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Simplification of dosimetry in ^{90}Y -radioembolization therapy using dual planar images.

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Aim: The purpose was to provide practical and effective method for performing ^{90}Y dosimetry with $^{99\text{m}}\text{Tc}$ -MAA. The impact of scatter and attenuation correction (AC) on the injected ^{90}Y activity and absorbed doses to critical organs was also further target beyond this study.

Material and Methods: 18 patients (F: 3, M: 15) were subjected to ^{90}Y therapy. $^{99\text{m}}\text{Tc}$ -MAA (111-222 MBq) was injected into the targeted liver, followed by a whole-body scan (WBS) with peak-window at 140 keV (15% width), and one down-scatter window. SPECT/CT scan was acquired over the lungs and liver regions. The lung shunt fractions were fashioned from the standard WBS, scatter corrected WBS, only scatter corrected SPECT and SPECT/CT with attenuation and scatter correction. The absorbed doses to tumor and surrounding healthy tissue were estimated with alternative approaches involving AC-SC (SPECT/CT), NoAC-SC (SPECT), NoAC-NoSC+LSF (SC-WBS), AC-SC+LSF (WBS), and NoAC-NoSC+LSF (WBS).

Results: The average LSF deviations between the standard LSF and those obtained from AC-SC, NoAC-SC, and SC-WBS was -50% (-29/-71), -32%(-8/-67), and -45%(-13/80), respectively. The prescribed ^{90}Y activity (GBq/Gy) was decreased by a range of 2-11%, 1-9%, and 2-7% with using LSFs from AC-SC, NoAC-SC, SC-WBS images. The absorbed dose to tumour and healthy liver tissue were calculated as 112 ± 90 Gy and 30 ± 18 Gy/GBq by AC-SC (SPECT/CT), 117 ± 108 and 30 ± 22 by NoAC-SC (SPECT), 110 ± 100 and 31 ± 21 Gy/GBq by NoAC-NoSC+LSF (SC-WBS), 106 ± 84 and 28 ± 17 Gy/GBq by AC-SC+LSF (WBS), while the absorbed dose was 90 ± 85 and 28 ± 20 Gy/GBq by using NoAC-NoSC+ LSF (WBS). Overall, no significant difference ($p < 0.05$) in the tomour and the health liver dose between all the approaches with/and without scatter correction. However, the scatter correction caused a significant difference in the lung shunt fractions ($p < 0.05$).

Conclusion: Scatter correction has a significant effect on the lung shunt fractions, planned activity and number of ^{90}Y treatments. However, a minimal or negligible change was occurred on the absorbed dose to tumours and surrounding healthy liver. The good agreement between SPECT/CT approach, and scatter corrected whole-body scan might be practical and effective route for ^{90}Y dosimetry.

Introduction

Hepatocellular carcinomas and secondary liver metastases are widespread disorders with potential liver failure in the vast majority of patients. Unfortunately, a small percentage of patients are eligible for curative therapy like resection and liver transplantation.¹ While, the inoperable cases undergo well-established palliative treatments including chemoembolization, radiofrequency, and ⁹⁰Y radioembolization.²

⁹⁰Y-radioembolization is widely applied for the treatment of hepatocellular carcinomas and liver metastases. The therapy procedure involves injecting micron-sized embolic particles loaded with ⁹⁰Y via percutaneous intra-arterial techniques.³ The loco-regional injection of radioactivity enables delivering high radiation doses to the tumor and a limited dose to the normal tissue. ⁹⁰Y activity decays by beta emission with a mean energy of 932 keV, while no significant radiation is emitted except a very small positron yield that enables Y-90 PET imaging.⁴ Therefore, ^{99m}Tc-MAA is alternatively used to surrogate ⁹⁰Y microspheres and tailor the injected activity for therapy.

Scintigraphy imaging is performed within one half to one hour after injection in order to evaluate the distribution and leakage of the injected radioactivity.⁵ The classic imaging protocol invariably involves a whole-body scan to determine the lung shunt fraction, and a SPECT scan to recognize the tumor and non-tumor regions. More recently, SPECT integrated with CT has been extensively used with definite anatomical information and attenuation correction. The toxicity risk of ⁹⁰Y therapy is inseparably connected with the microsphere's leakage to the lungs and the surrounding healthy liver. Conventionally, the standard lung shunt fraction is computed from a ^{99m}Tc whole-body scan with a 15-20% peak-window. Then, a SPECT scan is acquired to precisely quantify uptake in tumor and surrounding healthy tissues.⁶ However, scatter radiation may have a significant impact on the dose calculation and ⁹⁰Y activity assignment. Particularly, the true events are properly registered when the emitted gamma rays perpendicularly pass from the collimator and interact with the NaI (TI) crystal by photoelectron effect. Instantly, scatter events are originated from the Compton interaction with the crystal. The scattered photons might undergo subsequent interactions in the crystal/or completely escape from the detector. The pulse height analyser (PHA) may fail to reject the scatter events that would be ultimately accepted in false locations. Furthermore, the recorded events from object scattering in the entire organs might be accepted as true events. As the energy of the scattered rays partially decreases, a weak signal is recorded in the detector and then excluded by the energy discriminator. However, in case the scattering angle is small, the interaction may be accepted as true event with a shifted position up to a few centimetres from the origin of emission.⁷

To this end, the potential effect of scatter and attenuation correction has not been extensively explored in ^{90}Y radioembolization dosimetry. Consequently, this study aimed to elucidate the impact of attenuation and scatter correction on the lungs' shunt fraction and the liver compartments dose. Also, a simplified dosimetry approach was tailored for ^{90}Y dosimetry and compared with SPECT/CT as a gold standard.

Methodology

18 patients (F: 3, M: 15) (8: colon Ca, 2: HCC, others: 8) were included in the current study. An assigned consent form was obtained from each participant. A range of 3-6 mCi $^{99\text{m}}\text{Tc}$ -MAA was intra-arterially injected in the targeted liver at interventional radiology department of Istanbul university-cerrahpsa. After injection, whole-body scan (WBS) was acquired with settings adjusted to include: peak-window at 140 keV (15% width), and one down-scatter window (15% width). According to this protocol, two planar images were created for each patient, as seen in figure 1. The standard lung shunt fraction was calculated from the peak-window image as:

$$\text{LF} = \frac{\sqrt{La \times Lp}}{(\sqrt{La \times Lp} + \sqrt{Lva \times Lvp})} \quad (1)$$

La) lungs anterior counts. Lp) lungs posterior counts. Lva) liver anterior counts. Lvp) liver posterior counts.

A dual-energy window ($\pm 15\%$) was used for scatter correction as follows:

$$C_{\text{true}} = C_{\text{main}} - \left[\frac{C_{\text{low}}}{W_{\text{low}}} \right] \cdot \frac{W_{\text{main}}}{2} \quad (2)$$

C_{main} : organ's counts from peak window. C_{low} : organs' counts from down scatter window

W_{low} : window fraction. C'_{main} : organ's vtrue counts.

At that point, scatter corrected LSF was calculated and symbolized as SC-WBS.

Figure 1: Dual energy images. (A+B): anterior and posterior images of the peak window; (C+D): anterior and posterior images of the scatter window.

SPECT/CT scan was instantly conducted after planar scintigraphy encompassing the lungs and liver. The windows settings were selected similar to the whole-body scan and 64 projections were acquired with 25 seconds/ projection. Dual-energy window ($\pm 15\%$) was used for scatter correction, and OSEM (ordered subsets expectation maximization) algorithm was selected for iteration reconstruction with 10 iterations and 8 subsets. Then, low pass filtering (Gaussian 9 mm) was applied for noise suppression. The projections were repeatedly reconstructed to generate three types of tomographic images as revealed below:

- 1- SPECT images with attenuation and pixel-wise scatter correction, coded as (AC-SC).
- 2- SPECT images with no attenuation and no scatter correction, coded as (NoAC-NoSC).
- 3- SPECT images with scatter correction and no attenuation correction, coded as (NoAC-SC).

Example of manually delineated ROIs over different image formats is illustrated in figure 2 and 3. The lung shunt fractions were calculated from (AC-SC), (NoAC-NoSC), and (NoAC-SC) SPECT images using the following equation:

$$LSF_{\text{spect}} = Lc / (Lc + LVc) \quad (3)$$

LSF_{spect} : lung shunt fraction from SPECT images, Lc : lungs count, LVc : liver counts.

Figure 2: Liver and lungs ROIs over the SPECT images of A): NoAC-NoSC, B): NoAC-SC, and C): AC-SC.

Figure 3: A) Target and tumour ROIs on the SPECT images including A): NoAC-NoSC, B): NoAC-SC, and C): AC-SC.

The absorbed dose (Gy/GBq) of the tumour and non-tumour healthy tissue was estimated using the MIRD scheme as follows:⁸

$$\text{Liver uptake} = (1 - SF) \left[\frac{m_{\text{liver}}}{(m_{\text{tumour}} \times TLR) + m_{\text{liver}}} \right] \quad (4)$$

Activity to be administered for a certain absorbed dose:

$$\text{Activity}_{\text{admin}} (\text{mCi}) = \frac{\text{dose}_{\text{liver}} (\text{rad}) \times m_{\text{liver}} (\text{gm})}{184,000 \times \text{liver fractional uptake}} \quad (5)$$

$$\text{Tumour uptake} = (1-SF) \left[\frac{TLR \times m_{\text{tumour}}}{(m_{\text{tumour}} \times TLR) + m_{\text{liver}}} \right] \quad (6)$$

$$\text{Dose}_{\text{tumour}} (\text{rad}) = \frac{\text{Activity}_{\text{total}} (\text{mCi}) \times 184000 \times \text{UPTAKE}_{\text{tumour}}}{m_{\text{tumour}} (\text{g})} \quad (7)$$

The lung shunt fraction was calculated by different methods involving 1-the standard whole-body scan (peak140 keV), 2- AC-SC from SPECT/CT, 3- NoAC-SC from SPECT, and 4- the scatter corrected whole-body scan (SC-WBS).

Lung dose was calculated by the following equation:

$$D \text{ (Gy)} = A \text{ (GBq)} \times 49.33 / M \text{ (Kg)} \quad (8)$$

D: dose, A: activity, M: mass.

Statistical Analysis

The statistical analysis was performed via IBM/SPSS statistics 20 software. Non-parametric paired t-test (Wilcoxon signed rank test) was used to compare the means according to the normality test result.

Results

The lung shunt fractions of 18 patients underwent ^{99m}Tc-MAA procedure were explicated in table 1. The deviation in the calculated LSFs between WBS and other image formats were reported in table 2. The obtained results indicated that the lung shunt fractions from the standard whole-body scan were considerably larger than those generated by SPECT/CT with attenuation and scatter correction (mean = 50%). On the contrary, the generated LSFs from scatter corrected whole-body scan (SC-WBS) exhibited a very good agreement with SPECT/CT (AC-SC), as seen in figure 4. However, smaller deviation (mean -32%) was found between the LSFs from scatter corrected SPECT (NoAC-SC) and the standard LSFs.

An excellent agreement was demonstrated in the target volumes between all the SPECT image-types as seen in figure 5. Therefore, the discrepancy in the suggested activity and lungs doses were determined using different LSFs and fixed target volume from (AC-SC) image as reported in table 3. Accordingly, all of the LSF calculation models resulted in a slight disparity (-2 to -11%) in the suggested activity compared to the standard LSF from whole-body scan. In contrast, vast variation was noted in the lungs doses with utilizing different LSF models. For instance, the computed lungs doses using SPECT/CT (with AC-SC) registered the highest deviation with average of -53% (range: -34/-72%). In like manner, the scatter corrected LSFs from whole-body scan were considerably equivalent to SPECT/CT with mean deviation of -48% (range: -18/-72%). While, the least deviation in lungs doses

170 was in favour of scatter corrected SPECT (NoAC-SC) with -33 % mean deviation and range between
171 -12% to -64%.

172 The absorbed radiation doses to tumour and healthy tissues (target-tumor) according to different
173 approaches were summarized in table 4. The absorbed doses to tumour and healthy tissues from
174 attenuation and scatter corrected SPECT/CT images (AC-SC) were 112 ± 90 and 30 ± 18 Gy/GBq,
175 Respectively. While the corresponding doses from only scatter corrected SPECT image were
176 calculated as 117 ± 108 Gy/GBq to tumour, and 30 ± 22 Gy/GBq to healthy component. In contrast,
177 using the standard lung shunt fraction from WBS scan with NoAC-NoSC SPECT images resulted in
178 the least tumor dose as 90 ± 85 Gy/GBq. However, replacing the uncorrected LSFs from WBS with
179 scatter corrected ones (SC-WBS) augmented the absorbed dose to tumor and normal tissues as 110 ± 100
180 and 31 ± 21 Gy/GBq, respectively. Moreover, the approach of [NoAC-NoSC+ LF(SC-WBS)] showed
181 comparable results to the SPECT/CT with scatter and attenuation correction as well as with SPECT
182 and planar LSF [(AC-SC)+LF(WBS)].

183 Overall, no significant difference was observed in the healthy tissue and tumor doses ($p > 0.05$) between
184 all the calculation approaches with standard LSF from the whole-body scan or those using LSFs with
185 scatter and attenuation correction. Whereas, a significant difference was seen in the lung doses (p
186 < 0.05) amidst the aforementioned dosimetry approaches. Furthermore, a very good correlation
187 ($R_2 = 0.90$) was demonstrated between the lung shunt fractions from scatter corrected WBS and scatter
188 corrected SPECT as seen in figure 6. Besides, no significant difference ($P_{\text{value}} \geq 0.05$) between the
189 LSFs with AC-SC from SPECT/CT, and those derived from SC-WBS and NoAC-SC SPECT.
190 However, the significant difference was only observed in the lungs fractions from standard WBS (P_{value}
191 < 0.05).

192 **Table 1.** Lung shunt fractions from different image formats.

WBS	AC-SC SPECT/CT	SC-WBS	NoAC-SC SPECT
0.186	0.110	0.162	0.166
0.066	0.042	0.036	0.054
0.032	0.012	0.010	0.019
0.049	0.027	0.010	0.044
0.078	0.043	0.036	0.032
0.075	0.025	0.015	0.036
0.094	0.055	0.070	0.071
0.143	0.044	0.075	0.073
0.200	0.098	0.160	0.116
0.077	0.034	0.045	0.050
0.131	0.070	0.076	0.090

	0.150	0.088	0.110	0.105
	0.043	0.015	0.015	0.029
	0.077	0.022	0.026	0.025
	0.072	0.031	0.041	0.050
	0.098	0.060	0.061	0.075
	0.180	0.110	0.150	0.160
	0.085	0.061	0.050	0.078
Mean	0.102	0.053	0.064	0.071
SD	0.049	0.031	0.049	0.042

Table 2. The deviation in LSFs between the standard whole-body scan (WBS) and different images formats

Method	AC-SC	NoAC-SC	SC-WBS
Mean %	-50	-32	-45
Min/Max %	-29/-71	-8/-67	-13/-80

Table 3. The deviation in the suggested activity and lung doses between standard LSFs from WBS and LSFs from AC-SC, SC-WBS and NoAC-SC images.

	AC-SC	NoAC-SC	SC-WBS
Suggested Activity	Mean -5.3 % Range (-2/-11)	Mean -3.2 % Range (-1/-9)	Mean -5.5% Range (-2/-7)
Lung Dose	Mean -53 % Range (-34/-72)	Mean -33 % Range (-12/-64)	Mean -48% Range (-18/-72)

Table 4. The absorbed dose to tumour and surrounding healthy tissue with different calculation approaches.

AC-SC (Spect/ct) ¹	NoAC-NoSC + LF(WBS) ²	NoAC-SC (Spect) ³	NoAC-NoSC + LF(SC-WBS) ⁴	AC-SC + LF (WBS) ⁵
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Tumor dose (Gy/GBq)	112 ± 90	90± 85	117±108	110±100	106 ± 84
Healthy tissue dose (Gy/GBq)	30 ±18	28 ± 20	30 ± 22	31±21	28 ±17

1: lung shunt fraction, tumour and target quantification were all made by SPECT/CT images with AC and SC. 2: lung shunt fractions were calculated from the standard WBS, while the tumour and target quantification was from NoAC-NoSC SPECT images. 3: lung shunt fractions, tumour and target quantification were all obtained from scatter corrected SPECT images. 4: lung shunt fractions were calculated from scatter corrected whole-body scans (SC-WBS), while the tumour and target quantification were made by SPECT images (NoAC-NoSC). 5: lung shunt fractions were computed from the standard WBS, while the tumour and target quantification was made from SPECT/CT (AC-SC).

Figure 4. The relationship between LSFs from scatter corrected whole-body scan (SC-WBS) and LSFs from SPECT/CT with scatter and attenuation correction (AC-SC).

219

220

221 **Figure 5.** The agreement in the target volumes obtained by AC-SC and both NoAC-SC and NoAC-
222 NoSC SPECT images.

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224

225 **Figure 6.** The association between the LSFs obtained by scatter corrected whole-body scan (SC- WBS)
226 and scatter corrected SPECT (NoAC-SC) images.

227

Discussion

^{99m}Tc -MAA has been widely used as a surrogate for ^{90}Y labelled microspheres regardless of outstanding argumentation around the non-uniform kinetics of the particles and the heterogynous dose distribution. ^{99m}Tc -MAA is typically injected into the hepatic artery, with approximately 0.5×10^6 MAA particles, while about 2×10^6 microspheres are found in 1.5 GBq ^{90}Y .⁹ A post-injection scintigraphy is routinely acquired to assess the lung shunt fraction and speculate the therapeutic ^{90}Y activity.

Nowadays, personalized treatment is preferentially followed in order to deliver effective dose to tumour while minimally irradiating healthy compartments. In ^{90}Y dosimetry, lungs and liver parenchyma are the main organs at risk that must remain within tolerable radiation exposure. Currently, the safe doses have been updated with respect to the normal tissue complication probability (NTCP). The dose limit of liver parenchyma was set as 70 Gy corresponds to an approximately 15 % NTCP and liver decompensation. Whereas, liver complication probability arises to 40% with increasing the absorbed dose to as high as 70-105 Gy.¹⁰

Lung shunt fractions were originally estimated from ^{99m}Tc planar imaging (whole-body scan) and the single-treatment dose limit was historically adopted as 30 Gy.¹¹ In resin microsphere, the whole activity is safely injected to the patients with LSF <10 %, while ^{90}Y therapy is contraindicated with LSFs exceeding 20%. Moreover, the injected activity is reduced by 40 % for patients with LSF between 15 and 20 %, and down to 20% in case of 10-15%LSF range.¹² In this respect, scatter radiation and overlying tissue attenuation remain crucial issues and key-factors in nuclear imaging and punctual quantification. In particular, scatter radiation substantially degrades image contrast by adding counts to both the background and the true signal. Thus, the overall impact of the mentioned quantification degrading factors was beyond the scope of this work. Accordingly, it was revealed that the variation in the computed lung shunt fractions between the uncorrected WBS and SPECT/CT (AC-SC) varied from 28-71% with an average of 50%. This variation has great impact on the lung dose estimation and the prescribed ^{90}Y activity. In other words, scatter corrected LSFs might be a reasonable justification for the ‘excluded’ patients with LSF $\geq 22\%$. Also, multiple ^{90}Y therapies can be applied taking into consideration the cumulative dose limit ≈ 50 Gy.¹¹ For instance, one patient with 33% LSF using standard WBS was injected by 0.99 GBq ^{90}Y according to the corresponding SPECT/CT LSF 21%. Upon to that, the mean dose to tumour was 165 Gy, the mean dose to the healthy tissue was 74 Gy and the mean lung dose was 10 Gy. Later, the patient was monitored for 3 months with no toxicity indications has been recorded.

On the other hand, no statistical difference was observed in the absorbed doses to tumour and healthy components between all the approaches addressed in table 4. In comparison, Gallio et al. reported that NoAC-SC images led to amount of activity not significantly different from the reference AC-SC images; while AC-NoSC and NoAC-NoSC images yielded significantly different activity prescriptions.¹³ Likewise, our study exhibited a minimal variation between AC-SC and NoAC-SC with no statistical difference ($p_{\text{value}} > 0.05$). However, the effect of attenuation and scatter correction is clearly visualized in the lung shunt fraction and the resultant absorbed doses. Allred et al. have recently reported a liver/lung torso phantom study demonstrating an improved accuracy in LSF estimation using SPECT/CT with AC and SC compared with planar imaging (up to 44% overestimation). Also, no significant different was found between the LSFs from $^{99\text{m}}\text{Tc}$ -MAA SPECT/CT and ^{90}Y PET/CT, while a poor correlation ($R_2=0.44$) was illustrated between the planar and SPECT/CT based LSFs.¹⁴ It was hence deduced that the calculated LSFs by scWBS in this study would be similarly closer to ^{90}Y PET/CT than standard WBS.

On the other hand, misalignment between SPECT and CT images might occur due to respiratory motion causing potential errors in the liver and lungs true counts. One technique has been recently described to capture mis-registered signals due to differences in SPECT and CT resolutions, and to minimize the impact of liver shine-through into the right lung contours by 1-expanding the liver contours for a couple of centimeters (e.g 2 cm), 2- estimating lungs counts from the left lung only and 3- multiplying the counts/cm³ by the total lung mass.¹⁵ Accordingly, the obtained uncertainties in LSF, and Lung dose measurements attributable to variability in contouring were 9%, 10%, and 13%, respectively. The Lung shunt fraction and lung mean dose were on average 63% and 53% lower than planar LSF and lung dose, respectively.¹⁵ Since, the purpose was mainly to investigate the effect of scatter and attenuation correction, the current study lacks analytical method accounting for the shine effect, however, the presented findings in here were comparable with the study involving shine-effect correction. On the other hand, the partitioning dosimetry method accounts for the microspheres' distribution ratio between the tumorous and non-tumorous regions, and the calculated absorbed dose is basically attributed to an entire region. However, the real dose distribution is variable throughout the volume because of liver microvessels structure, in addition to long β particles range that might escape farther changing the absorbed dose in the selected ROI. Therefore, clusters of point-sources emitting beta irradiation sounds the most appropriate model for ^{90}Y radioembolization dosimetry, but in fact this model is not easy to use in clinical practice.¹⁶ Instead, the administered ^{90}Y activity can be prescribed in higher thresholds based on the current work with utmost absorbed radiation dose and improved outcomes. Meanwhile, there is indispensable need to establish appropriate dose limits for

293 ^{90}Y -radioembolization induced toxicities depending upon $^{99\text{m}}\text{Tc}$ -MAA SPECT/CT with attenuation
294 and scatter correction.

295 To this end, no statistically significant difference was found in the absorbed doses to tumour and
296 healthy liver between all the dosimetry approaches with/and without attenuation and scatter correction.
297 However, the effect of SC and AC saliently predominates in the lung shunt fractions and the mean lung
298 dose indicating to re-verification of the normal liver and the lungs dose limits based on $^{99\text{m}}\text{Tc}$ -MAA
299 SPECT/CT.

300 **Conclusion**

301 This study emphasized that attenuation correction has trivial impact on the absorbed dose to tumour
302 and surrounding liver in ^{90}Y therapy. However, scatter correction has significant impact on the lung
303 shunt fraction and number of ^{90}Y treatments. In addition, a feasible agreement was shown between the
304 LSFs from SPECT/CT and scatter corrected WBS that might be useful for convenient and accurate ^{90}Y
305 dosimetry.

306 **Declarations**

307 *Ethics approval and consent to participate*

308 This work was approved by the local Ethics Committee of Cerrahpaşa Medical School/Istanbul
309 University-Cerrahpaşa in accordance with the Declaration of Helsinki (No: 83045809-604.01.02-).
310 Informed consent was obtained from all of the participant patients.

311 *Consent for Publication*

312 Not applicable.

313 *Availability of data and materials*

314 The datasets used and/or analysed during the current study are available from the
315 corresponding author on reasonable request

316 *Competing interests*

317 The authors declare that they have no competing interests.

318

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Author's contribution

MA and ÖA were major contributors in the data analysis and interpretations. KS, MD and SA made the patients' clinical examinations. All authors read and approved the final manuscript.

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Figures

Figure 1

Dual energy images. (A+B): anterior and posterior images of the peak window; (C+D): anterior and posterior images of the scatter window.

Figure 2

Liver and lungs ROIs over the SPECT images of A): NoAC-NoSC, B): NoAC-SC, and C): AC-SC.

Figure 3

A) Target and tumour ROIs on the SPECT images including A): NoAC-NoSC, B): NoAC-SC, and C): AC-SC.

Figure 4

The relationship between LSFs from scatter corrected whole-body scan (SC-WBS) and LSFs from SPECT/CT with scatter and attenuation correction (AC-SC).

Figure 5

The agreement in the target volumes obtained by AC-SC and both NoAC-SC and NoAC-NoSC SPECT images.

Figure 6

The association between the LSFs obtained by scatter corrected whole-body scan (SC- WBS) and scatter corrected SPECT (NoAC-SC) images.