Reduction of Operator Radiation Dose by a Pelvic Lead Shield During Cardiac Catheterization by Radial Access

Comparison With Femoral Access

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Objectives This study sought to determine the efficacy of patient pelvic lead shielding for the reduction of operator radiation exposure during cardiac catheterization via the radial access in comparison with the femoral access.

Background Cardiac catheterization via the radial access is associated with significantly increased radiation dose to the patient and the operator. Improvements in radiation protection are needed to minimize this drawback. Pelvic lead shielding has the potential to reduce operator radiation dose.

Methods We randomly assigned 210 patients undergoing elective coronary angiography by the same operator to a radial and femoral access with and without pelvic lead shielding of the patient. Operator radiation dose was measured by a radiation dosimeter attached to the outside breast pocket of the lead apron.

Results For radial access, operator dose decreased from 20.9 ± 13.8 μSv to 9.0 ± 5.4 μSv, p < 0.0001 with pelvic lead shielding. For femoral access, it decreased from 15.3 ± 10.4 μSv to 2.9 ± 2.7 μSv, p < 0.0001. Pelvic lead shielding significantly decreased the dose-area product–normalized operator dose (operator dose divided by the dose-area product) by the same amount for radial and femoral access (0.94 ± 0.28 to 0.39 ± 0.19 μSv × Gy⁻¹ × cm⁻² and 0.70 ± 0.26 to 0.16 ± 0.13 μSv × Gy⁻¹ × cm⁻², respectively).

Conclusions Pelvic lead shielding is highly effective in reducing operator radiation exposure for radial as well as femoral procedures. However, despite its use, radial access remains associated with a higher operator radiation dose. (J Am Coll Cardiol Intv 2012;5:445–9) © 2012 by the American College of Cardiology Foundation

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Radial access is gaining increasing acceptance in catheterization laboratories because of its lower vascular complication rate, less patient discomfort, and lower cost (1–5). Higher operator radiation exposure has been recognized as a drawback contributing to the skepticism held by many interventional cardiologists against the transradial route (6–9). Despite the efficacy of conventional lead aprons in blocking nearly 95% of scatter radiation to the body, radiation-induced neoplasms of the unprotected brain, nasopharyngeal tract, and upper extremities remain a concern for high-volume operators (10–12). Additional measures to reduce operator radiation during radial procedures have been proposed, such as a tubing extension allowing for greater distance between the x-ray tube and the operator, and a special radiation protection board (13,14). Pelvic lead shielding of the patient has been reported to reduce operator radiation exposure during femoral access cardiac catheterization, but its effect for radial access has not been investigated (15). In this study, we evaluated the efficacy of a pelvic lead shield for transradial cardiac catheterization and compared it with the femoral access.

### Methods

#### Study design

Patients scheduled for elective, outpatient coronary angiography with an interventional cardiologist (H.W.L.), who has extensive experience in radial access procedures, were asked to participate in the study. After informed consent was obtained, the catheterization procedures were randomly allocated by time period to a femoral or radial approach with or without the pelvic lead shield in place. After completion of the procedure, only cases fulfilling the following criteria were included in the study: the procedure was uncomplicated, and the right radial or right femoral artery could be accessed without difficulties; aortic valve stenosis or bypass grafts were not present; and aortography was not performed. If coronary intervention was performed immediately after the diagnostic procedure, fluoroscopy time and radiation measurements were recorded before the intervention was started.

#### Cardiac catheterization

Procedures were performed on a digital single-plane cineangiography unit (Integris, Philips Medical Systems, Best, the Netherlands) with an undertable x-ray tube. In general, 17.8-cm magnification and a film speed of 12.5 frames/s was used except for selected views. For radial procedures, the patient’s right arm was placed on an arm board with the wrist extended. All cases were done from the right arm. Radial access was accomplished by puncture with a 20-gauge needle and insertion of a 5-F hydrophilic sheath. Judkins left 3.5, right 4.0, and pigtail catheters were used initially in radial cases, a Judkins left 4.0 in femoral cases.

#### Radiation protection

Attention was given in all cases to cone in as much as possible. An overhead-suspended lead acrylic shield with a patient contour cutout (0.5-mm lead equivalent; MAVIG, Munich, Germany) was pulled down to the patient’s abdomen. An undertable pivotal leaded side shield (0.5-mm lead equivalent) was mounted to the side of the table. The 17.8-cm upper shield flap was folded down in all cases. An additional table-to-floor flap (0.5-mm lead equivalent) extended 30 cm along the table. The pelvic lead shield used was a custom-made lead blanket (0.5-mm lead equivalent; MAVIG; list price currently $1,500) measuring 70 × 90 cm extending from the patient’s diaphragm to the knees. The upper portion is shaped diagonally to permit caudal projections. There are 1 or 2 15 × 15-cm cutouts for the femoral puncture sites (Fig. 1).

#### Radiation measurements

An electronic Geiger Muller radiation dosimeter (R. A. Stephen 6000, Centronic, Croyden, United Kingdom) was used to measure operator radiation exposure. It was attached to the breast pocket on the outside of the lead apron. The dosimeter has an energy response ± 20% between 35 keV and 1.0 MeV and a dose range displayed from 0 to 9,999 mSv in steps of 0.0001 mSv = 0.1 μSv. The operator radiation dose was recorded at the beginning and the end of each procedure. The patient radiation dose, expressed as dose-area product (DAP) (Gy·cm²), and the fluoroscopy time were recorded for each case. To account for low-energy scatter radiation below 35 keV and other dosimetric effects, the Stephen 6000 dosimeter was calibrated with a verified ionization chamber dosimeter (EG&G Berthold TOL/F, Berthold Technolo-
gies, Bad Wildbad, Germany), which has a reliable energy response between 10 keV and 7 MeV. Calibration measurements using an Alderson Rando phantom (Radiology Support Devices, Long Beach, California) at a height of 130 cm during fluoroscopy revealed that the Stephen 6000 dosimeter underestimated the ambient dose equivalent at tissue depth of 10 mm, that is, H*(10), by a factor of 1.7.

Data analysis. All data are expressed as mean ± standard deviation. Comparisons between groups were done with the Mann-Whitney U-test and the chi-square test. A p value <0.05 was considered significant. To take into account differences in patient radiation dose between radial and femoral cases, the DAP-normalized operator dose (operator dose divided by the DAP) was calculated.

Results

Of 305 cases scheduled for cardiac catheterization, 210 (69%) fulfilled the inclusion criteria. One hundred seven cases were done from a radial access, 51 without and 56 with pelvic lead shielding; 103 cases were done from a femoral access, 50 without and 56 with pelvic lead shielding.

Analysis of patient characteristics revealed no differences in age, sex, body surface area, and the prevalence of cases in whom a left ventriculogram was done in addition to coronary angiography (Table 1).

Fluoroscopy time was higher for the 107 radial cases than for the 103 femoral cases: 2.7 ± 1.4 min for radial versus 2.1 ± 1.1 min for femoral cases (p < 0.001). Fluoroscopy times were similar when the same access was used. Patient radiation dose (DAP) was not different when comparing all radial and all femoral cases (23.2 ± 13.7 vs. 21.9 ± 13.7 μSv × Gy⁻¹ × cm⁻²; p = 0.51), and there were no differences between the groups with standard protection or those with the pelvic shield (Table 2). Operator radiation dose with standard protection was 20.9 ± 13.8 μSv in the radial group and 15.3 ± 10.4 μSv in the femoral group (p < 0.001). Pelvic lead shielding decreased operator exposure to 9.0 ± 5.4 μSv (p < 0.0001) in the radial group and to 2.9 ± 2.7 μSv (p < 0.0001) in the femoral group. The absolute reduction in DAP-normalized operator dose (operator dose in μSv divided by DAP in Gy × cm²) was the same (0.55 and 0.54) (Fig. 2) for radial and femoral cases (from 0.94 ± 0.28 to 0.39 ± 0.19 μSv × Gy⁻¹ × cm⁻² and 0.70 ± 0.26 to 0.16 ± 0.13 μSv × Gy⁻¹ × cm⁻², respectively).

We used the SAS procedure General Linear Model (SAS Institute, Cary, North Carolina) to analyze the influence of shield (yes, no), route of access (radial, femoral), and the interaction term shield × access on operator radiation dose and DAP-normalized operator radiation, respectively. In both models, we observed a significant influence of shield and route of access, whereas the interaction term shield × access was not significant (p = 0.82 and p = 0.91 for operator radiation dose and DAP-normalized operator radiation dose, respectively).

Discussion

Transradial cardiac catheterization is well known to be associated with an increase in radiation dose to the patient and the operator, even for highly experienced cardiologists and despite the use of optimal strategies to reduce radiation exposure (6–9). The degree of increase in radiation with radial access varies between operators, suggesting different measures to protect against radiation exposure (7,8).

Factors responsible for the increased radiation are procedure related and operator related: first, technical challenges

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<th>Table 1. Patient Characteristics</th>
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<td>Female</td>
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<td>Age, yrs</td>
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<td>Body surface area, m²</td>
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<td>Left ventriculogram</td>
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<td>Values are n (%) and mean ± SD.</td>
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<th>Table 2. Fluoroscopy Time and Radiation Measurements</th>
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<tr>
<td>Fluoroscopy time, min</td>
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<td>Operator radiation dose, μSv</td>
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<td>DAP-normalized operator radiation dose, μSv × Gy⁻¹ × cm⁻²</td>
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<td>Values are mean ± SD. <em>Dose-area product (DAP); †ambient dose equivalent H</em>(10), where 10 indicates a depth of 10 mm.</td>
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lead shield on the patient’s arm rest. It was found to reduce radiation dose for diagnostic radial cases from 19 to 12 µSv (14). Comparisons of the efficacy of radiation protection devices between studies are difficult since dosimeters used in their study may have a different dose response. Based on the data provided, we estimate that the transradial protection board and the pelvic lead shield have similar efficacy.

For the assessment of the relative efficacy of an added radiation protection device, the DAP-normalized operator dose, defined as the dose (µSv) received by the operator with each Gy·cm² applied to the patient, has been advocated and was applied in our study (16). We found that the absolute reduction by the use of pelvic lead shielding was similar for radial and femoral access (0.55 and 0.54 µSv × Gy⁻¹ × cm⁻², respectively). Thus, pelvic lead shielding is equally effective for the femoral approach, reducing the radiation dose to as little as 0.16 µSv × Gy⁻¹ × cm⁻². However, when comparing radial and femoral access routes with optimal radiation protection by pelvic lead shielding, a radial-access operator still received a markedly higher DAP-normalized dose (0.39 ± 0.19 µSv × Gy⁻¹ × cm⁻²) than a femoral-access operator. However, this radiation exposure was less than that received by a femoral operator without the benefit of pelvic lead protection (0.70 ± 0.26 µSv × Gy⁻¹ × cm⁻²). Looking at our results from a different perspective, we can conclude that the use of pelvic shielding enables the operator to perform 4 times more femoral cases and more than twice as many radial cases with the same radiation exposure.

Because the use of pelvic lead shielding is associated with very little inconvenience to the patient, the operator, or the laboratory personnel, it has been readily accepted in our institution by femoral operators as well. The lead cover has a Velcro fastener that allows for easy removal with the sterile draping of the patient intact when tortuous iliac arteries need to be visualized or abdominal aortography needs to be performed. For percutaneous coronary intervention of chronic total occlusions, pelvic lead covers with 2 custom-made holes for bilateral femoral access are routinely used in our institution.

Although pelvic lead shielding is highly effective in reducing radiation, it cannot close the “radiation gap” for the operator between radial and femoral access. We believe that further reductions in radiation exposure for radial operators are possible and should be aimed for, such as a combination of the pelvic lead shield and the protection board. These measures may eventually eliminate the difference in operator radiation exposure associated with the radial approach, which still exists today.

**Study limitations.** We only included highly selected procedures, that is, elective uncomplicated diagnostic coronary angiograms by the same experienced operator. We choose this study design to be able to analyze uniform and highly

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**Figure 2. Effect of a Pelvic Lead Shield During Cardiac Catheterization**

The dose-area product (DAP)-normalized radiation dose of the operator (µSv × Gy⁻¹ × cm⁻²) by radial access (left) and femoral access (right). The amount of reduction is similar for both routes.

**Graph:**
- **Standard protection:** 0.94
- **Pelvic lead shield:** 0.39 and 0.16

**Table:**
- **Radial:** 0.94 to 0.39
- **Femoral:** 0.7 to 0.16

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in maneuvering the catheters into the coronary ostia lead to more fluoroscopy time, which will diminish with increasing expertise of the operator (9). In our study, fluoroscopy time was only slightly longer (2.7 vs. 2.1 min; p < 0.001) without increasing the DAP to a statistically significant degree. The increase in fluoroscopy time and DAP due to the transradial route is less for percutaneous coronary intervention compared with diagnostic angiography since catheter positioning claims a much smaller portion of the total procedure (6,7). A recent study in 5,954 cases estimated the overall increase in patient radiation exposure due to the radial approach at 23% (8). Second and most important for the need of improved radiation protection, the closer position of the operator relative to the x-ray tube is inherent to the radial procedure. We have previously reported that the operator dose was doubled for diagnostic procedures and 50% higher for interventions (6).

Exploratory measurements in our laboratory (data on file) showed profound amounts of scatter radiation from the pelvic bones emerging from the angle between the ceiling-mounted transparent lead shield positioned at a 90° angle to the table and the undertable pivotal side shield (Fig. 1), which can be nearly abolished by a shield covering the patient’s pelvis and thighs. Our study proves that the pelvic lead shield is a highly effective protection device reducing radiation dose from 20.9 to 9.0 µSv for radial coronary angiography. Two previous studies investigated additional ways to improve radiation protection for radial access catheterization. A 10-mm tube extension of the coronary catheter failed to reduce operator dose significantly (13). The “transradial radiation-protection board,” developed by Hildick-Smith, addresses the same radiation leak of scatter radiation by mounting a 20-cm-high vertical plane of a
comparable cohorts, thus avoiding the need to adjust for differences in operator experience and procedural factors. However, the relative efficacy of radiation protection provided by a pelvic lead shield may be different in an unselected cohort with different operators and coronary interventional procedures.

Conclusions

Pelvic lead shielding offers effective radiation protection to the operator working from a transradial access. The absolute amount of dose reduction per DAP applied to the patient is similar for radial and femoral procedures. Despite the use of the pelvic shield, the operator radiation dose for transradial diagnostic coronary angiograms remains higher compared with the femoral route.

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REFERENCES


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