

Is It Safe to Use a Lead Screen During Hip Arthroscopy?



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Purpose: To assess the radiation attenuation of lead screens in comparison to lead gowns in a simulated hip arthroscopy setting. **Methods:** In this quantitative laboratory study, a phantom pelvis was used to simulate the scatter produced by patients during hip arthroscopy. Radiation measurements were taken using a handheld radiation detector positioned perpendicular to the phantom pelvis at 1.5 m and 2 m. Measurements were taken without shielding as a control, behind a lead gown (0.4-mm lead equivalent), and behind a lead screen (0.5-mm lead equivalent). **Results:** With the detector at 1.5 m perpendicular to the hip, equivalent radiation was attenuated by the lead screen (94%) and the lead gown (94%). With the detector at 2 m perpendicular to the hip, the lead screen at 1.7 m attenuated 95% of radiation. **Conclusions:** In hip arthroscopy, using lead screens is a safe and more comfortable alternative to wearing lead gowns. The lead screen should be at least 1.2 m from the radiation source, with the surgeon standing closely behind the screen, fully covered. **Clinical Relevance:** Lead screens can be safely used in hip arthroscopy.

The incidence of hip arthroscopy has increased from 3.6 to 16.7 per 100,000 patients between 2005 and 2013,¹ for the treatment primarily of femoroacetabular impingement and acetabular labral tears.² A recent multicenter randomized controlled trial has shown that

hip arthroscopy produces better patient outcome scores than conservative treatment for femoroacetabular impingement.³

Intraoperative radiography is often required throughout the procedure, especially when ostectomy of the femoral neck or acetabulum is required. However, there are circumstances when intraoperative radiography is only required during the initial guidewire placement.

The ionizing radiation dose in hip arthroscopy changes with factors such as patient size,^{4,5} complexity of the procedure,^{4,6} and surgeon skill.⁷ Although advances in intraoperative image intensifier technology have produced reductions in ionizing radiation dose and scatter,^{3,6,8} this remains an important safety consideration in hip arthroscopy.

The current standard intraoperative radiation protection for surgical procedures is a lead gown of minimum 0.25- to 0.35-mm lead equivalency.⁴ These gowns weigh between 5 and 8 kg. Many orthopaedic surgeons are familiar with the muscle fatigue and discomfort associated with full days of operating while wearing a lead gown. Lead gowns can be defective without the wearer realizing it and are vulnerable to damage due to incorrect handling and storage.⁹ Lead-alternative gowns can be lighter and more robust but may not provide the same level of protection.^{4,6}

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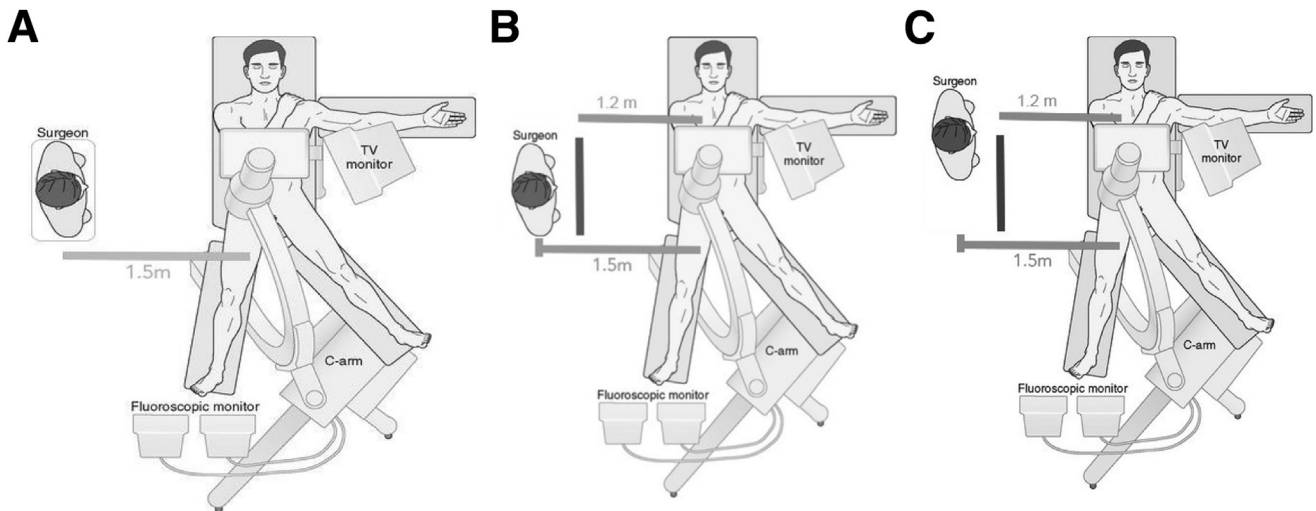


Fig 1. Detector at 1.5 m. (A) Lead gown setup. (The box around the surgeon represents the lead gown.) (B) Lead screen setup. (C) Lead screen setup showing incorrect use of screen.

Lead screens have been shown to be a comfortable and safe alternative to lead gowns when used during intraoperative breast irradiation¹⁰ and endoscopic retrograde cholangiopancreatography.¹¹ They can provide a uniform ionizing radiation attenuation of 0.5- to 1-mm lead equivalent and effectively cover the eyes and thyroid. In addition, breaches in a lead screen are easily detected by visual inspection. However, lead screens can be large and take up a significant amount of space in the operating room. Furthermore, to be used in accordance with radiation safety guidelines, surgeons must stand completely covered behind the screen, removing them from the operative field.

The efficacy of lead screens during hip arthroscopy has yet to be established. The purpose of this study was to assess the radiation attenuation of lead screens in comparison to lead gowns in a simulated hip arthroscopy setting. Our hypothesis was that lead screens would provide equivalent attenuation of ionizing radiation to lead gowns during simulated hip arthroscopy.

Methods

Design

This was a quantitative laboratory study. The project was approved by the Local Research Ethics Committee as a low-risk ethics study. The study was designed by an experienced arthroscopic hip surgeon and the head medical physicist and radiation safety officer at our hospital. The data collection and study were conducted by an orthopaedic resident (A.R.) and the aforementioned medical physicist (L.B.).

A mock-up of a standard hip arthroscopy setup was created, using the same operating table and image intensifier used in the operating theater (Fig 1A). A phantom pelvis (ATOM Adult Male, model 701; CIRS) was positioned supine in the middle of the operating table, with the fluoroscopic source (OEC 9900 Elite C-arm; GE Healthcare) beneath the table. The image intensifier was located approximately 15 cm above the right hip of the phantom pelvis. A handheld detector

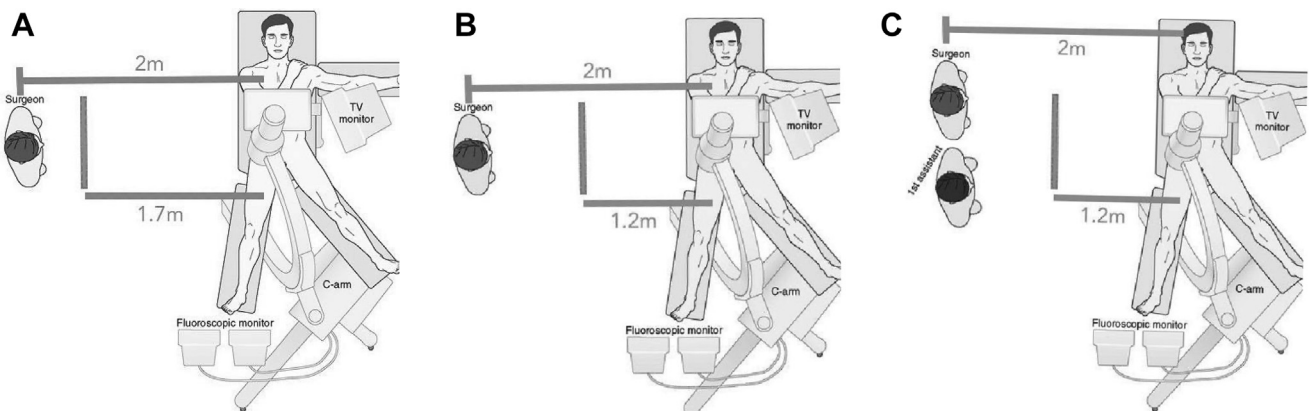


Fig 2. Lead screen setup: lead screen at 1.7 m (A), lead screen at 1.2 m (B), and lead screen with partial protection (C).

Table 1. Detector at 1.5 m

1.5 m Perpendicular to Hip	Average $\mu\text{R}/\text{DAP}$	% Attenuation	<i>P</i> Value
Control (no shielding)	4,217.9	0.0	
Lead gown (0.4-mm lead equivalent)	266.4	93.7	
Lead screen (0.5-mm lead equivalent)	15.8	94.1	
Lead screen with partial protection	1,276.9	69.7	<.001

DAP, dose area product; μR , microroentgens.

(10x5-180 Ion Chamber; Radcal) and reader (9060 Electrometer; Radcal) were used to measure the radiation in microroentgens \cdot square meters. The ion chamber response measured ± 1.03 , with uncertainty of 1.2%; calibration was conducted by the Australian Radiation Protection and Nuclear Safety Agency in January 2018 and was traceable to Australian primary standards (Appendix Fig 1, available at www.arthroscopyjournal.org).

The lead gown was a Bar-Ray Products gown with 0.4-mm lead equivalent. Prior to the study, the lead gown was tested to be fully operational. The lead screen was a MAVIG WD257 mobile lead screen, 700 mm wide. Owing to the accuracy of the detector and radiation source for this study, no power analysis was conducted.

Procedure

Control data (detector unshielded) were collected 1.5 m (chest height for the surgeon) from the floor with the detector located 1.5 and 2 m from the radiation source. Distances occupied by staff from the patient are highly

variable during a case. The distances represented typical locations of staff members during intraoperative radiation exposure. The distances were selected based on the advice of the surgeon-investigator (P.T.). The location at 1.5 m represents a position to which a surgeon might step back, whereas 2 m is a reasonable position for a lead screen to be placed while not being too close to the field.

The experimental data were taken at the same height. We reviewed the last 50 hip arthroscopy cases and recorded the kilovolts (peak), frame rate, and milliamperes. The median values from these cases were calculated. The same parameters were then used in our study. Because dose area product (DAP) and exposure time vary significantly between patient cases, a standardized exposure time of 5 seconds was used for each exposure, chosen to make the measurements reproducible. Six repeated exposures were conducted at each position and distance, and the average radiation dose, measured in microroentgens, and DAP were recorded. Comparing microroentgens per DAP allowed for comparison of our setup with any case, independently of kilovolts (peak), milliamperes, or time for the case because DAP is inclusive of these. At the dose level typical for hip arthroscopy, scattered radiation is relatively low. To increase the scattered radiation detected by the ion chamber, an additional 8 cm of Perspex (Perspex International) was added to the exit side of the pelvis phantom. This increased the accuracy of the radiation dose measurements.

The lead gown configuration, shown in Figure 1A, consisted of the detector at 1.5 m and 2 m from the radiation source totally covered by the lead gown. In the lead screen configuration, the detector was positioned behind the top of the screen (0.5-mm lead

Fig 3. Comparison between lead gown and lead screen at 1.5 m. *Pb*, lead equivalent.

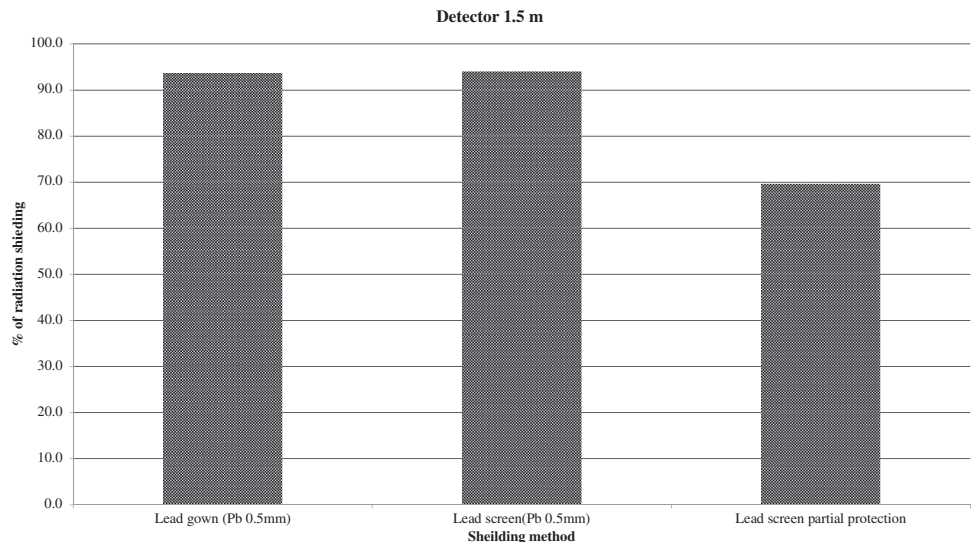


Table 2. Detector at 2 m

2 m Perpendicular to Hip	Average μR/DAP	% Attenuation	P Value
Control (no shielding)	2,294.6	0	
Lead screen at 1.7 m	117.2	94.9	
Lead screen at 1.2 m	131.4	94.3	
Lead screen at 1.2 m with partial protection	143.4	93.7	.186

DAP, dose area product; μR, microroentgens.

equivalent). The lead screen configurations are shown in Figures 1B and 2.

The lead screen configurations with the detector at 1.5 m are summarized as follows: (1) lead screen at 1.2 m and 30 cm behind the screen and (2) lead screen at 1.2 m and offset to cover approximately 50% of the detector and 30 cm behind the screen. The second configuration simulated incorrect use of the lead screen by standing in the incorrect position.

The lead screen configurations with the detector at 2 m are summarized as follows: (1) lead screen at 1.7 m from the operating table and 30 cm behind the screen (Fig 2A), (2) lead screen at 1.2 m (0.8 m from the detector) (Fig 2B), and (3) lead screen at 1.2 m (0.8 m from the detector) and offset to cover approximately 50% of the detector (Fig 2C). The second configuration simulated incorrect use of the lead screen by increasing the distance between the detector and the lead screen, whereas the third configuration was used to simulate standing behind the lead screen in the incorrect position by both distance and coverage.

Statistical Analysis

Attenuation was measured in microroentgens. Differences were expressed as a percentage of attenuation compared with the amount of radiation reaching the

detector in the control setup. For the 1.5-m distance, a 1-way analysis of variance (ANOVA) was used (Fig 1 A and B). Likewise, for the 2-m distance, a 1-way ANOVA was used (Fig 2). ANOVA (3 × 2) with post hoc Bonferroni adjustment was used to explore the similarity between the 3 conditions (control, lead gown, and lead screen) at the 2 distances (1.5 and 2 m).

Results

Lead Screens Versus Lead Gowns

At 1.5 m perpendicular to the hip, equivalent radiation was attenuated by the lead screen (94%) and the lead gown (94%) (Table 1). When the detector was placed only partially protected by the lead screen at 1.5 m, 70% was attenuated; this represented a significant difference compared with the lead gown at the same distance (P < .001) (Fig 3).

With the detector at 2 m perpendicular to the hip, the lead screen at 1.7 m attenuated 95% of radiation (Table 2). When the screen was moved to 1.2 m perpendicular to the hip, 94.3% was attenuated. Equivalent radiation was attenuated by the lead screen at 1.7 and 1.2 m (P = .186), and both of these results were not statistically different compared with the lead-gown attenuation at 1.5 m. The partially protected detector at 2 m perpendicular to the hip attenuated 93.7% of ionizing radiation (Fig 4).

Discussion

Our study showed that lead screens may provide equivalent attenuation of ionizing radiation to lead gowns during a simulated hip arthroscopy when used in accordance with radiation safety guidelines. This finding supports our hypothesis. At 1.5 m from the radiation source, a surgeon standing close to (within 30

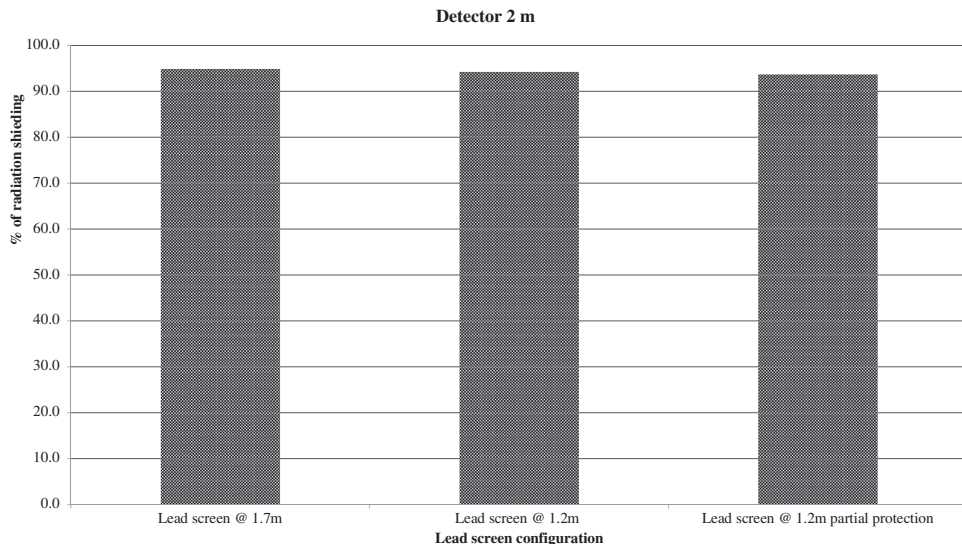


Fig 4. Changing distance between detector and screen at 2 m.

cm), and fully protected by, a lead screen has equivalent protection (94% or 15.8 average microroentgens/DAP) from ionizing radiation to that provided by a lead gown (93.7% or 266.4 average microroentgens/DAP) (assuming a lead equivalency of both a screen and gown of 0.5 mm).

If the surgeon is only partially protected at 1.5 m, the protection is not equivalent and would not be within reasonable radiation safety practices.⁴ At 2 m from the radiation source, the lead gown, lead screen, and lead screen with partial protection are equivalent (Fig 4).

This study shows that a correctly applied lead screen can be used as a safe alternative in hip arthroscopy. A lead screen offers the benefit of increased surgical comfort.

Clinical Relevance

Orthopaedic surgeons performing hip arthroscopy are exposed to ionizing radiation. Lead gowns are used as radiation protection during hip arthroscopy; however, they can be heavy and uncomfortable. Lead screens may offer safe and more convenient radiation protection.

The use of a lead screen has several potential benefits over a lead gown. Although lead gowns remain the current standard, damage to the internal lead may be difficult to appreciate. Damage to a lead screen is more likely to be easily visually identifiable than damage to a lead gown.

Lead screens provide thyroid and eye protection. There is variable compliance with the use of thyroid protectors among orthopaedic theater personnel. The compliance rate has been reported to be as low as 4% in a case series of 223 orthopaedic theater personnel.¹² Furthermore, lead screens offer the additional benefit of eye protection, which is particularly important for trainee surgeons who have higher eye exposure to radiation than their mentors.^{13,14}

Lead screens may help to reduce occupational musculoskeletal strain and fatigue. Musculoskeletal injuries among orthopaedic surgeons and residents have been reported mainly in the neck, shoulders, and lower back,¹⁵⁻¹⁷ with up to 44% of orthopaedic surgeons reporting musculoskeletal injuries directly attributable to their work.¹⁶ However, the use of a lead screen does potentially create some practical difficulties regarding space, particularly in small operating theaters, and does not allow live screening of the hip if simultaneous manipulation of the leg by the surgeon is required.

Strengths of Study

The phantom pelvis allowed for accurate reproducible and controlled simulation of a hip arthroscopy. Through the different shielding configurations, the pelvis and the image intensifier remained in the same position. The radiation safety officer at our institution operated the image intensifier.

As previous articles have shown, the total ionizing radiation dose in a hip arthroscopy case is highly

variable.¹⁸ Factors such as the size and composition of the patient, the image intensifier settings, and the procedure being performed all influence the amount of radiation exposure a surgeon receives.¹⁹ Our study controlled for these factors by using a set pelvis thickness and image intensifier setting.

Limitations

Regarding study limitations, our study could have taken intraoperative radiation measurements to correlate the data with the simulated operation. Although we correlated the radiation dose recorded from image intensifier reports of hip arthroscopies performed at our institution, it may have been advantageous to correlate the average ionizing radiation dose to the surgeon, measured with a wearable dosimeter device, with the measurements we took in the trial.

Conclusions

In hip arthroscopy, using lead screens is a safe and more comfortable alternative to wearing lead gowns. The lead screen should be at least 1.2 m from the radiation source, with the surgeon standing closely behind the screen, fully covered.

References

1. Maradit Kremers H, Schilz SR, Van Houten HK, et al. Trends in utilization and outcomes of hip arthroscopy in the United States between 2005 and 2013. *J Arthroplasty* 2017;32:750-755.
2. Pasciak AS, Jones AK, Wagner LK. Application of the diagnostic radiological index of protection to protective garments. *Med Phys* 2015;42:653-662.
3. Griffin DR, Dickenson EJ, Wall PDH, et al. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): A multicentre randomised controlled trial. *Lancet* 2018;391:2225-2235.
4. Australian Radiation Protection and Nuclear Safety Agency. *Radiation protection in diagnostic and interventional radiology*. Canberra: Commonwealth of Australia, 2008.
5. Salvo JP, Zarah J, Chaudhry ZS, Poehling-Monaghan KL. Intraoperative radiation exposure during hip arthroscopy. *Orthop J Sports Med* 2017;5:2325967117719014.
6. Schueler BA, Vrieze TJ, Bjarnason H, Stanson AW. An investigation of operator exposure in interventional radiology. *Radiographics* 2006;26:1533-1541. discussion 1541.
7. Smith KM, Duplantier NL, Crump KH, et al. Fluoroscopy learning curve in hip arthroscopy—A single surgeon's experience. *Arthroscopy* 2017;33:1804-1809.
8. Mygind-Klavsen B, Gronbech Nielsen T, Maagaard N, et al. Danish Hip Arthroscopy Registry: An epidemiologic and perioperative description of the first 2000 procedures. *J Hip Preserv Surg* 2016;3:138-145.
9. Oyar O, Kislalioglu A. How protective are the lead aprons we use against ionizing radiation? *Diagn Interv Radiol* 2012;18:147-152.

10. Eaton DJ, Gonzalez R, Duck S, Keshtgar M. Radiation protection for an intra-operative X-ray device. *Br J Radiol* 2011;84:1034-1039.
11. Chung KH, Park YS, Ahn SB, Son BK. Radiation protection effect of mobile shield barrier for the medical personnel during endoscopic retrograde cholangiopancreatography: A quasi-experimental prospective study. *BMJ Open* 2019;9:e027729.
12. Devalia KL, Peter VK, Madanur MA, Braithwaite IJ. Exposure of the thyroid to radiation during routine orthopaedic procedures. *Acta Orthop Belg* 2006;72:615-620.
13. Cheriachan D, Hughes AM, du Moulin WS, Williams C, Molnar R. Ionizing radiation doses detected at the eye level of the primary surgeon during orthopaedic procedures. *J Orthop Trauma* 2016;30:e230-e235.
14. Kesavachandran CN, Haamann F, Nienhaus A. Radiation exposure of eyes, thyroid gland and hands in orthopaedic staff: A systematic review. *Eur J Med Res* 2012;17:28.
15. Auerbach JD, Weidner ZD, Milby AH, Diab M, Lonner BS. Musculoskeletal disorders among spine surgeons: Results of a survey of the Scoliosis Research Society membership. *Spine (Phila Pa 1976)* 2011;36:E1715-E1721.
16. Davis WT, Sathiyakumar V, Jahangir AA, Obremskey WT, Sethi MK. Occupational injury among orthopaedic surgeons. *J Bone Joint Surg Am* 2013;95:e107.
17. Knudsen ML, Ludewig PM, Braman JP. Musculoskeletal pain in resident orthopaedic surgeons: Results of a novel survey. *Iowa Orthop J* 2014;34:190-196.
18. Gaymer CE, Achten J, Auckett R, Cooper L, Griffin D. Fluoroscopic radiation exposure during hip arthroscopy. *Arthroscopy* 2013;29:870-873.
19. Saroki AJ, Wijdicks C, Philippon MJ, Bedi A. Orthopaedic surgeons' use and knowledge of ionizing radiation during surgical treatment for femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc* 2016;24:3962-3970.