Radiation Exposure in Fluoroscopy of the Shoulder: A Comparison between Mini and Conventional C-arm Image Intensifier

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Objective: *To compare the radiation exposure of the primary surgeon while using the conventional c-arm and mini c-arm fluoroscopy at the shoulder.*
Material and Method: *Twelve shoulders of six fresh cadavers were used to simulate this experimental study. Radiation exposure of the primary surgeon was measured at the head and neck region. The average radiation dose was measured using both the conventional c-arm and mini c-arm, then the findings were compared.*
Results: *Mean radiation energy of the conventional c-arm was significantly lower than the mini c-arm at 59.39$\pm$1.43 kV and 70.58$\pm$4.01 kV, respectively ($p<0.001$). Dose rates to which the primary surgeon was exposed from the conventional c-arm and the mini c-arm were 81.46$\pm$30.37 µSv/hour and 87.54$\pm$43.69 µSv/hour, respectively. However, the difference was not statistically significant ($p = 0.875$).*
Conclusion: *There is no difference in the level of radiation safety for the primary surgeon when using the conventional c-arm vs. the mini c-arm for a fluoroscopic-assisted shoulder procedure. Therefore, selection of the methodology should be based on equipment availability and clinical considerations.*

Keywords: *Radiation, Exposure, Fluoroscopy, Shoulder, Mini c-arm*

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In current clinical setting, fluoroscopy is extensively used in many specialties of orthopaedic surgery, both for diagnostic and therapeutic purposes. The primary objective is to improve the accuracy of procedures, especially minimally invasive techniques performed in the operating theatre and the outpatient clinic(1-3). Predictably, radiation safety is also a major concern of both orthopedic surgeons and operating room personnel(4-10). Many solutions have been introduced in order to minimize the radiation hazard, including reduction of the radiation dosage by using the mini c-arm fluoroscope(11-14).

Several studies have been conducted to evaluate the radiation exposure comparing the mini c-arm and conventional c-arm in many regions of application, such as the hand and wrist, the foot and ankle, as well as the cervical spine(12,15-19). The shoulder is another area for clinical application of the mini c-arm. However, knowledge regarding radiation exposure when using the image intensifier in this particular region is still inconclusive. The authors, therefore, conducted this experimental study to determine the radiation exposure of the primary surgeon when using a mini c-arm at the shoulder, as compared with doses received when using a conventional c-arm.

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Material and Method

Twelve shoulders from six fresh cadavers were selected for this study. Each body was positioned supine with a 30-degree head elevation on a radiolucent operating table. This positioning simulated the position required for common procedures of the shoulder, such as fracture reduction, implant fixation, diagnostics, and therapeutic injection. A mini c-arm (Fluoroscan, Hologic, Danbury, CT, USA) was used to take an AP image of the shoulder. The radiation dose was detected by a dosimeter (MyDose PDM-117, Hitachi Aloka Medical, Tokyo, Japan) that can measure radiation exposure in 1 µSv increments. The dosimeter was securely attached to a post at a height representing the head and neck region of a 175 cm tall doctor hypothetically performing a procedure on the shoulder (Fig. 1). The automatic mode of the c-arm was selected in order to minimize the effect of technical factors and to better simulate a realistic situation. In each testing condition, the x-ray was taken continuously until 1 μSv of radiation exposure was detected on the dosimeter, at which point the exposure time shown on the c-arm screen was recorded. The particular condition was repeated three times per shoulder in order to calculate the average values. For purposes of comparing the mini c-arm to a conventional c-arm, identical testing conditions were repeated using a 12-inch conventional c-arm (BV Pulsera, Phillips, Andover, MA, USA) instead (Fig. 2). Radiation exposure was measured by the dose rate and calculated as radiation dose (μSv) per unit of time (hour). The data were statistically analyzed using the Students t-test. The power of the test was set as 100%.

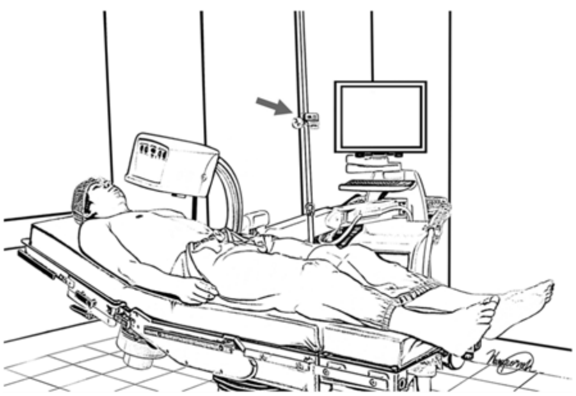

Fig. 1 Positioning of the mini c-arm for shoulder procedure (Black arrow: dosimeter positioned at a height consistent with the head and neck region of the surgeon).

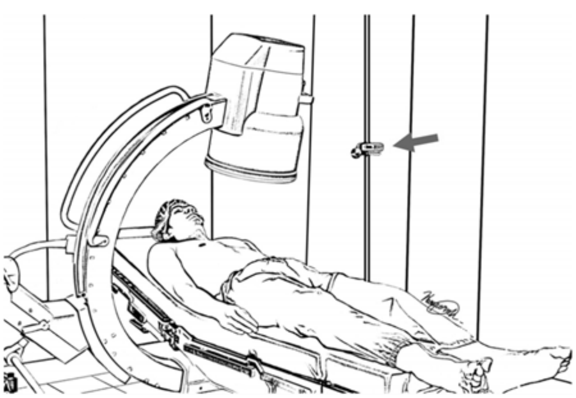

Fig. 2 Positioning of conventional c-arm for shoulder procedure (Black arrow: dosimeter positioned at a height consistent with the head and neck region of the surgeon).

Results

Radiation energy, tube current, and dose rate in both the mini and conventional c-arm simulations are presented in Table 1. The mean radiation energy from the conventional c-arm was statistically significantly lower than that of the mini c-arm. Their values were 59.39 ± 1.43 kV and 70.58 ± 4.01 kV, respectively ($p<0.001$). In contrast, the tube current of the conventional c-arm was significantly higher than that of the mini c-arm, at 1.18 ± 0.13 mA and 0.10 ± 0.01 mA, respectively ($p<0.001$). The dose rates at which the primary surgeon was exposed from the conventional and mini c- arm were 81.46 ± 30.37 μSv/hour and 87.54 ± 43.69 μSv/hour, respectively. However, no statistically significant difference was found ($p = 0.875$). Further evaluation using the 95% confidence interval demonstrated that dose rates between the two different types of c-arm were not statistically different.

Discussion

Fluoroscope has been used to assist many surgical procedures on different parts of the body for over a decade. Its use has gained popularity over time among not only orthopedic surgeons, but also physicians in other specialties. As a result, radiation safety has become a major concern and remains a focal topic among researchers. Several approaches, such as technique of radiation dose measurement, fluoroscopic setting, and patient positioning have been studied in order to minimize the radiation exposure of the surgeon, operating room personnel, and the patient[13]. There have also been attempts to develop new and innovative devices that are easier for clinical application and that lower radiation doses; one such example is the mini c-arm. Many studies have confirmed improved radiation safety by using the mini c-arm, as compared to using a standard c-arm, to many regions of the upper and lower extremities including the cervical spine[12,15-19]. However, information on radiation exposure remains limited regarding application of this procedure to the shoulder. This experimental study, therefore, endeavors to fill the gap in the literature in this area.

Fresh frozen cadavers were employed as targets of interest to simulate radiation scattering on actual human soft tissue. The study setting simulated a normal clinical environment. The head and neck area of the primary doctor was selected as the target area

Table 1. Comparison of radiation dose, tube current, and dose rate between conventional c-arm and mini c-arm

	Conventional c-arm (n = 12)	Mini c-arm (n = 12)	Mean difference	*p*-value
Radiation energy (kV)				
Mean (SD)	59.39 (1.43)	70.58 (4.01)	-11.19 (3.29)	<0.001
95% CI	58.48, 60.30	68.04, 73.13		
Tube current (mAmp)				
Mean (SD)	1.18 (0.13)	0.10 (0.01)	1.08 (0.13)	<0.001
95% CI	1.10, 1.26	0.09, 0.10		
Dose rate (µSv/hour)				
Median (range)	77.36 (43.37 to 152.11)	74.23 (45 to 200)	-	0.875
Mean (SD)	81.46 (30.37)	87.54 (43.69)		
95% CI	62.17, 100.76	59.79, 115.30		

The *p*-value was for the paired t-test; except dose rate, which was for the Wilcoxon signed ranks test

for radiation measurement, as this region and particularly the eyes are usually unprotected while performing image-guided procedures. Because of low radiation dose-detection by the mini c-arm fluoroscopy[11,14] and in order to minimize the c-arm workload during the study, time to obtain a pre-determined level of micro Sievert radiation exposure and the radiation dose rate were used as parameters to compare between the two different types of c-arm.

The findings of the present study show no significant difference in the radiation exposure of the head and neck region of the primary doctor between the mini c-arm and standard c-arm on the shoulder. This result may be explained by the position of the radiation source of the conventional c-arm, which is under the table. As a result, the radiation scatters down to the floor instead of onto the surgeon. Comparatively, the control panel at the source side of the mini c-arm and the small gantry might be potential factors that increase the radiation scatter of the mini c-arm. Moreover, radiation scatters while using the mini c-arm may be higher because of the shorter distance between the radiation source and the target of interest.

There were some limitations in this study in terms of the type of fluoroscope and variety of testing positions. In addition, the use of a dosimeter that can only measure radiation exposure in 1 microSv increments means that radiation of less than 1 microSv cannot be detected.

Conclusion

Based on the findings of the present study, there is no difference in the level of radiation safety for the primary surgeon performing a fluoroscopic-assisted shoulder procedure when using the conventional c-arm and the mini c-arm. Therefore, machine selection should depend on clinical considerations and availability of equipment.

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Potential conflicts of interest

None.

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การศึกษาเปรียบเทียบการกระจายรังสีจากการใช้เครื่องฟลูออโรสโคปชนิดปกติและชนิดขนาดเล็กที่บริเวณข้อไหล่

ดิเรก ตันติเกตุ, ก้องเขต เหรียญสุวรรณ, ไววิทย์ สงวนวงศ์วาน, บรรจง มไหสวริยะ

วัตถุประสงค์: *เป็นการศึกษาเปรียบเทียบการกระจายของรังสีต่อศัลยแพทย์ที่ใช้เครื่องฟลูออโรสโคปชนิดปกติและชนิดขนาดเล็กที่บริเวณข้อไหล่*

วัสดุและวิธีการ: *การศึกษานี้เป็นการจำลองการใช้ฟลูออโสโคปชนิดปกติและชนิดขนาดเล็กที่บริเวณข้อไหล่โดยใช้ fresh cadaver จำนวน 12 ข้อไหล่ และทำการวัดปริมาณรังสีโดยใช้เครื่องวัดปริมาณรังสีที่บริเวณศีรษะและลำคอ ของศัลยแพทย์ผู้ทำผ่าตัดและนำค่าเฉลี่ยของผลการวิจัยมาเปรียบเทียบทางสถิติ*

ผลการศึกษา: *ปริมาณรังสีที่ใช้จากเครื่องฟลูออโรสโคปขนาดปกติมีขนาดน้อยกว่าชนิดขนาดเล็กอย่างมีนัยสำคัญทางสถิติ 59.39±1.43 kV และ 70.58±4.01 kV ตามลำดับ ($p<0.001$) ส่วนอัตราปริมาณรังสีจากเครื่องฟลูออโรสโคปขนาดปกติมีขนาดน้อยกว่าชนิดขนาดเล็ก 81.46±30.37 μSv/hour และ 87.54±43.69 μSv/hour ตามลำดับ แต่อย่างไรก็ตามไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p = 0.875$)*

สรุป: *ความปลอดภัยจากรังสีในการใช้เครื่องฟลูออโรสโคปทั้งสองชนิดที่ข้อไหล่นั้นไม่มีความแตกต่างกัน ดังนั้นการเลือกใช้ชนิดของเครื่องฟลูออโรสโคปีควรขึ้นอยู่กับความสะดวกและความเหมาะสมในผู้ป่วยแต่ละราย*
