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Short Communication

Python software for patient exposure analysis in radiology

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Abstract

Introduction: The values describing the patient's exposure in X-ray diagnostics and interventional radiology should be compared with several independent criteria: diagnostic reference levels, dose levels associated with potential unintended exposure, and dose levels requiring specific action in interventional radiology. Radiation dose monitoring software (RDMS) is not always available, and may not perform all the tasks or cover all radiological devices. The aim of the work was to create software that would allow the analysis of dose data from various sources.

Material and Methods: Python programming language was chosen due to the availability of libraries enabling access to information stored in DICOM files (pydicom, rdsr-navigator) and data analysis functions (pandas). The software was created, able to import data from various sources (Excel files, DICOM files, RDSR dosimetry reports), reject data based on the indicated criterion, multiply selected numerical data by the indicated factor, compare dose information with preset criteria (including diagnostic reference levels), and create summary reports. Data describing how to analyse data from a specific source has been placed in easy-to-modify external configuration files (Excel spreadsheets). The results of the dose analysis are saved in Excel spreadsheets.

Results: The software was tested on DICOM files from mammography and radiography devices (obtained from PACS), RDSR dosimetry reports from interventional radiology units (obtained from PACS or exported directly from the radiology device), Excel files with data exported from a commercially available RDMS system. It has been confirmed that it is possible to change the data analysis method (e.g. add a new radiological device) by modifying the configuration file without changing the program code.

Conclusion: The software allows users to analyse patient exposure data from various sources, compare it with different dose levels, and prepare reports useful in internal clinical audits.

Keywords: dose monitoring; diagnostic reference level; unintended exposure; Python.

Introduction

The total effective dose received by a statistical resident of Poland in 2023 was 4.36 mSv.[1] About 2.55 mSv came from natural sources, and the remaining 1.81 mSv was primarily related to medical diagnostics. The number of radiological devices and examinations is constantly growing.[2]

The relationship between the dose and the probability of stochastic effects is assumed to be linear and non-threshold (LNT); therefore, even a low radiation dose is treated as potentially harmful.[3] Medical use of ionising radiation should be justified and optimised. In diagnostic imaging, the dose should be limited to the lowest level sufficient to obtain the desired information (ALARA, as low as reasonably achievable). At the same time, it should be emphasised that no limits are set to medical exposure for patients. However, there are rules requiring recording doses and taking action in the event of exceeding certain dose levels.[4]

One of the tools used to optimise patient exposure is diagnostic reference levels (DRL), which are dose levels for typical examinations for groups of standard-sized patients.[3-5] The national reference levels are usually determined as the third quartile of the median doses obtained at many radiological centres.[5,6] The national diagnostic reference levels are specified in Poland in the regulation of the Minister of Health.[7] Typical patient exposure levels in individual radiological procedures are compared with the reference levels during internal clinical audits carried out in Poland at least once a year.[8] In addition, the doses received by patients should be regularly monitored to detect unintended exposures. Unintended exposure is medical exposure significantly different from intended for a given purpose, e.g., unusually high or low.[4] Unintended exposure can

Authors' contribution:
A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article.

be suspected if the dose is exceeding four times the reference level.[9]

It is assumed that doses obtained in radiological diagnostic examinations may cause stochastic effects, i.e., cancer induction. In interventional radiology, the dose to the skin may reach a level of several Gy, and tissue reaction is possible (e.g. skin erythema). Therefore, there are rules requiring the monitoring of dosimetric values related to the size of the dose to the skin. If the dose exceeds certain levels, specific actions are necessary (the dose should be recorded, and the patient should be monitored).[9-11]

To summarise, the values describing the patient's exposure in X-ray diagnostics and interventional radiology should be compared with several independent criteria: diagnostic reference levels, dose levels associated with potential unintended exposure, and dose levels requiring specific action in interventional radiology. Some criteria are assigned to a particular radiological procedure (diagnostic reference levels), and some apply to all exposures of a particular modality (dose levels in interventional radiology). Some comparisons may be performed periodically/retrospectively (comparison of doses with reference levels), and some should be done continuously (in Poland, unintended exposures must be reported to an external authority within seven days).[7-10]

Radiation dose monitoring software (RDMS) is a proper tool for accomplishing the abovementioned tasks.[12,13] Unfortunately, not every RDMS system can perform all the tasks. In addition, the dose monitoring system in our centre does not cover all radiological devices. Therefore, the analysis of dose information from different radiological devices in our centre was performed in other ways. Various data sources were used, including data exported from the RDMS, DICOM images downloaded from the PACS server, and Radiation Dose Structured Report (RDSR) files acquired directly from the radiological device (C-arm in the operating theatre). Some analyses were performed manually using Microsoft Excel, and some with short Python scripts.

The aim of the work was to create software that would allow the analysis of dose data from various sources in an identical way.

Material and Methods

It was decided that the software should perform the following functions:

- importing selected data from Excel files, DICOM files and RDSR dosimetry reports;
- rejecting data based on the indicated criterion;
- multiplying selected data by the indicated factor;
- comparing dose information with preset criteria, including diagnostic reference levels;
- creating summary reports of the number of examinations, exposures, dose statistics, and exceedances of reference levels in individual radiological procedures.

Python programming language (ver. 3.11.2) was chosen due to the availability of libraries enabling access to information stored in DICOM files and data analysis functions. The functionality of importing data from Excel files, DICOM files, and RDSR dosimetry reports was implemented using the *openpyxl* (ver 3.1.2), *pydicom* (ver. 2.3.1), and *rdsr-navigator* (ver. 0.3.1) libraries, respectively. Data analysis was primarily based on various functions of the *pandas* library (ver. 1.5.3), and the results are saved in Excel spreadsheets using the *XlsxWriter* library (ver. 3.0.9).

It was also decided that the software should be suitable for people without programming experience. Therefore, data describing how to analyse data from a specific source has been placed in easy-to-modify external configuration files (Excel sheets). The software was equipped with a simple graphical interface. Finally, the software was compiled into an executable file (*pyinstaller* library, ver. 5.9.0).

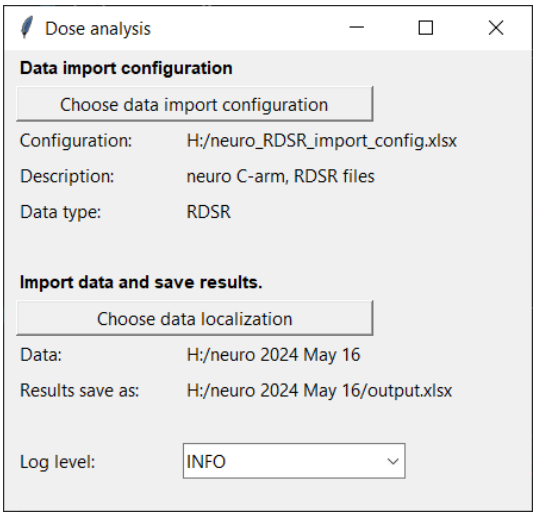

Figure 1. The software's graphical user interface (presented in English, routinely used in the Polish language version).

Results

The software requires minimal user interaction (**Figure 1**). In the first step, the user selects a configuration file (Excel sheet) that contains all the parameters describing the analysis method (one workbook for one analysis step or one radiological device). In the second step, the user chooses the location of the data to be analysed (e.g. a folder containing RDSR files). The software then performs the following actions (some of the steps are optional):

1. Data import:
   a. import from DICOM or RDSR: analysis of all files in the folder (including subfolders), automatic exclusion of non-DICOM or non-RDSR files, import of selected

DICOM fields (**Figure 2**), import of selected information from RDSR;

b. import from Excel file (exported from commercial RDMS system): open xlsx file (uncompress from zip file if necessary), import of selected columns, vendor-specific corrections (e.g. replacement of BMI values equal to -1 with "not a number").

2. Rename selected columns and multiply data in selected columns: this is used in radiography/fluoroscopy to convert dose-area product (DAP) units and in mammography to convert breast thickness units (**Figure 2**).
3. Skip selected cases (such as cases with "Series protocol name" equal to "Test").
4. Assign radiological unit (based on identifiers such as "AE Title" or "Station Name").
5. Assign examination procedure using a unit-specific dictionary (based on identifiers as "Series Protocol Name").
6. Based on the examination procedure, assign DRLs to each examination/exposure. DRLs in two or more dosimetric quantities may be simultaneously assigned (e.g., CTDI and DLP in computed tomography).
7. Compare doses with DRLs simultaneously for one or more DRL quantities.
8. Add "alarms" for doses larger than the given multiplication of DRL (currently set at four in accordance with Polish regulations[9]) and, simultaneously, for doses exceeding numerically set value (e.g. "Dose Area Product Total [Gy.cm2]" ≥ 170) (**Figure 3**).
9. Add statistics, including the number of examinations/exposures of various types (by gender), the average and quartiles of dose values, and the number of dose exceedances.

column	DICOM_fie	rename	multiply	comment
Study Date	(0008,0020)			
Study Time	(0008,0030)			
Station Name	(0008,1010)			
Study Description	(0008,1030)			
Series Description	(0008,103E)			
Protocol Name	(0018,1030)			
Organ Dose	(0040,0316)	Average Glandular Dose [mGy]	100	dGy -> mGy
Entrance Dose Inm Gy	(0040,8302)	Entrance Dose [mGy]		
Body Part Thickness	(0018,11A0)	Breast thickness (cm)	0.1	mm -> cm
Image Laterality	(0020,0062)			
View Position	(0018,5101)	View position		
Anode Target Material	(0018,1191)			
Filter Material	(0018,7050)			
Focal Spots	(0018,1190)			
KVP	(0018,0060)			
Exposure	(0018,1152)	Exposure [mAs]		
Exposure Inu As	(0018,1153)	Exposure [microAs]		
Compression Force	(0018,11A2)	Compression Force [N]		

Figure 2. Selection of data to import from DICOM files in mammography (part of the configuration file).

Finally, the analysis results are saved as an Excel file (**Figure 4**) and can be reviewed by a medical physicist.

The software was tested on DICOM files from mammography and radiography devices (obtained from PACS), RDSR dosimetry reports from interventional radiology units (obtained from PACS or exported directly from the radiology device), Excel files with data exported from a commercially available RDMS system. It has been confirmed that it is possible to change the data analysis method (e.g. add a new radiological device) by modifying the configuration file without changing the program code.

dose_data_column	analysis_per	DRL	alarm	alarm_DRL_mult	alarm_value	comment
DLP (mGy.cm)	series	yes	yes	4		DLP per phase/series
Mean CTDI vol (mGy)	series	yes	yes	4	120	CTDI per phase/series
Total DLP (mGy.cm)	exam					DLP per exam (in future?)
SSDE (mGy)	series					SSDE per series (in future?)

Figure 3. Analysis of doses in computed tomography (part of the configuration file). DLP and CTDI are compared with DRL on a per-series basis. An alarm is raised if the dose exceeds 4xDRL or CTDI exceeds 120 mGy.

KVP	Exposure (mAs)	BMI	Protocol name	DAP (cGy.cm2)	unit	exam_ty	DRL_DAP	DAP vs DRL	mult_DAP	alarm
125	1.2	22.1	Chest PA WD	7.9	Chest unit	Chest PA	15	OK		
125	3.7	22.1	Chest LAT WD	21.3	Chest unit	Chest LAT	50	OK		
53.4	6.1	23.7	T Extremity AP	9.2	General1	other				
53.4	5.5	23.7	T Extremity LAT	9.17	General1	other				
125	1.2	30.9	Chest PA WD	8.5	Chest unit	Chest PA	15	OK		
125	3.0	30.9	Chest LAT WD	17	Chest unit	Chest LAT	50	OK		
125	0.5	23.4	Chest PA WD	6.6	Chest unit	Chest PA	15	OK		
125	1.2	23.4	Chest LAT WD	7.6	Chest unit	Chest LAT	50	OK		
125	2.4	36.7	Chest PA WD	17.2	Chest unit	Chest PA	15	exceeded	1.15	
125	10.1	36.7	Chest LAT WD	69.5	Chest unit	Chest LAT	50	exceeded	1.39	
125	1.2	26.2	Chest PA WD	10.8	Chest unit	Chest PA	15	OK		
125	6.2	26.2	Chest LAT WD	35.2	Chest unit	Chest LAT	50	OK		
125	1.8	28.9	Chest PA WD	11.4	Chest unit	Chest PA	15	OK		
125	3.7	28.9	Chest LAT WD	21	Chest unit	Chest LAT	50	OK		
80.9	34.5	26.1	T Abdomen	244.62	General1	Abdomen	270	OK		

Figure 4. Results of data analysis for general radiography (selected columns). Dose statistics are saved in separate workbooks.

Discussion

The software automates repetitive data acquisition and analysis tasks, previously performed mainly by manually analysing data in Excel files and using simple, ad hoc modified Python scripts. It is currently regularly used in our centre. However, it is different from a fully functional radiation dose monitoring software. First, it does not communicate with radiological devices or a PACS server; it only analyses locally available data. Also, each analysis is carried out for one type of data, and the results of each analysis are saved in a separate Excel file. There is no automated way to combine data from different sources in one analysis (e.g. from an Excel file and set of RDSR files) or to combine results of several analyses (from various sources, from multiple periods).

Other limitations of the current software version include assigning information based on a single identifier. As an example, the procedure can be assigned based on "Series protocol name" but not on a combination of "Study protocol name" and "View position". Also, the RDSR files are not scanned for all radiation events; only the information on the whole procedure is retrieved (e.g., total DAP and total time of fluoroscopy). Data for all patients is analysed using the same criteria, with no possibility of dose criteria dependent on patient characteristics (BMI, breast thickness). In the future, the software may be further developed to overcome the limitations.

Two aspects of dose monitoring unrelated to specific software are worth noting. Firstly, the range of radiological procedures for which national diagnostic reference levels have been defined does not cover the range of procedures performed in Poland.[14,15] Typical CT scan at our centre covers the entire chest-abdomen-pelvis area. In contrast, the national reference levels refer to examinations of single anatomical regions (chest, abdomen and pelvis separately).[15] Secondly, examination protocols are often defined and named differently in different radiological devices and sometimes are inconsistently selected during the examination. In this case, it is difficult to correctly assign the radiological procedure (and DRL) to the study based on available data (e.g. the RDSR dosimetry report).[13]

Conclusions

The software allows users to analyse patient exposure data from various sources, compare it with different dose levels, and prepare reports useful in internal clinical audits. However, it is not equivalent to fully functional radiation dose monitoring software.

Editor's comment

The abstract of the work was submitted to the 18th Congress of the Polish Society of Medical Physics (held in Poznań, Poland, 19-21 September 2024). The authors of the work were invited by the Scientific Committee of the Congress and the Editor-in-Chief of the Polish Journal of Medical Physics and Engineering to present their work in the form of a Short Communication in the Journal.

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