ORIGINAL ARTICLE

# Occupational Dose and Dose Limits: Experience in a Large Multisite Hospital System

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## Abstract

**Purpose:** The Nuclear Regulatory Commission (NRC) has recently proposed changes that reduce the occupational dose limits for lens dose equivalent (LDE), embryo/fetus dose, and administrative control levels (ACLs) related to deep dose equivalent (DDE). This study collected occupational dose data from a large hospital system and determined how proposed NRC regulatory changes may affect worker and hospital workflow.

**Methods:** Radiation badge data were collected for 1,305 workers, from between 2013 and 2014, and 180 pregnancies, from between 2009 and 2014. Median values for LDE, DDE, and embryo/fetus dose were determined. Current and proposed NRC regulations were applied, and the percentage of workers exceeding regulatory limits/ACLs was recorded. Fisher's exact test was applied to determine if physicians were disproportionately affected by dose regulations.

**Results:** Median doses were one to two orders of magnitude lower than current annual dose limits prescribed by the NRC. Proposed NRC regulations significantly increased the percentage of workers who exceeded limits and ACLs. Interventional radiologists, pain medicine physicians, and cardiologists working in catheter laboratories were most affected by LDE limits and DDE ACLs. Nuclear medicine technologists were most affected by embryo/fetus limits. Physicians were disproportionately affected by regulations (odds ratio 26.86; $P < .0001$).

**Conclusions:** Proposed NRC regulatory changes will cause a small increase in the number of workers who exceed ACLs and limits. Physicians and pregnant nuclear medicine workers are most affected and may need to alter their workloads. Practical difficulties in implementing cumulative dose tracking, and use of an LDE shielding factor, should be considered.

**Key Words:** Regulation, nuclear regulatory commission, NRC, occupational dose, radiation safety, government relations

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## INTRODUCTION

In recent years, published evidence from the international community has resulted in a divergence between the occupational dose limits typically adopted internationally, as suggested by the International Commission on Radiological Protection (ICRP), and those prescribed in the United States by the Nuclear Regulatory Commission (NRC). In 2007, the ICRP released Publication 103, which recommends a maximum conceptus (embryo/fetus) dose of ≤1 mSv after a worker declares her pregnancy [1]. This dose is similar to that for a member of the public, and substantially lower than the 5-mSv maximum during the time period of the pregnancy, as set by the NRC [2]. Two more recent ICRP publications recommended decreasing the limit for eye-lens dose equivalent (LDE) to ≤50 mSv in any one year and ≤20 mSv averaged over a 5-year period [3,4]. This value is substantially lower than the 150-mSv annual limit prescribed by the NRC [5].

For several years, the NRC has considered altering their limits based on recently published data and to better align with the international community [6]. Further, the NRC has proposed prescribing specific administrative control levels (ACLs) for implementation in mandatory ALARA (as low as reasonably achievable) planning programs [7]. Several possible ACLs are proposed, including one based on ICRP Publication 60, which recommends an effective dose limit of 20 mSv averaged over five years, and no more than

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50 mSv in a single year [8]. This limit is much lower than the current total effective dose equivalent limit of 50 mSv per year prescribed by the NRC [5].

Although the NRC publishes calls-for-comment from stakeholders and the general public when considering regulatory changes, published information is lacking relating to typical occupational doses for a hospital system and how regulations affect workflow [9]. This study reviews a subset of radiation-badge data from a large multisite hospital system, which acts as both a community hospital and a tertiary referral hospital. We report typical occupational doses that are lower than NRC regulations, and estimate the possible impact of proposed regulations. We hypothesize that proposed NRC regulatory changes will significantly increase the number of workers who are receiving radiation levels that exceed occupational dose limits, and that physicians are disproportionately affected by such regulations.

## METHODS

### Data Collection

Radiation-badge data from 2013 and 2014 were collected as part of a quality improvement initiative. This work was determined to be not in the category of human subjects research by the Florida Hospital Institutional Review Board. Badge data consisted of the worker's department, whether the worker was a physician, and two occupational dose metrics: lens dose equivalent (LDE) and deep dose equivalent (DDE). Department categories included the following: radiology (with a nuclear medicine subcategory); cardiology (with subcategories of cardiac catheter laboratory and nuclear medicine); radiation oncology; and other (with surgery, endoscopy, and pain medicine subcategories).

### Corrections Applied

After the collection of badge data, several corrections were applied. The minimum recordable dose for radiation badges used at our hospital (Luxel+; Landaur, Glenwood, Illinois) is 0.01 mSv. All badge data with an indication of dose >0 mSv, but <0.01 mSv, were set to 0.005 mSv. The radiation badge is typically worn outside the lead apron (for workers using a single badge); thus, the actual dose received by the worker is lower than that recorded by the badge, owing to attenuation from the lead. The NRC allows use of a DDE shielding factor (typically reducing the dose to one third that of the badge reading) under certain circumstances to account for the lead apron worn by the worker. For purposes of this study, the shielding factor was applied according to US NRC Regulatory Guide 8.40 [10]. The terms "uncorrected DDE" and "corrected DDE" are used in the current study to denote the DDE for workers without and with the shielding factor applied, respectively. The shielding factor was applied to all DDE >1.25 mSv, and was not applied to DDE from workers in the radiation oncology or nuclear medicine categories because a lead apron is not routinely used or effective in those settings.

### Summary Statistics

The number and proportion of workers in each department, and whether they were physicians, were determined for both years for which badge data were collected. Summary statistics are provided for LDE, uncorrected DDE, and corrected DDE. As expected, dose data were not normally distributed, so all dose data are presented as median (25th percentile, 75th percentile). Differences between recorded doses for 2013 and 2014 were tested for significance, using two-tailed sum-rank tests at the 0.05 level.

The subset of workers with dose data available for both years, called "common data" in this study, was determined as well. The numbers and percentages of workers exceeding current and proposed occupational dose limits and ACLs were determined for each year. Further, 95% confidence intervals (CIs) for the percentage of workers exceeding each limit were determined by the binomial exact (Clopper-Pearson) method. Fisher's exact test was implemented to determine if being a physician was associated with exceeding any of the current or proposed occupational dose limits or ACLs at the 0.05 level. Odds ratios with 95% CIs are reported.

### Lens Dose-Equivalent Limits

The NRC proposed lowering the yearly LDE limit from 150 to 50 mSv, based partially on ICRP-recommended limits of 50 mSV in any one year, and no more than 20 mSv averaged over any five years [11]. The 50-mSv limit was applied for each year of collected data. A full set of data for five years was not available for each worker, so the 20-mSv limit was tested per year, and with the 2-year average for those workers who had data available for both years.

### Deep Dose-Equivalent Administrative Control Levels

The number and percentage of workers with yearly DDE exceeding the current total effective dose equivalent limit