 26 at the maximum and -423 ± 98 on average, and the CT number in the bright streak artifact region was 459 ± 64 at the maximum and 252 ± 22 on average. The number in the dark and bright streak artifact region was approximately 1,301.21% and 4,206.77% higher, respectively, than that in the artifact free region.

In the PET scan, the SUV in the artifact free region was 1.18 ± 0.59 at the maximum and 1.18 ± 0.47 on average. The SUV in the dark streak artifact region was 1.00 ± 0.34 at the maximum and 1.00 ± 0.24 on average, and the SUV in the bright streak artifact region was 1.60 ± 0.75 at the maximum and 1.40 ± 0.54 on average. The SUV in the dark streak artifact region was approximately 18.10% lower than in the artifact free region ($p < 0.05$), whereas the SUV in the bright streak artifact region was 18.00% higher ($p > 0.05$) (Fig. 5)(Table I).

TABLE II. CT NUMBER AND SUV IN DENTAL IMPLANT

Dental Implant					
Region		*Patient*		*Phantom*	
		CT(HU)	*PET(SUV)*	*CT(Number)*	*PET(SUV)*
Artifact Free	Maximum	62.25 ± 13	0.75 ± 0.16	37 ± 23	1.4 ± 0.72
	Mean	43.83 ± 13	0.74 ± 0.15	33 ± 12	1.4 ± 0.52
Dark Streak Artifact	Maximum	-522.25 ± 333	1 ± 0.43	-138 ± 96	1.3 ± 0.42
	Mean	-649.58 ± 363	0.99 ± 0.42	-347 ± 121	1.3 ± 0.33
Bright Streak Artifact	Maximum	1021 ± 372	1.5 ± 0.46	463 ± 263	1.5 ± 0.46
	Mean	801.08 ± 348	1.45 ± 0.4	297 ± 87	1.4 ± 0.4

In CT of the patients with the dental implant, CT number in the artifact free region was 62.25 ± 13 at the maximum and 44.83 ± 13 on average. In contrast, the CT number in the dark streak artifact region was -522.25 ± 333 at the maximum and -649.58 ± 363 on average, and the CT number in the bright streak artifact region was 1,021 ± 372 at the maximum and 801.08 ± 348 on average. The number in the bright and dark streak artifact region was 1,548.88% lower and 1,796% higher than that in the artifact free region.

In the PET scan, the SUV in the artifact free region was 0.75 ± 0.16 at the maximum and 0.74 ± 0.15 on average. The SUV in the dark streak artifact region was 1.00 ± 0.43 at the maximum and 0.99 ± 0.42 on average, and the SUV in the bright streak artifact region was 1.50 ± 0.46 at the maximum and 1.45 ± 0.4 on average. The SUV in the dark and bright streak artifact region was approximately 19.1% lower and 96.62% higher ($p < 0.05$), respectively, than that in the artifact free region (Fig. 4).

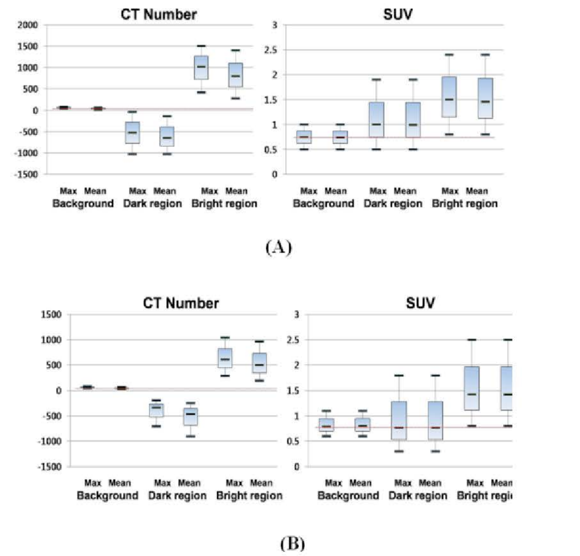

Figure 4. Boxplots of CT number and SUV in patients with dental implants (A), metal prostheses (B)

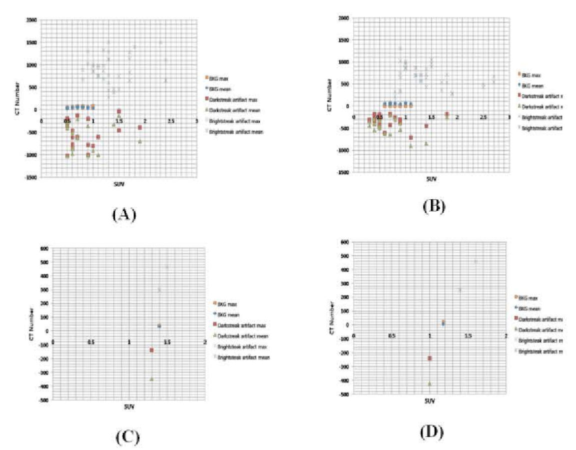

Figure 5. These graphs represent CT number and SUV relation of patients with dental implants (a), patients with dental metal prostheses (B), phantom with dental implants (C), phantom with dental metal prostheses (D)

In CT of the phantom with the dental implant, the CT number in the artifact free region was 37 ± 23 at the maximum and 33 ± 12 on average. In contrast, the CT number in the dark streak artifact region was -138 ± 96 at the maximum and -347 ± 121 on average, and the CT number in the bright streak artifact region was 463 ± 263 at the maximum and 297 ± 87 on average. The number in the bright and dark streak artifact region was approximately 1,014.72% lower and 967.42% higher, respectively, than that in the artifact free region.

In the PET scan, the SUV in the artifact free region was 1.40 ± 0.72 at the maximum and 1.40 ± 0.52 on average. The SUV in the dark streak artifact region was 1.30 ± 0.42 at the maximum and 1.30 ± 0.33 on average, and the SUV in the bright streak artifact region was 1.50 ± 0.46 at the maximum and 1.40 ± 0.4 on average. The SUV in the dark and bright streak artifact region was approximately 14.10% lower and 7.0% higher ($p > 0.05$), respectively, than that in the artifact free region (Fig. 5)(Table II).

IV. Discussion and Conclusion

Computerized tomography (CT) is a diagnostic imaging technique that is currently most useful for a diagnosis of cancer and a determination of its stage. Recently, PET-CT, which is based on positron emission tomography (PET) and computerized tomography (CT) simultaneously, was introduced to make an early diagnosis of a metastasis to the lymph node and distant metastasis. This modality enables a determination of the precise cancer stage and a proper treatment of the cancer, and makes a significant contribution to improving the prognosis. For these reasons, PET-CT has been used widely [3]. Furthermore, a wide range of studies have been conducted on FDG (fluorodeoxyglucose) uptake because the glucose metabolism varies according to the histological cell type of the tumor [4].

In general, PET-CT is a functional diagnostic imaging technique based on the fact that tumor cells are more active in glycolysis than normal cells so that the glucose uptake tends to increase in tumor cells. In this technique, 18F-FDG is used, which is a glucose analogue that is labeled with a radioactive isotope of fluorine. If this substance is absorbed by the cell, as is the case with glucose, the metabolism does not occur any longer due to phosphorylation, but the substance accumulates within cell. The accumulated FDG is detected by a PET camera [5]. Therefore, the glucose uptake in a cell might be affected by biological factors in the cell, which influence the glucose metabolism.

This study examined the effects of artifacts caused by dental materials on the uptake in a PET/CT image. The results showed that dental materials influenced the CT number as a CT-based correction image in PET/CT scan was realized, which also affected the SUV in a PET image.

Previously, a method to realize a PET image includes an attenuation correction method that uses 137Cs or 68Ge, but in present that uses CT. A PET image can be realized without any influence by artifacts that appear in CT. Shimamoto et al. highlighted the influence of the artifacts of dental materials in a phantom experiment using two sets of PET/CT equipment and one set of PET equipment. Nevertheless, the paper provided insufficient information on the PET equipment that used Cs [2]. Theoretically, there will be no effect by artifacts in case of 137Cs or 68Ge, which have high energy. Unfortunately, a comparative experiment was not conducted in that study [7, 8]. As mentioned previously, the CT number was found to influence the SUV in the PET/CT image [9-12]. In most cases, the region with a high CT number showed a high SUV. On the other hand, the region with a low CT number did not show a low SUV by a large margin. Therefore, it is useful to examine non-attenuation corrected PET image, which means no correction with CT or no influence by the CT number, to determine if the PET/CT image is affected by the CT number.

When a CT-based attenuation corrected image in a PET/CT scan was realized, dental materials affected the CT number, which also influenced the SUV in the PET image. In addition, a more excessive attenuation correction was made when the metal prosthesis was used instead of a dental implant. In particular, the SUV decreased by 19.64% in the dark streak artifact region when a metal prosthesis was used. This suggests the possibility of a false negative in the diagnosis of oral and maxillofacial cancer. Therefore, in a PET/CT scan of patients with a metal prosthesis or dental implant, if it is doubtful that the patient has lesions in mouth, it would be useful to examine the non-attenuation corrected PET image, which means no correction with a CT image, to make a precise diagnosis. In further study, we should find the cause of artifact and the appropriate solutions for this problem.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0010310).

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