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COMPUTED TOMOGRAPHY

National survey on dose data analysis in computed tomography

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Abstract

Objectives A nationwide survey was performed assessing current practice of dose data analysis in computed tomography (CT).

Material and Methods All radiological departments in Switzerland were asked to participate in the on-line survey composed of 19 questions (16 multiple choice, 3 free text). It consisted of four sections: (1) general information on the department, (2) dose data analysis, (3) use of a dose management software (DMS) and (4) radiation protection activities.

Results In total, 152 out of 241 Swiss radiological departments filled in the whole questionnaire (return rate, 63%). Seventy-nine per cent of the departments (n = 120/152) analyse dose data on a regular basis with considerable heterogeneity in the frequency (1-2 times per year, 45%, n = 54/120; every month, 35%, n = 42/120) and method of analysis. Manual analysis is carried out by 58% (n = 70/120) compared with 42% (n = 50/120) of departments using a DMS. Purchase of a DMS is planned by 43% (n = 30/70) of the departments with manual analysis. Real-time analysis of dose data is performed by 42% (n = 21/50) of the departments with a DMS; however, residents can access the DMS in clinical routine only in 20% (n = 10/50) of the departments. An interdisciplinary dose team, which among other things communicates dose data internally (63%, n = 76/120) and externally, is already implemented in 57% (n = 68/120) departments.

Conclusion Swiss radiological departments are committed to radiation safety. However, there is high heterogeneity among them regarding the frequency and method of dose data analysis as well as the use of DMS and radiation protection activities.

Key Points

- *Swiss radiological departments are committed to and interest in radiation safety as proven by a 63% return rate of the survey.*
- *Seventy-nine per cent of departments analyse dose data on a regular basis with differences in the frequency and method of analysis: 42% use a dose management software, while 58% currently perform manual dose data analysis. Of the latter, 43% plan to buy a dose management software.*
- *Currently, only 25% of the departments add radiation exposure data to the final CT report.*

Keywords Surveys and questionnaires · Patient safety · Radiation protection · Quality improvement · Computed tomography

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Abbreviations

AGFA	Actien-Gesellschaft für Anilin-Fabrication
ALARA	As low as reasonably achievable
CT	Computed tomography
DICOMSR	Digital Imaging and Communication in Medicine-Structured Report
DLP	Dose-length product
DMS	Dose management software
DRL	Diagnostic reference levels
FOH	Federal Office of Health
GE	General Electric
IT	Information technology
PACS	Picture-archiving and communication system
PET	Position emission tomography
SPECT	Single-photon emission computed tomography

Introduction

The radiation burden to the population due to medical imaging has been continuously growing since the 1990s, mainly caused by computed tomography (CT). In fact, the number of CT scans per 1000 inhabitants has increased by more than 2.5-fold in just 2 decades [1, 2]. In parallel to this increase, there is assumed to be substantial room for improvement regarding dose reduction as shown by recent studies, assessing radiation dose management of CT from different countries worldwide [3, 4]. To support the radiological community in radiation protection, various radiation awareness campaigns have been established over the last 10 years. Campaigns such as image wisely [5], image gently [6] or the EuroSafe Imaging Campaign [7] form the background and justification for the present study. Moreover, the importance of radiation safety was emphasised by the European Union in their latest directive (2013/59/Euratom), which contains basic safety standards for protection against the potential dangers from exposure to ionising radiation. The directive must be adopted by the member states as national law by 6 February 2018. Among other issues, the new directive includes recommendations and instructions to improve the justification and optimisation process in medical imaging [8, 9]. It requires the use and regular review of diagnostic reference levels (DRLs). Furthermore, radiological departments are obliged to register and record complete patient doses and relevant parameters from all procedures and need to ensure the transfer of this dosimetric information to the examination report [8–10]. Even though Switzerland does not belong to the European Union, the Swiss Federal Office of Health (FOH) decided to adopt the new directive and to include it in the recently revised ordinances on radiation protection [11]. To get an impression of how radiological departments in Switzerland are already prepared to answer the new legal provisions and what their status in radiation protection is, a nationwide survey was conducted. For that purpose, a questionnaire was designed assessing the process of registration, tracking, analysis as well as reporting of patient doses in CT, as required by the new ordinances, also having in mind the future goal to establish a Swiss dose registry. In contrast to other nationwide surveys performed so far, neither dose values nor CT protocols were evaluated [1].

Materials and methods

Nationwide survey

The survey was organised by the Swiss Society of Radiology in conjunction with the Swiss Society of Radiobiology and Medical Physics and the Swiss Federal Office of Health (FOH). The departmental heads of all public and private hospitals as well as out-patient practices in Switzerland that operated at least one CT scanner were contacted by email and asked to participate in the study. Nuclear medicine and radiation oncology departments with position emission tomography CT (PET-CT) scanners, single photon emission computed tomography CT (SPECT-CT) scanners or CT scanners for planning of radiation therapy were not included in the study. Participation was voluntarily.

Questionnaire

The email contained a link that directly guided the participants to the questionnaire (Appendix). Instructions as well as contact addresses for clearing any queries were given at the beginning of the questionnaire. The participation period lasted 1 month (mid August 2017-mid September 2017) and a reminder was sent out to all departments 2 weeks after the first contact. The questionnaire consisted of 19 questions, of which 16 were multiple choice and 3 free text. It was structured in four sections: (1) general information regarding the departments (e.g. number of CT scanners installed); (2) current practice of dose data analysis; (3) use of a dose management software (DMS), if applicable; (4) current activities to improve radiation exposure in CT. Data collection was performed anonymously.

Data analysis

Analysis was carried out by a board-certified radiologist with post-graduate education in quality management. Answers from the questionnaire were transferred to Excel spreadsheets and, if applicable, descriptive statistics (measures of frequency) were calculated using Microsoft Excel 2010 (Redmond, WA, USA).

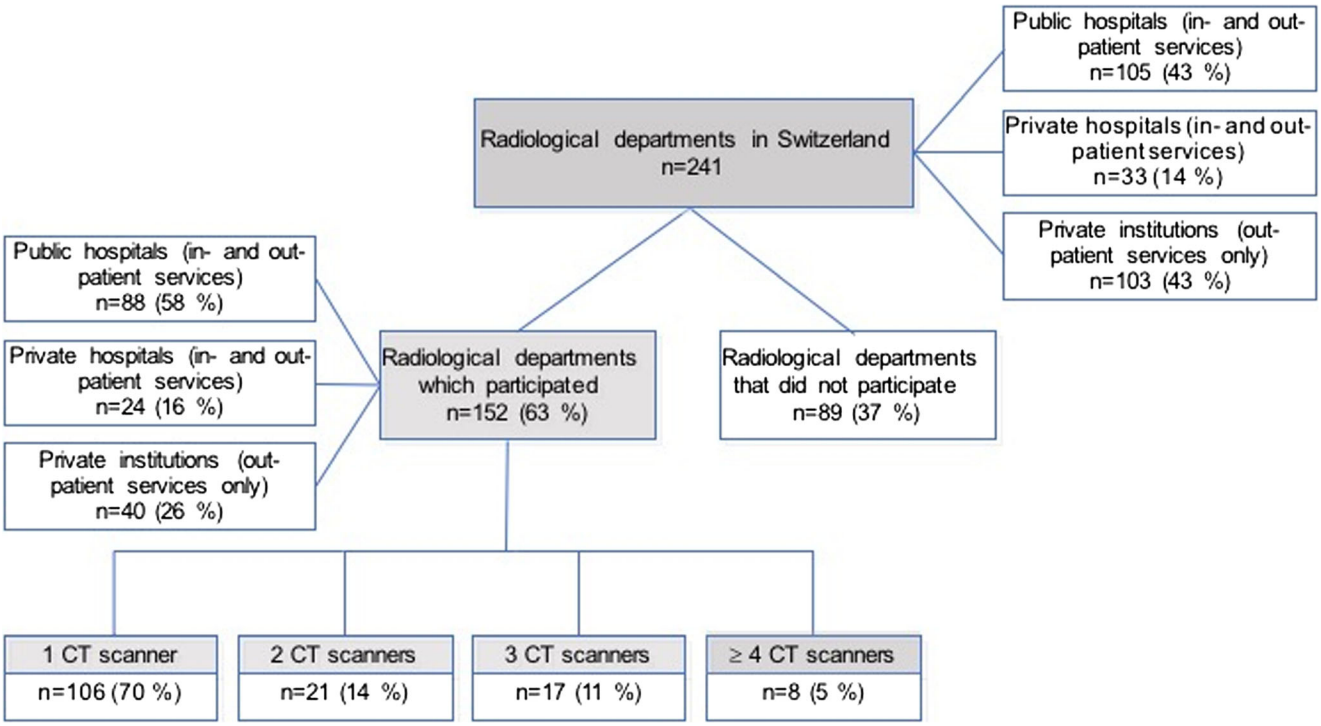

Fig. 1 General information on the radiological departments, including number of CT scanners installed: Participation rate in study was 63%

Results

General information on the departments is provided in Fig. 1.

Dose data analysis

Mainly two methods are currently used to collect dose data in CT: the first possibility is to store the Digital Imaging and Communication in Medicine-Structured Report (DICOM-SR), which contains the dose information, in the picture-archiving and communication system (PACS). The other method is to transfer the dose data to an external database, which in most cases is connected with software applications for data analysis. Almost half of the departments (49%, $n = 75/152$) apply both methods in parallel, while 40% ($n = 61/152$) only store data in the PACS, and in the remaining 11% ($n = 16/152$) of the departments other methods of dose data collection are carried out. Radiation exposure data are added to the final CT report in one quarter of the departments ($n = 38/152$), while 75% ($n = 114/152$) store data without providing it in the report, except if it is requested by the patient or referring doctor. Within the report, predominantly the dose-length product (DLP; 98%, $n = 37/38$) is given and less frequently the CT dose index for single series (36%, $n = 14/38$) and the effective dose (12%, $n = 5/38$) are also provided.

In addition to just storing the dose data, 79% ($n = 120/152$) of the departments also analyse exposition data on a regular basis, but the frequency of data analysis varies considerably between the different departments as summarised in Table 1.

In most departments such an analysis is done by medical physicists (68%) and to a lesser degree by radiographers (16%) or by the chief physicians/senior consultants (14%). The remaining 21% ($n = 32/152$) of departments indicated not analysing dose data on a regular basis for the reasons given in Table 2.

Use of a dose management software (DMS)

Current practice of dose data analysis in Switzerland, including the use of a dose management software (DMS), is summarised in Fig. 2. If a DMS is in place, dose data are evaluated at least monthly in $n = 26/50$ departments (once or twice per year, $n = 14/50$; 3-4 times per year, $n = 6/50$; 5-6 times per year, $n = 2/50$; 9-10 times per year, $n = 2/50$). In clinical routine, the DMS can be accessed in almost three-quarters of the departments ($n = 37$) by the chief physician/senior consultants, radiographers and

Table 1 Dose data analysis is executed once or twice per year by most departments. Thirty-two departments do not perform regular dose data assessment

Analysis per year	1–2 times	3–4 times	5–6 times	7–8 times	9–10 times	≥ 11 times
No. of departments	54 (45%)	18 (15%)	4 (3%)	0 (0%)	2 (2%)	42 (35%)

Table 2 Reasons given by the departments for why a regular dose data analysis is currently not carried out (only one answer per department possible)

Reason to not regularly analyse dose data	Number of departments
- Has no consequence for the department as dose exposure is already optimised according to ALARA	13
- Is an upcoming project	6
- Is too time consuming and expensive	6
- Is so far not possible/no dose management software	5
- Spot checks are performed occasionally	2

ALARA = as low as reasonably achievable

medical physicists, but only 20% (n = 10/50) of departments give residents the opportunity to monitor dose data in parallel to reading images (Fig. 3).

Real-time monitoring of dose data, which involves assessment of the radiation dose upon completion of the scan, provides immediate feedback about whether the patient's dose was within predefined dose limits or not. Such a process is part of clinical routine in 42% (n = 21/50) of the departments with a DMS. Compared with this, 52 (n = 26/50) of the departments can perform real-time dose monitoring but refrain from doing so for various reasons (e.g. too time-consuming, no personal resources). For the remaining 6% (n = 3/50) of departments with a DMS, real-time dose reading is available because of technical issues.

Activities for improvement of radiation exposure

To further improve radiation protection, a dose team is implemented in 57% (n = 68/120) of the departments. Members of a dose team are usually the chief physician/senior physician staff (81%, n = 97/120), at least one radiographer (90%, n = 108/120) and medical physicists (80%, n = 96/120). In almost two-thirds of departments (63%, n = 76/120), part of the dose team's work is to regularly communicate the department's performance regarding radiation exposure within the department.

The Swiss National Diagnostic Reference Levels (DRLs) are used by almost all departments (96%, n = 146/152). In addition, some departments also have local DRLs, which are specific for the equipment and CT protocols in use (32%, n = 49/152).

Discussion

In early 2018, the new Euratom directive will come into effect. It includes basic safety standards for protection against the dangers from exposure to ionising radiation and, together with other awareness campaigns, has brought radiation protection and safety into the focus of the radiological community. A response rate of 63% (n = 152/241) in the present survey underlines the interest in and commitment to radiation safety among radiological departments in Switzerland.

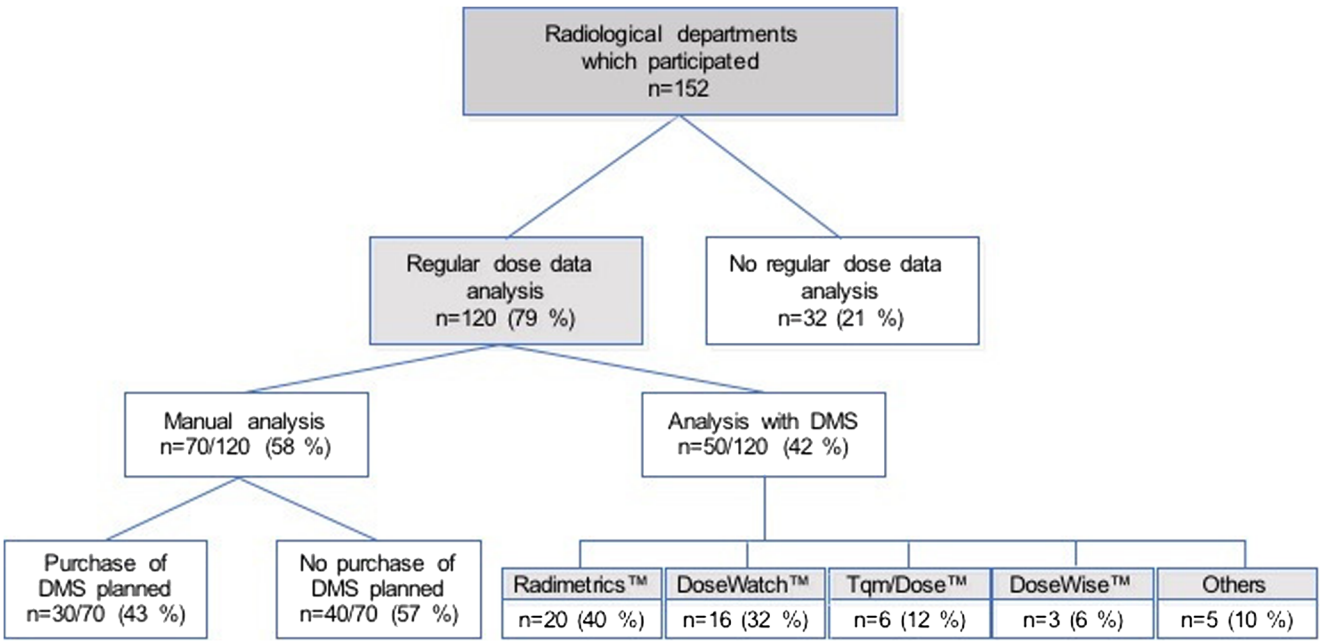

Fig. 2 Dose data analysis as currently performed in Switzerland: The majority of departments conduct a regular analysis of dose data, which is predominantly done manually. Forty-three per cent of the departments with manual analysis plan to purchase a dose management software (DSM) soon. Within the different types of DSM especially Radimetrics™ (Bayer) and DoseWatch™ (GE) are installed. "Others" summarises DMS with a share of less than 5% (e.g. Teamplay™, Siemens Healthcare; Radiance™, open source; Novadose™, Novarad)

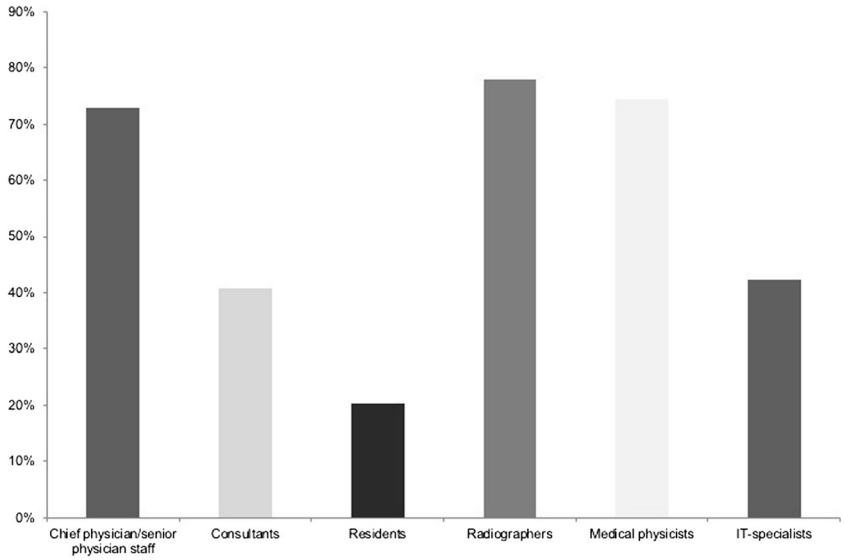

Fig. 3 Access to DMS in clinical routine: Mainly chief physicians/senior physician staff, radiographers and medical physicists have the chance to access dose data in clinical routine. Numbers are relative values with the number of participating departments as the base

One of the most relevant points addressed in the directive is the obligation to have a structured optimisation process [9], ensuring that acquisition parameters are as much adapted to local conditions as possible in order to find the best compromise between diagnostic image quality and radiation exposure. Such a continuous optimisation process with regular analysis of dose data is already established in 79% (n=120/152) of the participating departments. However, the frequency of data assessment varies considerably between the different departments: 35% (n = 42/120) of departments have implemented an at least monthly dose data analysis compared with almost half of the departments (54%, n = 54/120) with a review only once or twice per year. However, frequent dose data analysis is imperative as it leads to an earlier detection of equipment error, human failure or faulty examination protocols. Consequently, patients might be prevented from unnecessary high radiation exposure because countermeasures can be initiated subsequently before causing even more harm. Moreover, common dose data evaluation supports the process of constant modifications and optimisations of CT protocols [10] and therefore contributes to a culture of safety [12].

One of the counterarguments given by the departments without a regular dose data reading is that it is too cost and time intensive. This points to the fact that Swiss departments currently receive no reimbursement for radiation protection and safety activities, which should be included in future accounting and accreditation systems. Such an approach is already present in the USA, in which an obligation came into effect that requires each hospital clinically operating CT scanners to have automated dose monitoring [13, 14]. One possibility to fulfil this obligation is the purchase of a DMS, as had already been done by 42% (n = 50/120) of the interviewed departments. Several studies proved that DMSs are feasible and could lead to an improvement in both radiation safety and quality control in radiology [10, 15–19]. DMSs not only allow for processing and merging data from all examinations and interventions performed at different modalities, but include a dose notification tool in case of high doses, thus supporting workflow analysis [16, 20, 21]. In a simplified view, DMSs make radiation exposure visible, point out the need for optimisation and could contribute to big data analytics in healthcare. On a departmental level, a DMS often represents the starting point of a larger optimisation process. As a consequence, 43% (n = 30/70) of the departments without a DMS still plan to purchase one soon as for them these benefits outweigh the often long and cost-intensive implementation process of DMS in clinical routine.

Our survey revealed that currently mainly four types of DMS are available, but many more companies offering such software solutions are on the Swiss market; therefore, a wider spread of manufacturers is expected in a few years, possibly being accompanied by more sophisticated technical features of the DMS. Currently, one considerable downside to the use of DMS is the restricted possibility to transfer data from one DMS to the other when both systems stem from different manufacturers. Together with a wide variation in nomenclature and CT protocols, this forms a significant obstacle for the implementation of a national dose registry in Switzerland. Therefore, (more) attempts to standardise the nomenclature, CT protocols and technical level should be made to facilitate an automated and accurate assignment [10] and installation of a dose registry, as already available in the US from the American College of Radiology [22]. Such a national dose register would offer major opportunities to further reduce radiation exposure and would allow for more detailed national diagnostic reference levels (DRLs), which are applied by almost all departments (96%, n = 46/152). Moreover, a national dose registry would enable departments to benchmark and compare their dose data with data from other departments, potentially prompting them to refine and optimise their own

protocols [4, 10]. However, when comparing our own dose data with national DRLs or dose data of other departments, it should be kept in mind that DRLs are valuable indicators of good clinical practice in terms of radiation safety. However, there is widespread consensus that DRLs are neither dose limits nor constraints. On an individual level there are many potential reasons that justify dose values above the DRL with the most frequent one being patient overweight [15, 16]. Other possible causes, which cannot directly be influenced by the radiological department, could be scan repetition due to patient movement or orthopaedic hardware lying in the scanning area.

A DMS also offers the chance to monitor patient dose upon completion of the scan and to have the possibility to compare it with other patients' dose data, who underwent the same CT protocol. By receiving subsequent feedback departments have the chance to derive measures for improvement. However, of the departments with a DMS dose data reading upon completion of the scan is carried out by 42% (n = 21/50) only, while most departments refrain from doing so for cost reasons (52%, n = 26/50). This once again underlines the necessity that radiation protection activities should be reimbursed.

Education is of utmost importance in radiation awareness and safety; therefore, residents should have access to the DMS in clinical routine to get an idea on their patient's radiation exposure and to increase their radiation dose awareness. However, only 20% (n = 10/50) of the residents can access their department's DMS in the present survey, which should be improved. Besides in residents, radiation awareness has to advance in the whole department as well as in the entire hospital and in referring doctors, which might be supported by regular internal and external communication of a department's radiation protection performance [21]. In addition, radiation awareness might increase if dose data are added to the final examination report as recommended by the Euratom directive. However, momentarily only one quarter (n = 38/152) of the radiological departments follow this recommendation, while the rest refrain from doing so for technical reasons to prevent patient's uncertainty and queries as well as to avoid legal issues in case of high doses.

Planning, coordination and performance of radiation safety activities are teamwork and therefore require an interdisciplinary collaboration consisting of medical physicists, radiologists and radiographers, supported by information technology (IT) specialists. Such a dose team has already been founded in 57% (n = 68/120) of the radiological departments and its competencies as well as its responsibilities need to be recorded in the quality management handbook.

The survey has limitations: it consisted of both quantitative and qualitative questions with answers to the qualitative questions remaining subjective to a certain degree. Data collection was done anonymously to avoid departments' non-participation because of fears or sceptics that data might be transferred to the FOH or to another inspection authority. Furthermore, it was assumed that answers would be more reliable and less sugarcoated if given anonymously. Because of the anonymity, it was impossible to contact departments that did not completely fill out the questionnaire or to gain a deeper insight in a department's radiation safety activities.

In conclusion, the present nationwide survey revealed that there is interest and commitment to radiation safety among the Swiss radiological departments. However, currently considerable heterogeneity exists between the departments regarding the method, frequency and profundity of dose data analysis and the use of a DMS. Already more than half of the departments engage in radiation protection activities (e.g. foundation of a dose team); nevertheless, further activities should be carried out to optimise radiation protection even more to reduce patient's radiation exposure and to meet challenges such as the installation of a Swiss dose registry.

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Compliance with ethical standards

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Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry No complex statistical methods were necessary for this paper.

Ethical approval Institutional Review Board approval was not required because no patient data were analysed.

Informed consent Written informed consent was not required for this study because no patient data were analysed.

Methodology
- retrospective
- cross-sectional study
- multicentre study

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