

BREAKING THE TREND OF INCREASED RADIATION EXPOSURE TO PATIENTS THROUGH DOSE MONITORING

This white paper raises the issue of the increase in patient exposure to radiation doses in diagnostic medical imaging over the last three decades. The aim is to inform about the problem and highlight the importance of collecting and monitoring doses when it comes to lowering radiation exposure for patients within imaging medicine.

An alarming increase in patient radiation exposure

A recently released American study showed that the amount of radiation the U.S. population is exposed to as a result of diagnostic medical imaging increased by a factor of six between 1980 and 2006 [1]. This increase was mainly driven by three factors:

Firstly, the growing use of new imaging technologies such as computed tomography (CT) and fluoroscopy and nuclear medicine [1]. For example, the number of CT scans performed in the U.S. has grown by about 10% on an annual basis [2]. On average, these new imaging technologies use a much higher amount of radiation per examination than conventional X-ray examinations [1]. For example, a CT head examination gives approximately 100 times the radiation dose to the patient compared to a conventional chest X-ray [3]. An article published in *Radiology* documented that CT scans only constituted about 13% of the diagnostic imaging orders for hospitals in the U.S. but represented an amazing 70% of the total dose [4].

Secondly, the growing patient size and increase in cases of obesity also contribute to the increase in radiation exposure. It has been shown that the effective dose received by a patient is greatly affected by their body size. Higher tube currents are normally used for larger patients to maintain image quality. [5].

The third main contributor to the increase in radiation exposure is the growth in the number of radiography studies, which increased from 25 million in 1950 to 293 million in 2006 [1]. The number of examinations is still growing, partly a result of overtesting due to; the fear of being sued by patients, a lack of training and financial incentives [6].

Radiation exposure concerns

The alarming increase in patient exposure to medical radiation is currently a hot topic. The concerns are mainly two-pronged: Firstly, there is the danger of radiation induced burn, mainly driven by the increase in complex interventional fluoroscopy procedures which have led to long exposure times and direct skin damage [7]. Secondly, and probably even more discussed, is the long-term danger of radiation elevating a person's lifetime risk of cancer. Although the cancer risk to a patient from a single exam may not itself be large, millions of exams are performed each year, making it an important public health issue. [3].



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Experts currently disagree about the extent of the cancer risk due to medical radiation. But there is a consensus that care should be taken to find a balance between the benefits of imaging exams and the risks posed by taking them. [3]. One of the most comprehensive studies on the topic, which was conducted on the survivors of the atomic bombs in Japan, showed that even small doses, comparable to two or three CT scans, significantly increased the induction of cancer [8]. The central assumption is that there is a linear dose-response relationship for the induction of cancer, an increment increase in dose results in a proportional increase in risk [9]. Recent studies have also triggered the discussion with some alarming results showing that the cancer risk from increased exposure to radiation doses is much higher than previously thought, especially when it comes to children. For example:

- An Australian study found that the risk of developing cancer later in life was 24% higher if the patient had a CT examination during the first 19 years of life [10].
- Another English study showed that the risk of suffering a brain tumour or leukemia almost tripled if the patient had been exposed to a CT examination during childhood [11].
- Berrington de Gonzalez et al. [12] estimated that approximately 29,000 future cancer cases could be related to CT scans performed in the U.S. in 2007 alone.

The fast technological advancements in medical imaging have led to concerns that the fundamental responsibilities for patient safety have not kept pace with technical developments [13].

When discussing radiation risk it must be kept in mind that the new technologies are invaluable diagnostics where the benefits almost always exceed the potential risks. Still, there is a small but statistically significant risk from the dose given by just one CT examination and it must be considered since the number of examinations is growing at an alarming rate. [1].

Challenges in dose reduction

Today, most modern medical imaging devices allow for post processing of images and compensation can be made for errors in exposure technique. The ability to adjust the image during post processing can lead the radiographers' attention away from the fundamental exposure technique, and image errors do not lead to improved methods as they did with film-screen. This creates a disconnection between the image capture and the exposure of the patient. [1]. Up to a point, using a higher dose can produce a higher image resolution [3]. Hence, the feedback the radiographer receives from radiologists is often image-quality focused, which creates incentive for the radiographer to increase doses to get better images and to reduce repeats. The tendency to be less concerned about exposure technique and use more radiation than necessary is referred to as "dose creep". [1].

The determination of an optimal dose for a specific patient and examination is often not standardized within medical imaging. The lack of information and standards are hindering a systematic lowering of radiation exposure. [3]. The radiation dose for a specific procedure is often not even standardized for the same facility. This was identified in a study by Smith-Bindman et al. [14], where they found a mean variation that was 13-fold between the highest and lowest dose for each type of study assessed.

The equipment is another element of the radiation exposure problem. There is a high variety in radiation exposure between equipment and systems and, furthermore, devices are in many cases inadequate for supporting the lowering of radiation exposure. [15]. While new CTs and fluoroscopy devices include displays of dose metrics [3], these are routinely not reviewed [16]. Many modalities lack other safeguards such as default parameter settings that optimize doses, or alerts that are triggered when the radiation dose in a given exam exceeds a particular reference level [3].

There are also several deficiencies in the ordering physician's information technology. For example, the physician does not have the patient dose history or medical imaging records that could inform their decisions when ordering or justifying a medical imaging examination. The main problem is that procedures are performed in different facilities and information is not shared across the Electronic Medical Record (EMR). [15]. Insufficient information can lead to physicians ordering unnecessary imaging examinations that have already been conducted, thereby exposing the patient to unnecessary radiation. The radiation record may also influence the physician's decision regarding the selection of another safer examination type. [3]. By some estimates, more than 20 percent of diagnostic imaging was repeats [17].

The problems raised by the disconnection between image quality and dose exposure as well as the lack of information sharing, guidelines, training, standards, supporting equipment and systems are all obstacles to lowering the dose.

Benefits of tracking doses

After three decades of substantial increases in patient radiation exposure, society has started to treat radiation exposure as a major public health issue [3]. Facility-level dose monitoring and comparison with national reference levels has been required by law in many European countries for the last 10 years. The same development can now be seen in the U.S., but at a state level rather than a national level. [13]. One example is the state of California where diagnostic radiologists from July 2012 must include radiation dose levels in all CT reports and assess the dosage units in every protocol [18]. Still, many professionals in medical imaging are not working under any regulatory enforcements. Instead they adhere to the guidelines known as *As Low As Reasonably Achievable (ALARA)*. [3].

Today there are several initiatives for creating reference levels and guidelines for radiation dose monitoring. Groups including the American College of Radiology (ACR), the American Association of Physicists in Medicine (AAPM), the Food and Drug Administration (FDA) and the National Council on Radiation Protection (NCRP) have conducted work to establish nationally recognized diagnostic reference levels for a variety of examination types to provide radiation benchmark levels [3]. For example, the Dose Index Registry (DIR) is a data registry operated by the ACR that allows hospitals to compare their dose indices from CTs with regional and national values. They provide facilities with periodic feedback reports comparing the facilities' results by examination type and body part to others', thereby facilitating the assessment of the given radiation doses. [19]. Despite various efforts to initiate more systematic monitoring, many pieces of radiology equipment do not include dose information in an easily accessible form, thus making it difficult for imaging centers to monitor their dose estimates and participate in the DIR [16]. A tool used to automatically collect doses from all kinds of modalities should ease reporting to these authorities.

Both authorities and groups seem to work with a two-pronged solution: establishing dose reference levels on one side and, on the other, seeking to ensure that facilities store the radiation exposure for each patient. The dose collection system should accumulate each patient's history of exposure to determine the possible risk and benefits of giving additional radiation doses. The collection of dose data is the first step in assisting with policy development and better clinical decisions. [15]. Gibson et al. [7] state that the need for monitoring and tracking of patient doses is a necessary component of any effective radiation safety program.

Regardless of whether a hospital is legally required to collect and report patient doses or not, a patient dose collection and monitoring system comprises a powerful tool for lowering radiation exposure and ensuring patient safety. Frush et al. [13] argue that to close performance gaps in radiation exposure, structures and systems must be put into place to provide a continuous flow of information to key roles within the radiology and nuclear medicine departments. The dose information comes from multiple sources and informs leaders at all levels about risks, hazards and performance gaps that contribute to patient safety issues. The radiation risk can be managed only when the organization has been informed and can then take explicit actions to fill these gaps. [13]. The International Commission on Radiological Protection (ICRP), the primary body in protection against ionising radiation, heavily promotes three principles of radiation protection: Optimization, justification and the application of dose limits [9]. This paper will use a similar categorization of the benefits of collecting and monitoring dose levels, as that made by Frush et al. [13]: Optimization of radiation dose, justification of orders, individual risk assessment and the provision of a basis for research. The benefits reach across many stakeholders when it comes to lowering dose levels, including the radiographer, radiologist, medical physicist, patient, regulators, researchers and policymakers. To attain these benefits, patient doses should be easily determined and recorded in an electronic health-care record or centralized database. [13].

Optimization of radiation dose

A monitoring tool can automatically compare doses against a benchmark level, which gives the radiographer direct feedback on the exposure techniques used. This direct feedback allows radiographers to continuously improve their skills in balancing image quality with lower radiation exposure. Accordingly, the comparison between doses and a reference level enhances the connection between the two. By utilizing a rejection analytical tool, overexposed and underexposed images can be identified and repeats investigated.

The collection and monitoring of dose levels also helps to identify trends and prevent “dose creep”. [1].

Comparing dose levels between equipment allows medical physicists to routinely survey modalities to ensure that they are producing acceptable image quality with the lowest possible dose. Physicists should also run programs to monitor the radiation activities and, together with radiologists, optimize protocols. Based on dose information, training can be initiated and performed, performance gaps in patient safety identified and the organization informed about how to minimize radiation [19].

Justification of orders

To lower the number of examinations, it is important to provide decision support at the point of care that will provide the proper guidance for physicians thereby enabling them to order the most appropriate procedure [15]. A dose collection and monitoring system supports ordering decisions. The avoidance of unnecessary examinations and the justification of orders can only be allowed for when the physician has access to the patient dose history. The patient dose record can guide referring physicians to the selection of the most appropriate imaging procedure. [3].

Some physicians have little or no training in radiation safety issues and do not routinely consider the dose as a factor when ordering imaging examinations. By displaying the relative radiation level for a specific examination the physician is steered towards considering the choice with the lowest radiation level but with the same clinical value. Regularly posting individual physician ordering patterns may also positively influence order behaviour through peer pressure. When it comes to radiographers and radiologists, they comprise a “safety net” if given access to patient dose records. They can identify patients that are scheduled to make a duplicate or similar examination as one already performed and unnecessary examinations can be avoided. [19]. Avoiding redundant orders also improves resource utilization and frees up time in an already strained hospital care system [13].

Individual risk assessment

The radiographer is often the first and, perhaps, the only individual to interact with the patient. Through access to the patient dose level and image history, this also becomes a point where high risk patients can be directed to other, safer types of examination. A dose monitoring system should provide the radiographer with the patient's previous examinations and doses received, thereby allowing for a risk assessment before the examination. It is often the responsibility of the radiographer to determine the need for additional radiation safety procedures prior to exposure of a high risk patient (e.g. if pregnant or a child). [19].

A dose monitoring system also facilitates informing patients of the risks entailed by an examination. For example, fluoroscopy can give very high radiation doses during complex interventional procedures. The patient should be told about the associated risks as a part of a pre-procedure patient consent process. Dose data from fluoroscopy should also periodically be reviewed to determine patients at risk. Patients exposed to radiation dose levels exceeding specific threshold values should be notified as well as the hospital's safety officer. [7].

Provision of a basis for research

Finally, collected dose levels provide a quantitative basis for the development of best practices, guidelines, and appropriateness criteria. A database with ordered patient-specific radiation doses may provide valuable data to research studies. [13].

Conclusion

The trend of increasing radiation exposure in medical imaging has led to major concerns about patient safety. Performance gaps in medical imaging must be managed to be able to break the trend and reduce the risks. The collection and monitoring of dose levels is fundamental to lowering radiation exposure and, accordingly, to reducing the risk of patient injury. The benefits of tracking dose levels are many; studies agree that collecting and monitoring dose data is the first step towards developing policies and improved clinical decisions.

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