Investigating Patient-Level Radiation Exposure in Hand and Wrist Surgery

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Introduction

While occupational exposure to radiation has been previously studied in the hand surgery literature[1,2], there is a paucity of studies looking at radiation exposure to the patient during fluoroscopy-guided upper extremity surgery. We aim to describe the level of radiation experienced by patients undergoing common hand and wrist fracture fixation and to identify risk factors for increased radiation exposure.

Materials and Methods

After obtaining IRB approval, all patients in the University of Pennsylvania Health System who underwent fracture fixation of the hand, wrist, or forearm from 01/01/2016-12/31/2020 by three hand/upper extremity surgeons (DRS, DJB, ICL) were retrospectively identified using CPT codes. Patients were excluded if their case did not require the use of intra-operative fluoroscopy in the form of a mini c-arm, if the digital fluoroscopy report was not available for review, or if they were having concurrent procedures that also required fluoroscopic guidance (i.e. more than one fracture pinning).

The electronic medical record (EMR) was reviewed for data extraction. Patient demographics collected were age, gender, and race. Operative details included procedure CPT code, date of procedure, senior surgeon. Fracture repairs were considered proximal or distal based on the anatomic location of injury, with proximal repairs including radial/ulnar shaft fractures and distal radius fractures, and distal repairs including metacarpal fractures and phalangeal fractures. Fracture repairs were also further classified as open or closed (percutaneous) repairs. Radiation exposure was measured as reported in the Dose Area Product Hologic Insight Report for the corresponding surgical procedure. The report includes the number of radiographic images acquired, the total exposure time (seconds), and the total dose-area product (DAP) ($cGv*cm^2$). The effective dose (ED) was calculated using the DAP, field size, and a previously-established conversion factor[3].

$$\mathrm{ESD} = \frac{\mathrm{DAP}}{A_p}$$

$$A_p = A_{ii}(d_p/d_{ii})^2$$

Anatomic Area	Conversion factor (µSv/cGy)
Forearm/Wrist	4.8
Hand	3.5

Crawley et al. 2000

Primary outcomes included the total number of intra-operative images taken, total fluoroscopic exposure time, DAP, and ED of each hand/upper extremity surgery. Descriptive statistics were used to report counts and frequencies for categorical data. Comparative univariate analyses were completed using 2-sample t-tests. Statistical significant was set at $p<0.05$ and all analyses were performed using STATA/IC 16.0 (StataCorp, LLC; College Station, TX).

Results

Table 1. Patient Demographics and Procedural Details	
Average Age (year)	46.1
Gender	
Female	204 (56.5%)
Male	157 (43.5%)
Procedure	
Radial/Ulnar Shaft Fractures	12 (3.3%)
Distal Radius Fractures	129 (35.7%)
Metacarpal Fractures	111 (30.8%)
Phalangeal Fractures	109 (30.2%)
Mean DAP ($cGy*cm^2$)	6.1017
Mean ED (µSv)	0.17
Mean Images Acquired (# of images)	45
Mean Fluoroscopy Time (sec)	55.7

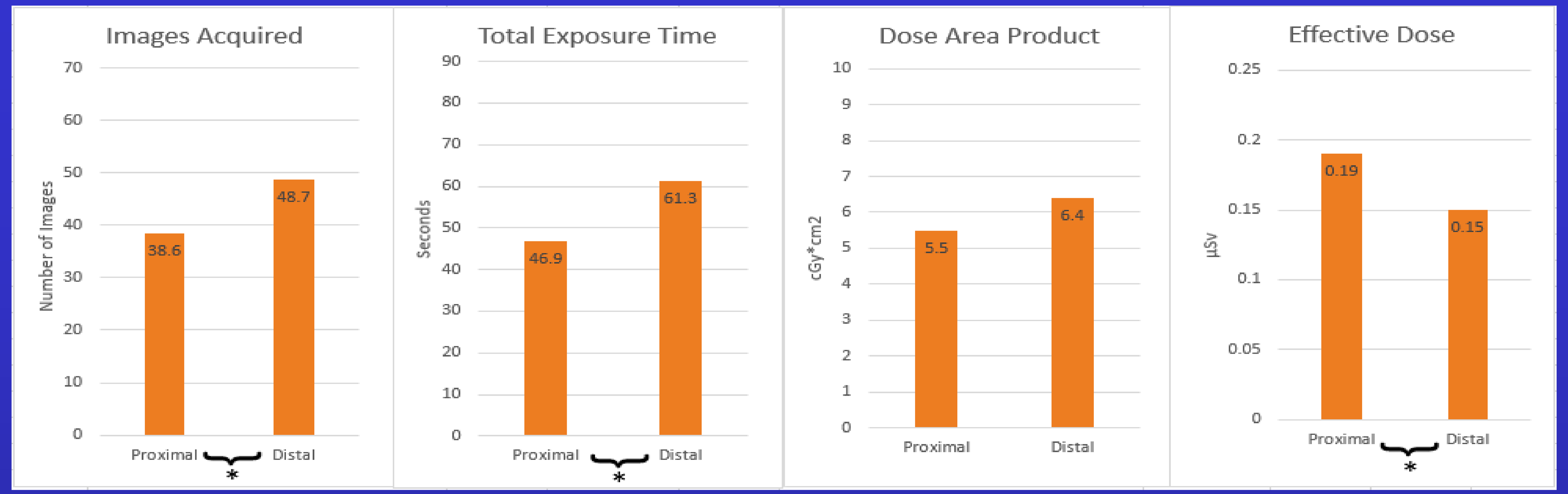

Figure 1
Comparative Analysis of Images Acquired, Total Exposure Time, Dose Area Product, and Effective Dose between Proximal and Distal Procedures, * = p<0.05

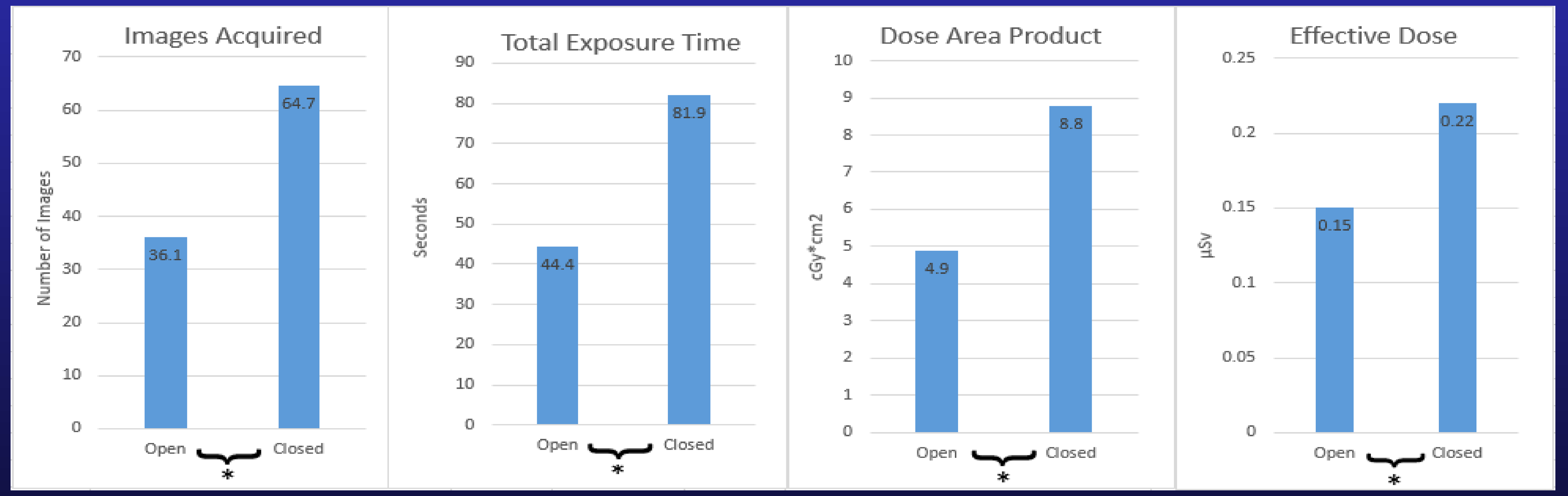

Figure 2
Comparative Analysis of Images Acquired, Total Exposure Time, Dose Area Product, and Effective Dose between Open and Closed Procedures, * = p<0.05

The final sample included 361 patients. Average patient age was 46 years with the majority being female (56.5%). Procedures included fixation of forearm fractures (3.3%), distal radius fractures (35.7%), metacarpal fractures (30.8%), and phalangeal fractures (30.2%). The average number of intraoperative images acquired was 45 images [95% CI = 41-48]. Average total fluoroscopic time was 55.7 seconds [95% CI = 50.9-60.5], average DAP was 6.1017 cGycm2 [95% CI = 5.5153-6.6881], and average effective dose was 0.17 µSv [95% CI = 0.15-0.18]. Distal (metacarpal and phalangeal) fractures required more intra-operative images and longer total fluoroscopy time (49 images, 61.3 seconds) compared to proximal (forearm and distal radius) fractures (39 images, 46.9 seconds) (images: p = 0.0011, exposure time: p = 0.0009). However, distal fractures had a lower average ED compared to proximal fractures (0.15 µSv vs. 0.19 µSv, p=0.0138). When compared to open procedures like open reduction internal fixation, closed procedures such as closed reduction percutaneous pinning were associated with higher DAPs (8.8359 vs 4.9191 cGycm2, $p < 0.0001$), higher ED (0.22 vs 0.15 µSv, p=0.0007), more intraoperative images (65 vs 36 images, $p < 0.0001$), and longer total fluoroscopy time (81.9 vs 44.4 seconds, $p < 0.0001$).

Conclusions

Overall, patient-level radiation exposure during fluoroscopy-guided hand and wrist fracture fixation is low. The average ED for these procedures seen in our study is lower than that of other commonly-utilized medical imaging modalities like dental radiographs (ED ~5 µSv) and chest xrays (ED ~100 µSv)[4].

Fixation of more distal fractures requires more intra-operative images and longer fluoroscopy time but results in lower ED due to the smaller area and decreased thickness of irradiated tissue distally in the fingers compared to proximally in the forearm. Compared to open procedures, closed treatment of fractures is associated with more intra-operative images, longer fluoroscopy time, and higher DAP and ED values.

References

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