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Digital Imaging and Communications in Medicine (DICOM) information conversion procedure for SUV calculation of PET scanners with different DICOM header information

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ABSTRACT

Purpose: In nuclear medicine, the standardized uptake value (SUV) obtained using positron emission tomography with 2-deoxy-2-fluoro-D-glucose (FDG-PET) is widely used as a semi-quantitative diagnosis factor. We found that the header file of the Philips Allegro PET scanner using the Digital Imaging and Communications in Medicine (DICOM) standard was stored differently than with other scanners. Thus, the purpose of this study was to develop a DICOM header information conversion program to ensure compatibility between Allegro and other equipment.
Methods and results: The NEMA IEC Body phantom was scanned using the Allegro PET scanner. We conducted measurements and performed calculations by using commercial software and the proposed self-developed program, respectively, to compare the SUVs by using conversion data. The program consists of three parts: an input part that can load data regardless of the number of DICOM images, and conversion and output parts that can be used to convert the DICOM header information and store it in the order of slices. The results of the calculation are in good agreement with the data measured at 12 circular regions of interest. The percent difference was lower than the 20%.
Conclusion: In conclusion, this study suggested a simple and convenient method to solve the incompatibility through conversion of the DICOM header information. This study thus provides physicians more accurate information for diagnosis and treatment.

1. Introduction

In nuclear medicine, positron emission tomography (PET) scanners are widely used for lesion detection [1–5]. In particular, the PET scan with glucose analogue 2-[^{18}fluorine]-fluoro-2-deoxy-d-glucose (^{18}F-FDG) has emerged as an important method to evaluate the presence or absence of cancer, its staging, and prognosis in accordance with the characteristics of the FDG [6,7].

The standardized uptake value (SUV) is commonly used in FDG studies as a semi-quantitative factor that can be obtained from PET images [8–10]. Although the SUV has uncertainties in the region of interest (ROI) or subject size, it has become one of the most important factors for the lesion detectability, owing to its usefulness, as demonstrated in many studies [8–13]. The SUV is derived as the ratio of the dose radioactivity at scan time and at the injected time according to the patient's body weight. The SUV can be calculated using the following equations [8,10,14–16]:

$$SUV_{body\ weight\ \left(\frac{kg}{cc}\right)} = \frac{Activity\ Concentrationin\ ROI_{\left(\frac{Bq}{cc}\right)}}{\left(\frac{Injected\ Dose\ (Bq)}{Body\ weight\ (kg)}\right)} \quad (1)$$

where, *Activity Concentration* is the activity per volume of the ROI at the image acquisition time, and the *Injected Dose* is the dose at injection time. [8,10,14–16].

$$SUV_{body\ weight\left(\frac{kg}{cc}\right)} = \frac{(Pixel\ value \times Image\ Rescale\ factor \times dosecalibration)}{\left(\frac{Actual\ activity}{Body\ weight}\right)} \quad (2)$$

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where *Pixel Value* is the pixel intensity value in the ROI, the *Image Rescale Factor* indicates the conversion factor for conversion pixel value to Bq, the *Dose Calibration* factor is a correction factor from MBq/cc to Bq/cc, and the *Actual Activity* is that of the image acquisition time [10,16]. The factors necessary for calculating the SUV should be determined for use in the unified Digital Imaging and Communications in Medicine (DICOM) standard. Since the first version of DICOM standard was published by the American College of Radiology and National Electrical Manufacturers Association, the contents of the DICOM standard have been modified and improved [17]. The DICOM file is composed of a medical image and a header file that contain information including image parameters, and this information includes interoperability between medical information systems [17,18]. However, if a manufacturer does not follow the DICOM standard, then there is no compatibility between products, and this can lead physicians to make incorrect assessments when they diagnose diseases by using PET imaging. We found that the DICOM header file of the Philips Allegro PET scanner (Philips Medical Systems; Milpitas, CA, USA) that includes the factors for SUV calculation was stored differently when compared to General Electric (GE) and Siemens equipment. Thus, the purpose of this study was to develop a DICOM information conversion program to ensure compatibility between the Allegro and other equipment. For this purpose, we measured the SUVs before and after DICOM conversion and compared them to the calculated value.

2. Methods and Materials

2.1. Phantom preparation

The National Electrical Manufacturers Association(NEMA) International Electrotechnical Commission (IEC) Body Phantom was scanned using the Philips Allegro PET scanner [19]. The NEMA IEC Body phantom is widely recommended for evaluation of whole-body PET imaging. As this phantom had 6 spherical phantoms with different diameter, we set the 6 ROIs on the spheres and 6 ROIs on the background region. These spherical phantoms had inner diameter of 10, 13, 17, 22, 28, and 37 mm, respectively. The size of ROI was set as 70% of sphere's physical inner diameter. The activity ratio between sphere and background area is 4:1 based on the NEMA NU 2-2007 standard [20]. Data were acquired in 3D mode. The data were reconstructed in a 144 $\times$ 144 matrix with a slice thickness of 4 mm. For the image reconstruction, the 3D RAMLA reconstruction algorithm was applied to phantom datasets. The effective axial field of view was 14.8 cm.

The phantom was filled with 56 MBq of ^{18}F, and the weight of the phantom was 12 kg including the radiopharmaceuticals. We measured the SUVs by using commercially-available software (GE advantage 4.6 Workstation, GE Healthcare, Milwaukee, WI, USA) and calculated the SUVs by using MATLAB (Mathworks Inc., Sherborn, MA, USA) for comparison.

2.2. DICOM header information conversion and SUV calculation

To solve the problem of the incompatibility between products, we developed a program based on self-developed MATLAB code (R2014a, Mathworks, Inc., MI). The primary reason for the incompatibility between the Philips Allegro and GE and SIEMENS equipment is due to the different units used to present the image information. The Allegro uses the counts (CNTS) as units, but the other manufacturers use Bq/cc. These differences result an incompatibility in reading the Allegro data by using GE's commercial software for the SUV. As shown in Fig. 1, the data obtained from the PET scanners of different companies can be processed by their respective software. However, if they are incompatible, the process of SUV measurement may not be possible. The proposed system is compatible with the non-compatible parts through the DICOM header information conversion.

According to the DICOM technical report for the Allegro and the Gemini System, the additional private data element does not conform to standard PET information object definition [19]. Among such private data, the related attributed tag, which can identify the element as private data (7053, 1000), is used to convert from counts to SUV. However, because this information is the conversion factor per selected slice and not for the ROI, it is not helpful at all when specifying the ROI. Thus, the conversion program is useful and essential for measuring the SUV within the ROI. Eq. (3) was used to convert the units from intensity to activity (Bq/cc) within the ROI.

$$Activity\ Concentration\ \left(\frac{Bq}{cc}\right) = \alpha X + \beta \tag{3}$$

where α is the rescale slope (0028, 1053), X is the original pixel intensity, and β is the rescale intercept (0028, 1052). Because αandβ have different values for each slice, the calculated *Activity Concentration* is the activity concentration on the ROI at the selected slice. In addition, the conversion program was composed of input, conversion and output stages, as shown in Fig 2. The input stage can be loaded regardless of the number of the DICOM images, and the conversion and output stages convert the DICOM header information and store it in the order of the slices. The key function and precautions which we used in the MATLAB code are as follows.

Input stage: we used the function 'dicomread' for the DICOM image file input and 'dicominfo' for the DICOM header information. In this procedure, since the data may not be input in the order of slice, it is essential to sort based on the image index, which indicates the slice number known through 'dicominfo'. The precautions for this process is to use the 'fileparts' function to determine the required data format such as DICOM. During the conversion stage, as stated in this section, factors for SUV calculation can substitute and compute the values in the DICOM header information, such that the user can view the factors using the 'dicominfo' function. Output stage: To merge the DICOM image file and the header information, we use the 'dicomwrite' function. To do this, the image file and the converted DICOM header information are entered as the input factor of 'dicomwrite', and the file name is saved as specified by the user.

3. Results and discussion

Fig. 3 indicated the DICOM header information shown on MATLAB window. With this process, it is possible to use the MATLAB internal function such as dicominfo('filename'). As shown in Fig 3, the DICOM header information consisted of the factors based on the DICOM standard and the private factors depended on the company or the device. Therefore, if users hope to access and convert the DICOM data, it is important to know the meaning of these factors. Fig. 4 shows the NEMA IEC Body phantom image acquired using the Philips Allegro equipment. Commercial software (GE advantage 4.6 Workstation, GE Healthcare, Buckinghamshire, UK) was used to measure the SUVs on 12 circular ROIs, as shown in Fig. 4(a). To verify the conversion process and calculate the SUVs, ImageJ (Rasband, W.S., U. S. National Institutes of Health, Bethesda) and MATLAB code were used to select the ROI and calculate the SUVs. To confirm that the converted data was functioning normally, we measured the SUVs using the commercial software and calculated the SUVs using Eqs. (1) or (2). However, the converted activity values from the pixel intensity do not consider the acquisition time, scan time, and the radiation decay time. To take these values of time into consideration, the decay correc-