Analysis of Safety Aspects in Nuclear Medicine in the Comparison of Cardio Cameras

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Original Article

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Abstract:

Introduction: Examinations in nuclear medicine brings several problems for the patient and the staff from the point of view of radiation protection. The solution should be to reduce the radiation load. Therefore, ways are being sought to minimize the radiation of both the patient and the staff. This is related to the development of new diagnostic devices in nuclear medicine that enable a reduced radiation load by reducing the applied dose of the radiopharmaceutical, shortening the examination time and using a radionuclide with a favourable effective half-life and energy. The essence of diagnostics and treatment in nuclear medicine is the introduction of an open emitter into the body and, using the tracer principle, the detection of ionizing radiation emitted from the patient's body. This enables the monitoring of regional physiology and biochemistry in the organism using special devices - gamma cameras.

Objective: At our workplace, we started working with a new cardio camera, CZT 530c, which reduces the patient's radiation load, brings more valid results, etc. The goal was to compare the radiation load per patient when comparing two cameras.

Research sample group and methodology: In this retrospective cohort study, records of patients who underwent myocardial scintigraphy were used and evaluated. In the first monitored group of patients, during the years 2003-2016 at the Central Military Hospital in Ružomberok, these examinations were performed with 18,000 patients using the Millenium gamma camera, VG Hawkay f. GE. We analysed a set of 4,270 individuals that were examined in the years 2014-2016 by myocardial perfusion scintigraphy. In the second set of respondents, for a period of two years (2019-2021), we performed perfusion scintigraphy of the myocardium in 2,900 individuals on a cardiology gamma camera CZT 530c f. GE. We compared these two files. The data were processed in the STATISTICA program using a z-test of relative values.

Results: In the first monitored group, there were 61% negative findings and 39% positive findings. Of the number of positive findings, conservative treatment was recommended in 19%, MSCT coronary angiography in 7% and SCA in 13%. The sensitivity was around 95% and the specificity around 92%. In the second group, we found a negative finding in 49% of individuals and a positive finding in 51% of individuals. Of the positive findings indicative of coronary heart disease, we recommended coronary angiography in 24% of those examined, namely MSCT in 13% and SCA in 11% of individuals. For the remaining 27% of the examined patients, medical treatment was recommended.

Conclusion: The new type of cardio gamma camera "Discovery NM CZT 530c f. GE" enables the speeding up of the examination, increasing the sensitivity and specificity of the examination, at the same time reducing the dose of the radiopharmaceutical, thus reducing the radiation burden of patients by 50%. During the assessment, it allows for a better evaluation of the hemodynamic parameters. The result is more valid when compared with coronary angiography.

Introduction

Nuclear medicine is a relatively young field, as it has been around for about 70-80 years. The era of nuclear medicine began in the late 1940s, and with its gradual development, especially regarding of computer technology, a separate medical field was created that deals with diagnostics and treatment with open emitters. The essence of the examination is the administration of an open emitter into the organism, which is characterized by two principles: the tracking principle using the detection of ionizing radiation emitted from the patient's body and the principle of targeted administration of a radioactive substance with sufficient energy to irradiate a defined volume of tissue for the purposes of treatment. The tracer principle was discovered by George de Hevesy (1). It is used to monitor regional physiology and biochemistry inside the body, using devices that detect the radiation of a radiopharmaceutical labelled with a radionuclide from the organism under investigation. On the same basis, but with a different purpose, it is also used in radionuclide treatment, when the radiopharmaceutical is deliberately introduced into the target volume of the tissue (organ), which must be irradiated with a high dose. Nuclear medicine is unique in that it provides information about a patient's condition that may not be easily detected or obtained at all by other investigative methods. Examinations with open emitters mainly determine the function and the course of metabolic processes. It does not focus on the anatomical structure of the examined parts of the body. In many diseases, functional pathological changes precede the appearance of structural morphological changes. The results of examinations in nuclear medicine are complementary to structural imaging methods, which also led to the emergence of hybrid imaging.

Radiation protection in nuclear medicine

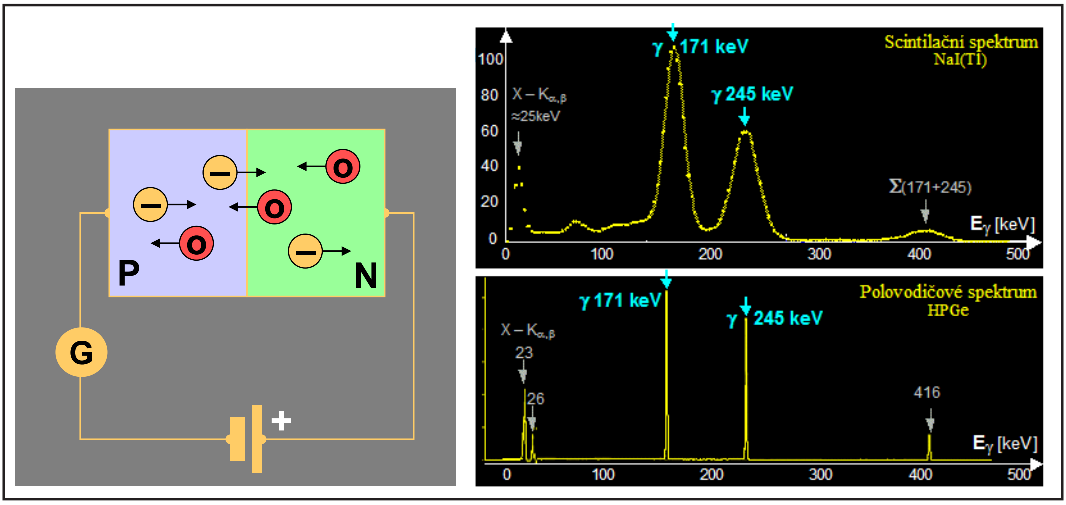
Examination in nuclear medicine brings several problems from the point of view of radiation protection. The effective detection efficiency of diagnostic devices is low, because the emitted radiation spreads in all directions and we scan only a small part falling on the detector. This causes some limitations that make it difficult to reduce the applied activity. This problem also affects the radiation load of the patient, to whom we have to apply a sufficient amount of radiopharmaceutical to ensure a high-quality recording. Another problem is the effect of radiation on personnel. The above shows the importance of radiation protection for all nuclear medicine workers (starting with radiopharmacists, through physicists, doctors, nurses, radiological technicians, reception and cleaning service workers). A patient is always exposed to radiation. Therefore, ways are being sought that should lead to the minimization of radiation to the lowest possible level so that the necessary diagnostic and treatment effect is achieved. This is related to the development of new diagnostic devices in nuclear medicine, which enable a reduced radiation load (reduction in the dose of the radiopharmaceutical, shortening of the examination time, etc.). It is very important to know the physical properties of radionuclides that are used in nuclear medicine. Here belong:

- type of radiation emitted
-energy of radiation emitted
- the physical half-life of the transformation (1).

The basic imaging device in nuclear medicine is a gamma camera (called Anger's scintillation camera, according to the inventor). The gamma camera is used to perform scintigraphy or single-photon emission computed tomography (SPECT). Currently, only digital gamma cameras and so-called hybrid tomographs (integrating functional imaging of nuclear medicine with a morphological imaging modality into one device) are being produced (2). There is a new type of gamma camera, which instead of a large surface scintillation detector is based on a principle of semiconductor detectors, and it belongs to the group of semiconductor gamma cameras. Work had already begun in 1991 on the construction of small cameras with semiconductor CdTe (Cadmium Telluride) detectors. The first commercially available cameras with semiconductor detectors were special single-purpose cameras for nuclear cardiology. A breakthrough after 2016 was brought by a new commercially available dual-head gamma camera for general SPECT/CT use (Discovery CZT fy GE). The abbreviation CZT means semiconductor composition (Cadmium-Zinc-Tellur) (3).

Semiconductors are solid substances that have higher electrical conductivity than insulators, but lower than metals. Electric current is transferred using electron-hole pairs. The properties of semiconductors significantly depend on their composition. Radiation particles are capable of directly or indirectly ionizing semiconductor atoms and thus creating free charge carriers. The resulting electron (-)-hole (0) pairs increase the current flow, the value of which provides information on the energy spectrum of the incident particles. When comparing semiconductor detectors with gas-filled ionization detectors, their advantage is ten times less energy (2.96eV-Ge) required to create one ion pair, resulting in their higher resolution. Compared to scintillation detectors, they have significantly more accurate energy resolution and significantly (20x) higher sensitivity (Picture 1).

Picture 1 The principle of the semiconductor detector (SD) - a comparison of the energy spectrum from a semiconductor detector shows a significantly higher resolution compared to the spectrum from a scintillation detector (1).

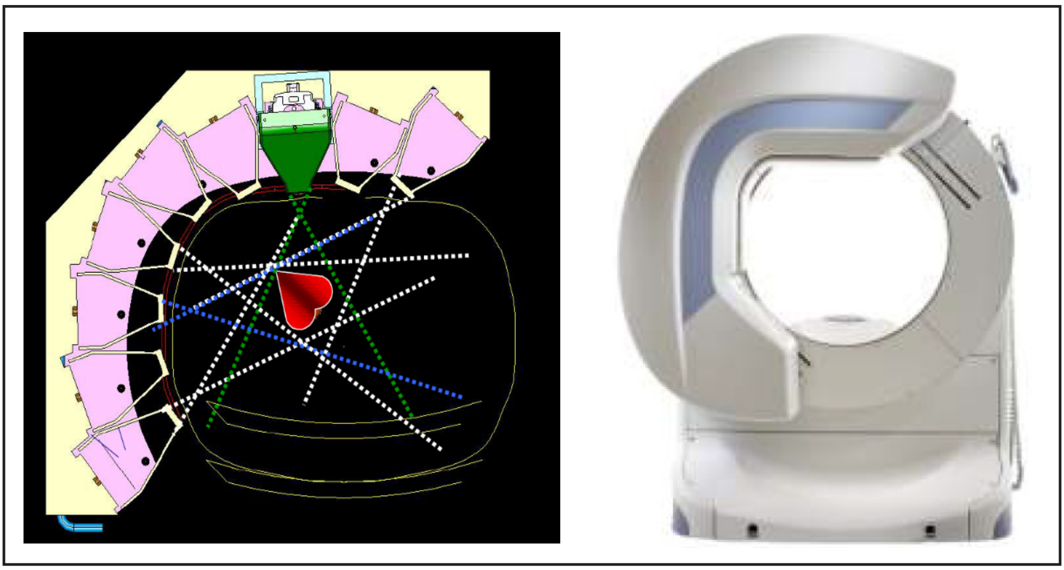


Cadmium-Zinc-Telluride semiconductor detector:

- electric current is transmitted by a pair: electron-hole,
- one semiconductor detection unit corresponds to one hole on the collimator (**pinhole**), one image point (pixel),
- the detector is arranged in a semicircle, without rotation,
- sensitivity increases (4x) and resolution improves (4).

Cardio camera "Discovery CZT 530c" has a semiconductor detector of ionizing radiation. In digital semiconductor gamma cameras with direct conversion of gamma radiation, one hole on the collimator (pinhole) corresponds to one detection unit of the semiconductor and also to one resulting image point (pixel). This design principle practically corresponds to the old multi-detector gamma cameras, which had high sensitivity and low dead time. The difference is that the spatial resolution of the new semicon-

Picture 2 Cadmium-Zinc-Telluride semiconductor detector (5)



ductor cameras (given by one pixel) is 2.5 mm, which is 5-10 times better than that of multi-detector cameras and almost 2 times better than that of scintillation cameras of a classic design, see Picture 2 (6).

Cardiology tomographic gamma camera „Discovery CZT 530c"

Special gamma cameras for cardiology use (SPECT) take advantage of the fact that the heart is a relatively small organ that does not require a large detector. Initially, they were just a downsizing of standard instruments (which achieved a reduction in price) (5). However, new semiconductor systems with new type detectors have significant design deviations (Picture 3):

- A larger number of (new type) solid semiconductor cadmium-zinc-telluride (CZT) detectors, arranged in a semicircle, without rotation around the patient during scanning, simultaneously scanning from multiple angles.
- The entire detection process takes place simultaneously and not sequentially, as with classic SPECT, dynamic recording can also be performed.
- Semiconductor detectors CZT (Cadmium-Zinc-Tellur) significantly increase the sensitivity of detection, the result is a reduction of the detection time, a reduction of the applied activity and thus of the effective dose.
- The duration of the examination was reduced from 15 minutes to 5 minutes.
- Speeding up the examination, thereby increasing work efficiency.
- Higher sensitivity (4x) for standing detectors, ensures better resolution.
- Reduction of the radiopharmaceutical dose (radiation load for the patient by 50%).
- More accurate evaluation of hemodynamic parameters.
- Possibility of dynamic scanning in 3D projection.
- A more valid result when compared with coronary angiography (7).

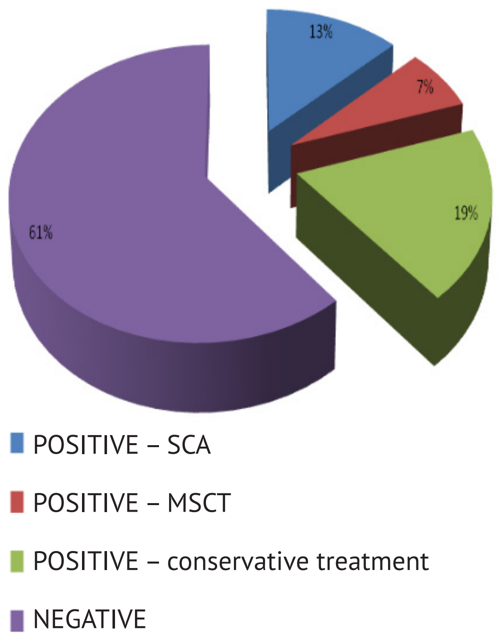
A set of examined patients

During the years 2003-2016, we performed myocardial perfusion scintigraphy on a gamma camera Millenium ,VG Hawkay f. GE in 18,000 patients. We analysed a set of 4,270 individuals examined in the years 2014-2016, who were examined by myocardial perfusion scintigraphy. In this group, there were 61% negative findings and 39% positive findings. Of the number of positive findings, conservative treatment was recommended in 19%, MSCT coronary angiography in 7% and SCA in 13%. The sensitivity was around 95% and the specificity around 92%. (Graph 1).

Over a period of two years, in the period 2019-21, we performed myocardial perfusion

Picture 3 Discovery NM CZT 530c f. GE (Nuclear Medicine Clinic at Central Military Hospital Ružomberok SNP – FN)

Graph 1 Analysis of a set of 4,270 patients with negative and positive findings

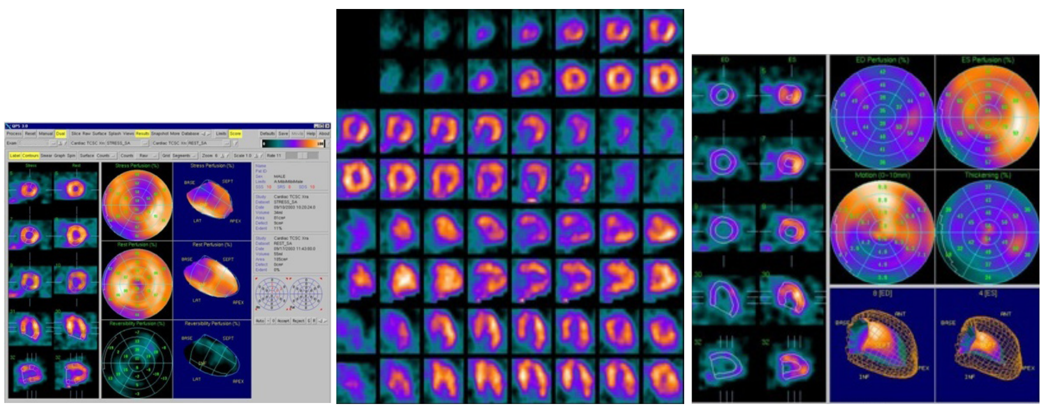


scintigraphy in 2,900 individuals on a cardiology gamma camera CZT 530c f. GE.

Here we found negative findings in 49% of individuals and positive findings in 51% of individuals. Of the positive findings indicative of coronary heart disease, we recommended coronary angiography for 24% of the examined patients, namely MSCT for 13% and SCA for 11% of individuals. For the remaining 27% of the examined patients, medical treatment was recommended (Graph 2). In the group of patients examined by coronary angiography, normal coronary angiographic findings were found in 2% of individuals.

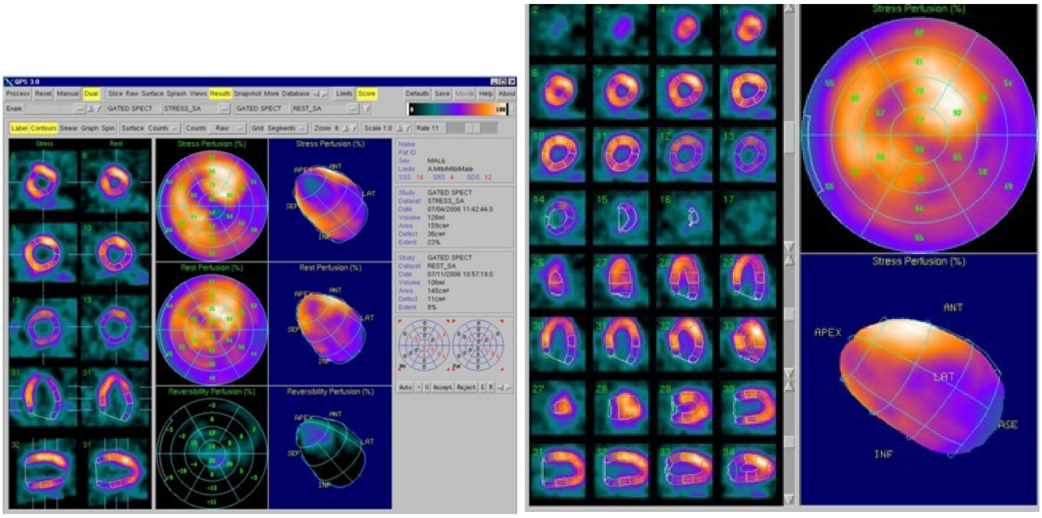
We statistically evaluated the significance of the capture of positive findings between the Hawkae gamma camera and the CZT 530c cardio camera using a test of relative values, a so-called z-test. The test showed a statistically significant difference in the capture of positive findings between the Hawkeye gamma camera (39%) and the CZT 530c cardio camera (51%) at the level of significance $p > 0.00001$.

Figure 1 SPECT-SCA (1947): overcome nonSTEMI, exertional stenocardia, poor tolerance to physical exertion.



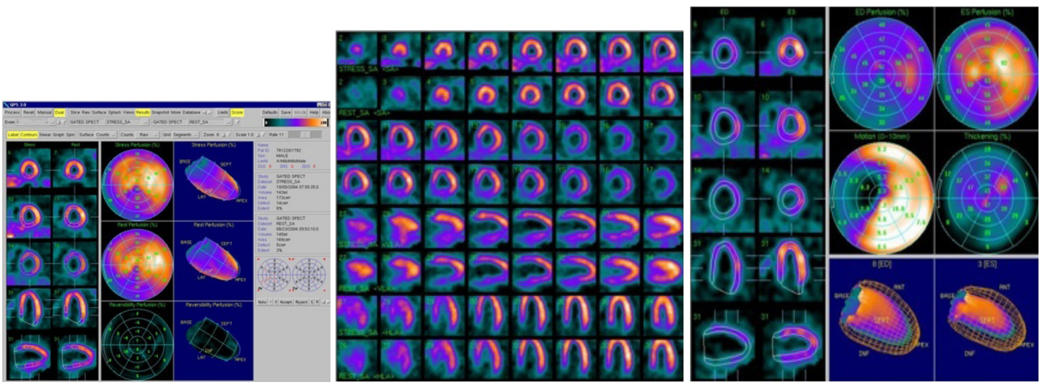
ECG during exertion, ascending depression of ST I, aVL.
Scintigraphy 99mTcMyoview: hypoperfusion (ischemia) on the front wall during exertion - top right, in the middle - at rest, bottom - reversed perfusion). The image on the right shows the individual sections of the LV. In the bottom image, in the upper part, perfusion in end-diastole and in end-systole,
Bottom left - evaluation of LV kinetics - hypokinesis of the lower LV wall and bottom right - violation of LV wall thickening
SCA: RIA 95% stenosis, PCI on RIA with imp. stent

Figure 2 Positive scintigraphic finding in a diabetic- left above after exertion, below at rest, with signs of silent ischemia on the side wall.



ECG and ECHO-CG normal.
SCA: 70% narrowing RCX, implanted stent. Left before treatment, right after treatment.

Figure 3 A healthy athlete (1976) sudden resting stenocardia



Ecg elevation of ST II, III, aVF, acute lower STEMI,
Urgent SCA without changes.
Scintigraphy 99mTc Myoview signs of hypoperfusion (ischemia) on the lower wall, with a kinetic disorder in the area of the septum (bull´s eye and individual sections). ECG already normal.

Conclusion

A scintigraphic examination records changes at the molecular level, allowing timely recording of changes in coronary flow in the area of microcirculation. It is very important in screening at-risk individuals. From a holistic point of view, however, it also includes the need to focus on the ability of the management of healthcare organizations to work with the obtained information and make the right decisions (8). With a negative coronary angiographic finding, with a positive clinical picture, a scintigraphic finding may record changes at the level of small vessels, "small vessels disease". In some cases, on the contrary, we can save the patient from invasive coronary angiography. A New type of cardio gamma camera “Discovery NM CZT 530c f. GE”, enables speeding up of examinations and increases the sensitivity and specificity of the examination. At the same time, it reduces the dose of the radiopharmaceutical, thus reducing the radiation burden of patients by 50%. During the assessment, it allows for a better evaluation of the hemodynamic parameters. The result is more valid when compared with coronary angiography.

References

1. LEPEJ J, LACKO A (2018) *Nuclear medicine* 1,2,3. Košice: Equilibria, 2018.
2. LEE B, FICARO E (2016) *Methods for the Estimation of Myocardial Blood Flow and Coronarary Flow Reserve with 99mTc SPECT in Corridor 4DM*. Invia Medical Imaging Solutions, 2016.
3. CREA F, LANZA A G, CAMICI P G (2014) *Coronary microvascular dysfunction.* Springer-Verlag Rome 2014. p256.
4. WELLS R G, TIMMINS R, KLEIN R et al. (2014) Dynamic SPECT meassurement of absolute myocardial blood flow in a porcine model. In *J.Nucl.Med*. 2014,Oct; 55(10): 1685-91.
5. MIGNERONE A (2014) Low dose and Fast exams are a win discovery NM 530c.for patients and clinicians alike. In *GE*, 2014.
6. UDELSON E J, DILSIZIAN V, BONOW O R (2015) *Nuclear cardiology*.p.293-339. In: Braunwalds heart disease. A textbook of Cardiovascular Medicine.2015.p.2021.
7. WILLEY CH (2009) *Improving productivity, patient comfort, and dose management were the big driving factors for purchase of the Discovery NM* 530c.GE, 2009.
8. JANKELOVA N, CZARNECZKI P (2021) *Managerial Knowledge and Skills in the Practice of Healthcare Managers 1st Edition*. - Warsaw: Collegium Humanum - Warsaw Management University, 2021. 171 p.