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Original article

Real-time dosimetry reduces radiation exposure of orthopaedic surgeons

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ABSTRACT

Background: Cancer prevalence of orthopaedic surgeons is elevated and chronic exposure to occupational ionizing radiation is seen as one reason.
Hypothesis: Use of a new dosimeter enabling radiation dose monitoring in real-time may reduce radiation exposure of orthopaedic surgeons.
Materials and methods: Over a period of four months, the surgeon and the C-arm operator were equipped with a novel dosimeter called DoseAware® (DA) while using the C-arm fluoroscope intraoperatively. Data of 68 patients DA were retrospectively compared using matched-pair analysis with 68 controls without DA. Both groups were assessed regarding fluoroscopic time (FT) and radiation dose (RD). Seven types of operative procedures were performed: internal fixation of subcapital humerus fractures, midshaft clavicular fractures, distal radius fractures, pertrochanteric femoral fractures, ankle fractures, traumatic vertebral fractures and osteoporotic vertebral fractures.
Results: Concerning the FT, use of DoseAware® led to a significant reduction for all evaluated operation types except for internal fixation of distal radius fractures ($P = 0.0511$). Regarding the RD, use of DoseAware® led to a significant reduction for all evaluated operation types except trochanteric femoral fractures with a PFNA® ($P = 0.0841$).
Conclusion: DoseAware® allowing real-time radiation dose monitoring reduces radiation exposure of the orthopaedic surgeon and instantly demonstrates the effects of dose-reduction techniques.
Level of evidence: Level III retrospective case control study.

1. Introduction

The C-arm fluoroscope as the most commonly used intraoperative imaging system in orthopaedic surgery provides real-time moving images of osseous structures. It enables the surgeon to reduce fractures and perform implant placement without extensive soft tissue devitalisation resulting in a trend of minimally invasive surgery in the past decades.

Adhering to these guiding principles can require numerous fluoroscopic examinations resulting in exposure to high levels of radiation, especially if the C-arms continuous mode is used extensively [1]. The use of fluoroscopy is a major concern for the operating team that performs this type of operations on a regular basis. In the recent years, there is a rising alertness concerning the harmful effects of exposure to long-term low-dose irradiation. Mastrangelo et al. found a highly significant cumulative cancer incidence in orthopaedics, exposed to irradiation in contrast to unexposed workers [2]. Zabel et al. reported an elevated risk of developing thyroid cancer in female radiologic technologist [3]. Ronckers et al. assume that ionization radiation exposure is an established breast cancer risk factor [4]. Chou et al. confirm that cancer prevalence of female orthopaedic surgeons is 1.9-fold increased, the prevalence of breast cancer even 2.9-fold increased than that of the general U.S. female population [5,6]. They suppose that continuous ionizing radiation exposure is jointly responsible for the elevated risk of developing cancer. Therefore, the use of ionising radiation must follow the “ALARA” (as low as reasonable achievable)-principle to ensure the safety of the caregivers occupational exposed by irradiation. The International Commission on

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Radiological Protection recommends a limit for occupational irradiation exposure an effective dose of 20 milliSievert (mSv) per year, averaged over defined 5 year periods (100 mSv in 5 years) [7].

Although lead aprons, protective eyeglasses and even lead shields are mainly available in the operation rooms, consequent usage is questionable. Chou et al. report only 80.4% of the female orthopaedic surgeons use protective shielding > 75% of the time; moreover only 42.2% reported use of a thyroid shield [5].

Medical staff exposed to radiation is officially monitored by use of thermoluminescence dosimeter (TLD) badges worn below the lead apron. The issue data are analysed retrospectively at a later stage. Therefore, the staff members can hardly reflect the circumstances of increased exposure to irradiation and whether it might have been preventable. For this reason, a dosimeter which gives information about the actual radiation exposure is desirable. It might help to decrease irradiation in the operation room by creating a rising awareness for the acute radiation exposure.

A new dosimeter called DoseAware® which visualizes radiation exposure in real-time has been shown to reduce staff radiation doses in an angiography room and during pediatric interventional radiological procedures [8–10].

We hypothesized that using this new dosimeter during orthopaedic surgeries, radiation will be reduced in comparison to operations without using this tool.

Within a matched-pair analysis, we compared orthopaedic procedures, the surgeon and the C-arm operator used this new tool to a control group without using this device.

Fig. 1. Dose Aware® badge worn upon the lead apron (red circle).

2. Materials and methods

Between July and October 2012, the surgeon and the C-arm operator were equipped with a novel dosimeter called DoseAware® (RaySafe™, Billdal, Sweden, distributed by Philips, Eindhoven, The Netherlands) while operative treatment of 104 patients in the orthopaedic and trauma surgery department of the University of Bonn Medical Center. For all 104 patients, a Philips mobile C-arm system (BV Pulsera®, Eindhoven, The Netherlands) was used for the fluoroscopic examinations in the conventional 2D mode.

DoseAware® is a dosimeter badge that was worn upon the lead apron (Fig. 1) (in addition to the official dosimeters, regularly worn below the lead apron). It measured the individual radiation exposure and sent the dose rates wireless and in real-time to a display placed in sight of the operating team. Surgeon and C-arm operator could watch their individual amount of exposure online and parallel on this display. Scatter dose rates were shown in a logarithmic scale with bars increasing in size and changing colour from green to yellow to red (green bar: 0.02–0.2 mSv/h; yellow bar: 0.2–2 mSv/h; red bar: 2–20 mSv/h; Fig. 2) with increasing dose rates in real-time. In this way, the staff members were warned of high scatter dose rates instantly and could react to decrease radiation exposure by limiting fluoroscopic time, use pulsed fluoroscopy, tight collimation or avoid suboptimal X-rays by use of the laser cross-hair.

Dose information, stored at the individual dosimeter, could be transferred to a computer after each operative procedure and a database might be created with the help of special software (Dose Manager®, RaySafe™) as a further tool. In this way, the history of the individual dose rate profiles (date, time, personal dose rates and accumulated personal dose rates of the yearly maximum [20 mSv]) achieved by different operations and different staff members could be stored. As the personal irradiation history of each operative procedure was not the focus of this study, the individual databases were not evaluated.

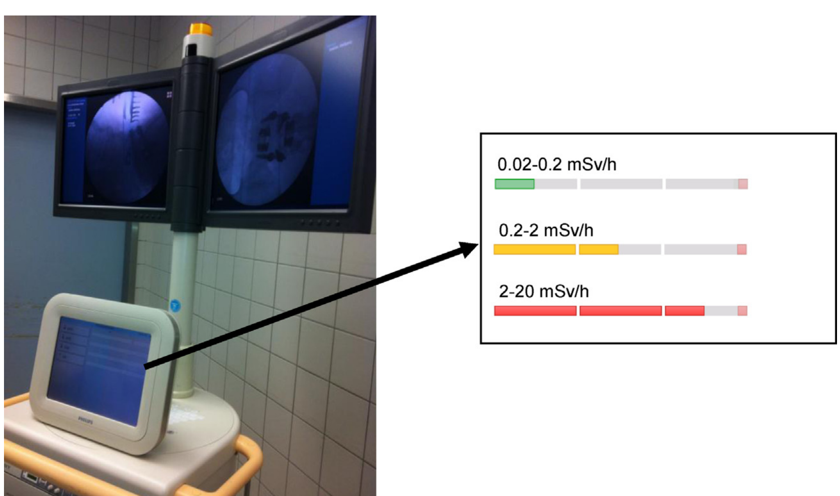

Fig. 2. A logarithmic scale with bars increasing in size and changing colour from green to yellow to red (green bar: 0.02–0.2 mSv/h; yellow bar: 0.2–2 mSv/h; red bar: 2–20 mSv/h) shows the individual scatter dose rates.