Comparison of operator radiation exposure with optimized radiation protection devices during coronary angiograms and ad hoc percutaneous coronary interventions by radial and femoral routes

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Received 23 April 2007; revised 10 September 2007; accepted 9 October 2007; Online publish-ahead-of-print 13 November 2007

Aims
Although underestimated by interventional cardiologists for a long time, radiation exposure of operators and patients is currently a major concern. The objective of the present operator-blinded registry was to compare related-peripheral arterial route radiation exposure of operators.

Methods and results
During 420 consecutive coronary angiograms (CAs) and percutaneous coronary interventions (PCIs), four interventional cardiologists were blindly screened. Radiation exposures were assessed using electronic personal dosimeters. Protection of operator was ensured using a lead apron, low leaded flaps, and leaded glass. Radiation exposure of operators was significantly higher using the radial route when compared with the femoral route for both CAs and CAs followed by ad hoc PCIs: 29.0 [1.0–195.0] mSv vs. 13.0 [1.0–164.0] mSv; *P* 0.0001 and 69.5 [4.0–531.0] mSv vs. 41.0 [2.0–360.0] mSv; *P* = 0.018, respectively. Similarly, radiation exposure of patients was significantly higher using the radial route when compared with the femoral route for both CAs and CAs followed by ad hoc PCIs. Moreover, procedural durations and fluoroscopy times were significantly higher throughout the radial route.

Conclusions
Although the radial route decreases peripheral arterial complication rates, increased radiation exposure of operators despite extensive use of specific protection devices is currently a growing problem for the interventional cardiologist health. Radial route indication should be promptly reconsidered in the light of the present findings.

Keywords
Percutaneous coronary intervention • Radial artery • Stent • Operator radiation exposure

Introduction
The radial route is widely used to perform coronary angiograms (CA) and percutaneous coronary interventions (PCI) in order to reduce vascular peripheral arterial complications, to improve patient comfort, and to lower costs.¹⁻³ When specific radiation protection devices were barely used in clinical practice, previous studies have reported that the radial route was related to increased operator and patient radiation exposure, when compared with the femoral route.⁴⁻⁷ However, in logic of reinsurance, such differences between radial and femoral approaches have been reported to be inversely related to increasing operator experience, leading many operators to believe that special radiation exposure precautions were unnecessary with greater experience in the...
Operators. Although underestimated by interventional cardiologists for a long time, radiation exposure of operators and patients during CAs and PCIs is currently a major concern, mainly due to the stochastic risk of cancer induction. The main objective of the present operator-blinded registry was to compare accurately, using specific radiation exposure protection devices, the related peripheral arterial route radiation exposure of experienced operators.

**Methods**

**Study design**

The primary aim of the present study was to compare operator radiation exposure during CAs and CAs followed by ad hoc PCIs between radial and femoral routes. The secondary aims of this study were to compare patient radiation exposure, procedural duration, and fluoroscopy time in such conditions, and to assess potential relationship between operator and patient radiation exposure.

The special feature of this study was that operators were blinded to the collection of data and its purpose. In practice, operators were using left-arm and thoracic electronic personal dosimeters for 2 years when the collection of data started, and they were blinded to the beginning of data collection. This analysis was made on the radioprotection team’s initiative. Indeed, while not randomized, this registry reflects the ‘real world’ practices in terms of radiation exposure and use of the radial route in the setting of using optimized radiation protection devices.

**Patients**

Between October 2005 and March 2006, 420 consecutive procedures of CAs and CAs followed by ad hoc PCIs were screened. The radial approach represented 57% of the procedures performed during this period with respect to criteria of exclusion. Procedures were performed by four interventional cardiologists with a radiation protection-specific formation background and with similar experience in CAs and PCIs through the radial route, since each of them started to perform such procedures through radial access in 2001.

Criteria of non-inclusion were as follows: acute coronary syndrome with ST-segment elevation, previous coronary artery bypass grafting, indication of right-heart catheterism or other vascular exploration during the same session (i.e. carotid or aortography), repeated CAs and/or PCIs and CAs or PCIs performed by two operators. Procedures were either CAs or CAs followed by ad hoc PCIs. Prior to collecting the data, informed consent had been obtained from the patients.

**Procedures**

CAs and CAs followed by ad hoc PCIs were performed on 9-year-old digital single-plane cineangiography units (Integris, Phillips Medical Systems) with an undertable 10-ray tube. A film speed of 12.5 frame/s was selected for CAs and PCIs, and a film speed of 25 frame/s was selected for ventricular angiograms. All procedures were performed with respect to current guidelines using either 5 or 6Fr catheters. Conventional diagnosis and guiding-catheters were used. Medium contrast was manually injected using a 10 mL syringe connected to catheters using a 10 cm extension tube without specific assistance injection devices. Patients were pre-treated by aspirin and clopidogrel, and they received a 50 IU/kg intravenous bolus of unfractionated heparin in the case of PCI.

**Radiation protection**

Protection of operators was ensured using a lead apron, low leded flaps, and leded glass (0.5 mm leaded-equivalent for each) in all procedures (Figure 1). Standard protective measures, i.e. keeping a maximum distance from the X-ray source (inverse square law) and minimization of the field of view, were equally applied in all cases.

**Radiation measurements**

Operator radiation exposure was assessed using electronic personal dosimeters with silicon diode (μSv) located on both left arm and thorax (Figure 1). Briefly, the left-arm dosimeter was located out of personal protection; in contrast, the thorax dosimeter was located under the lead apron. Passive dosimetry of operators assessed under the lead apron was recorded as well. Patient radiation exposure was assessed using a plate ionisation chamber (diamentor) on the digital apparatus of radiology. Effective dose on electronic dosimeters (μSv), dose-area products delivered to patients (Gy cm²), durations of procedures and fluoroscopy times (min), and body-mass index of patients were recorded. Radiation doses were recorded at the completion of each procedure. The dosimeter has an energy response between 15 keV and 1.5 MeV and a dose range displayed from 0 to 9 999 mSv in steps of 0.0001 mSv = 0.1 μSv. Moreover, we aimed to assess angular response of such dosimeters, i.e. to evaluate changes in radiation exposure measurements with rotation.

**Data analysis and statistics**

Continuous variables were expressed as mean value ± SD or median [min-max] values, as appropriate. Differences between groups were assessed by bilateral unpaired Student’s t test or Mann–Whitney U test as appropriate. Correlations between continuous variables were obtained by the Pearson correlation coefficient or the Spearman test.

![Figure 1](https://example.com/image.png)

**Figure 1** Radiation protection devices for operators, i.e. low leded flaps and leded glass (0.5 mm leaded-equivalent for each) (A). Assessment of operator radiation exposure using (i) electronic personal dosimeters located on the left arm (B) and the thorax under the lead apron (C), and (ii) passive dosimetry assessed under the lead apron (C). See online supplementary material for a colour version of this figure.
correlation coefficient if variables were not normally distributed. Categorical variables were expressed as count and percentage and were tested with χ² test or Fisher’s exact test, as appropriate. Differences between operators were tested using an ANOVA test completed with a post hoc Bonferroni test. Statistics were performed with Statview 5.0 software (SAS institute, Cary, NC, USA). Statistical significance was considered as P-value < 0.05.

Results

Patients

During the period of the study, 847 patients underwent a coronary invasive procedure in our catheterization laboratory; 85 were excluded because of ACS with ST-segment elevation (10.0%), 47 were excluded because of bypass graft angiography (5.5%), 108 were excluded because of right-heart catheterism in the same session (12.8%), 125 were excluded because of other vascular exploration in the same session (14.8%), and 61 were excluded because of scheduled PCI (7.2%), only one patient was excluded because of coronary angiography reasons, i.e. complex lesions and/or multi-vessel disease. Mean weight of patients was significantly higher in the radial group when compared with the femoral group (80.0 ± 17.7 vs. 76.4 ± 15.2 Kg, P = 0.03, respectively). In contrast, other baseline demographic and angiographic characteristics were similar between both groups (Table 1).

Radiation exposure of operators and patients, procedural durations, and fluoroscopy times according to operators

Operator radiation exposure, patient radiation exposure, procedural duration, and fluoroscopy time were similar among all the operators (Table 2).

Radiation exposure of operators

Electronical dosimetry and passive dosimetry assessed under the lead apron of operators were insignificant. As assessed at the left arm of operators, radiation exposure was significantly more important using the radial route when compared with the femoral route for both CAs and CAs followed by ad hoc PCIs: 29.0 [1.0–195.0] μSv vs. 13.0 [1.0–164.0] μSv; P < 0.0001 and 69.5 [4.0–531.0] μSv vs. 41.0 [2.0–360.0] μSv; P = 0.018, respectively (Figure 2). Operator radiation exposure was 82.7% higher for radial CAs and 38.1% higher for radial CAs followed by ad hoc PCIs.

Radiation exposure of patients

Similarly to operators, radiation exposure of patients was significantly more important using the radial route when compared with the femoral route for both CAs and CAs followed by ad hoc PCIs: 59.0

Table 1 Baseline characteristics

<table>
<thead>
<tr>
<th></th>
<th>Radial n = 240</th>
<th>Femoral n = 181</th>
<th>P</th>
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<tbody>
<tr>
<td>Demographic characteristics</td>
<td></td>
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<tr>
<td>Male, n (%)</td>
<td>191 (79.6)</td>
<td>136 (75.1)</td>
<td>0.28</td>
</tr>
<tr>
<td>Mean age ± SD (years)</td>
<td>60.0 ± 12.3</td>
<td>60.2 ± 11.8</td>
<td>0.85</td>
</tr>
<tr>
<td>Mean weight ± SD (Kg)</td>
<td>80.0 ± 17.7</td>
<td>76.4 ± 15.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>96 (40.0)</td>
<td>71 (39.2)</td>
<td>0.87</td>
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<tr>
<td>Diabetes, n (%)</td>
<td>48 (20.0)</td>
<td>39 (21.6)</td>
<td>0.77</td>
</tr>
<tr>
<td>Hypercholesterolemia, n (%)</td>
<td>151 (62.9)</td>
<td>117 (64.6)</td>
<td>0.72</td>
</tr>
<tr>
<td>Smoking, n (%)</td>
<td>149 (62.1)</td>
<td>110 (60.8)</td>
<td>0.78</td>
</tr>
<tr>
<td>Previous PCI, n (%)</td>
<td>48 (20.0)</td>
<td>37 (20.4)</td>
<td>0.91</td>
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<tr>
<td>Interventional characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA alone, n (%)</td>
<td>150 (62.5)</td>
<td>98 (54.1)</td>
<td>0.07</td>
</tr>
<tr>
<td>CA and ad hoc PCI, n (%)</td>
<td>90 (37.5)</td>
<td>83 (45.9)</td>
<td></td>
</tr>
<tr>
<td>LAD, n (%)</td>
<td>93 (38.8)</td>
<td>72 (39.8)</td>
<td>0.95</td>
</tr>
<tr>
<td>Cx, n (%)</td>
<td>46 (19.2)</td>
<td>34 (18.8)</td>
<td></td>
</tr>
<tr>
<td>RCA, n (%)</td>
<td>101 (42.1)</td>
<td>75 (41.4)</td>
<td></td>
</tr>
<tr>
<td>Type-A lesion*, n (%)</td>
<td>61 (25.4)</td>
<td>55 (30.4)</td>
<td>0.65</td>
</tr>
<tr>
<td>Type-B1 lesion*, n (%)</td>
<td>63 (26.3)</td>
<td>49 (27.1)</td>
<td></td>
</tr>
<tr>
<td>Type-B2 lesion*, n (%)</td>
<td>65 (27.1)</td>
<td>42 (23.2)</td>
<td></td>
</tr>
<tr>
<td>Type-C lesion*, n (%)</td>
<td>51 (21.3)</td>
<td>35 (19.3)</td>
<td></td>
</tr>
<tr>
<td>Mean number of lesion ± SD</td>
<td>1.35 ± 0.61</td>
<td>1.31 ± 0.58</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Continuous variables were expressed as mean value ± SD. Categorical variables were expressed as count and percentage. PCI: percutaneous coronary intervention; CA: coronary angiogram; LAD: left anterior descending; Cx: circumflex; RCA: right coronary artery. 

*American College of Cardiology–American Heart Association classification.
0.0001 and rad ad hoc for radial and femoral routes, respectively) and CAs followed by ad hoc CAs and CAs followed by ad hoc CAs, respectively). Moreover, patient radiation exposure was 65.8% higher for radial CAs and 28.2% higher for radial CAs followed by ad hoc CAs and CAs followed by ad hoc CAs, respectively. Moreover, patient radiation exposure was significantly more important patient radiation exposures are significantly more important for radial procedures, special radiation pre-
s特殊工具的使用在临床实践中非常少见。因此，作者建议广泛使用特殊工具。

**Related factors**

Procedural durations and fluoroscopy times were significantly higher through the radial route for both CAs and CAs followed by ad hoc PCIs (Figure 2).

Operator radiation exposure was related to procedural duration for CAs (r = 0.50, P < 0.0001, using the radial route only) and CAs followed by ad hoc PCIs (r = 0.44, P < 0.0001 and r = 0.47, P < 0.0001 for radial and femoral routes, respectively). Moreover, operator radiation exposure was related to fluoroscopy time for CAs (r = 0.58, P < 0.0001, using the radial route only) and CAs followed by ad hoc PCIs (r = 0.46, P < 0.0001 and r = 0.47, P < 0.0001 for radial and femoral routes, respectively).

Similarly, patient radiation exposure was related to procedural duration for CAs (r = 0.70, P < 0.0001 and r = 0.51, P < 0.0001 for radial and femoral routes, respectively) and CAs followed by ad hoc PCIs (r = 0.69, P < 0.0001 and r = 0.79, P < 0.0001 for radial and femoral routes, respectively). Moreover, patient radiation exposure was related to fluoroscopy time for CAs (r = 0.71, P < 0.0001 and r = 0.55, P < 0.0001 for radial and femoral routes, respectively) and CAs followed by ad hoc PCIs (r = 0.72, P < 0.0001 and r = 0.67, P < 0.0001 for radial and femoral routes, respectively).

Finally, body-mass index was related to dose-area products delivered to patients using the radial route for CAs alone (r = 0.53, P < 0.0001) but not to operator radiation exposure.

**Angular response of dosimeters**

Angulation of the dosimeter from the source of radiation influences radiation exposure measurements, since the more the rotation the less the measurement of radiation exposure (Figure 4).

**Discussion**

This registry demonstrates that CAs alone and CAs followed by ad hoc PCIs through the radial route are related to increased operator radiation exposure when compared with the femoral route, despite using optimized radiation protection strategy. In this setting, patient’s radiation exposure, procedural duration, and fluoroscopy time are significantly more important through the radial route when compared with the femoral route.

Similar findings have already been reported when the use of special devices for radiation protection was uncommon. Authors therefore advocated for an extensive use of special devices for radiation protection which were barely used in clinical practices. However, they reported that operators believed that with greater expertise in radial procedures, special radiation precautions were superfluous because fluoroscopy times and radiation exposures trended to similar levels when compared with the femoral route. The results of the present registry invalidate these assumptions. First, we demonstrated that operator and patient radiation exposures are significantly more important

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**Table 2** Operator radiation exposure, patient radiation exposure, procedural durations, and fluoroscopy times according to operators

<table>
<thead>
<tr>
<th></th>
<th>Operator 1</th>
<th>Operator 2</th>
<th>Operator 3</th>
<th>Operator 4</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>All procedures (n = 420)</td>
<td>n = 135</td>
<td>n = 133</td>
<td>n = 88</td>
<td>n = 64</td>
<td>0.53</td>
</tr>
<tr>
<td>Operator radiation exposure (μSv)</td>
<td>21.0 [1.0–445.0]</td>
<td>34.0 [1.0–531.0]</td>
<td>37.5 [2.0–265.0]</td>
<td>49.0 [1.0–283.0]</td>
<td>0.47</td>
</tr>
<tr>
<td>Patient radiation exposure (Gy cm²)</td>
<td>64.0 [17.0–383.0]</td>
<td>62.0 [20.0–398.0]</td>
<td>89.0 [10.0–263.0]</td>
<td>75.5 [10.0–358.0]</td>
<td>0.71</td>
</tr>
<tr>
<td>Procedural duration (min)</td>
<td>19.0 [4.0–90.0]</td>
<td>21.0 [4.0–86.0]</td>
<td>20.3 [2.0–71.0]</td>
<td>16.0 [6.0–103.0]</td>
<td>0.72</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>4.3 [0.5–30.9]</td>
<td>4.8 [0.8–26.5]</td>
<td>5.0 [0.8–28.0]</td>
<td>4.4 [1.0–34.8]</td>
<td>0.74</td>
</tr>
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</table>

| Radial route (n = 239) | n = 53    | n = 76    | n = 66    | n = 44    | 0.53      |
| Operator radiation exposure (μSv) | 30.0 [1.0–445.0] | 37.5 [1.0–531.0] | 39.5 [4.0–265.0] | 57.5 [1.0–283.0] | 0.47      |
| Patient radiation exposure (Gy cm²) | 79.0 [18.0–334.0] | 65.0 [20.0–398.0] | 95.0 [15.0–263.0] | 81.0 [17.0–358.0] | 0.64      |
| Procedural duration (min) | 25.0 [4.5–90.0] | 22.0 [4.0–86.0] | 21.3 [5.0–71.0] | 20.0 [6.0–95.0] | 0.43      |
| Fluoroscopy time (min) | 5.9 [1.2–28.4] | 5.5 [1.1–26.5] | 5.5 [1.0–28.0] | 5.2 [1.1–34.8] | 0.93      |

| Femoral route (n = 181) | n = 82    | n = 57    | n = 22    | n = 20    | 0.53      |
| Operator radiation exposure (μSv) | 17.5 [1.0–360.0] | 30.0 [2.0–245.0] | 20.5 [2.0–164.0] | 16.0 [1.0–200.0] | 0.69      |
| Patient radiation exposure (Gy cm²) | 50.0 [17.0–383.0] | 57.0 [21.0–276.0] | 43.0 [10.0–217.0] | 55.0 [10.0–351.0] | 0.93      |
| Procedural duration (min) | 16.5 [4.0–90.0] | 21.0 [4.0–64.0] | 15.3 [2.0–54.0] | 13.5 [7.0–103.0] | 0.67      |
| Fluoroscopy time (min) | 3.1 [0.5–30.9] | 3.3 [0.8–18.4] | 3.1 [0.8–9.4] | 2.4 [1.0–21.4] | 0.79      |

Variables were expressed as median [min-max] values. Differences between operators were tested using an ANOVA test completed with a post hoc Bonferroni test.
through the radial route when compared with the femoral route, in a mild to moderate transradial volume centre. Secondly, we demonstrated that despite extensively used, radiation protection devices have not decreased the difference in radiation exposure of both operators and patients between radial and femoral routes. These findings would need to be confirmed in a high transradial volume centre. Lange has recently reported in a single-operator and randomized study that operator radiation exposure was higher during CAs and PCIs by the radial approach when compared with the femoral approach. However, the radiation protection strategy was divergent between both groups since the additional 7000 upper protective shield flap was used only in femoral cases, whereas it was flipped down in radial cases. Finally, based on the 5-year background of the radial route for CAs and PCIs, we showed that radial experience does not balance radiation exposure between radial and femoral approaches. The special feature of the present study was that operators were blinded to the collection of data and its purpose, since this study was performed on the radioprotection team’s initiative. While not randomized, this study reflects the ‘real world’ practices in terms of radiation exposure when using optimized radiation protection devices in routine, despite an attrition bias in the choice of arterial access which has to be taken into account in such differences in interpretation. Another bias might be related to higher mean body weight of patients in the radial group, since body weight is related to fluoroscopy time and radiation exposure. Less ad hoc PCI rate following CA in the radial group reflects the non-randomized design of the present study. It is therefore the policy of our institution to perform 5 French catheterization and ad hoc PCI as frequent as possible, except when expected difficulties of PCI require a conversion to femoral access after the radial CA. In such situations, PCI are delayed lowering ad hoc PCI in the radial group when compared with the femoral group.

Fortunately, as assessed by electronical dosimetry and passive dosimetry assessed under lead aprons, radiation exposure of thoracic, abdominal, and upper portion of lower limbs of operators is insignificant. In contrast, despite the extensive use of radiation protection devices (i.e. low leaded flaps and leaded glass with 0.5 mm leaded-equivalent for each), radiation exposure of operators is not negligible and is significantly higher using the radial route. Increased radiation exposure of operators using the radial route is related to increase in fluoroscopy time, which reflects technical difficulties and the slightly closer operator position relative to the X-ray source and patient during the radial procedure when compared with the femoral route.
Similarly, radiation exposure is related to procedural duration for both operators and patients.

Surprisingly, operator and patient radiation exposures were higher in the present registry whereas fluoroscopy time was lower when compared with other studies.9,14,15 We hypothesize that these findings might be explained by several factors: (i) the present registry included CAs and CAs followed by ad hoc PCIs involving multiple and complex lesions, (ii) the lack of randomization leads to conform to ‘real world’ practices, i.e. treatment of multiple and/or complex lesions, which are obviously related to higher radiation doses,16,17 (iii) the use of 9-year-old digital single-plane cineangiography units might have influenced the radiation exposure of operators and patients, and (iv) radiation exposure of operators was assessed using left-arm dosimeters.

We demonstrated in the present study that angulation of the dosimeter from the source of radiation influences radiation exposure measurements, since the more the rotation the less the measurement of radiation exposure. During CAs and/or PCIs, angulation between the dosimeter located in the breast pocket of the lead apron and the radiation source is \(30–45^\circ\). We therefore demonstrated that in such situation, radiation exposure measurements are lowered by \(>30\%\) when compared with direct radiation exposure measurement, i.e. located at the left arm. This position allows minimizing the angular response of such dosimeters in order to accurately estimate operator radiation exposure. To our knowledge, this registry first assessed ‘direct’ operator radiation exposure, avoiding minimization of measurement due to angular response of dosimeters. According to von Boetticher, radiation exposure of operators assessed using left-arm dosimeters reflects brain exposure, which is \(\sim63\%\) of the ambient dose equivalent measured at a height of 130 cm.18,19 We previously evaluated that location of dosimeters at a height of 130 cm was the accurate optimized position to evaluate the maximal radiation exposure.

In contrast to previous studies, fluoroscopy times reported in the present registry are lower than the data published in the literature. This difference might be related to the involvement of operators in radiation exposure reduction, which is the key parameter to minimize radiation exposure. To lower radiation delivery, operators extensively used specific radiation protection devices in both radial and femoral approaches, avoided angulation of the beam, used large field settings with additional collimation, reviewed previous run rather than repeating it, and mainly treated lesions using direct stenting strategy.20 Procedural and fluoroscopy durations were relatively less different in CAs followed by ad hoc PCIs when compared with CAs alone. Diagnosis phase through the radial approach implies to solve potential technical difficulties when compared with the femoral approach, i.e. (i) difficulties in progression of 0.035 in. guide wire or catheters in radial or humeral arteries because of vessel tortuosity or arterial spasm or (ii) advancing catheters across the aortic arch, or (iii) difficulties to selectively catheterize coronary arteries implying to change and use many different diagnostic catheters in some clinical situations. Once such difficulties are solved and the coronary is angiography
Comparison of operator radiation exposure with optimized radiation protection devices

Figure 4 Angulation response of the dosimeter. Radiation exposure was assessed keeping a 30 cm distance between the source and dosimeter, using a 20 cm thickness water ghost and a field of 25 x 25 cm. Ratio of radiation exposure assessment (%) was determined as follows: (radiation exposure measurement after angulation/axial radiation exposure measurement) x 100. Angulation of the dosimeter (°) was assessed using a goniometer.

performed, choosing appropriate guiding catheter and successful catheterization of coronary artery is directed by the diagnosis phase, lowering technical difficulties and subsequently procedural and fluoroscopy durations.

Ionizing radiation at high doses (i.e. 1–10 Gy), which are widely irrelevant to radiation exposure in the setting of CAs and/or PCIs, causes certain specific effects named deterministic effects including hematologic syndrome (pancytopenia), erythema, gastrointestinal syndrome (radiation sickness), and central nervous system syndrome. These effects are very predictable and range from blood and chromosome aberrations to radiation sickness to certain death, depending on the dose, the dose rate, age, immune capacity of an individual, and type of radiation exposure.21

In contrast, chronic low-dose radiation exposure is related to increased risk of stochastic effects. Stochastic means random in nature. In this setting, the odds of having any effect are extremely low. Unfortunately, a few people may experience an effect from the radiation exposure, but this cannot be predicted.22 Chronic effects of low-dose radiation exposure are mainly cancer induction. Leukaemia occurrence has been associated as a stochastic effect of chronic radiation exposure with doses as low as 100 mGy. Between 100 and 500 mGy, there is a linear correlation between dose and leukaemia incidence with an average latency period of 14 years from exposure to onset of the disease. Higher doses of ionizing radiation have also been associated with thyroid (more than 200 mGy), bone (8.000 mGy), skin (15.000 mGy), and various other cancers.21 Interestingly, there is no conclusive evidence that chronic low-dose radiation exposure causes any long-term ill-health effects in workers in the medical field.23 Furthermore, there is no evidence to suggest that regular background amounts of radiation exposure cause any long-term effects. Nevertheless, European (EURATOM) and North-American councils have defined principles of radiation exposure as low as reasonably achievable for medical and dental personnel because of stochastic risk.24

On the basis of our annual experience of 800 CAs alone and 700 CAs followed by ad hoc PCIs equally shared between four operators, the expected mean annual operator radiation exposure through radial alone, femoral alone, and radial plus femoral (57% of radial access) approaches are 17.96, 9.77, and 14.44 mSv, respectively. This annual operator radiation exposure is extrapolated from procedures performed using optimized radiation protection devices, as specified above. According to measurements performed in our angiography units, radiation exposure is lowered by 30 using radiation protection devices. Based on risks of stochastic effects after chronic low-dose radiation exposure, whole-body and limb annual radiation exposure limits are defined as <20 and 500 mSv, respectively. According to our experience, radial alone and radial plus femoral approaches are related to annual radiation exposure close to the whole-body annual radiation exposure limit, as assessed using the left-arm dosimeter. In contrast, the femoral approach alone allows half the annual radiation exposure when compared with the radial approach alone. However, when considering CAS and/or PCIs through the radial approach without specific protection devices, annual radiation exposure of operators is close to doses related to deterministic effects. Finally, the use of radiation protection devices is critical, mainly in the radial approach.

Conclusions

Although the radial route decreases peripheral arterial complication rate, increased radiation exposures of both operators and patients through the radial route is currently a growing problem for the interventional cardiologist health. Specific protection devices are available to minimize radiation exposure, and they have to gain widespread acceptance in the interventional community. Differences in radiation exposure of operator between radial and femoral approaches need to be interpreted in the setting of quite old angiography units (i.e. 9 years old) and would need to be confirmed in recent angiography units, which are usually associated with lower levels of radiation exposure. Indeed, radial route indications should be promptly reconsidered in the light of the present findings, especially when a long procedural fluoroscopy time is expected. Finally, effective radiation exposure of operators needs to be assessed using accurately located dosimeters.

Supplementary material

Supplementary material is available at European Heart Journal online.
Acknowledgements

We gratefully thank the overall catheterization laboratory staff, especially Michel Gawron and Gerard Crépin, for their assistance. Moreover, we gratefully thank Marie Haincourt for carefully reviewing this manuscript.

Conflict of interest: none declared.

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