Applied Radiation and Isotopes 100 (2015) 65–69

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Evaluation of occupational and patient radiation doses in orthopedic surgery

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HIGHLIGHTS

- Occupational exposure was evaluated during two intervention orthopedic procedures.
- Radiation doses were measured using a calibrated TLD GR200A.
- The radiation dose to orthopedic surgeons was shown to be well below the limits for prevention of tissue reactions.
- The radiation dose per hip procedure is low compared to previous studies.

ARTICLE INFO

Article history:
Received 28 July 2014
Received in revised form
7 November 2014
Accepted 24 November 2014
Available online 28 November 2014

Keywords:
Occupational exposure
Radiation dosimetry
Patient dose
TLD

ABSTRACT

This study intends to measure the radiation dose to patients and staff during (i) Dynamic Hip Screw (DHS) and (ii) Dynamic Cannula Screw (DCS) and to evaluate entrance surface Air kerma (ESAK) dose and organ doses and effective doses. Calibrated Thermoluminescence dosimeters (TLD-GR200A) were used. The mean patients' doses were 0.46 mGy and 0.07 mGy for DHS and DCS procedures, respectively. The mean staff doses at the thyroid and chest were 4.69 mGy and 1.21 mGy per procedure. The mean organ and effective dose for patients and staff were higher in DHS compared to DCS. Orthopedic surgeons were exposed to unnecessary radiation doses due to the lack of protection measures. The radiation dose per hip procedure is within the safety limit and less than the previous studies.

1. Introduction

Interventional fluoroscopy presents a tremendous advantage over invasive surgical procedures, because it requires only a very small incision, which substantially reduces the risk of infection and allows for shorter recovery time compared to surgical procedures (Miller, 2009). These interventions are used by a rapidly expanding number of health care providers in a wide range of medical specialties. An increasing number of medical specialists are using fluoroscopy outside imaging departments without full consideration of radiological protection coverage of fluoroscopy machines. Radiation protection and dose evaluation are important for orthopedic staff during the intervention since they are usually at close proximity to the patient during procedures. As a consequence, areas of the body not protected by the lead apron may receive significant radiation doses from scattered X-rays (Kim et al., 2008; Bedetti et al., 2008; Rehani and Ortiz-Lopez, 2006; ICRP, 2010; UNSCEAR, 2000; ICRP[b], 2007; Trianni et al., 2005; Delichas et al., 2003; Barry, 1984; Hynes et al., 1992; Miller et al., 2010; Radford et al., 1993). Thus, they are potentially at risk of developing radiation-induced cataracts, and complexity of invasive procedures (Rehani et al., 2011; Jacob et al., 2013; ICRP, 2012; Vano et al., 1998; Worgul et al., 2007; Ainsbury et al., 2009; Haskal and Worgul, 2004; Kleiman, 2006). Moreover the risk that

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http://dx.doi.org/10.1016/j.apradiso.2014.11.020
0969-8043/

orthopedic surgeon develop cancer (e.g. thyroid carcinoma) is significantly higher than that of a non-orthopedic professional and eight times more than that of an unexposed worker (Heeckt, 2011; Giannoudis et al., 1998). Lack of radiological protection training in radiation science or protection measures for those working with fluoroscopy outside imaging departments can increase the radiation risk to staff and patients (ICRP, 2010). The radiation dose of a surgeon depends on many factors, including the exposure time, the distance from the beam's central axis, the orientation of the fluoroscopic beam relative to the patient, the position of the surgeon within the operative field and the use of protective shields (Bone and Hsieh, 2000). In addition, the radiation exposure is dependent on the unit's design: input screen sensitivity of image intensifier, conversion factor, x-ray generator type and irradiation geometry. The radiation doses delivered to patients in most orthopedic procedures under normal conditions will not cause effects such as skin injury (IAEA, 2010).

Measurement of the occupational and patients radiation doses in interventional procedures are recommended (ICRP, 2010); however, there are only a few studies published regarding the radiation doses received by the patients and staff during orthopedic intervention compared to its frequency (Osman et al.; 2011, Bahari et al., 2006; Osman et al., 2013; Osman et al., 2012; Rampersaud et al., 2000; Blattert et al., 2004; Arnstein et al., 1994; Jones and Stoddart, 1998; Moore and Heeckt 2011; Theocharopoulos et al., 2003). These studies show wide differences in terms of dose, fluoroscopic time, number of radiographic images, equipment and inter-examiners variability, suggesting that patient dose optimizations methods have not been accomplished yet. Furthermore, there is a need of information concerning the doses received by radiosensitive organs, dose optimization and the related risks. Reference dose levels for orthopedic procedures have not yet been adopted either in national or international levels in terms of entrance surface air kerma (ESAK), according to our knowledge. This study evaluates radiation dose during orthopedic fracture fixation. The objectives of the current study are to measure the radiation dose to patients and staff during four surgical interventional orthopedic procedures (i) Dynamic Hip Screw (DHS) (ii) Dynamic Canula Screw (DCS); to estimate the risk of the aforementioned procedures and to evaluate entrance surface dose (ESD) and organ dose to specific radiosensitive patients' organs.

2. Material and method

2.1. Patient population

A total of 76 patients in Medical Corps Hospital, Sudan were investigated (56 patients, 73.7% for DHS and 20 patients, 26.3% for and DCS procedures). Ethics and research committee approved the study and informed consent was obtained from all patients prior to the procedure. The collection of patient exposure parameters data was done using standard data collection sheet prepared for collection of patient exposure-related parameters.

2.2. TL dosimetry

Radiation dose measurements were made for patients using TL dosimeters GR-200A TLDs (LiF: Mg, Cu, P (FIMEL, France)). All TLD dosimeters shared the same thermal history. A calibrated X-ray machine Toshiba, model DRX-1603B was used under reproducible reference conditions to deliver a known absorbed dose to the TLDs. For the TLD and chamber irradiation, a polymethylmethacrylate (PMMA) calibration test bed was constructed having dimensions $30 \times 30 \times 10$ cm^3, which simulates the patient's lateral and backscatter conditions (Martin et al., 1998; Sulieman et al., 2007). The first PMMA slab was used to accommodate the TLD chips in an array of slots 10×10. Each TLD was identified by its position in the array. Individual calibration factors were obtained by irradiating the entire group to the same dose. The measured signal of each TLD was divided by the mean signal of the group. This process was repeated three times to reduce the effect of statistical variations and to determine the stability and reproducibility of the signal.

The TLD signal was read using PCL3 TLD automatic reader (FIMEL, France) which allows fast readings of a large number of TLD samples with a reproducibility of $0.3 \pm 0.5\%$. A set of measurements were performed using (PTW-CONNY II) ionization chamber with dimensions of $180 \times 100 \times 45$ mm^3, applicable to cardiology, radiology and mammography. After completing the calibration process, any chips that exceeded the 5% error were excluded from the study. The irradiated chips were read out at a 55 °C preheat temperature and the signal was acquired from 55 °C to 260 °C with heating rate of 11^0 C/s. All TLDs were annealed in annealing oven (TLDO, PTW: Freiburg, Germany) at 240 °C for 10 min, followed by fast cooling. The mean background signal for un-irradiated TLDs was subtracted before any calculation. The linearity of the TLD's response for the range of dose used in this study was verified.

2.3. X-ray machine

All procedures were performed using a C arm machine at Medical Corps Hospital, a Siremobil 2000 (Siemens, Germany) with a total filtration of 2.5 mm Al and equipped with automatic brightness control, footswitch and last image hold. The machine was installed in 2009.

2.4. Staff dose measurement

Three orthopedists performed all procedures at the five departments. Groups of 3 TLDs were packed in transparent plastic envelopes and were attached with surgical tape to five sites on the operator body: the forehead, the neck, the chest, over the lead apron, the hand and the leg. Surgeons' wore a rubber lead apron of 0.5 mm lead equivalent as protection from scattered radiation (Fig. 1). No lead rubber cola was worn during any of the procedures. At each department, a single operating team was chosen to perform all the procedures, in order to avoid inter operator variations that could result from the different skills and experiences of the orthopedists. The effective dose to the organs and tissues has been calculated using the methodology and tissue weighting

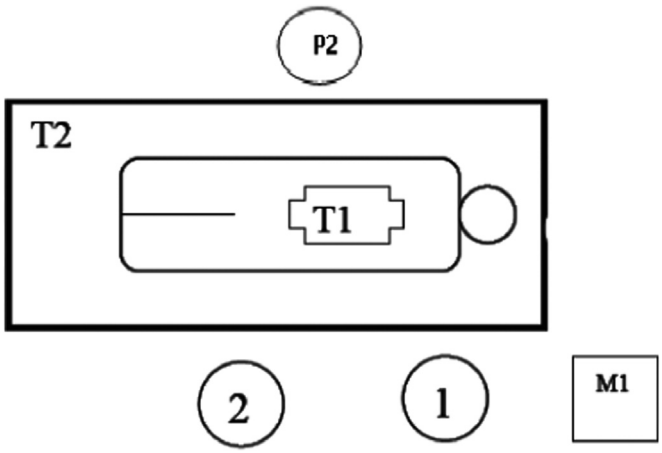

Fig. 1. Patient setup, staff positions during orthopedic surgery procedures. (1) Orthopedist; (2) assisstant; (3) technologist; (M1) fluoroscopic monitor; (T1) X-ray tube and (T2) table.