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ORIGINAL PAPER

Dedicated computer software to radiation dose optimization for the staff performing nuclear medicine procedures

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Abstract. Nuclear medicine techniques allow physicians to observe and diagnose physiology of chosen organs as well as the whole body of a patient. This visualization is possible not only because radioisotopes are applied, but there is also a significant progress in the computer software possibility. The advantage of the cooperation between medicine and informatics can be implemented in the radiation protection field of medical staff. The presented computer software, so-called Optimizer, was dedicated to the medical staff responsible for radiopharmaceutical preparation. It is known that the doses obtained in the nuclear medicine "hot labs" can be higher in comparison with the doses obtained by the rest of the personnel in the same department. The main advantage of the presented program is that the time needed for radiopharmaceutical preparation can be shortened and, as a result, the doses absorbed by personel can be reduced. The information of the volume containing planned radioactivity at the time of the application can significantly reduce the number of checking (volume and radioactivity), which normally takes place before the final handing over the radiopharmaceutical to the application. A user-friendly interface provides control at each step of the preparation protocol. For the convenience of medical staff all current examinations were coloured in one of the three colours: red (an application has to be done now), yellow (waiting) and green (done). The Optimizer was created for the Nuclear Medicine Department in the 5th Military Hospital in Kraków (Poland). What is more, currently it is successfully used and final TLD (thermoluminescent dosimetry) tests have been performed.

Key words: dose optimization • nuclear medicine • radiation protection

Introduction

Nuclear medicine uses imaging techniques to observe proper or pathological physiology of various human organs. To make this visualization possible, radioactive isotopes connected with ligands – known as radiopharmaceuticals, have to be administered to the patient [3]. Each application of radiopharmaceutical is proceeded by its suitable preparation. As a result, the medical staff working with radioisotopes is continuously exposed to the ionizing radiation. Moreover, the major value of an absorbed dose is observed for the staff working in the "hot labs" [2]. The dose overestimation mostly derives from the radiopharmaceutical's preparation protocol. The daily procedure contains a few (for an advanced employee) or many (for a beginner employee) volume and radioactivity verifications before the final handing over to the application. What is more, the time of radiation influence on the workers is lengthening and, as a result, the value of the absorbed radiation dose increases.

A radiation dose optimization could be performed by reducing preparation steps through real time estimation of radiopharmaceuticals' radioactivity dynamic changes in time. It is important to remember that the radioactive isotopes constantly undergo a radioactive

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decay process [6]. Additionally, the main problem is to estimate the volume containing a desired isotope activity at the time of application. The solution was found by COMECER (a manufacturer) producing a chamber for PET (positron emission tomography) preparation of radioisotopes. This chamber with an automatic dispenser provides a precise radiopharmaceutical preparation. It is required to deliver only the proper radioisotope, read in information about radioactivity in the specified volume and the time when it must be ready for the application. The dedicated computer software calculates the volume of the radiopharmaceutical and the volume of the physiological solution which must be taken into a syringe before application. The syringe is filled automatically, that is why the high precision is assured. For a PET diagnostics, it is obligatory to have "automatic time synchronization", because of the short half-time of radiopharmaceuticals. In SPECT (single photon emission computed tomography) this synchronization is not available as it is not so important from the patient's point of view (longer radiopharmaceutical half-time). However, it is important for the radiation protection of the medical staff [2]. That is why, dedicated computer software to accelerate the preparation process based on the real calculation time of radiopharmaceuticals' volume was designed and created.

Materials and method

The whole process of radiopharmaceutical preparation is based on several important steps. The first one is to receive the eluate, which is generated by a special radioisotope generator (e.g. ^{99}Mo-^{99m}Tc generator) (e.g. produced by POLATOM, Świerk, Poland), containing a predetermined radioisotope (e.g. ^{99m}Tc) activity. In the next step the eluate has to be divided into portions and connected with proper ligands (different for head, heart, kidneys etc. diagnostic). The number of portions depends on the examination type performed during the day. Finally, the radiopharmaceuticals (ligand + radioisotopes) in each group are portioned and, after final radioactivity checking, administered to the patients.

During the whole preparation process, the medical staff is exposed to ionizing radiation. Each day the personnel makes "K" procedures (1) including preparation and portioning of radiopharmaceuticals.

$$K = N + M \tag{1}$$

where: N – number of prepared radiopharmaceuticals; M – number of examinations.

Increasing the value of K-factor leads up to radiation dose growth. What is more, each examination is preceded by an effort to obtain the desired radiopharmaceutical activity in a suitable volume by making as few trials as possible. For the advanced medical staff, only a few radioactivity checkings are required. Unfortunately, usually the number of preparation verifications is more than five and, as a result, the dose level increases. The permissible deviation from the expected activity value is $\pm 10\%$.

The main goal of this work was to create the software which could ensure that the sum of volume estimation is equal to the sum of the preparation and portioning number. This situation is almost impossible to be obtained without application of a support.

The program, so-called Optimizer, was designed for Windows platform [4]. The application was written in C# programing language based on NET 4.0 framework. The support for a database was provided by NHibernate framework to make the software more flexible in usage with different (already existing in hospitals) database systems. NHibernate is an ORM (object-relational mapping) framework for NET platform. It supports the following database systems: Microsoft SQL Server 2000/2005, Oracle, Microsoft Access, PostgreSQL, MySQL, Firebird, DB2 UDB, SQLite, and is implemented in the application by default after the installation. It is planned to create a version for Linux/Unix systems.

The data flow diagram is shown in Fig. 1.

Results

Work with Optimizer is preceded by the user verification. Login and a password are assigned to each

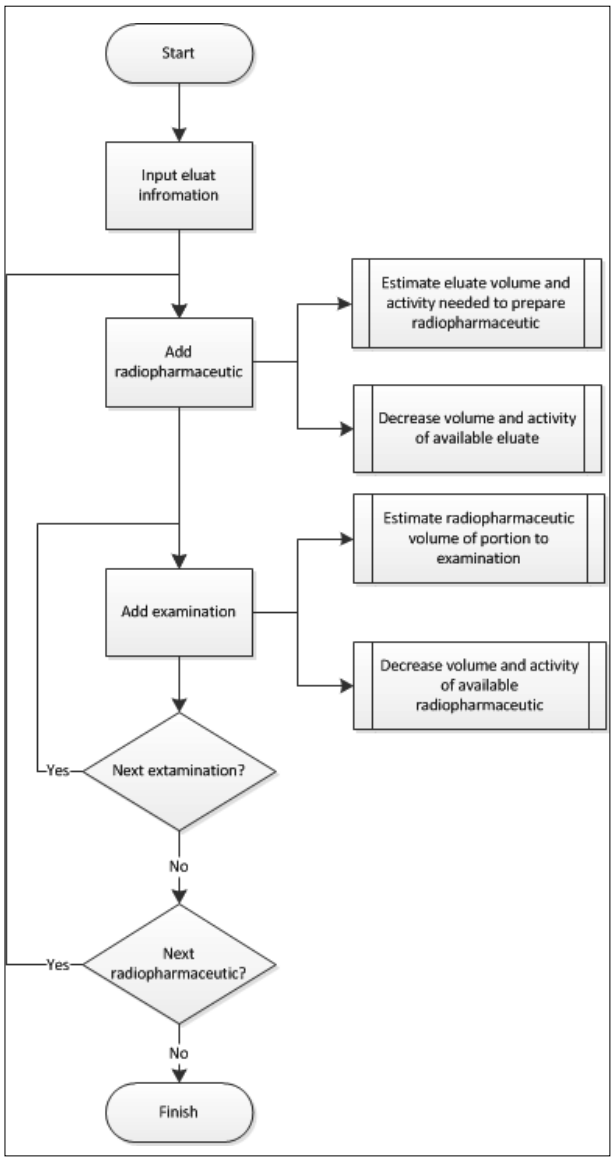

Fig. 1. Data flow diagram.

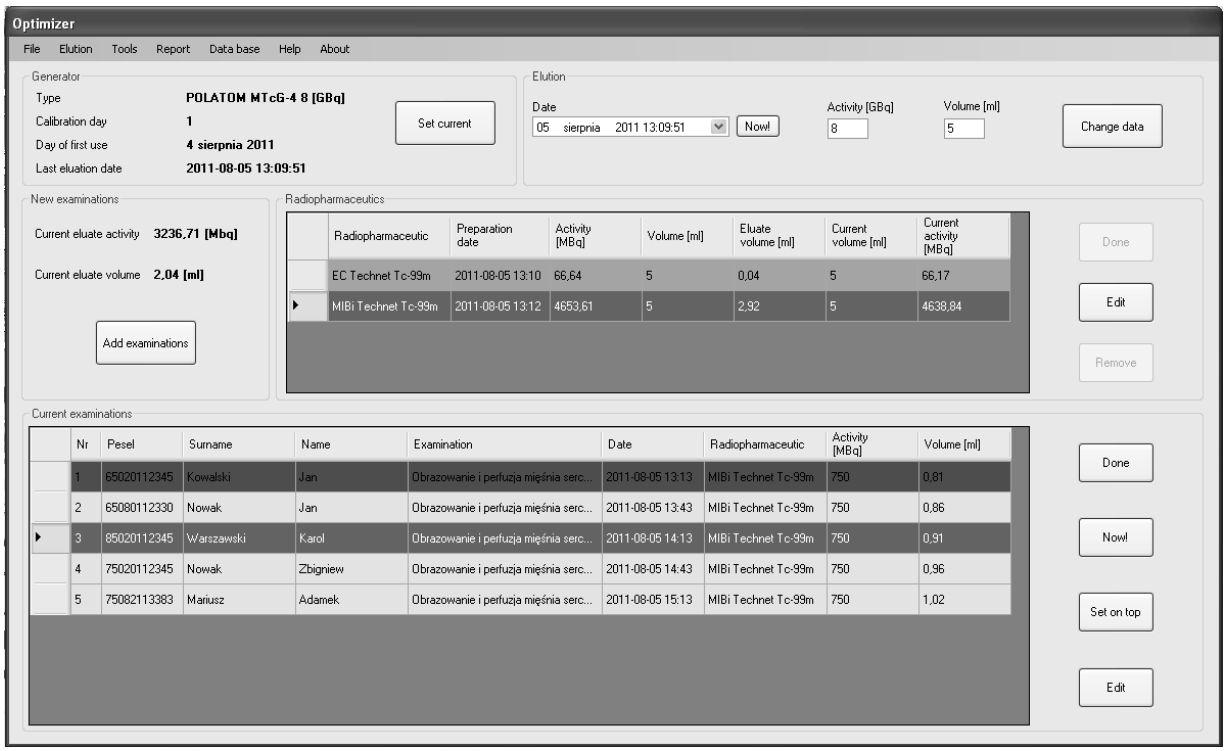

Fig. 2. Main window.

worker not only for the data security, but also for the individual radiation dose estimation. After getting access to the program, the user is transferred to the main window (Fig. 2). The latter is divided into five sections containing information about: the generator, elution process, new examinations, radiopharmaceuticals, and current examination. It is important to remember that all information provided by the users is the basis for all calculations which are taking place in the presented application. Therefore, it has to be entered as carefully as possible.

In the generator section it is required to enter information about a generator type (it can be taken from the list provided by the program administrator), the day of calibration and the date of the first use. As a result, the medical staff has the possibility to work with the same application while using generators produced by different manufacturers. The information about the calibration day and the day of the first generator use, gives the possibility to plan properly procedures which can be done during a day. After the approval, all the entered data are shown in the left corner of the main window. Changing of data can be done by a special button *Set current.*

In the second section (Fig. 2), the elution data such as the hour, activity and eluate volume must be provided. These data are obligatory, because they are the basis for all other operations connected with time decreasing of the activity in the constant volume of eluate. According to this, it is required to enter as precise data as possible to get the most accurate results. A special button *Now* is available to set up the current date and hour (taken from the computer system).

In the next step, information about new examinations to be conducted in the current working day and radiopharmaceuticals which should be prepared has to be set. Because of a strong connection between examinations and radiopharmaceuticals, the process of adding both of them takes place at the same time. To enter this section a button *Add examinations* has to be used and, as a result, a new window is opened (Fig. 3). It looks similar to the main window. The division into sections can be observed. Firstly, the data connected with radiopharmaceuticals (e.g. the name, volume, date/hour of preparation, desired activity) have to be provided. After the above information is accepted, it is possible to add the type of examinations based on the currently added radiopharmaceuticals. For each new examination, it is necessary to provide information about the patient – the name, the desired radioactivity, the date/hour of the examination (optionally the patient could be chosen from a list). All examinations are automatically sorted within one hour and after that each addition is checked if there is enough eluate to prepare radiopharmaceutical and, if there is enough radiopharmaceutical to carry out all examinations. After the approval of all information shown in the examination's window (Fig. 3), the user is transferred to the main window.

In the main window (Fig. 2), in the new examination section, information about the available activity and volume is shown. It is helpful when the decision about additional procedures must be taken. The information about radioactivity of the radiopharmaceutical is changing in time according to the progress of the decay process. In the radiopharmaceutical section the prepared radiopharmaceuticals are presented.

The last but not the least section connects information about current examinations. One can see patient's data as well as information about the radiopharmaceutical prepared for them, type of procedure, required activity and volume which must be taken at the acquisition time. For the convenience of the staff's, all displayed information has one of the three colours: green, yellow or red. A green colour is connected with

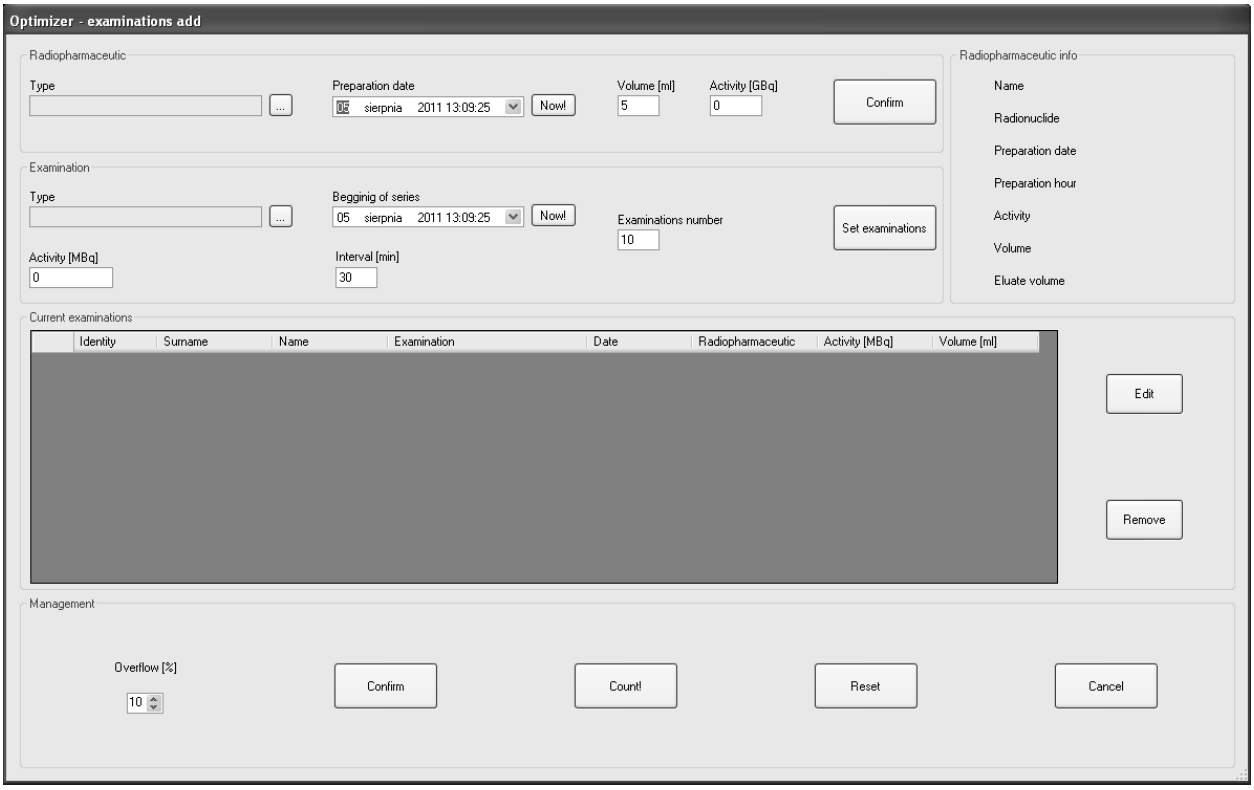

Fig. 3. Information of examination.

the carrying out examinations. This colour is displayed after the radiopharmaceutical application to the patient and after clicking the button *Done* by the staff. Yellow colour indicates all examinations that are waiting. Red one reminds that this procedure should have already been done by now. Because of the work specificity, it is possible to change the procedure order (a button *Set on top*) or even recalculate data for the examination which is delayed (a button *Now*) – automatically, all other examinations would be recalculated as well.

After work, a daily report (Fig. 4) can be generated.

Conclusion

Dose optimization for medical staff working with radioisotopes, especially in the "hot labs", is the main goal of this study. To carry out this project a new dedicated computer software was created. The optimization was based on a few levels.

First, the preparation and portioning processes were supported by automatic computer calculations. The necessary volume of radiopharmaceuticals as well as the time of their application is shown. The values of radioactivity calculated by the program were compared with the experimentally data obtained during obligatory measurements (using Atomlab100 Dose Calibrator). The staff responsible for radiopharmaceutical preparation can be present in the laboratory only for a few minutes before the preparation, because all necessary information is known (e.g. the volume which should be taken to obtain the required radioactivity, and the exact examination time).

The second one is connected with the radioactive waste reduction. Optimizer provides two ways of calculations. The first one (standard) is based on the information about radiopharmaceutical activity set by the staff. In this case the software can automatically estimate the maximum number of examinations which can be done. In the second one (optional), where the activity of radiopharmaceutical is not set by the user, all calculation are based on other information about examinations, e.g. the number of patients, the standard radioactivity required for selected protocols. Each way provides different benefits. When the work schedule is full and the precise examinations number is known, the first type of calculations is recommended. Moreover, it is more flexible for a possible delay or a cancellation of an examination. Unfortunately, the cancellation of the examination may generate an increase in the radioactive waste. The second type of calculations is less flexible for any changes in the work schedule, but it always generates radioactive waste as low as possible. Additionally, the activity can be calculated with an overflow option, which can be treated as a backup in the case of unplanned examinations.

The next level of dose optimization is connected with the time which the personnel spend in the "hot labs". To achieve this goal the application is equipped with a graphical user interface (GUI) to make the work easier and faster. Most operations are performed in the main application window. When the connection with the existing hospital database is provided, much of the necessary information is available after adding the name of the patient to the list. As a result, the time needed for filling in all information is shorter, and the absorbed dose decreases. Additionally, an automatic day report generation reduces the time needed for writing the day report.

The presented program is not free from disadvantages. Mostly they come from independent factors. The

first one is connected with the lack of ability to get the exact eluate volume from the generator. A manufacturer provides only a few volume which can be obtained. What is more, the precision of this manual device is not as good as expected. From everyday practise, it is known that the eluate volume is always different from the required one. The information about the volume and activity eluted from the generator is the basis for the program calculation. As a result, the eluted activity is not sufficient or the radiation waste is bigger than expected.

The second one is connected with the difference between the radioactivity volume suggested by the program and this one which can be obtained by the staff in the syringe. Even the smallest one has a scale not as precise as required by the program calculation. Additionally, the personal abilities play an important role. Fortunately, despite the fact that the uncertainty

Daily report

Generator

Name	Activity [GBq]	Day of first use	Calibration day
POLATOM MTcG-4	8	2011-08-04	1

Eluate

Date	Activity [GBq]	Volume [ml]	Waste [MBq]
2011-08-05 13:09:51	8	5	3247,01

Radiopharmaceutics

Name	Date	Volume [ml]	Eluate volume [ml]	Activity [MBq]	Background	Waste [MBq]
EC Technet Tc-99m	2011-08-05 13:10:00	5	0,04	66,64	10	6
MIBi Technet Tc-99m	2011-08-05 13:12:00	5	2,92	4653,61	10	335,26

Examinations

Patient	Date	Examination type	Radiopharmaceutic	Activity [MBq]	Volume [ml]
65020112345 Kowalski Jan	2011-08-05 13:13:00	Obrazowanie i perfuzja mięśnia sercowego lewej komory	MIBi Technet Tc-99m	750	0,81
71021101365 Waszkawka Zbigniew	2011-08-05 13:15:00	Badanie opróżniania żołądka	EC Technet Tc-99m	60	4,55
65080112330 Nowak Jan	2011-08-05 13:43:00	Obrazowanie i perfuzja mięśnia sercowego lewej komory	MIBi Technet Tc-99m	750	0,86
85020112345 Warszawski Karol	2011-08-05 14:13:00	Obrazowanie i perfuzja mięśnia sercowego lewej komory	MIBi Technet Tc-99m	750	0,91
75020112345 Nowak Zbigniew	2011-08-05 14:43:00	Obrazowanie i perfuzja mięśnia sercowego lewej komory	MIBi Technet Tc-99m	750	0,96
75082113383 Mariusz Adamek	2011-08-05 15:13:00	Obrazowanie i perfuzja mięśnia sercowego lewej komory	MIBi Technet Tc-99m	750	1,02

Note

Personnel note	Doctor note

Daily report - 2011-08-05

Fig. 4. Daily report.

Table 1. Number of checking needed to achieve the planned radioactivity (with and without "Optimizer" support)

Medical staff (ID[a])	Number of radioactivity checkings	
	without "Optimizer"	with "Optimizer"
1	5	4
	6	4
	4	5
	5	3
Average	5.00	4.00
SD[b]	0.41	0.41
2	3	3
	4	3
	3	2
	3	2
Average	3.25	2.50
SD	0.25	0.29
3	6	3
	7	6
	5	4
	7	4
Average	6.25	4.25
SD	0.48	0.63
4	3	2
	3	4
	4	2
	3	3
Average	3.25	2.75
SD	0.25	0.48

[a] ID – identification number.
[b] SD – standard deviation.

of prepared activity is less than 10%, it can be accepted in the normal clinical practice.

Nowadays, the application has been tested in the Nuclear Medicine Department of 5th Military Hospital in Kraków. The verification process has been conducted in a few steps. First, it was checked if all data were correctly entered to the database system and if all calculations were precise. Secondly, the coincidence between values proposed by the program and measured by the staff (in Atomlab100 Dose Calibrator) was defined. Additionally, in a daily practice, the correctness of the program's calculations is constantly verified by simultaneous measurements done with Atomlab100 Dose Calibrator. This is an obligatory procedure according to the Polish law [1, 5]. Next, the number of radioactive checkings in Atomlab100 with and without using "Optimizer" were compared. Selected results of that comparison are shown in Table 1. Presented data were obtained for four persons (with different level of experience) preparing one (the same) radiopharmaceutical four times. The biggest benefits are observed for inexperienced medical staff.

Working with the software increases the speed of the preparation process by reducing the number of radioactivity checking and, therefore, the time spent in the vicinity of the radioactive sources has been minimized. As a result, the absorbed dose level may be reduced. It has been continuously verified by simultaneously done TLD (thermoluminescent dosimetry) measurements. The dosimetric data will be obtained at the beginning of the year 2012 and published as soon as possible.

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