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Y-90 PET imaging for radiation theragnosis using bootstrap event resampling

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1. Introduction

Liver is known as susceptible to metastatic disease from various kinds of tumors or cancers. Surgical resection is the most effective method to recover the liver function [1]. However, Yttrium-90 (Y-90) has been used as a new treatment due to the fact that it can be delivered to the tumors and results in greater radiation exposure to the tumors than using external radiation nowadays since most treatment is palliative in case of unresectable stage of hepatocellular carcinoma (HCC) [2]. Recently, 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 PET imaging is required due to low sensitivity and resolution. The purpose of this study was to assess statistical characteristics and to improve count rate of image for enhancing 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 3 min using 18.5 MBq Ge-68 and 60 min using 74 MBq Y-90 in case of phantom. In case of mouse, listmode data for 20min using 74 MBq Y-90 was acquired from the scanner after injection via tail vein. 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.

2.2 PET Listmode Data Format

Acquired listmode data format consists of packet of 48 bit composed of 8 bit header and 40 bit payload space. The first bit of header is always zero and the next three bits are composed of gray code remedying fault of binary code to evaluate sequence of each packet.

2.3 Bootstrap with Non-Parametric Approach

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 10 times and 100 times of n. This process is called resampling.

Realigned sinogram was generated from resampled data of original listmode data using non-parametric bootstrap method creating new set of data extracted randomly from original data set. Generated sinogram was reconstructed using ordered subsets expectation maximization (OSEM) 2D algorithm with 4 iterations.

2.4 Image Analysis

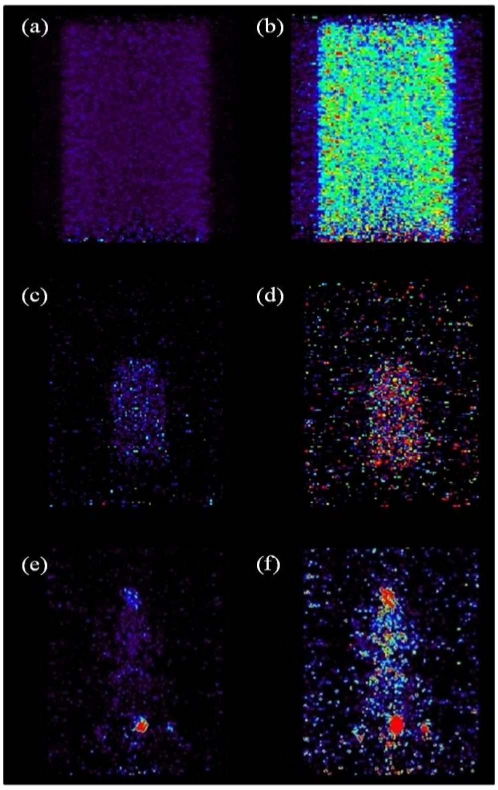

Fig. 1. PET images of original and bootstrapped data; left, original data; right, 10 times bootstrapped data; (a), (b) Ge-68 phantom; (c),(d) Y-90 phantom; (e),(f) Y-90 mouse

PET images of phantom and mouse using bootstrap are showing improved count rate in Fig.1. Image quality was evaluated by uniformity and signal to noise (SNR). Bootstrapped data of 10 times and 100 times was generated from original listmode data using bootstrap method with buffer size of 50 million in this study. Uniformity variation is described in Table I below and uniformity was improved for 3.4% and 8.1% in both images of Ge-68 and Y-90 phantom, respectively.

Table I: Uniformity of original and bootstrapped data of Ge-68 and Y-90 phantom image

	Uniformity	
	Ge-68	Y-90
Original	3.79×10^{-1}	1.48
10 times Bootstrapped	3.78×10^{-1}	1.40
100 times Bootstrapped	3.66×10^{-1}	1.36

In case of Y-90 mouse, uniformity and SNR were improved also. Uniformity changed from 2.25 to 1.99 and 1.90 for bootstrapped data of 10 times and 100 times, respectively. SNR was changed from 7.31×10^{-1} to 9.77×10^{-1} and 9.78×10^{-1} for bootstrapped data of 10 times and 100 times, respectively.

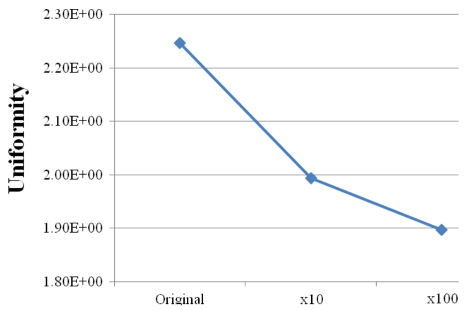

Fig. 2. Uniformity of original and bootstrapped data of Y-90 mouse image

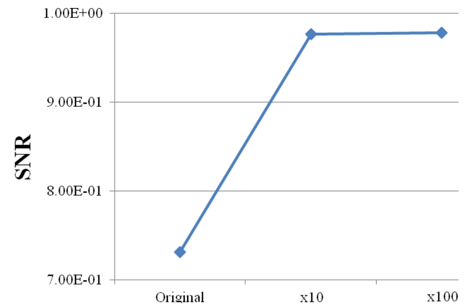

Fig. 3. SNR of original and bootstrapped data of Y-90 mouse image

3. Conclusions

PET data was able to be improved using non-parametric bootstrap method and it was verified with showing improved uniformity and SNR. Uniformity showed more improvement under the condition of low count rate, i.e. Y-90, in case of phantom and also uniformity and SNR showed improvement of 15.6% and 33.8% in case of mouse, respectively. Bootstrap method performed in this study for PET data increased count rate of PET image and consequentially time for acquisition time can be reduced. It will be expected to improve performance for diagnosis.

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