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Review

The Great Unknown—A systematic literature review about risk associated with intraoperative imaging during orthopaedic surgeries

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ABSTRACT

Introduction: Modern techniques in orthopaedic surgery using minimally invasive procedures, and increased use of fluoroscopic imaging present a potential increased risk to surgeons due to ionizing radiation exposure. This article is a systematic review of recent literature on radiation exposure of orthopaedic surgeons.

Materials and methods: Pubmed and Cochrane searches were performed on intraoperative radiation exposure covering English and German articles published between 1.1.2000 and 11.8.2014. Inclusion criteria were clinical studies and systematic literature reviews focusing on radiation exposure of orthopaedic surgeons during surgical procedures of the musculoskeletal system reporting either effective dose (whole body) or equivalent dose at the organ level.

All included articles were reviewed with focus on the surgical specialty, the procedure type, the imaging system used, the radiation measurement method, the fluoroscopy time, the radiation exposure, the use of radiation protection, and any references to specific safety guidelines.

Results: Thirty-four eligible publications were identified. However, the lack of well-designed studies focusing on radiation exposure of surgeons prevents pooling of data. Highest exposure and subsequent equivalent doses were reported from spinal surgery (up to 4.8 mSv of equivalent dose to the hand) and intramedullary nailing (up to 0.142 mSV of equivalent dose to the thyroid). Radiation exposure was reduced by 96.9% and 94.2% when wearing a thyroid collar and a lead apron.

Conclusions: With the increasing use of intraoperative imaging, there is a growing need for radiation awareness by the operating surgeon. Strict adherence to radiation protection should be enforced to protect in-training surgeons. Strategies to reduce exposure include C-arm position, distance, protective wear, and new imaging technologies. Radiation exposure is harmful and action should be taken to minimize exposure.

Contents

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Introduction

There is a consistent trend in orthopaedic surgery towards less invasive procedures to minimize iatrogenic soft tissue trauma. There is a balance between direct visualization of the fracture and soft tissue dissection. Increasing dissection leads to better direct visualization at the cost of blood supply to the fracture. With minimally invasive techniques, the soft tissue dissection is minimized, the blood supply is spared, but direct visualization is hampered. Consequently, more careful intraoperative imaging is required. A smarter instead of an increased use of fluoroscopy is indicated to avoid increased radiation exposure to the patient and the surgeon. While minimal invasive surgery is considered beneficial for patients, there remains the question whether it may increase the risk of radiation exposure for the treating surgeons.

Exposure is mainly through scatter radiation as the x-ray beam interacts with objects in its path, such as the patient and operating room table. Of the emitted photons, only 2% reach the image intensifier, 10–20% are scattered, and the rest are absorbed in the operative field. Primary radiation occurs if the surgeon's hand or other body part is in the primary beam and the resulting radiation exposure is much higher [1,2].

The effects of long-term low-dose ionizing radiation are not fully known, but are thought to include modest increased risk of cancer, cataracts, and possibly connected to the development of hereditary and other chronic diseases including the circulatory and immune systems [3,4]. Studies demonstrate increased levels of chromosomal abnormalities in medical workers with low-level occupation radiation exposure below recommended limits [5,6]. At a small hospital in Italy where radiation protective measures were sporadic, orthopaedic surgeons had an increased cumulative cancer incidence, 29% versus 4% in unexposed workers [7]. A large cohort study of female radiation technologists and a survey of female orthopaedic surgeons found an increased prevalence of breast cancer [8,9]. An increased risk of cataracts has been found in individuals exposed to long-term low-dose ionizing radiation [10].

The International Commission on Radiological Protection (ICRP)'s recommended annual occupational exposure limits are 20 mSv averaged over five years, with limits on equivalent dose to the lens of the eye of 20 mSv, and of 500 mSv to the skin, hands and feet, respectively [11,12]. For reference, the average individual is exposed to 3 mSv per year of background radiation, whereas a diagnostic radiograph is around 0.6 mSv. Musculoskeletal CT can result in equivalent doses (to patients) from 0.03 mSv in case of a wrist CT up to 19.15 mSv resulting from a lumbar spine CT. In contrast, the effective dose experienced by orthopaedic surgeons using fluoroscopy range from 0.005 mSv in a typical hip fluoroscopy up to 0.25 mSv in kyphoplasty [13].

The increasing use of intraoperative fluoroscopy, especially in high case-load centres, and the resulting exposure of orthopaedic surgeons triggered this systematic literature review. The goal was, to 1) extract information about radiation exposure resulting from the use of intraoperative imaging, 2) relate this information to potential biological effects, and 3) collect recommendations for surgeon's self-protection.

Materials and methods

This review is focused on studies reporting effective dose E or equivalent dose H_T in Sievert to derive potential biological risks. "Sievert" (Sv) is the SI unit of the effective dose, where 1 Sv represents a 5.5% chance of developing cancer [11]. Effective dose is calculated by the sum of tissue-weighted equivalent doses in all affected tissues and organs of a person. The type of radiation and the nature of the targeted organs or tissues are considered by using weighting factors. The effective dose values allow for comparison with the dose limits recommended by the ICRP, which are provided in Sievert. The unit is joule per kilogram (J kg-1). Rem is an older, non-SI unit which is also used for the effective dose. Values measured in rem can be converted to Sievert (1 Sv = 100 rem).

A systematic literature review was performed as a base for information extraction. The database PubMed was searched on August 7, 2014. The filters "Publication date from 2000/01/01 to 2014/08/07" and "Language English, German" were activated for every search. The search strategy is shown in Table 1. The search terms and number of hits are presented in the electronic search documentation (Table 2).

All 616 abstracts of the last search were screened. Only publications about clinical trials or systematic literature reviews were included for further assessment. 523 non-eligible articles were excluded during abstract or full text screening. In the next step, only studies where effective radiation to the surgeon was directly measured in the operating theatre were further considered for this review. Studies using indirect measurements or formulas to back calculate surgeon exposure [14–24] as well as studies measuring radiation exposure in Gray only were not further reviewed because of the problem of comparability [25–31].

Table 1
PICOT scheme for the search strategy of the literature review.

Population	Intervention	Control	Outcomes	Time
Orthopaedic surgeons Specialities: • General trauma and orthopaedics • Spinal surgery/neurosurgery	Surgeries of the musculoskeletal system using intraoperative imaging	N/A	Radiation exposure: • of different body parts of the surgeon • for different surgical procedures • for different surgical specialties Radiation protection used by the surgeon Radiation dose guidelines	N/A

N/A: not applied for this search.