SIMULATION OF SUBENDOCARDIAL MYOCARDIAL INFARCTION USING A HEART PHANTOM FOR Tc-99m SPECT

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Abstract: The myocardial infarction can involve the whole thickness of heart wall (transmural myocardial infarction) or only its part (subendocardial infarction). Nuclear imaging of heart is a noinvasive procedure that reveals the cardiac structure and physiology enabling evaluation of cardiac function. The heart phantom elaborated referring to the ICRU Report 48 (International Commission on Radiation Units and Measurements) has been filled with 45-50 MBq of Technetium-99m solution and placed in a water filled anthropomorphic torso phantom. Next the subendorcordial myocardial infarction has been simulated by lead plates placed on the cardiac phantom. The studies were performed with gamma camera X-Ring SPECT (64x64 matrix, 32 projections, angle 180^{o}). In study static heart phantom was used to diagnose different stages of myocardial ischaemia using SPECT method. We showed that average uptake of ^{99m} Tc-MIBI in the deficiency regions depends on lead plates thickness. This simulation keeps all physiological inhomogeneous which can be also seen in radioisotope diagnostic of human heart and use to finding the best geometry of the mesurment. The use of this heart phantom can reduce patient's and also staff's exposure to ionising radiation.

Introduction

Radioisotope imaging applied in medical diagnostication can provide both anatomical and functional information. Single photon emission computed tomographic (SPECT) imaging of myocardial perfusion provides a sensitive means of detecting and localizing coronary artery disease [1]. The SPECT (Single Photon Emission Computed Tomography) can be used to determine qualitatively and quantitatively the severity of the myocardial infarct [2-4]. Three-dimensional display (Fig. 1) is helpful for correlating coronary anatomy with the perfusion data. The perfusion defects should be characterized by their location as they relation to specific myocardial walls (apical, anterior, inferior and lateral). Defect severity is typically expressed qualitatively as mild, moderate or severe [2]. Quantitative and semi-quantitative analysis is use as supplement for visual interpretation and is particularly helpful in describing changes between two studies in the same patient, in the purpose to prognose an assessment of the disease extent.

Several technetium-labelled tracers are now available for clinical use. They belong to two main pharmacological classes, lipophilic cations and neutral compounds. The myocardial uptake of lipophilic cations was first noted by Deutsch et al. [5] and is a feature common to wide variety of technetium-99m (^{99m}Tc) complex types, including the isonitryles and the phosphine complexes [6-8].

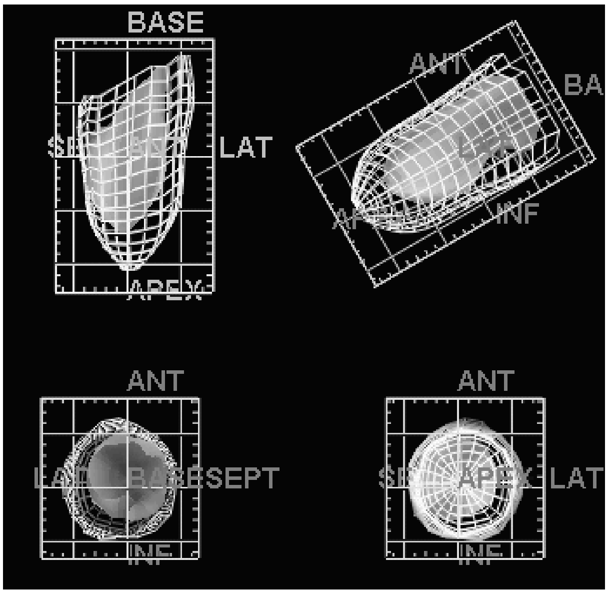

Figure1: Three-dimensional reconstruction of heart.

Quantification of SPECT images may be obtained using short-axis and long-axis circumferential profiles.

More comprehensible quantification is provided by polar map which allows to assess of myocardial tracer uptake percentage of the reference zone (Fig.2) [9]. Abnormal areas are quantified in reference to a normal population database, specific for the tracer and protocol use. Pixel-by-pixel lower limit of normal thresholds are calculated using the distribution of normal values. Polar maps are also useful to quantitative evaluation of perfusion defect size and severity [10-12].

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The advantage of the polar map is that all areas of the myocardium are represented in a single image, but this image is less familiar to cardiologists.

Because not all studies can be unequivocally designed as clearly normal or abnormal, due to possible sources artifacts, or when the defects are observed in locations with highly variable count statistics five-point scoring system to explain study is used (Fig. 3). This five-category system allow to analyze semi-quantitatively defect severity as:

0 – definitely normal
1 – probably normal
2 – equivocal
3 – probably abnormal
4 – definitely abnormal

The myocardial infarction can involve the whole thickness of heart wall (transmural myocardial infarction) or only its part (subendocardial infarction). Nuclear imaging of heart is a noinvasive procedure that reveals the cardiac structure and physiology enabling evaluation of cardiac function [13].

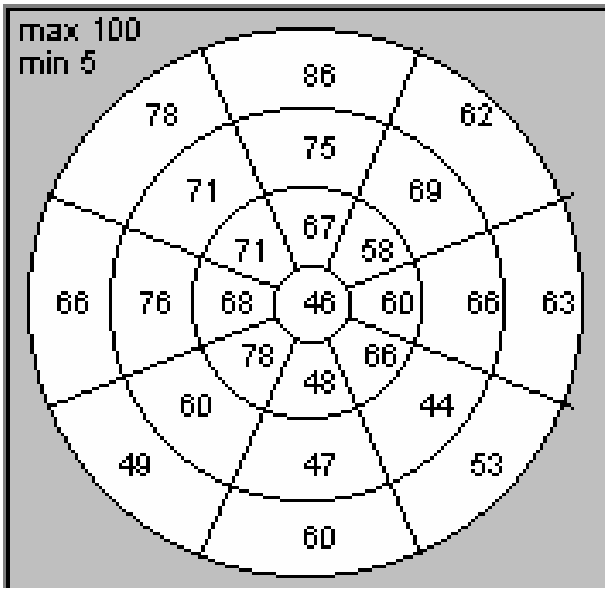

Figure 2: Polar map: uptake of the tracer [in %].

The quality of myocardium perfusion examinations depends on a number of factors [9, 10].
Using phantoms (such as cardiac phantom) in SPECT imaging allows accurate interpretation of studies and recognizing the sources of artifacts caused by low counts number, patient motion, breast and diaphragmatic attenuation, etc. [1].

The aim of this study was to determine the size of myocardial defects caused by subendocardial infarction which can be detected by SPECT using ^{99m}Tc.

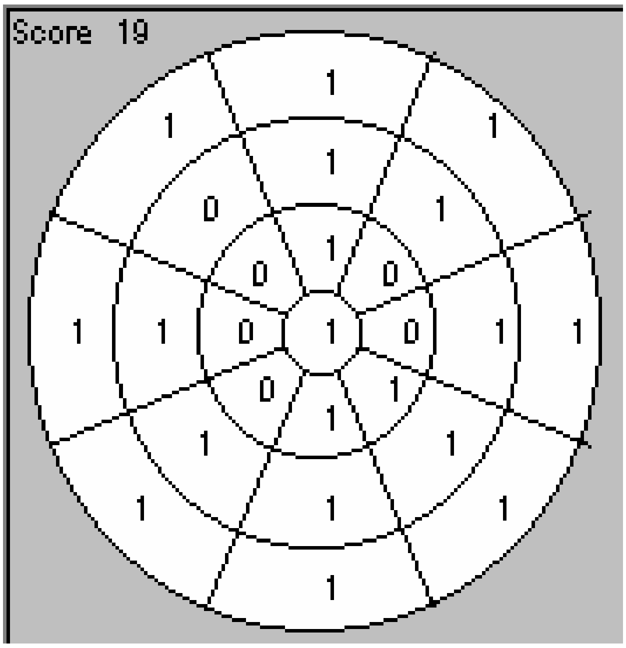

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Figure 3: Polar map: defects of perfusion in scores.

Materials and Methods

The heart phantom (Fig. 4) elaborated referring to the ICRU Report 48 (International Commission on Radiation Units and Measurements) has been filled with 45-50 MBq ^{99m}Tc labelled metoxy isobutyl isonitrile (MIBI) solution and placed in a water filled anthropomorphic torso phantom. Next the subendorcordial myocardial infarction has been simulated by lead plates placed on the cardiac phantom. There were used the lead plates of two sizes 119x185 mm^2 and 159x225 mm^2 with the same thickness of 0.4 mm. The different degrees of the deficiency of the cardiac perfusion have been simulated by the size and thickness of the plates. The studies were performed with single-head gamma camera Nucline X-Ring (Mediso, Hungary). The acquisition protocol obtained 32 projections for 30 seconds each (64x64 matrix, angle 180^o) using low-energy, high resolution collimator. The processing protocol with using Interview software consisted of prefiltering each projection prior to backprojection, using Butterwoth filter. After reconstruction average uptake of ^{99m}Tc in the deficiency region was measured.

Results

The simulation of the subendocardial myocardial infarction have been performed for six different stages of this disease. The results presented as a ratio of the ^{99m}Tc activity detected in the deficiency area to its maximum radioactivity in the heart can be expressed as an average uptake in %.

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Figure 4: The heart phantom.

The simulation of the subendocardial myocardial infarction usimg lead plates with different size allow to estimate perfusion defect size on the base quantitative method. Table 1 summarizes the results of measurement.

Table 1: Results of simulation of myocardial ischaemia

Lead Plate Size [mm^2]	Plate Thickness [mm]	Average Uptake of ^{99m}Tc in the Deficiency Region (min-max) [%]
119 x 185	0.4	42 (40-43)
	0.8	28 (27-29)
	1.2	17 (14-20)
159 x 225	0.4	34 (31-36)
	0.8	22 (20-24)
	1.2	4 (2-6)

In the same examination using cardiac phantom differences between lead plate thickness and average uptake of the radiotracer in deficiency region was measured.

Discussion

The static heart phantom is an imaging phantom, which can be used for the assessment of image quality. The use of lead plates with different size enables observe how extensive space of ischaemia can be registered during radioisotope diagnostic. The results of simulation of myocardial ischaemia summarized in table 1 show that average uptake of ^{99m}Tc-MIBI in the deficiency regions depends on lead plates thickness. The big (15.9x22.5mm^2) lead plates in comparison with the small one (11.9x18.5mm^2) have smaller average uptake of ^{99m}Tc but both are registered by the gamma camera. So it is possible to use heart phantom to check the smallest region of ischaemia which can be measure.

Conclusions

This study demonstrates that SPECT method and static heart phantom can be used to diagnose different stages of myocardial ischaemia.

The static heart phantom may be used with all cardiological radiopharmaceuticals labelled with e.g. ^{99m}Tc, ^{201}Tl and others radioisotopes, because of good simulation of myocardial diseases. This simulation includes all physiological inhomogeneities which can be also seen in radioisotope diagnostic of human heart.

The heart phantom can be also use to finding the best geometry of the measurement. The use of this heart phantom can reduce patient's and also staff's exposure to ionising radiation.

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