Effects of CT-based attenuation correction on quantitative SPECT/CT of jawbone

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Abstract

Objective: With single photon emission computed tomography (SPECT)/computed tomography (CT) quantitative examinations, CT-based attenuation correction (CTAC) is considered necessary, though its effect on the quantitative values of an examined area close to the body surface, such as the jawbone, has not been elucidated. We performed an investigation to determine whether quantitative evaluation using a bone SPECT standalone device without CT is possible. **Subjects and Methods:** The calculated indices were maximum standardized uptake value (SUVmax) and SUVpeak. Grouping was performed based on the presence or absence of CTAC. The CTAC group underwent CTAC, while the noAC group did not. Validation was performed using clinical data of patients who underwent a jawbone SPECT/CT examination. Becquerel calibration factor (BCF) is required for calculation of SUV, and was determined with values obtained with both phantom and syringe methods. The index for the uptake areas in each group was assessed using a paired t-test. **Results:** Using BCF obtained with the phantom method, both SUVmax and SUVpeak were higher in the noAC group. In contrast, BCF obtained with the syringe method showed no significant difference between the CTAC and noAC groups in regard to SUVmax and SUVpeak. This tendency was found regardless of the device used. Also, a high correlation was observed between the groups for both devices (r=0.95 and 0.93). **Conclusions:** Our findings show that BCF obtained with a syringe method should be used when performing quantitative evaluation without CTAC. They also indicate that quantitative evaluation using a SPECT standalone device may be possible for jawbone SPECT/CT examinations.

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Introduction

It has been reported that fusion images provided by mandibular single photon emission computed tomography (SPECT) and computed tomography (CT) are useful for diagnosis and lesion spread of osteomyelitis of the mandible (OM), as well as for determining treatment strategy [1-3]. Recent advances in integration of CT for attenuation correction together with a sophisticated reconstruction technique and positron emission tomography (PET) have enabled SPECT/CT to produce quantitative measurement findings suitable for derivation of standardized uptake value (SUV) [4-8]. Several studies conducted in Japan have also reported such findings in relation to bone SPECT/CT quantification [9-11].

A quantitative evaluation found that CT-based attenuation correction (CTAC) is a mainstream procedure. Results of a recent review article suggest that the incorporation of CT-based high-resolution tissue zones in the reconstruction of SPECT bone imaging imparted improved image quality and higher reader concordance as compared to conventional SPECT with CT attenuation, scatter compensation and distance-dependent resolution recovery [12]. However, Ross et al. (2019) proposed that the quantitative bone SPECT is still in its infancy and significant amounts of research and technological improvements are required before it becomes a part of routine clinical practice [13]. In bone SPECT quantitative examinations of area close to the body surface, such as the lower extremity, a recent study has reported that quantitative evaluation without CTAC may be possible without the use of scatter correction or resolution recovery [14]. The effect of the application of CTAC in quantitative SPECT of areas close to the body surface, the jawbone, has not been evaluated yet.

We examined quantitative values obtained with and without CTAC using clinical findings in patients who underwent a SPECT/CT examination of the jawbone. Based on our results, we concluded that the use of a SPECT standalone device without CT could be used to derive valuable quantitative information for jawbone examination.

Subjects and Methods

SPECT/CT scanners and data analysis

Two different SPECT/CT scanners were used, a Bright View X with XCT (Philips Medical System) designed for cardiac high resolution (CHR) and a Discovery NM/CT 670 (GE Healthcare) designed for low energy high resolution (LEHR). Delineation of the volume of interest (VOI) was performed using the commercially available GI-BONE software package (AZE Co., Ltd., Tokyo Japan),which reports statistics for various SUV, such as max (SUVmax), mean (SUVmean), and peak (SUVpeak), as well as metabolic bone volume (MBV) and total bone uptake (TBU). Figure 1 shows VOI settings using GI-BONE [9-11].

For calculation of SUV with GI-BONE, becquerel calibration factor (BCF) is required, which is defined using the following equation: radioactivity at the start of the scan [Bq]/(total count [counts]/scan time [sec]). There are two measuring techniques used with BCF, a phantom method and syringe method. With the phantom method, SPECT acquisition and CT imaging are performed using a cylindrical phantom filled with a known amount of radioactivity, with BCF calculated from the volume of the cylindrical phantom and the count in the region of interest obtained by image reconstruction. As for the syringe method, SPECT acquisition and CT imaging are performed using a syringe filled with a known amount of radioactivity, with BCF calculated from the count in the region of interest obtained by image reconstruction. Single photon emission computed tomography acquisition, CT imaging, and image reconstruction were performed under conditions similar to clinical cases.

Nuclear medicine imaging

Planer bone scintigraphy was performed 3-4 hours after intravenous administration of 555MBq technetium-99m-hydroxymethylene disphosphonate (^{99m}Tc-HMDP). Immediately after acquisition of the planar image of the jaw area, quantitative SPECT/CT images were acquired using a hybrid system.

In Bright View X with XCT, CT images were first obtained using the following parameters: tube voltage 120kV, tube current 80mA, and a 512×512 matrix, then divided into 3.75-mm -thick sections. Next, SPECT images were acquired using the following parameters: energy peak 140KeV with a 5% window (133-147KeV), continuous mode acquisition (15 seconds per step, 64 steps per detector) with an angular increment of 5.625° and the body contour scanning option. Single photon emission computed tomography images were reconstructed using an iterative ordered subset expectation maximization algorithm (10 iterations, 8 subsets) with CT-based attenuation and scatter correction. A post-reconstruction filter (Butterworth filter with frequency of 0.35 cycles/cm and order of 8) was applied. Reconstructed images were set at a matrix of 64×64, with a section thickness of 5.03mm and zoom factor of 1.85.

Similarly, with the Discovery NM/CT 670, CT images were first obtained using the following parameters: tube voltage 120kV, tube current 40-80mA with the "AutomA" function and noise level of 35, X-rays collimation of 20mm (16× 1.25mm), table speed 55mm/second, table feed 27.5mm per rotation, tube rotation time 0.5 seconds, 1.375:1 pitch, and a matrix of 512×512. The CT images were reconstructed using an adaptive statistical iterative reconstruction algorithm (ASiR; GE Healthcare) into 3.75-mm -thick sections. Single photon emission computed tomography images were acquired using the following parameters: energy peak 140.5KeV with a 7.5% window (130-151KeV), step-and-shot mode acquisition (15 seconds per step, 60 steps per detector) with 6° angular increments, and a body contour scanning option. The extra window for scatter correction was set at 120KeV with a 5% window (114-126KeV). Single photon emission computed tomography images were reconstructed using an iterative ordered subset expectation maximization algorithm (10 iterations, 10 subsets) with CT-based attenuation correction, scatter correction, and resolution recovery applied using the vendor-supplied software package (GENIE Xeleris; GE Healthcare). A post-reconstruction filter [Gauss filter with full width at half maximum (FWHM) (11.05 mm) along the x-, y-, and z-direction] was applied. Reconstructed images were set at a matrix of 128×128, with a section thickness of 4.42mm and zoom factor of 1.0.

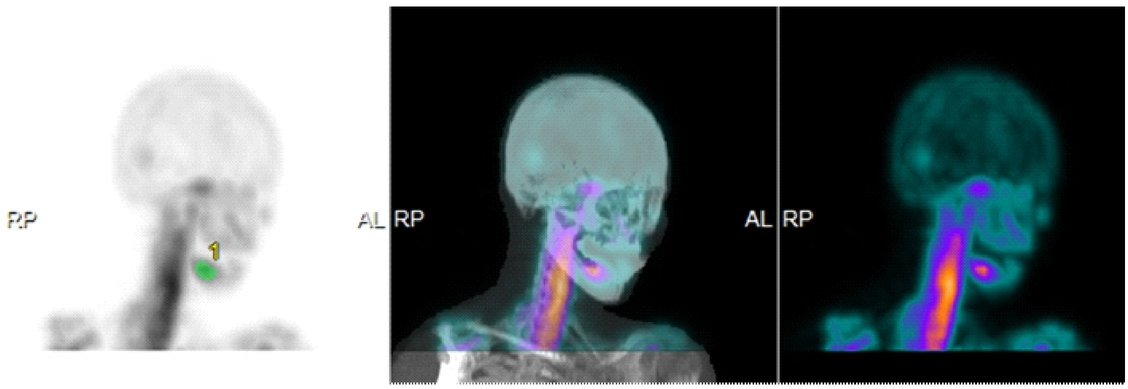

Figure 1. Volume of interestsetting method using GI-BONE. Nuclear medicine image (green part is the set VOI) (left). SPECT/CT fusion image (middle). Nuclear medicine image (right).

Grouping and BCF values

Grouping was performed based on the presence (CTAC group) or absence (noAC group) of CT-based attenuation correction (Table 1).

Table 2 shows the BCF values for each device and each measuring techniques.

Effects of CT-based attenuation correction on quantitative values

We performed a retrospective analysis of 19 patients (6 males, 13 females; age 71.4±13.4 years, mean±standard deviation) who underwent jawbone SPECT/CT examinations using Bright View X with XCT and 30 patients (11 males, 19 females; 72.8±12.2 years) who underwent jawbone SPECT/CT examinations using Discovery NM/CT 670. The subject were patients diagnosed with OM or osteonecrosis of the jaw. This study was approved by the institutional review board of our hospital.

Data for the CTAC and noAC groups were obtained using the manual VOI installation function of the GI-BONE data analysis software package. The uptake values were extracted by setting a threshold of 40% or more of the SUVmax in the VOI. Analysis was performed for all uptake values obtained in cases with multiple uptake results. The calculated indices were SUVmax and SUVpeak. Becquerel calibration factor in the present analysis was obtained with both a phantom method and syringe method. Differences between the groups were assessed using a paired t-test and the correlation was evaluated using the correlation curve and correlation coefficient.

Results

In Bright View X with XCT findings of cases that used BCF obtained with the phantom method, SUVmax for the noAC group was significantly higher as compared to the CTAC group (P<0.01), with the difference between the groups 1.72±1.03. Additionally, a high correlation was observed between them (r=0.95). Similarly, the SUVpeak value for the noAC group was significantly higher than that for the CTAC group (P<0.01), with the difference between the groups 1.54±0.93. Again, a high correlation was observed (r=0.95) (Figure 2).

As for BCF obtained with the syringe method, the difference between the CTAC and noAC groups in regard to SUVmax was 1.06±1.04, which was not significant. Additionally, a high correlation was observed between the groups (r=0.95). Similarly, the difference between the CTAC and noAC groups for SUVmax was 0.95±0.95, which was also not significantly different, and again a high correlation was observed (r=0.95) (Figure 3).

Using the Discovery NM/CT 670, for cases with BCF obtained with the phantom method, SUVmax for the noAC group was significantly higher as compared to the CTAC group (P<0.01), with the difference between the groups 1.01±0.91.

Table 1. *Protocol for reconstruction in CTAC group and noAC group with Bright View X with XCT and Discovery NM/CT 670.*

	Bright View X with XCT		Discovery NM/CT 670	
	CTAC group	**noAC group**	**CTAC group**	**noAC group**
CT-based attenuation correction	On	Off	On	Off
Scatter correction	On	Off	On	On
Resolution recovery	Off	Off	On	Off

Table 2. *Becquerel calibration factor values for each measuring techniques in CTAC group and noAC group with Bright View X with XCT and Discovery NM/CT 670.*

	Bright View X with XCT		Discovery NM/CT 670	
	CTAC group	**noAC group**	**CTAC group**	**noAC group**
Syringe method	10285.5	27580.6	5177.2	17079.1
Phantom method	9448.9	31401.1	5483.5	15729.1

Additionally, a high correlation was observed between them (r=0.93). Similarly, the SUVpeak value for the noAC group was significantly higher than that for the CTAC group (P<0.01), with the difference between them 0.91±0.82. A high correlation between the groups was noted (r=0.93) (Figure 4).

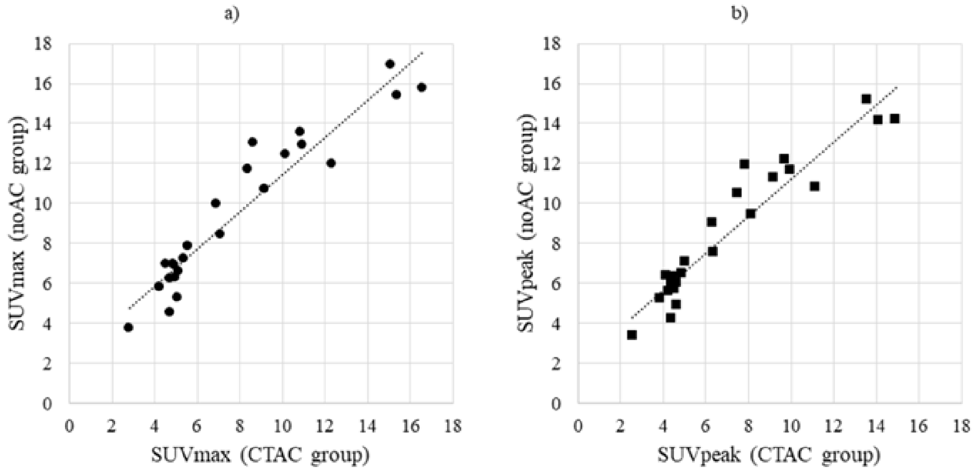

Figure 2. Effects of CT-based attenuation correction on quantitative values when using BCF obtained with phantom method and Bright View X with XCT. Comparison between CTAC and noAC group. a) SUVmax, b) SUVpeak. Regression line added.

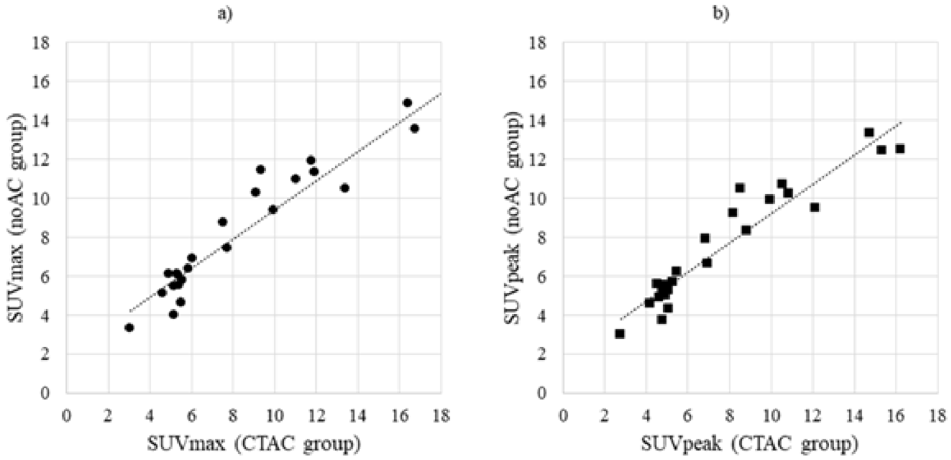

Figure 3. Effects of CT-based attenuation correction on quantitative values when using BCF obtained with syringe method and Bright View X with XCT. Comparison between CTAC and noAC group. a) SUVmax, b) SUVpeak. Regression line added.

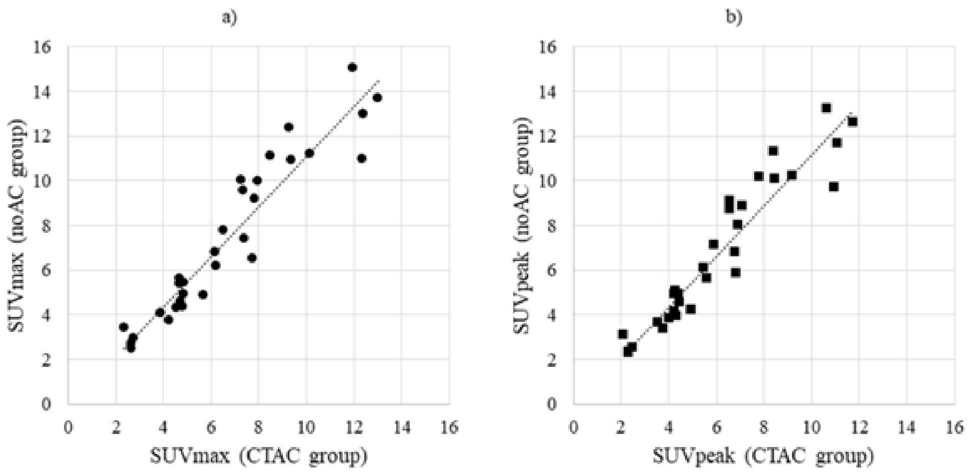

Figure 4. Effects of CT-based attenuation correction on quantitative values when using BCF obtained with phantom method and Discovery NM/CT 670. Comparison between CTAC and noAC groups a) SUVmax, b) SUVpeak. Regression line added.

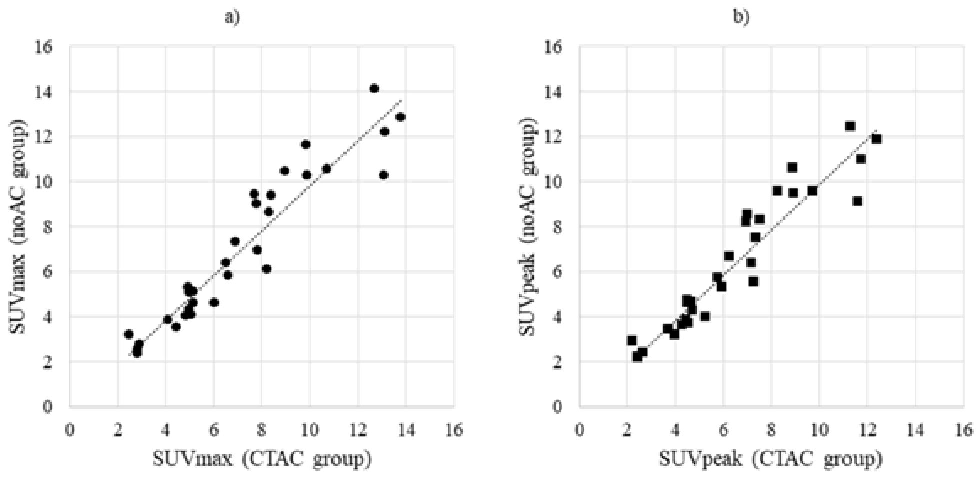

Figure 5. Effects of CT-based attenuation correction on quantitative values when using BCF obtained with syringe method and Discovery NM/CT 670. Comparison between CTAC and noAC groups a) SUVmax, b) SUVpeak. Regression line added.

When using BCF obtained with the syringe method, the difference between the CTAC and noAC groups for SUVmax was 0.85±0.64, which was not significant and a high correlation was observed between them (r=0.93). Similarly, the difference between the groups for SUVpeak was 0.75±0.57, which again was not significant and a high correlation was observed (r=0.93) (Figure 5).

Discussion

In the present study, we used clinical data to examine the effects of CTAC on quantitative values obtained in bone SPECT/CT examinations of the jawbone and clarified that quantitative evaluation without CTAC may be possible without the use of scatter correction or resolution recovery as well aslower extremity bone [14]. Previous studies have reported that attenuation correction, scatter correction and resolution recovery are necessary for improving the quantitative accuracy of SPECT examinations [7,15]. However, we consider that quantitative evaluation of the uptake parts of body surfaces such as in the jawbone and lower extremity is possible without the use of attenuation correction.

When using BCF obtained with the phantom method, SUVmax and SUVpeak values were higher for most of the noAC patients. This tendency was seen without device dependence and considered to be related to the use of BCF for calculating SUV. The phantom method was used to obtain findings from a cylinder phantom, in which the activity concentration is uniform and counts in the deep parts of the phantom are known to reducein noAC as compared to CTAC patients [15]. As a result, the BCF value was increased in the noAC group because the total count was decreased. That total count used for calculating BCF was obtained from a circular ROI that included both the deep and wall parts of the cylinder phantom. Thus, it is considered that BCF for the deep region in the noAC group was underestimated and that for the superficial region overestimated, because of the method used for setting the circular ROI. As for the clinical results, the area of uptake targeted in this study was the superficial part, which is considered to be less affected by attenuation. The noAC group had higher values than the CTAC group, likely because BCF was overestimated. In contrast, when BCF was obtained with the syringe method, there was no significant difference between the CTAC and noAC groups for either SUVmax or SUVpeak values. It is considered that BCF obtained with the syringe method is not affected by attenuation, as seen with the phantom method, even without CTAC.

Panin et al. (2006) [16] reported that the use of resolution recovery has an effect to reduce deterioration of peripheral resolution of the visual field by improving spatial resolution and noise properties. Thus, it contributes to the improvement of quantitative accuracy. On the other hand, it has also been shown that quantification is reduced due to the influence of Gibbs artifacts caused by resolution recovery [17], indicating that the quantitative value is overestimated due to the influence of Gibbs artifacts.

This study has some limitations, including the small subject population. In addition, the clinical utility of diagnosis, the evaluation of treatment response, and determining treatment strategy of jawbone disease is lacking.

In conclusion, the present study showed that BCF obtained with the syringe method should be used when performing a quantitative evaluation without CTAC. In addition, quantitative evaluation using a SPECT standalone device may be possible for jawbone SPECT/CT examination.

The authors declare that they have no conflicts of interest.

Funding Source
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