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COMMENTARY

Challenges for managing the cumulative effective dose for patients

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ABSTRACT

Notwithstanding that 100 mSv is not a threshold for radiation effects, cumulative effective dose (CED) for patients of ≥ 100 mSv derived from recurrent imaging procedures with ionising radiation has been recently the topic of several publications. The International Commission on Radiological Protection has alerted on the problems to use effective dose for risk estimation in individual patients but has accepted to use this quantity for comparison the relative radiation risks between different imaging modalities. A new International Commission on Radiological Protection document on the use of effective dose (including medicine), is in preparation. Recently published data on the number of patients with CED ≥ 100 mSv ranged from 0.6 to 3.4% in CT and around 4% in interventional radiology. The challenges to manage the existing situation are summarised. The main aspects identified are: 1) New technology with dose reduction techniques. 2) Refinements in the application of the justification and optimisation for these groups of patients. 3) Patient dose management systems with alerts on the cumulative high doses. 4) Education on the proper use of cumulative effective dose for referrers and practitioners including information for patients. 5) Future research programmes in radiation biology and epidemiology may profit the patient dose data from the groups with high cumulative dose values.

Cumulative effective doses for patients derived from recurrent imaging procedures with ionising radiation has been a topic of interest in the scientific literature since many years. However, its attention has been heightened in the last year with numerous publications, stating that at 100 mSv of effective dose, many organs may receive doses of 100 mGy or more.

It was in 2009 when on one hand, IAEA announced its smart card project to track radiation exposure history of patients and on other hand a paper by Sodickson et al provided data on patients who underwent recurrent diagnostic CT examinations over the prior 22 years.^{1,2} The approach was well received by the professional community³ but with the fear of its misuse.^{4,5} In 2012, Durand et al⁴ considered it “dangerous” to use this approach for cancer risk estimations. Sometimes, it may cause patients or poorly informed physicians “to irrationally decide against medically indicated CT scans.” The authors remind the International Commission on Radiological Protection (ICRP) advice on this issue: “The use of effective dose is not appropriate for estimating the risk to an individual patient resulting from a diagnostic X-ray exam.”

In 2014, Walsh et al revisited the topic in a Commentary in the *British Journal of Radiology* focussing on the justification.⁶ One of the main aspects was if the radiation risks from previous examinations should affect the future procedures. The authors indicate that allowing cumulative dose estimates to influence whether a patient should get a scan would be equivalent to introducing dose limits for patients and, rather than improving patient safety, would unnecessarily restrict access to radiation-based diagnostic examinations.

In the first ever multinational survey among referring physicians from 28 countries, the support for a system that provides radiation exposure history of the patient was demonstrated.⁷ A study from Finland covering 33 institutions in the Helsinki-Uusimaa Hospital District indicated that patient-specific justification and optimisation becomes possible using the tracking of radiologic procedures and radiation dose of individual patients.⁸

Some recent papers have collected data to estimate number of patients with cumulative effective doses (CED) ≥ 100 mSv derived from recurrent CT examinations alone.^{3,9,10} The papers estimated that around 0.9 million patients with CED ≥ 100 mSv are likely occurring every year globally.^{3,9}

The dose management systems used in some of the hospitals involved in these studies were able to calculate organ and effective doses allowing the analysis of the cumulative doses in the patients. In one of the papers,⁹ data were collected from 324 hospitals involving a total of 488 CT scanners in USA and 1 country in Central Europe (2.5 million patients with 4.8 million CT exams). The patients with CED ≥ 100 mSv vary from 0.64% to 3.4% in the different hospitals or institutions included in the study. Another paper contains the data of about 70,000 patients from 20 countries: 18 of them in Europe, 1 in Africa, and 1 in Asia with an average of 0.65% of 702,205 patients undergoing CT scans with CED ≥ 100 mSv.³

The IAEA convened a meeting in 2019 with participants from 26 countries, representatives of various organisations, and experts in radiology, medical physics, radiation biology, and epidemiology.³ The meeting led to a Call for Action stating the need for urgent actions by all stakeholders to address the issue of high cumulative radiation doses to patients. The actions include development of appropriateness criteria/referral guidelines by professional societies for patients who require recurrent imaging studies, development of CT machines with lower radiation dose than today by manufacturers, and development of policies by risk management organisations to enhance patient radiation safety. Alert values for cumulative radiation exposures of patients should be set up and introduced in dose monitoring systems.³

In another recent study with interventional radiology practices, Xinhua et al studied 25,253 patients who underwent 46,491 fluoroscopy-guided procedures (from January 2010 to January 2019). It was concluded that in 4% of them, the CED was ≥ 100 mSv and median age of the first procedures was 60 years. Around 80% patients underwent all of their procedures within 365 days.¹¹

The automatic patient dose registries are able to set alarms informing clinicians in special situations. The referral criteria for patients with several (or many) previous imaging procedures involving moderated or high doses may be revisited¹⁰ and specific optimisation strategies could be considered in some cases. The European Working Group on “Dose Management” launched by the Eurosaf Imaging from the European Society of Radiology recommended setting alert trigger levels, to be able to send these alerts to professionals and to store and display cumulative patient dose values.¹²

In a very recent paper Kachelrieß and Rehani identified several technology-related factors of the CT systems that can be used by manufacturers of CT equipment to achieve substantial reduction in radiation dose to the patients while maintaining or improving the image quality¹³ in line with need identified in recent papers.^{3,9,10} The advances in the new systems used for interventional procedures may also allow remarkable decreases in patient doses.

According to the ICRP recommendations, we should not use the radiation protection quantity “effective dose” to estimate radiation risks for individual patients.¹⁴ A new ICRP document

on the use of effective dose (including medicine) is in preparation. Nevertheless, effective dose is useful to compare the doses and relative risks of different imaging modalities (e.g. CT, fluoroscopy-guided interventional procedures and nuclear medicine). This comparison is also useful for referrers when they balance the benefits and risks of the different examinations before suggesting one imaging modality.⁷ The quantity effective dose may also be useful to inform patients when they ask on the meaning of the different radiation units that may be included in the clinical reports: “mGy.cm” for CT, or Gy.cm² for interventional procedures, or MBq of a certain radiopharmaceutical in nuclear medicine procedures.

The use of effective dose may have important limitations as the uncertainty in the calculation, the different implications on the patient risk depending on the age and gender, the radiation dose for the different organs and tissues may be distinct despite having the same value for effective dose. In many cases, effective doses can be estimated from a single conversion factor multiplying the practical radiation unit offered by the X-ray system or the activity of the radiopharmaceutical, and with this approach, the uncertainty may be much higher than using Monte Carlo calculations.

The five main aspects to consider in the management of the cumulative effective doses could be summarised as follow:

- (1) **Impact of technology:** New technology with dose reduction techniques, especially for the high dose imaging modalities (CT, Interventional and PET-CT)^{15,16} should be developed and promoted. Moreover, when available in health centres, they must be used for the high dose procedures. COCIR, the European Trade Association representing the medical imaging, radiotherapy, health ICT and electromedical industries, is doing an important effort to reduce the age of the imaging equipment in Europe to allow introducing the low dose techniques.¹⁷
- (2) **Justification and optimisation:** Professional societies could develop appropriateness criteria for patients who need series of imaging studies using ionising radiation. This group of patients may require some re-evaluation of the justification criteria, and improvements in the optimisation strategies for future procedures.
- (3) **Patient dose management systems:** Some alerts based on the cumulative dose should be included in the dose management systems. If effective doses are not available, other dosimetric quantities available from the X-ray systems may be used. However, these alerts should not be used to discourage any procedure if it is medically indicated. The clinical decision support systems may incorporate these alerts. The European Directive 2013/59/Euratom requires estimation of population doses from medical exposures and these data are required for the UNSCEAR surveys.
- (4) **Proper use of cumulative dose:** Education on the proper use of cumulative effective dose should be included in the training programmes for referrers and practitioners including the proper information for patients. In some cases, patients may accept a small additional radiation risk for a fast diagnosis or a second opinion, and this may be ethically acceptable as part of the autonomy and rights of the patient.¹⁸

- (5) **Data for research:** The future research programmes in radiation biology and epidemiology could use the data from the groups of patients with high dose values collected by the dose management systems allowing to estimate organ and effective doses.

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REFERENCES

1. Rehani MM. Patient radiation exposure and dose tracking: a perspective. *J Med Imaging* 2017; **4**: 031206. doi: <https://doi.org/10.1117/1.JMI.4.3.031206>
2. Sodickson A, Baeyens PF, Andriole KP, Prevedello LM, Nawfel RD, Hanson R, et al. Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. *Radiology* 2009; **251**: 175–84. doi: <https://doi.org/10.1148/radiol.2511081296>
3. Brambilla M, Vassileva J, Kuchcinska A, Rehani MM. Multinational data on cumulative radiation exposure of patients from recurrent radiological procedures: call for action. *Eur Radiol* 2020; **30**: 2493–501. doi: <https://doi.org/10.1007/s00330-019-06528-7>
4. Durand DJ, Dixon RL, Morin RL. Utilization strategies for cumulative dose estimates: a review and rational assessment. *J Am Coll Radiol* 2012; **9**: 480–5. doi: <https://doi.org/10.1016/j.jacr.2012.03.003>
5. Rehani MM, Szczykutowicz TP, Zaidi H. Ct is still not a low-dose imaging modality. *Med Phys* 2020; **47**: 293–6. doi: <https://doi.org/10.1002/mp.14000>
6. Walsh C, Murphy D. Should the justification of medical exposures take account of radiation risks from previous examinations? *Br J Radiol* 2014; **87**: 20130682. doi: <https://doi.org/10.1259/bjr.20130682>
7. Rehani MM, Berris T. International atomic energy agency study with referring physicians on patient radiation exposure and its tracking: a prospective survey using a web-based questionnaire. *BMJ Open* 2012; **2**: e001425. doi: <https://doi.org/10.1136/bmjopen-2012-001425>
8. Seuri R, Rehani MM, Kortelainen M. How tracking radiologic procedures and dose helps: experience from Finland. *AJR Am J Roentgenol* 2013; **200**: 771–5. doi: <https://doi.org/10.1136/bmjopen-2012-001425>
9. Rehani MM, Yang K, Melick ER, Heil J, Šalát D, Sensakovic WF, et al. Patients undergoing recurrent CT scans: assessing the magnitude. *Eur Radiol* 2020; **30**: 1828–36. doi: <https://doi.org/10.1007/s00330-019-06523-y>
10. Rehani MM, Melick ER, Alvi RM, Doda Khera R, Batool-Anwar S, Neilan TG, et al. Patients undergoing recurrent CT exams: assessment of patients with non-malignant diseases, reasons for imaging and imaging appropriateness. *Eur Radiol* 2020; **30**: 1839–46. doi: <https://doi.org/10.1007/s00330-019-06551-8>
11. Li X, Hirsch JA, Rehani MM, Ganguli S, Yang K, Liu B. Radiation effective dose above 100 mSv from Fluoroscopically guided intervention: frequency and patient medical condition. *AJR Am J Roentgenol* 2020; **1–7**. published online ahead of print, 2020 Jun 6.
12. Loose RW, Vano E, Mildemberger P, Tsapaki V, Caramella D, Sjöberg J, Schindera S. Dose Management – Requirements and Recommendations for Users. 2020. EuroSafe Imaging 2020 / ESI-11078. Available from: <https://epos.myesr.org/poster/esr/eurosafeimaging2020/ESI-11078> [accessed 27 June 2020].
13. Kachelrieß M, Rehani MM. Is it possible to kill the radiation risk issue in computed tomography? *Phys Med* 2020; **71**: 176–7. doi: <https://doi.org/10.1016/j.ejmp.2020.02.017>
14. International Commission on radiological protection. radiological protection in medicine. *ICRP Publication 105. Ann. ICRP* 2017; **37**: 1–63.
15. Einstein AJ, Johnson LL, DeLuca AJ, Kontak AC, Groves DW, Stant J, et al. Radiation dose and prognosis of ultra-low-dose stress-first myocardial perfusion SPECT in patients with chest pain using a high-efficiency camera. *J Nucl Med* 2015; **56**: 545–51. doi: <https://doi.org/10.2967/jnumed.114.150664>
16. Badawi RD, Shi H, Hu P, Chen S, Xu T, Price PM, et al. First human imaging studies with the explorer total-body PET scanner. *J Nucl Med* 2019; **60**: 299–303. doi: <https://doi.org/10.2967/jnumed.119.226498>
17. COCIR. Medical imaging equipment. 2016. Age profile & density. Available from: https://www.cocir.org/uploads/media/16052_COC_AGE_PROFILE_web_01.pdf [accessed 11 August 2020].
18. Vano E. Recurrent imaging procedures with ionising radiation on the same patient. should we pay more attention? *J Radiol Prot* 2020; **40**: E14–17. doi: <https://doi.org/10.1088/1361-6498/ab7fbb>