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FLÚOR-18 HEART DOSIMETRY IN MYOCARDIAL PERFUSION IMAGING

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ABSTRACT

This paper conducts a recalling in myocardial perfusion imaging (MPI) followed by a spatial dosimetric investigation of the Fluor-18 distributed at the myocardium by self-absorption of the heart uptake. Methods and Results: Radiological data manipulation was prepared and a computational heart voxelized model was assembled. A set of images from the abdominal aorta and angiotomography of the thorax was set up providing anatomic and functional information for heart modeling in SISCODES code. A homogeneous distribution of fluor-18 was assumed into the heart myocardial wall. MCNP – Monte Carlo Code was used to provide the photon transport into the heart model taken in consideration the interactions into the tissues. The spatial dose distribution and histogram dose versus volume are presented. An analytical alternative model was addressed to the data validation. The present developed tools can produce spatial dose distribution in MPI at heart. Specially, the dosimetry performed elucidates imparted dose in the myocardial muscle per unit of injected Fluor-18 activity by self-absorption of the heart uptake, which can contribute to future deterministic effect investigations.

1. INTRODUCTION

In the early twentieth century, cardiovascular disease (CVD) accounted for less than 10% of all deaths worldwide. At the end of the century, CVD was responsible for nearly half of all deaths in developing countries and 25% in developing countries. In 2020, CVD will be responsible for 25 million deaths annually, and coronary artery disease (CAD) will overtake infectious diseases as the world's number one cause of death and disability. [3]

In Brazil, cardiovascular diseases account for 26.6% of total recorded deaths, ranking the first place when considering only those over 50 years. In recent years, there is an increase in patient survival, because of the possibility of early and late recanalization by percutaneous coronary intervention and thrombolytic revascularization. The proper selection of patients with coronary artery disease (CAD) in acute and chronic diagnostic procedures is based in part on the perception of the extension of affected myocardium, but potentially viable, with the aim of reversing ventricular dysfunction. [8]

The overall increase in CVD is the result of the drastic change in health status of individuals during the twentieth century. Before 1900, infectious diseases and malnutrition were the most common causes of death. These have gradually been supplanted, in some countries, for chronic diseases such as cardiovascular disease and cancer, thankful in large part to nutrition improvement and public health measures. These changes are called epidemiological

transition, and it never occurs in isolation, but intertwined with changes in public and personal health (economic transition), social structures (social transition) and demography (the demographic transition). And, as the transitions are linked to the evolution of social and economic forces, this change comes in different speeds around the world. During this era, the increased caloric intake (particularly saturated fats from animal and manipulated vegetable fats), the reduction of daily physical activity, the large smoking rates associated with diabetes and hyperlipidemia cause further increases of hypertensive disease and rapid increases in CVD and peripheral vascular disease. [3]

Despite improvements in health technology and better access to these decreases the likelihood of death among patients with acute manifestations of atherosclerotic disease, better survival means that more and more individuals are living for a longer period with CVD such as angina pectoris, congestive heart failure and cardiac arrhythmias. [3]

On this scintigraphy, a radiopharmaceutical is injected through a peripheral vein and was subsequently captured by myocytes - cells of the heart. This process is called myocardial perfusion. In many parts of the heart, the injected radioisotope emits radiation that is converted into a luminous image (flicker), observed through a cardiac CT. The images are obtained in two stages: rest and stress when there is increased blood flow to the heart. Radiopharmaceuticals, accumulate in proportion to regional myocardial blood flow, is analyzed for a decreasing in the intensity of radioisotope uptake in some part of the heart muscle. When this uptake is transient, coronary ischemia is pointed out; when it is persistent, fibrosis is the situation. Thus, myocardial perfusion imaging allows you to search the viable areas of the case, separating the viable areas from those involved in the treatment. In this case, the search is called myocardial viability. [1]

There are several indications for myocardial perfusion scintigraphy. The main ones are for the diagnosis of myocardial ischemia due to coronary disease in patients with intermediate pretest probability. Examples are asymptomatic patients with positive exercise test, symptomatic patients with normal stress test, and women with atypical angina, among others. [10]

In patients with known coronary disease, scintigraphy is important in assessing the impact of ischemic lesion boundary (30 to 60% obstruction by coronary angiography). Coronary artery disease is important in risk stratification and prognostic evaluation of patients with stable angina, and consequently aid in the treatment decision (surgery versus clinic). [10]

It is also important in risk stratification after AMI (Acute Myocardial Infarction) and unstable angina and risk stratification for patients who will undergo non-cardiac surgery (especially vascular). It also includes the evaluation of ischemia after myocardial revascularization or angioplasty - detection of restenosis or complications. [10] Myocardial viability can be investigated in patients with ischemic cardiomyopathy with ventricular dysfunction. Early diagnosis of ischemia can be performed in chest pain units. The evaluation of ischemia can be taken in the pediatric population in cases of congenital coronary anomaly and Kawasaki disease [10]. Also, it can be indicated to evaluate left ventricular function in heart failure, to identify viable areas of the heart muscle and monitoring of patients receiving chemotherapy with doxorubicin, to evaluate cardiac function after heart transplantation and heart valve disease. [10]

Within the ischemic syndrome - ACS, myocardial perfusion scintigraphy is emerging as an important tool in estimating the functional significance of angiographic coronary stenoses, to evaluate the effectiveness of therapeutic interventions, and risk stratification after myocardial infarction. However, the ability of nuclear cardiology in predicting the occurrence of acute phenomena (fissure / plaque rupture with thrombosis), is still limited, although it has been the subject of intense research and new. [9] Studies have shown that individuals with a resting myocardial scintigraphy considered low risk, held in emergency, determines a risk of subsequent cardiac events reduced. On the other hand, patients with a high risk of scintigraphy are likely to develop acute, being revascularization (surgery or angioplasty) or coronary artery disease presenting to coronary angiography. [9]

Radiopharmaceuticals are radioactive chemical compounds used to diagnose and therapy. In nuclear medicine, about 95% of the radiopharmaceuticals is used for diagnosis and 5% for treatment. Since they are administered to humans, they must be sterile, pyrogen free agents and subject to all necessary measures for quality control like a conventional drug. [6]

The radiopharmaceutical can be a radioactive element, such as Xe-133, or an I-131-iodine labeled compound, or Tc-99m labeled protein It consists of two components, a radionuclide and a pharmaceutical. Its usefulness is dictated by the characteristics of its components. The pharmaceutical is chosen based on their localization in the organ and its involvement in the physiological function of the organ. [6]

2. MATERIALS AND METHODOS

A set of CT images of a heart with contrast agent and normal hear´s morphology is selected. The contrast is important in order to allow separation among the various cardiac structures. The images are taken from a set of CT sections of an adult´s chest. Sixty images, each one representing a 2mm layer, were selected from 355 axial slices of the CT, including the region of interest (heart and part of the mediastinum) [10]. The CT images were obtained in DICOM (Digital Imaging and Communications in Medicine) which is the standard for medical images storage and transmission [11]. The select image set was trimmed limiting the heart region. Those were converted to a voxel model of tissues by SISCODES (a computational system for dosimetry in neutron and photon based on stochastic methods). [10, 11]

At first, the tomographic images are converted into a three dimensional model based on the grayscale of each image region. This model is then "filled" by the tissues, identifying each structure with the aid of the gray tone of the image. The available tissues had its chemical composition and mass density previously entered into a database, as well as nuclear information, based on data from ICRU-46. Each tissue has also an associated color, which allows the identification of the distinct tissues used in the model. After identifying each tissue and organ in the model, the myocardial perfusion protocol can be simulated.

The images were converted from DICOM to JPEG format since the original format was not compatible with the SISCODES. After image conversion, the grayscale model was prepared and the model was “filled” with tissues corresponding to the various structures of the heart. Knowledge of the heart anatomy was required. The tissues used in the model were previously stored in the SISCODES database.

A set of voxels from myocardial muscle is selected to receive a distributed source of F-18. For each selected voxel a source was defined. The gamma source from F-18 was specified from literature (ENSDF Decay Data in the MIRD - Medical Internal Radiation Dose).

3. RESULTS

It was assumed a homogeneous distribution of F-18 in the heart muscle. Figure 1 shows respectively the cardiac tomography imaging, heart in voxel model and colored in isodose curves. Highlighted in red to the heart muscle and green water to the coronary artery. Figure 2 shows isodose areas in a heart section, following by the percentage absorbed dose of maximum value. Figure 3 represents a percentage absorbed dose of value maximum of dose in isodose curves.

Figure 1. Images of the heart respectively in computed tomography, voxel SISCODES. Red areas of the model represent the heart muscle and white is the coronary artery.

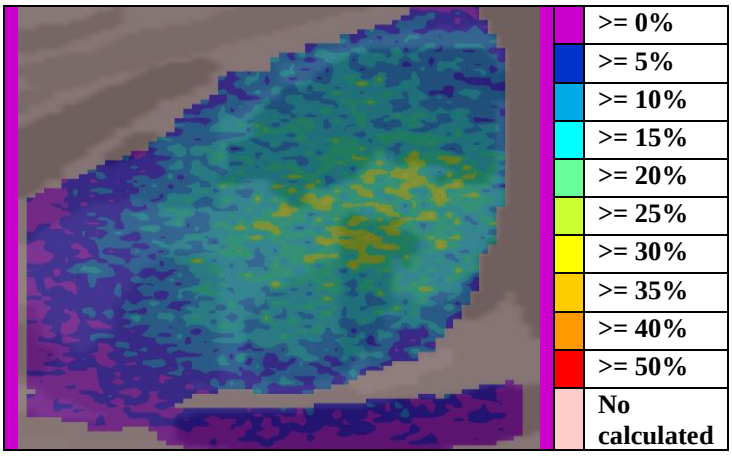

Figure 2. Isodose areas in a heart section, following by the percentage absorbed dose of maximum value.

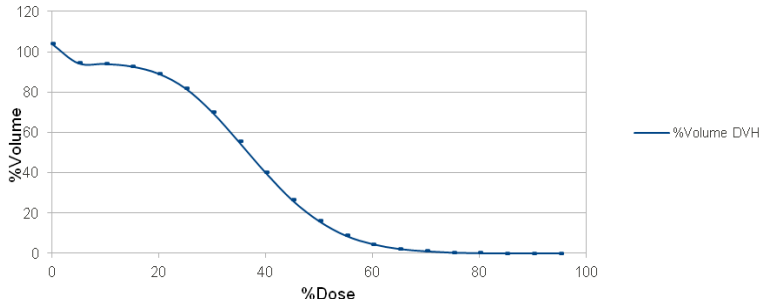

Figure 3. Dose versus volume histogram in the heart muscle, considering the photon and electron emission at the heart.

The percentage of absorbed dose represented by isodose curves is based on a maximum value which in this case was $2.11\text{-}10^{-11}$Gy/transition. All values are normalized to the maximum value. This value can be multiplied to the patient´s injected activity, in Bq, and the percentage of heart uptake of that same patient, in %, in order to have values in units of absorbed dose rate in Gy/s. The dose rate can be converted to dose multiplying by 1.44 and the effective half-live of the nuclide on the heart, in seconds. The effective half-life of the nuclide on the heart depends on the patient´s physiologic stage.

One can see that the dose deposition occurred even in the regions that represent heart muscle and coronary colored areas in red and green in the voxel model and warmer areas considered in the model of isodose curve. Indeed, the isodose is so disperses on the heart muscle that it cannot be easily interpreted. Therefore, a histogram dose versus volume may be applied.

A value of 100% of the volume received 5% of the maximum dose. For the following occurs coronary 80% of the volume received 15% of dose maximum, 70% of the volume received 20% of dose maximum, 60% of the volume received 25% of dose maximum, 40% of the volume received 30% of dose maximum. While for the heart muscle is 80% of the volume received 20% of dose maximum, 70% of volume received 25% of dose maximum, 60% of volume received 30% of dose maximum, 40% of the volume received little more than 30% of dose maximum.

The heart muscle received a greater percentage of the maximum dose when compared to percentage of doses received by the coronary artery.

3. CONCLUSIONS

As conclusion, the present computational tools are capable of generating doses distributed in myocardial perfusion image protocol. Further studies involving real patient´s images shall be made to obtain dosimetric data for each case. Specially, effective half-live of the radiopharmaceutical on the heart is needed to measure in order to accomplish this methodology.

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