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Original article

The influence of number of counts in the myocardium in the determination of reproducible functional parameters in gated-SPECT studies simulated with GATE

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ABSTRACT

Myocardial perfusion gated-single photon emission computed tomography (gated-SPECT) imaging is used for the combined evaluation of myocardial perfusion and left ventricular (LV) function. The aim of this study is to analyze the influence of counts/pixel and concomitantly the total counts in the myocardium for the calculation of myocardial functional parameters.

Material and methods: Gated-SPECT studies were performed using a Monte Carlo GATE simulation package and the NCAT phantom.

The simulations of these studies use the radiopharmaceutical ^{99m}Tc-labeled tracers (250, 350, 450 and 680 MBq) for standard patient types, effectively corresponding to the following activities of myocardium: 3, 4.2, 5.4–8.2 MBq. All studies were simulated using 15 and 30 s/projection.

The simulated data were reconstructed and processed by quantitative-gated-SPECT software, and the analysis of functional parameters in gated-SPECT images was done by using Bland–Altman test and Mann–Whitney–Wilcoxon test.

Results: In studies simulated using different times (15 and 30 s/projection), it was noted that for the activities for full body: 250 and 350 MBq, there were statistically significant differences in parameters Motility and Thickness. For the left ventricular ejection fraction (LVEF), end-systolic volume (ESV) it was only for 250MBq, and 350MBq in the end-diastolic volume (EDV), while the simulated studies with 450 and 680 MBq showed no statistically significant differences for global functional parameters: LVEF, EDV and ESV.

Conclusion: The number of counts/pixel and, concomitantly, the total counts per simulation do not significantly interfere with the determination of gated-SPECT functional parameters, when using the administered average activity of 450 MBq, corresponding to the 5.4 MBq of the myocardium, for standard patient types.

Influencia del número de cuentas en el miocardio, en la determinación de los parámetros funcionales en los estudios de Gated-SPECT, simulados con GATE

Palabras clave:
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Número de cuentas
Parámetros funcionales

RESUMEN

La gammagrafía de perfusión miocárdica sincronizada con el eletrocardiograma (Gated-SPECT) permite la evaluación de la perfusión miocárdica y la función ventricular izquierda. El objetivo de este estudio fue analizar la influencia de las cuentas/pixel y, las cuentas totales en miocardio en la determinación de los parámetros funcionales.

Material y métodos: Hemos simulado estudios Gated-SPECT, por el método Monte Carlo GATE y el uso de fantoma NCAT.

Las simulaciones de estos estudios han considerado un paciente estándar utilizando un radiofármaco marcado con ^{99m}Tc, con diferentes actividades (250, 350, 450 y 680 MBq) correspondientes a las siguientes actividades en miocardio: 3; 4,2; 5,4 a 8,2 MBq. Se simularon todos los estudios con un tiempo de 15 y 30 seg/proyección. Los datos simulados fueron reconstruidos, procesados y cuantificados por el software Quantitative-Gated-SPECT. El análisis de la influencia de las cuentas en los parámetros funcionales se llevó a cabo utilizando la prueba de Bland-Altman y Mann-Whitney-Wilcoxon.

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Resultados: En los estudios simulados con diferentes tiempos (15 y 30 seg/proyección), se encontró que para las actividades del cuerpo entero 250 y 350 MBq hubo diferencias estadísticamente significativas en los parámetros de motilidad y espesor; para la FEVI, VTS solo para 250 MBq, y VTD solo para 350 MBq. En los estudios simulados con 450 y 680 MBq no se encontraron diferencias estadísticamente significativas para los parámetros funcionales globales: FEVI, VTD y VTS.
Conclusión: Por simulación en un paciente estándar, el número de cuentas/píxel y, de forma concomitante, las cuentas totales no interfiere significativamente en la determinación de los parámetros funcionales generales de Gated-SPECT, cuando se utiliza la actividad media de 450 MBq, correspondiente a 5,4 MBq en miocardio.

Introduction

Myocardial perfusion gated-SPECT is an imaging technique that uses radiopharmaceuticals (*e.g.* ^{99m}Tc-tetrofosmin) to evaluate the distribution of blood flow in cardiac muscle and the myocyte functional viability.[1]

The advantages of using this imaging technique is a combination of the characteristics of myocardial SPECT studies, which allows the assessment of myocardial perfusion of the LV and quantitative parameters of myocardial function, such as LV ejection fraction (LVEF), end-diastolic volume (EDV), end-systolic volume (ESV) and quantification of movement and systolic thickening of the LV myocardium.[2,3]

The optimization of such acquisition protocols is not yet fully accomplished.[3] Based on the EANM *Guidelines*, there are several benchmarks in the activity (MBq) administered to "*standard type patients*", taking into account the acquisition protocol used in Europe or the country where it is performed.[1]

Standard protocols of the myocardial perfusion gated-SPECT studies require an average of 20 min/study.[2,3] The special position of the arms (raised above the head) to avoid artifacts of reconstruction and approaching the detectors as much as possible to the signal source – the myocardium – though uncomfortable for patients, a must to avoid movement artifacts during the acquisition.[3] It is therefore important for the total duration of image acquisition to be reduced as much as possible. However, it is known that this reduction leads to decrease on counts statistics per projection and doubts arise about the validity of the functional parameters determined by quantitative gated SPECT/quantitative perfusion SPECT (QGS/QPS) program.

For these reasons decreasing acquisition time without compromising the results, especially in the quantification parameters of cardiac function, is important.

Due to ethical, logistical and economical reasons, the acquisition and analysis of real patients were a problem, so simulated studies were performed for this purpose.

A previous implementation of the Monte Carlo simulation of the basic features of the GE Millennium MG SPECT gamma camera was used. This has already been validated by comparing data from simulated studies with experimental studies, showing a good agreement between the results obtained.[4]

Under this scope, the simulation parameters used in a previous work,[4] were used to simulate the gated-SPECT imaging of a healthy standard patient, using the NURBS phantom – based cardiac torso (NCAT).[5]

This phantom,[5] known today as XCAT phantom,[6] is a useful tool in the aid of the study of medical imaging modalities such as myocardial SPECT. It is a tridimensional matrix which can be used in Geant4 Application for Tomographic Emission (GATE), representing the whole body of a patient that can be modeled to simulate the physiological movements such as breathing and heartbeat.

NCAT phantom allowed the study of the activity in Bq/*voxel* in a myocardium with normal radiopharmaceutical biodistribution and derived the number of average counts per *pixel* and total counts in the myocardium, for which acquisition time per projection does not interfere in the determination of functional parameters determined with gated-SPECT studies.

The purpose of this study is to analyze the influence of the number of counts/*pixel* and concomitantly the total counts in the myocardium per acquisition, in the calculation of functional parameters of the myocardium: LVEF, EDV, ESV, motility and thickening of the LV myocardium.

Material and methods

NCAT is an application that allows generating phantoms in two different *pixelated* versions: the phantom with the distribution of the radionuclide and the phantom of attenuation coefficients for a desired energy.[5] This application includes a parameter file that allows the user to change shape and time dependency and control the generation of both distributions. In this study the *pixelated* version of NCAT describing the distribution of the radionuclide was used. A parameter file to build a phantom of a healthy male patient having 40 internal organs, with his arms lifted above his head, with a matrix of 128×128 *pixels*, with a heart rate of 72 beats/min, in which each cardiac cycle was divided into eight intervals, was used. This represents typical acquisition conditions used in the acquisition protocol of real studies.

The attenuation phantom was not simulated.

For the use of the NCAT phantom in GATE, the *voxelized* source was specified and for each *voxel* or *voxel* interval the activity and the type of particles emitted were also indicated in the GE Millennium MG macro.[4]

^{99m}Tc-tetrofosmin was chosen because it is the mostly used radiopharmaceutical in the majority of nuclear medicine services in Portugal in real studies to assess myocardial perfusion and function. The following reference values for standard type patients, *i.e.* a male patient carrying a weight of 70 kg and 170 cm height, suggested by EANM *Guidelines*[1] used were:

According to the recommendations made by national European regulatory authorities, national societies and others,[1] 250 MBq the lowest (the minimum) and 350 MBq as the highest (the maximum) are used as the protocol for most European countries, including Portugal.

Based on the study of Garcia et al,[7] for the first study of one-day protocol a 450 MBq and 680 MBq were used.

To calculate the activity in Bq/*voxel* in the NCAT phantom myocardium, the average percentage that is fixed in this myocardium was used, 30–60 min after intravenous administration, which represents 1.2% of total administered activity.[8]

This activity was, then, equally redistributed by the total number of myocardial *voxels* in the NCAT phantom, which is approximately 11,005 *voxels* resulting in the values showed in Table 1.[4,9]