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Diagnostic radiology dosimetry: Status and trends

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HIGHLIGHTS

- Advantages of TL dosimeters in diagnostic radiology are presented.
- Personal dosimetry showed over exposition in interventional procedures.
- Dose distribution in whole body by CT measurements are analyzed.
- Personal dosimetry in diagnostic veterinary procedures need care with X-ray dose.
- Integral dosimetry (INDOS) has been suggested as routinary dosimetric method in diagnostic radiology.

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ABSTRACT

Since 1970s the expression of protection standards shifted from a dose -to a risk-based approach, with dose limits established to yield risks to medical radiation workers. Worldwide interest in patient dose measurement was stimulated by the publication of Patient Dose Reduction in Diagnostic Radiology by the UK National Radiological Protection Board (NRPB). This has resulted in the development of new dosimetric measuring instruments, techniques and terminologies which present challenges to those working in the clinic al environment and those supporting them in calibration facilities. In this sense, thermoluminescent dosimetry (TLD) has been actively developed in the past last 3 decades thanks to their successful applications in diagnostic radiology. The present work analyzes current status and future trends of diagnostic radiology dosimetry using thermoluminescence phenomena.

1. Introduction

The risks of X-rays of the radiations rest on the studies of radiobiology and epidemiology are based on the determination of radiation dose namely dosimetry. The primary purpose of dosimetry in diagnostic radiology (DR) is to measure the amount of ionizing radiation (IR) doses from the made-man sources for comparison with dose limits, constraints and reference levels that relate to stochastic risks of whole-body radiation exposure (International Atomic Energy Agency, 1996). Dosimetry is an area of increasing importance in diagnostic radiology. There are three aspects to dosimetry in diagnostic radiology, measurement of performance of X-ray equipment, assessment of doses to patient and assessment of doses to workers. The interactions of X-ray with human anatomy come from the diversity and complexity of the X-ray delivery from the external sources. The best simplest dosimetry in an X-ray equipment, is perhaps the dose determination of the X-ray tube output for X-ray equipment. Another exposure factors (kilovolt, milliampere, exposure time) should be evaluated. The basic strategy for quality assurance (QA) in diagnostic radiology was firstly suggested by World Health Organization (WHO) (1982). The International Basic Safety Standards (BSS) provide also requirements for QA in DR (International Atomic Energy Agency, 2014). It is also a key component of the quality control of X-ray equipment and procedures (IEC: International Electrotechnical Commission, 2012). However, this is where the largest dosimetric problem occur, in many establishment because this dosimetric procedure is absent. Patient dosimetry (PD), may be is one the most important topic of this paper, the aim of the PD with respect to X-rays used in medical imaging is the dose determination to the skin at the surface where an X-ray beam enters the patient body and for comparative risk assessment (IAEA: International Atomic Energy Agency, 1991). There is a realization amongst health professionals that the radiation dose received by patients from modern X-ray examinations and procedures can be at a level of significance for the induction of cancer across a population, and in some unfortunate instances, in the acute damage to particular body organs such as skin and eyes. Assessments of doses are made for groups of patients for a representative selection of examinations carried out at each radiological procedure and the mean results are compared with diagnostic reference levels (DRLs) for a

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common examinations (IEC 61526, 2010). Radiation dosimetry (RD) of the patient can be achieved if the number of radio-diagnostic procedures is reduced to the minimum justified by the clinical condition of the patient, and if the examination sequence chosen by the specialist practicing diagnostic imaging is the most appropriate one. The above two conditions represent in essence the concept of 'rational use' and constitute the substance of the program developed by the WHO since 1977 (World Health Organization (WHO), 1982)). All procedures need to be performed by professional personal with the accompanying potential for occupational radiation exposure (ORE). The second importance of X-ray diagnostic radiology dosimetry is the workers dosimetry (ICRP, 2007). The role of dosimetry to workers is to determine the amount of radiation dose received by a professional worker during the radiological procedure. The formulation and measurement procedures for diagnostic radiology dosimetry have recently been standardized through an international code of practice which describes the methodologies necessary to address the diverging imaging modalities used in diagnostic radiology (IAEA, 2007; AAPM, 1990; National Radiologic Protection Board (NRPB), 2000; Rosenstein, 2008). Personal dosimetry (PD) is recommended for medical and supporting staff who assist in medical procedures that involve the use of diagnostic x-rays equipment. The purpose is to help employers and employees take appropriate actions to ensure such workers are aware of and are effectively protected against radiation exposure during these procedures. Employers need to be aware of their obligations to protect these workers in accordance with the requirements for ionizing radiation as recommended by international organizations (AAPM, 1991; Zoetelief et al., 2003; IEC, 1997). Then, International system code a critical and simple but important question is addressing. What amount of dose in a diagnostic procedure is delivered?. The question can be answered by addressing the following topic: patient dosimetry and worker dosimetry. The aim of the present work is to summarize points of current status and future trends of diagnostic radiology for workers and patient dose determination by thermoluminescent phenomena.

2. State of art of TL dosimetry in diagnostic radiology

2.1. X-ray

The story began in 1895, when a German physicist discovered a new kind of rays. This is almost 120 years. The development of diagnostic imaging has been the result of a fruitful relationship between doctors, radiographers, physicists and equipment manufacturers. New apparatus has stimulated the introduction of new techniques and medical needs have in their turn stimulated new developments in equipment. Many new techniques have been introduced in recent years. The principles of CT scanning were first described by Godfrey Hounsfield and the first prototype EMI scanner was installed in 1972 at Atkinson Morley's Hospital. These new techniques have displaced many of the older X-ray techniques and this process will continue.

In modern radiological practice it is not possible to consider techniques in isolation. An integrated approach is needed with the various techniques used as appropriate. Often it is better for a complex procedure to be used early in an investigation since a diagnosis may be reached quickly with minimal inconvenience and risk to the patient. In recent years the widespread use of percutaneous biopsy techniques and ultrasound and CT scanning have considerably reduced the need for exploratory surgery. The recent developments in diagnostic imaging have considerably facilitated the recent trend to investigate and treat patients as day cases or as outpatients with considerably less disruption to the patients life. Much has been said about the dangers of X-ray, but the use of this in medical applications continues to increase worldwide. X-ray sources provide by far the largest contribution to the population dose. The latest report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimates suggest that there are about 4 billions X-ray examinations per year (UNSCEAR, 2013). This frequency is about 12% higher than the period 1996-2000 and 10% higher than the previous estimate for the period 1991–1996 (UNSCEAR, 2000) indicating an increase in practice.

2.2. Harmonization with radiology

One of the major compromises that must be made in imaging procedures using ionizing radiation is between patient exposure and image quality. Diagnostic radiology is the field of medicine that uses imaging exams and procedures to diagnose a patient. Within certain limits, increasing image quality requires an increase in patient exposure. In any form of medical care, diagnostic radiology plays an integral part in the diagnosis of disease or injury. The need to obtain a clinical image of sufficient quality to provide the relevant diagnostic information is of paramount importance. The amount of ionizing radiation provide information about the potential health detriment from each medical exposure based on an assessment of dose. In the UNSCEAR 2000 report it was classified medical exposures into two distinct types, those using radioactive tracers, which are administered to patient and those using external (bremsstrahlung) X-ray sources (UNSCEAR, 2000). The second group makes up about 95% of the collective dose from medical diagnostic exposures (Hill et al., 2014) and can be subdivided into five categories, radiography, mammography, dental radiography, computed tomography, and Fluoroscopy. Radiography is the simplest form of X-ray procedure in which images are obtained from X-ray transmission, giving the classic X-ray image showing differences in tissue and bone attenuations with which everyone is familiar. Mammography has also undergone many technological changes. Originally it was performed with conventional X-ray tubes using industrial direct exposure X-ray film to have good image quality. The introduction of dedicated mammography equipment, having a specialized tube with a molybdenum target / molybdenum filtration, combined with the introduction of film screen cassettes with a rear phosphor screen, substantially reduced radiation dose. The introduction of digital mammography offers potential benefits in the imaging mainly for young women or women with dense breasts (Milano et al., 1998; Hendrick et al., 1994; Pages and van Loon., 1998; Gaona et al., 2014). Dental radiography is among the most common medical exposures (Napier, 1999). From UNSCEAR report, the weighted average total number of diagnostic examination is approximately 1180 per thousand population and approximately 350 dental examinations per thousand population (UNSCEAR, 2013). In the same report, it was noted that 37% of the collective dose due to medical exposures arose from computed tomography (CT) examinations. As a consequence, the dramatic increasing trend in annual CT examination frequency and the significant dose per examination have an important impact on the overall population dose due to medical exposures (ICRP, 2007; Grudzenski et al., 2009; Wall and Hart, 1997; ICRP, 2000). As consequence of this, it is generally agreed that the greatest need for a dose determination is urgent in the area of CT. However, this is where the largest dosimetric problems occur.

As well as the scientific and technical aspects of X-ray image production, interest was growing in the levels of radiation employed in diagnostic radiology and dosimetric measurement methods. During the late 1950s in the UK the Adrian Committee organized a survey of the extent of medical and dental radiology in

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