Review article

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Update on current and future developments in radiation protection of patients

Abstract

Objectives: In this review, we look upon the current literature on the advances in radiation production and prospective future developments.

Key Findings: PubMed was searched for all articles on the radiation protection of patients. These articles were reviewed and significant literature on the latest developments was included.

Conclusion: Various new methods have evolved for radiation protection. These methods are discussed in detail in this article.

Implications for practice: Radiologist should know the current updates on radiation protection to improve departmental safety.

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Introduction

More than 10 million diagnostic radiology procedures are performed every day.[1] The advantages from these procedures are massive, however, the stochastic and deterministic effects of radiation can potentially cause patient harm. Stochastic effects are chance events, with the probability of the effect increasing with the dose, but the severity of the effect is independent of the dose received. Deterministic effects are directly related to the absorbed radiation dose and as the dose increases so does the severity of the effect. Radiation protection means protecting from both unnecessary and unintended exposures.[2] As per the latest global figures, CT scans lead to 42% of the total collective effective dose arising from medical diagnostic radiology.[1] Also, the total collective radiation burden of the global population is increasing rapidly. This makes it extremely important for us to review the current updates and future developments in radiation protection.

Material and methods

Pubmed was searched for all articles published regarding radiation protection. These articles were analyzed for new information and updates. Only articles published in the last few years were included. Articles regarding radiation protection for medical workers were excluded.

Results

Various steps for radiation protection are discussed below.

Step 1: Justification of exposure

Any medical exposure to radiation needs to be justified and should be done only if it does more good than harm. Both the referring physician and the radiologist should agree that the radiation dose is justified for the management of the patient and that alternative techniques like ultrasound and Magnetic Resonance Imaging were considered. Patients should be well informed before the procedure and consent should be taken. Radiation should not be used for screening techniques unless well justified like in Mammography. Holmberg et al.[2] state that justification should be multilevel including justification in general, justification for specified procedure, and justification for the specific individual.

Step 2: Tracking patients' radiation exposure

As ever-increasing patients are undergoing repeated CT scans and radiological procedures the cumulative effective dose has exceeded in some cases beyond 1 Sv. This has led to skin erythema and hair loss which had started to appear in 2005 and led to intervention by the U.S Food and Drug Administration.[3,4] Thus total cumulative dose to a patient in his lifetime needs to be monitored. A smart card called "SmartRadTrack" has been developed by International Atomic Energy Association (IAEA) that can record the total dose received by any patient in his lifetime and thus future dosage can be modified based on his past exposure.[5] Transborder communication of Electronic Health Records (EHR) has started among 21 European countries allowing tracking of radiation exposure of patients across countries in the Europen Union.

In addition, the International Atomic Energy Association (IAEA) has included professional bodies such as the International Society of Radiology (ISR), the American College of Radiology (ACR), the International Radiology Quality Network (IRQN), the International Commission on Radiological Protection (ICRP), and the International Organization of Medical Physics (IOMP) to develop protocols to reduce patient exposure.

Step 3: Audit

European Commission[6] has mandated clinical audits of patient exposure due to medical procedures whereby the radiology practices are examined against agreed standards of quality care, with modifications as needed. This is required to be done by an independent third party, which will involve an onsite visit by a team of radiologists, medical physicists, radiographers. The audit team might look into dosimetry and share their report with the staff of the facility identifying the strengths and the weaknesses, thus providing a basis for future planning.

Step 4: Reporting of Radiation Injury

There is no structured reporting of radiation injuries post-exposure. Tsapaki et al.[7] describe an increase in the frequency of fluoroscopy-guided interventional procedures and some of them have high radiation associated with it. International Atomic Energy Association (IAEA) has launched a voluntary reporting system called Safety in Radiological Procedures (SAFRAD), in which patients who are exposed to defined trigger levels or events in fluoroscopically guided diagnostic and interventional procedures are included in an international database.[5]

A similar process is developed by International Atomic Energy Association (IAEA) for radiotherapy called Safety in Radiation Oncology (SAFRON). The SAFRON project aims to develop and implement a global safety reporting and learning system that includes retrospective reporting and prospective risk analysis within a learning environment thus improving the safe planning and delivery of radiotherapy.

Step 5: New techniques to reduce CT dose

New techniques have been developed to reduce the CT dosage since the time of its development. Among the technological advances reduction of radiation dose is possible the maximum with automatic tube current modulation. Initially the current used to be constant for the entire gantry rotation irrespective of the patient size. However various techniques in biomedical engineering have led to the ability to vary your current based on patient thickness. Singh et al.[11] have reported a 50–75% reduction in dose with the dose modulation techniques in chest and abdomen CT. For successful implementation of dose modulation strategy, the patient needs to be centered at the center of the CT gantry (iso-center) and the user-defined parameters are to be kept at optimal settings. Yu et al.[9] state that Tube voltage selection has the double advantage of lowering radiation dose and also improving the image contrast. This is especially true for small and medium-size patients, especially children. The latest scanners can provide images with voltage as low as 70 kV. Kroft et al.[10] have studied that the latest 320 detector MDCT scanners can scan 168 mm of anatomy, enabling large volume scan in a short period.

Thus high detector rows in the z-direction in a Volume CT scanner increase the volume covered per gantry rotation and that reduces the radiation exposure significantly. In infants, an entire scan can be performed in a single rotation thus eliminating the need for sedation, in some cases. Volume CT scanners can reduce exam time and minimize patient motion, both of which increase patient imaging quality. Yu et al.[9] state that dual-energy CT scanners that have 2 detectors mounted at 90° angle can cover large areas in a short period. So they provide an opportunity for optimal imaging especially among the pediatric population because of rapid table speed accompanied by high pitch values which can cover large anatomical areas in less than one second. These short scan times are critical to minimize patient motion, reduce the patient sedation needs, reduce the amount of contrast material and radiation. Also, new CT machines are equipped with very low-noise detectors nowadays that allow the acquisition of data with low radiation without affecting the signal-to-noise ratio. Conventional CT images are reconstructed using the filterback projection method. Khawaja et al.[11] state that new CT machines use iterative reconstruction which is not affected by the scan settings like the tube current. These new reconstruction algorithms acquire CT data at a much lower current and process raw data to lower image noise by performing multiple iterations to preserve image quality. Multiple scan series including non-contrast and contrast-enhanced CT images are not required in every patient and need to be reduced. This is especially true for the pediatric population.

Pindrilk et al.[12] Limited sequence series versus entire sequences are considered especially in children with shunted hydrocephalus who undergo frequent CT scans for the evaluation of potential shunt malfunction. New MRIs machines with rapid imaging protocols have also come up which can act as a replacement for city scans, especially in a non-emergent situation. Size-specific radiation dose reports need to be acquired and utilized in all CT machines, especially among the pediatric population. Structured dose reports form an important source of information for auditing and internal quality control purposes.[13]

Discussion

An increasing trend of the use of ionizing radiation for medical purposes has led to current issues of radiation protection for the patient. The rapid growth of CT scans is the major factor leading to increasing collective dosage to the global population. Many of these radiological investigations and procedures can be modified and dosage can be reduced by measures as described above in this article. Providing adequate justification before exposure, tracking patients' radiation exposure, post-exposure audits by independent third parties, and reporting radiation-induced injury are some of the measures that have been considered in recent times by the international atomic energy association and other relevant bodies. Various new techniques have evolved over the previous few years involving dose modulation, dual-energy CT, limited sequence series, and new faster MRI machines which are discussed in this article.

Conclusion

Many new measures have come up in the last few years for the radiation protection of the patient, especially during CT scans. Some of these measures are relatively new and further experience and research need to be put into this evolving field.

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