

## Fully Covered or Just the Front? Surgeon Radiation Exposure Varies Greatly With Location, Choice of Protective Equipment, and Surgeon Position

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**Purpose:** Despite safety standards requiring personal protective equipment (PPE) use during intraoperative fluoroscopy, compliance is not 100%. This may be due to lack of awareness or myths regarding exposure such as “chest lead is not important” or “at 6 feet away, there’s no radiation.” The purpose of this study was to determine which fluoroscopic views create the most radiation exposure and to determine which body region of the surgeon receives the most exposure in various positions relative to the source.

**Methods:** An anthropomorphic phantom was placed supine on a flat-top radiolucent table at comfortable working height for an average-height surgeon. A C-Arm (Phillips) was used to obtain fluoroscopic views at multiple lower extremity sites in the posteroanterior (PA) and lateral planes. An ion chamber (Ludlum Instruments) with applied correction factor was placed next to the patient in a typical working position at 3 height levels: thyroid, chest, and pelvis. We recorded the integrated radiation dose from 10 seconds of fluoroscopy at each location/level with/without PPE. This was repeated at 3 and 6 feet away. A Geiger counter (Ludlum Instruments) was used to record exposure rate under a 0.5-mm lead equivalent, non-circumferential protective apron placed on a phantom to assess exposure when a surgeon is facing the patient or turned to the side.

**Results:** For PA imaging, the femur had the most exposure ( $678 \mu\text{R} \pm 280$ ) followed by hip ( $598 \mu\text{R} \pm 257$ ), pelvis ( $493 \mu\text{R} \pm 158$ ), knee ( $312 \mu\text{R} \pm 102$ ), tibia ( $278 \mu\text{R} \pm 92$ ), and ankle ( $232 \mu\text{R} \pm 64$ ). For lateral imaging, the sacral view was highest ( $3476 \mu\text{R} \pm 1287$ ) followed by hip ( $1083 \mu\text{R} \pm 441$ ), femur ( $849 \mu\text{R} \pm 486$ ), knee ( $297 \mu\text{R} \pm 173$ ), ankle ( $133 \mu\text{R} \pm 59$ ), and tibia ( $116 \mu\text{R} \pm 58$ ). This was significantly different on both views ( $P < 0.001$ ). Overall the surgeon chest area received the most radiation ( $620 \mu\text{R} \pm 271$ ), followed by pelvis ( $365 \mu\text{R} \pm 184$ ) and thyroid ( $311 \mu\text{R} \pm 101$ ) during PA imaging. For lateral imaging, the chest received the most exposure ( $1441 \mu\text{R} \pm 1669$ ), followed by thyroid ( $1041 \mu\text{R} \pm 1234$ ) and pelvis ( $495 \mu\text{R} \pm 698$ ). The differences were significant on both views ( $P = 0.018$ ). Radiation exposure decreased by 94% and 98% when 3 and 6 feet away from the source, respectively ( $889 \mu\text{R} \pm 10.1$  vs  $53 \mu\text{R} \pm 2.5$  vs  $19 \mu\text{R} \pm 0.9$ ,  $P < 0.001$ ). Radiation exposure rate at the chest was decreased 98% ( $0.95 \text{ mR/hr}$  vs  $48.1 \text{ mR/hr}$ ,  $P < 0.001$ ) with PPE, consistent with regulatory standards (>95%). However, exposure rate was only decreased 22% ( $37.7 \text{ mR/hr}$  vs  $48.1 \text{ mR/hr}$ ,  $P < 0.001$ ) when the surgeon faced perpendicular to the source.

**Conclusion:** Radiation exposure is highest proximal to the knee and with lateral imaging. Standing 3 to 6 feet away results in decreased but not insignificant exposure. When wearing non-circumferential PPE, facing perpendicular or away from the xray source results in inadequate protection. Surgeons should wear fully circumferential PPE while utilizing fluoroscopy or be cognizant of exposure differences based on position.