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Quantitative Comparison of Y-90 and Ge-68 PET imaging

Sang-Keun Woo[a*], Shin Hye Kwak [a], Su Young Jeong [b], Jeong A Lee [a], Han Kyeol Song [a], Joo Hyun Kang [a], Sang Moo Lim [a], Kyeong Min Kim [a]
[a]*Molecular Imaging Research Center, Korea Institute of Raiological and Medical Sciences, 75 Nowon-gil, Gongneung-dong, Nowon-gu, Seoul 139-706*
[b]*Department of Nuclear Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, 108, Pyung-Dong, Jongno-Gu, Seoul, 110-746, South Korea*
[*]*Corresponding author: skwoo@kcch.re.kr*

1. Introduction

Yttrium-90 (Y-90) radioembolization is one of the treatment methods unrespectable stage of hepatocellular carcinoma (HCC) and metastatic colon cancer to the liver. However, Y-90 radioembolization is a catheter-based therapy that delivers internal radiation to tumors, it results in greater radiation exposure to the tumors than using external radiation [1]. Also, unlike other current therapies for the treatment of unresectable liver tumors, Y-90 radioembolization is much less often associated with toxicities such as abdominal pain, fever, nausea, and vomiting [2]. Therefore Y-90 has been received much interest and studied by many researchers. Imaging of Y-90 has been conducted using most commonly gamma camera but quantitative PET imaging is required due to low sensitivity and resolution. Y-90 imaging is generally performed with SPECT by bremsstrahlung photons. Unfortunately, the low image quality due to the nature of the bremsstrahlung photon limits the quantitative accuracy of Y-90 SPECT. To overcome this limitation in SPECT imaging, Y-90 PET has been suggested as an alternative. The purpose of this study was to assess statistical characteristics and to improve count rate of image for enhancing Y-90 image quality by using non-parametric bootstrap method.

2. Methods and Results

2.1 PET Data Acquisition

Listmode data was acquired from small animal PET scanner (Inveon^{TM}, Siemens) for 30 sec/60 sec using 18.5 MBq Ge-68 and 20 min/60 min using 74 MBq Y-90 in case of phantom. Usefulness of bootstrap method was verified thorough using Ge-68 having high count rate and it was applied to Y-90 having low count rate. Acquired inveon listmode data format consists of packet of 48 bit event composed of 8 bit header and 40 bit payload space. The first bit of header is always zero and the next three bits are gray code to prevent fault of binary code and it was used to evaluate sequence of packet.

2.2 Bootstrap using non-parametric method

The non-parametric bootstrap is a computer-based statistical method from empirical data [3]. Process of non-parametric bootstrap method used in this study is described below.

Step 1: Given the original data set $x = (x_1, \ldots, x_n)$ whose distribution estimates an unknown distribution is required.

Step 2: New data set described as $x^b = (x_1^b, \ldots, x_N^b)$ is created and each element x_i^b is obtained by randomly extracted from the original data set. In this study, N is resampling 10 times, 100 times, 1000 times and 10000 times of n. Realigned sinogram was generated using resampled data of original list mode data using non-parametric bootstrap method producing new data set whose elements was extracted randomly from the original data set with buffer.

2.3 Image Generation and Analysis

The realigned sinogram was reconstructed using ordered subsets expectation maximization (OSEM) 2D algorithm with 4 iterations. Y-90 coincidence rate was compared with Ge-68 event that is 0.17% rate. Ge-68 60 sec and Y-90 60 min prompts rate was 1.24E+07 and 8.40E+05, respectively.

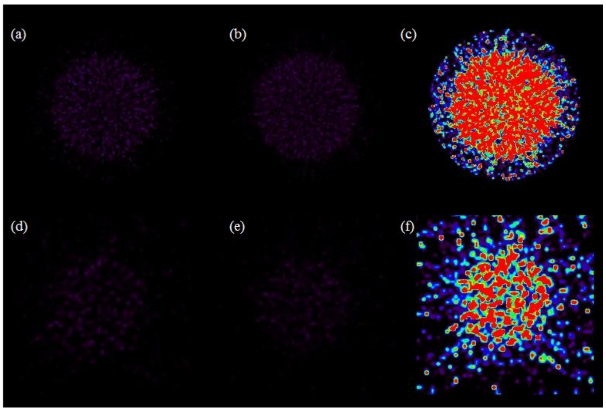

Fig. 1. Ge-68 and Y-90 original phantom PET images and 100 times bootstrapped image. (a) Ge-68 30 sec, (b) Ge-68 60 sec, (c) 100 times bootstrapped of Ge-68 30 sec data, (d) Y-90 20min phantom image, (e) Y-90 60min image, (f) 100 times bootstrapped of Y-90 20 min image.

Prompts rate was described in Table I below and rate was improved 4.94%, 54.39%, and 548.92% in 10 times, 100 times, and 1000 times of Ge-68 phantom data, respectively. Y-90 prompts rate was improved 0.91%, 2.12%, 21.45%, and 214.7% in 10 times, 100 times, 1000 times, and 10000 times bootstrapped data.

Table I: Prompts rate of original and bootstrapped data of 30 sec Ge-68 and 20 min Y-90 phantom image

	Ge-68 30 sec		Y-90 20 min	
	True coincidence	Prompts rate	True coincidence	Prompts rate
Original	6.11E+06	2.06E+05	2.84E+05	3.65E+02
10 times	6.41E+06	2.16E+05	2.85E+05	3.65E+02
100 times	9.43E+06	3.14E+05	2.90E+05	3.70E+02
1000 times	3.96E+07	1.29E+06	3.45E+05	4.15E+02
10000 times	–	–	8.94E+05	8.75E+02

PET images of phantom using bootstrap are showing improved prompts rate and true coincidence in Table 1. Image quality was evaluated by uniformity and signal to noise (SNR) of Ge-68 and Y-90 phantom image. Bootstrapped data of 10 times, 100 times, 1000 times and 10000 times was generated from original listmode data using bootstrap method with buffer size of 50 million in this study. SNR and uniformity of Ge-68 and Y-90 showed Fig. 2 and Fig. 3. SNR and uniformity was improved in Ge-68 and Y-90 data.

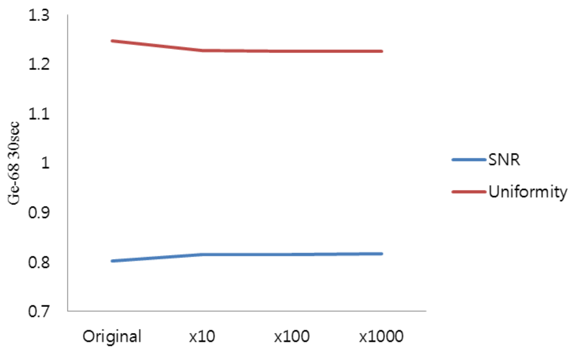

Fig. 2. SNR and uniformity of original and bootstrapped data of Ge-68 phantom image.

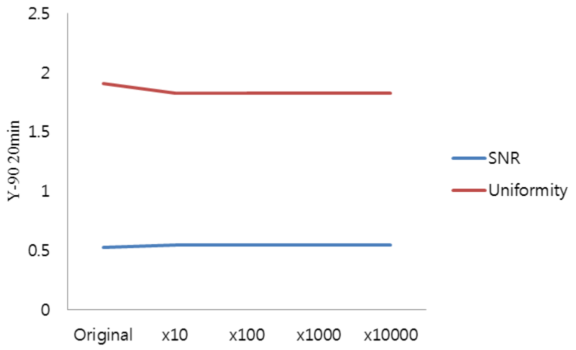

Fig. 3. SNR and uniformity of original and bootstrapped data of Y-90 phantom image.

3. Conclusions

The results showed that Y-90 PET image can be improved using non-parametric bootstrap method. PET data was able to be improved using non-parametric bootstrap method and it was verified with showing improved prompts rate. Y-90 PET image quality was improved and bias indicated that the bootstrapped image was more similar to the gold standard than other images. Conclusion is the non-parametric bootstrap method for Y-90 PET imaging may contribute to improvement of image quality for theragnostic study. The non-parametric bootstrap method will be useful tool for enhancing Y-90 PET image and it will be expected to reduce time for acquisition and to elevate performance for diagnosis and treatment.

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