Decreased Radiation Exposure Among Orthopedic Residents Is Maintained When Using the Mini C-Arm After Undergoing Radiation Safety Training

DAVID GENDELBERG, MD; WILLIAM L. HENNRIKUS, MD; CARISSA SAWYER, BA; DOUGLAS ARMSTRONG, MD; STEVEN KING, PhD

abstract

The resident curriculum of the American Board of Orthopaedic Surgery emphasizes radiation safety. Gendelberg showed that, immediately after a program on fluoroscopic safety, residents used less radiation when using the mini C-arm to reduce pediatric fractures. The current study evaluated whether this effect lasted. Residents underwent a new annual 3-hour session on mini C-arm use and radiation. Group A included 53 reductions performed before training. Group B included 45 reductions performed immediately after training. Group C included 46 reductions performed 11 months later. For distal radius fractures, exposure time and amount were 38.1 seconds and 83.1 mR, respectively, for group A; 26.7 seconds and 32.6 mR, respectively, for group B; and 24.1 seconds and 40.0 mR, respectively, for group C. When radiation time and amount were compared between group B and group C, \( P \) values were <.05 and <.01, respectively. When group C and group A were compared, \( P \) values were .525 and .293, respectively. For both bone forearm fractures, exposure time and amount were 41.2 seconds and 90.9 mR, respectively, for group A; 28.9 seconds and 30.4 mR, respectively, for group B; and 31.2 seconds and 43.6 mR, respectively, for group C. When radiation time and amount were compared between group B and group C, \( P \) values were .704 and .117, respectively. When group C and group A were compared, \( P \) values were .183 and .004, respectively. No significant difference in radiation exposure was noted immediately after training vs 11 months later. A sustained decrease in radiation exposure occurred after an educational program on safe mini C-arm use. [Orthopedics. 2017; 40(5):e788-e792.]

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The mini C-arm fluoroscope is a commonly used tool in pediatric fracture reduction, and consequent-
(ALARA). The ALARA concept seeks to decrease the amount of radiation exposure while obtaining the necessary imaging.\(^6\)

According to the National Council on Radiation Protection and Measurements, the recommended maximum annual dose of radiation to the whole body is 5000 mR and 50,000 mR to the extremities.\(^7\) Because orthopedic surgeons frequently use the mini C-arm, it is a common source of radiation exposure. Radiation safety has taken a central role in the American Board of Orthopaedic Surgery surgical skills curriculum for residents.\(^8\) Radiation safety is essential because radiation exposure is cumulative. Sumko et al\(^9\) showed the importance of technique and experience for radiation safety; more junior residents received greater radiation exposure than more experienced residents. Further, Gendelberg et al\(^10\) showed that an educational program on radiation safety decreased radiation time and radiation exposure among residents in the short term. However, it is unclear whether these effects are maintained. This study was conducted to determine whether the educational effect of the radiation safety program on safe use of the mini C-arm was sustained 11 months later, at the end of the academic year.

Materials and Methods

Study Design and Setting

The current study is a retrospective follow-up study to the work of Gendelberg et al.\(^11\) The current study examined whether radiation safety education was still effective in reducing radiation exposure at the end of the academic year. Radiation exposure time and the amount of whole body radiation incurred by the resident performing the reduction were compared among 3 groups: 53 consecutive pediatric patients undergoing fracture reduction before the educational session (group A), 45 consecutive pediatric patients undergoing fracture reduction in the emergency department after the session (group B), and 46 consecutive pediatric patients undergoing reduction for both bone forearm fracture and distal radius fracture in the emergency department at the end of the academic year, 11 months after the educational session (group C). The study was performed at an academic level I pediatric trauma center.

Participants

The study proposal was reviewed and authorized by the institutional review board of the college of medicine. The study group included residents at the end of their second academic year, 11 months after they underwent an annual radiation safety program. Comparison groups consisted of previously recorded data for second-year residents toward the end of the academic year who did not participate in the radiation safety educational program (control group) and a group of second-year residents immediately after they completed a radiation safety program. The groups did not include the same residents. Inclusion criteria included simple both bone forearm fractures and simple distal radius fractures requiring reduction in patients younger than 18 years treated within a 3-month period at the end of the academic year.

Safety Training

Initially, all orthopedic residents underwent an annual 3-hour educational session on proper mini C-arm use and radiation safety that was taught by the hospital health physics department at the beginning of the academic year. The program began with a 2-hour lecture on radiation physics, the function of the mini-C arm, and safety measures to decrease radiation exposure. After the lecture, residents practiced proper mini C-arm use for 1 hour in a controlled setting under supervision. The current study examined the residents at the end of the academic year to determine whether the principles covered in the educational session were maintained for 11 months and resulted in decreased radiation exposure.

Calculation of Radiation Exposure

Radiation exposure times for the patient and the resident performing the reduction were recorded from the mini C-arm. Three groups were compared: group A, with 53 pediatric fracture reductions performed before the implementation of annual fluoroscopic training; group B, with 45 pediatric fracture reductions performed immediately after fluoroscopic safety training; and group C, with 46 fracture reductions performed 11 months later. Radiation exposure among residents and patients and radiation emission from the mini C-arm were calculated by the radiation physicist (S.K.), based on the parameters recorded by the mini C-arm. Data from the 3 groups were compared.

Statistical Analysis

Statistical analyses were performed, with data expressed as mean radiation time and exposure with associated standard deviation. Normality analysis showed that data were normally distributed. Student’s \(t\) test was used, and significance was set at \(P<.05\).

Results

The radiation incurred during reduction of 144 fractures was examined: 53 fractures in group A, 45 in group B, and 46 in group C. Average age of patients in group A was 9.6 years compared with 9.5 years in group B and 8.0 years in group C. Of the 53 patients in group A, 31 were boys and 22 were girls; 20 had both bone forearm fractures and 33 had distal radius fractures. Of the 45 patients in group B, 32 were boys and 13 were girls; 19 had both bone forearm fractures and 26 had distal radius fractures. Of the 46 patients in group C, 32 were boys and 14 were girls; 24 had both bone forearm fractures and 22 had distal radius fractures.

Among patients with distal radius fractures, radiation exposure time and amount were 38.1 seconds and 83.1 mR, respectively, in group A; 26.7 seconds and 32.6 mR, respectively, in group B; and 24.1 seconds and 40.0 mR, respectively, in group C. Group A had the longest radiation exposure time and the greatest radiation exposure by the resident (Table, Figures 1-2). When group B and group C were
compared, \( P \) values for radiation time and amount of radiation incurred were .525 and .293, respectively. When group C and group A were compared, \( P \) values for radiation time and amount incurred were <.05 and <.01, respectively (Table).

Among patients with both bone forearm fractures, radiation exposure time and amount were 41.2 seconds and 90.9 mR, respectively, in group A; 28.9 seconds and 30.4 mR, respectively, in group B; and 31.2 seconds and 43.6 mR, respectively, in group C. Group A had the longest radiation time and greatest amount of radiation exposure by the resident (Table, Figures 1-2). When group B and group C were compared, \( P \) values for radiation time and amount incurred were .704 and .117, respectively. When group C and group A were compared, \( P \) values for radiation time and amount incurred were .183 and .004, respectively (Table).

**DISCUSSION**

The Pediatric Orthopaedic Society of North America has made implementation of its Quality, Safety, and Value Initiative (QSVI) a high priority.\(^\text{13}\) The goal of the initiative is to coordinate between institutions and implement a unified program to improve quality of care and safety while delivering value. Radiation safety is a QSVI priority.\(^\text{4,13,14}\) The current study evaluated the radiation safety of the mini C-arm with regard to the QSVI. Specifically, this study evaluated the change in radiation exposure to both the resident and the patient when using the mini C-arm at the end of the academic year, after official training on mini C-arm use by a radiation physicist (S.K.) at the beginning of the year.

Radiation safety is important to both the patient and the surgeon. The British Columbia Centre for Disease Control found that lead aprons and personal monitoring of radiation exposure were not required at distances of greater than 1 m from the image intensifier.\(^\text{15}\) Radiation safety was discussed in a symposium at the annual meeting of the American Orthopaedic Association in 2010, where the acronym DEBT (distance, exposure, bar-

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**Table**

<table>
<thead>
<tr>
<th>Group</th>
<th>Both Bone Time, s</th>
<th>Distal Radius Time, s</th>
<th>Both Bone Radiation, mR</th>
<th>Distal Radius Radiation, mR</th>
<th>( t )</th>
<th>Both Bone ( P )</th>
<th>Distal Radius ( P )</th>
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<td>.042</td>
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<td>33</td>
<td></td>
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<td>.525</td>
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<td>26.1</td>
<td>60.9</td>
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<td>.010</td>
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<td>26.7</td>
<td>30.4</td>
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<td>No.</td>
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<td>26</td>
<td>19</td>
<td>26</td>
<td></td>
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<td>.293</td>
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<td>15.8</td>
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<td>43.6</td>
<td>40.0</td>
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<td>22</td>
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<td>SD</td>
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<td>63</td>
<td>81</td>
<td></td>
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</table>
iers, technique) was described, referring to ways to decrease radiation exposure.16 In accordance with QSVI guidelines and ALARA, residents should take extra precautions to decrease radiation, such as standing away from the mini C-arm when possible (ideally, >1 m), wearing radiation badges to track cumulative exposure, decreasing magnification (the mini C-arm boosts radiation to maintain image brightness), avoiding the direct beam of radiation, inverting the C-arm, and keeping the hands out of the beam, in addition to use of a lead apron by both the surgeon and the patient.8,11,16-20

A previous study found that an educational program on radiation safety significantly decreased both radiation time and amount in the short term.12 For residents at the end of the second academic year who had undergone mini C-arm training at the beginning of the year, there was a statistically significant decrease in reduction time for distal radius fractures. Although no significant decrease was found for both bone forearm fracture reduction times, a reduction was noted in radiation emitted with these fracture types. The educational session on safe mini C-arm use decreased radiation exposure and time, and the program remained effective 11 months later, at the end of the academic year.

Lee et al2 reported that the use of a mini C-arm improved fracture alignment and decreased both reduction attempts and radiation exposure to the physician. Further, Sharieff et al3 reported that the mini C-arm could be used as an alternative to postreduction films. At the study institution, anteroposterior and lateral radiographs of a forearm generate 20 mR radiation. The current study showed that, before the training session, reduction of a both bone forearm fracture and a distal radius fracture generated 90.9 mR and 83.1 mR, respectively. However, immediately after the educational session, the amount of radiation exposure with both bone forearm fractures and distal radius fractures decreased to an average of 30.39 mR and 32.58 mR, respectively. By the end of the academic year, radiation exposure was maintained at 43.64 mR and 40.04 mR for both bone forearm fractures and distal radius fractures, respectively (P=.117 and P=.293, respectively).

For residents at the end of the second academic year who underwent the mini C-arm training at the beginning of the year, no statistically significant change in radiation exposure or reduction time was found compared with the group of residents evaluated immediately after they underwent the educational program. A slight increase was noted in radiation exposure for both fracture types and in reduction time for both bone forearm fractures, but these small increases were not significant. Additionally, the radiation values for group C were still significantly less than those obtained without any safety training. This finding suggests that the effects of the educational session on safe mini C-arm use were not just the result of increased experience among residents.

**Limitations**

This study had several limitations. First, radiation emission from the machine was calculated as opposed to actual radiation exposure to the resident or patient. The rationale for this was that radiation emission provides a reliable surrogate to radiation exposure. Although the actual dose, or radiation exposure, to the resident or patient was lower, the authors do not believe that this difference affects the significance of the findings. Further, in more complex cases and fractures in which more radiation is used, the decreased amount of radiation exposure is likely to be even greater and more significant. Second, the sustained reduction in radiation time and exposure may be the result of increased experience and technique by the residents. The finding of a significant improvement between group C and group A, both of which consisted of second-year residents at the end of the academic year, helps to refute the notion that the sustained improvement was the result of experience and technique alone. Third, the sustained results may be caused by variability between the different second-year classes. Each group consisted of second-year residents from different academic years, but the authors do not believe that either class was particularly more “talented” than the other. Further, all of the residents undergo
the same training and work with the same attending surgeons. Therefore, although there may be some variability among residents, it probably is not enough to cause a significant difference in the results.

**CONCLUSION**

Use of a mini C-arm is a useful adjunct to pediatric fracture reduction in the emergency department. Although it offers clear benefits, it does have risks. This study showed that the educational effect of a fluoroscopic radiation training program lasted for at least 11 months. No statistically significant difference was found in radiation exposure for distal radius fracture and both bone fracture reductions immediately after the training and at the end of the academic year. An educational program for safe C-arm use decreased the duration and amount of radiation exposure among residents performing reduction in both the short term and the long term.

**REFERENCES**


