Identification of Less-Irradiating Tube Angulations in Invasive Cardiology

Eberhard Kuon, MD,* Johannes B. Dahm, MD,† Klaus Empen, MD,† Daniel M. Robinson, MD,† Gereon Reuter, MD,* Michael Wucherer, PtD‡

Ebermannstadt, Greifswald, and Nuremberg, Germany

OBJECTIVES
We sought to identify tube angulations in invasive cardiology, which promise minimal radiation exposure to patients and operators.

BACKGROUND
Radiation exposure in invasive cardiology is high.

METHODS
We mapped the fluoroscopic dose-area product per second (DAP/s), applied to an anthropomorphic Alderson-Rando phantom and, in absence of radiation protection devices, the mean personal dose in the operator’s position in 10° steps from the 100° right anterior oblique (RAO) to the 100° left anterior oblique (LAO) projection, as well as for all geometrically feasible craniocaudal tube angulations.

RESULTS
For our specific setting conditions RAO 20°/0° tube angulation generated the lowest DAP/s and operator’s personal dose. The mean patient DAP/s and operator personal dose for all postero–anterior (PA) projections, cranialized and caudalized together, rose significantly: 3.7 and 10.6 times the PA 0° baseline values toward LAO 100° and 3.7 and 2.4 times toward RAO 100°, respectively. Patient and operator values for all PA projections, angulated to the right and left, increased ~2.5 times toward 30° cranio-caudal angulations. Caudal PA 0°/30°–angulation instead of caudal LAO 60°/20°–angulation for the left coronary main stem and cranial PA 0°/30°+ view in place of cranial LAO 60°/20°+ view for the left anterior descending coronary artery bifurcation enable 2.6-fold dose reductions to the patient and eight- and five-fold dose reductions to the operator, respectively.

CONCLUSIONS
The PA views and RAO views ≥40°, hereofore unconventional in clinical routine, should be favored over steep LAO projections ≥40° whenever possible. Tube angulations that are radiation intensive to the patient exponentially increase the operator’s radiation risk. (J Am Coll Cardiol 2004;44:1420–8) © 2004 by the American College of Cardiology Foundation

Typical mean patient dose-area products (DAP) due to coronary procedures are high and vary extensively with levels between 4 and 106 Gy × cm² for coronary angiography, between 8 and 109 Gy × cm² for coronary intervention, and between 70 and 191 Gy × cm² for combined interventions (1–8). Deterministic radiation risks, such as those leading to chronic radiodermatitis and deep skin and musculocutaneous injury (9,10), have been increasingly reported in conjunction with complex coronary interventions. Additionally, published data on mean entrance skin doses to the operator’s unprotected eyes, thyroid, and hands are considerable and range between 120 and 400 μSv, 390 μSv, and 240 to 510 μSv per coronary intervention, respectively (11,12).

Operators in a high-volume catheterization laboratory with a cumulative workload of 1,000 invasive catheterizations for stray radiation accordingly may reach and even exceed the recommended occupational yearly limits of 150 mSv for the lens of the eye, 300 mSv for the thyroid, and 500 mSv for the skin, hands, and feet (13,14).

With good reason, the International Commission on Radiological Protection therefore states that “...many interventionalists are not aware of the potential for injury from procedures, their occurrence, or simple methods for decreasing their incidence utilising dose control strategies” (15). Patient radiation exposure in invasive cardiology depends on obesity (5), equipment performance (7,16), picture-quality respective image intensifier entrance dose level (17), procedure complexity (8,18), operator fatigue (19), training and supervision in radiation-reducing techniques (5,20), and correct beam collimation (5,21), and it will increase due to high-resolution magnification (5,22). In consideration of the inverse-square law between the source and the radiation intensity, accepted regulations require a minimum distance to the patient’s skin of 38 cm (23). Keeping the image intensifier as close to the patient as possible minimizes the source-to-image distance (SID), which results in a decreased blurring of the image, and also allows the image intensifier to serve as a barrier between the patient and operator (23). The operator’s occupational exposure also depends on an adequate use and acceptance of lead protection devices (11,24–26), case load, and distance from the isocenter (22).

Doubling the source-to-operator distance (SOD) will likewise decrease the primary stray radiation scattered from the patient to approximately one quarter of the original occupational dose (27). Optimized interventional techniques (5,7,24) in clinical routine, however, have enabled mean DAPs of 4.2 ± 1.6 Gy × cm² for elective coronary angiography (7) and 7.8 ± 6.1 Gy × cm² for coronary angioplasty (8).

Tube angulation influences patient (5,17) and occupational operator radiation exposure (24,25,28,29) to an ex-
tensive degree (i.e., left anterior oblique [LAO] projections are most radiation intensive). Such data reported to date, however, cover only a small number of selected angulations favored by individual operators in experimental approaches or in clinical routine. They have not heretofore represented the wide range of tube angulations feasible in invasive cardiology.

For this reason, the goal of this experimental study on a male anthropomorphic Alderson-Rando phantom (Fig. 1) was to map, during fluoroscopy, for all tube angulations technically feasible in invasive cardiology, the DAP/s, applied to the phantom, and the respective local personal operator dose.

METHODS

Equipment. We employed a digital, single-arm Advantx LC+ undercouch tube system (GE Medical Systems, Fairfield, Connecticut) with the following installed in the X-ray beam: a 0.1-mm copper filter, a 2.9-mm aluminum filter, and, throughout all measurements, an antiscatter grid. For all fluoroscopy mode levels—high, medium, and low—the pulse rate is 50/s. However, to reduce radiation exposure to the investigator, throughout all experimental measurements, we consistently applied low-level fluoroscopy, which is achieved by a lower dose per frame. Under conditions of a focus-image intensifier distance of 1 m, and for a 2-mm thick copper absorber, an automatic dose-control algorithm regulated the image intensifier entrance dose rates during low-level fluoroscopy toward 0.21 and 0.30 $\mu$Gy/s for the 23- and 17-cm image intensifier area, respectively. During cine acquisition, the entrance-exposure rate was calibrated to 0.08 $\mu$Gy/frame (23-cm area; mode B of four different cine acquisition modes: A, B, C, and D). We measured the DAP by a flat, light-transparent ionization Diamentor M4 (PTW, Freiburg, Germany; total uncertainty <15%).

Characterization of in vivo conditions by an Alderson-Rando phantom. The first step of methodology was to validate the assessment of DAP obtained with the phantom as compared with that received by patients (body mass index 27.9 ± 4.0 kg/m$^2$) in an analysis of 122 coronary angiograms. The mean patient’s cinegraphic DAP/frame (17-cm intensifier field, cine acquisition mode B) obtained with the phantom versus that received by patients and measured in vivo did not differ significantly (i.e., 21.6 ± 7.7 vs. 24.0 ± 7.6 mGy × cm$^2$, respectively; $p > 0.38$). On the basis of straight-line regression, the correlation coefficient between the two methodological approaches for all various tube angulations was 0.91 (24,25).

The second step was to correlate stray radiation to the operator to the DAPs measured on the phantom. The correlation coefficient was 0.99 between a scattered dose at the operator’s position and DAP in the 0°/0° postero-anterior (PA) tube angulation at a table height of 95 cm and a dosimeter height of 100 cm at a distance of 100 cm from the isocenter (24). In concurrence with other investigators, the operator’s personal dose/DAP slightly increased with kilovolt and field size (29,30).

Data collection. We measured the low-level fluoroscopic DAP over the course of 60 s, applied to an anthropomorphic Alderson-Rando phantom for simulation of in vivo conditions (Fig. 1). At an operator’s position 100 cm from the isocenter (on the right side of the patient, 60 cm adjacent to and 80 cm caudal to the tube), we then measured scattered personal dose to the operator, which is defined as the sum of primary scatter emitted from the patient in all directions, secondary scatter from the walls, and the small fraction of tube-housing leakage (23). The unit of measurement is Sievert (Sv). We performed measurements in 20-cm increments within a height range of 20 to 200 cm (10

Figure 1. Catheterization laboratory with an Alderson-Rando phantom (A) simulating the patient; position of the tube (B) in undercouch and the image intensifier (C) in overcouch 60°/0° left anterior oblique position. The Diamentor M4 display (D) and the Szintomat 6134 A system (E) were used to measure fluoroscopic dose-area product, applied to the phantom, and the operator’s personal dose.

<table>
<thead>
<tr>
<th>Abbreviations and Acronyms</th>
</tr>
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<tbody>
<tr>
<td>DAP/s = dose-area product per second</td>
</tr>
<tr>
<td>LAD = left anterior descending coronary artery</td>
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<tr>
<td>LAO = left anterior oblique</td>
</tr>
<tr>
<td>PA = postero-anterior</td>
</tr>
<tr>
<td>RAO = right anterior oblique</td>
</tr>
<tr>
<td>SID = source-to-image distance</td>
</tr>
<tr>
<td>SOD = source-to-operator distance</td>
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</table>
positions) with a Szintomat 6134 A system (Automess, Ladenburg, Germany). The system was calibrated for a dose intensity range of 100 nSv/h to 100 mSv/h (total uncertainty <10%).

The fluoroscopic DAP/s (Table 1, Fig. 2) and the respective mean personal operator doses/h (Table 2, Fig. 3) were measured and calculated in 10° steps for all tube angulations from RAO 100° to LAO 100°. We investigated these 21 different angulations around the phantom and the table not only for the plane at right angles (PA 0°) to the phantom, but also in repetition for planes angulated cranially (+) and caudally (−) by 10°, 20°, and 30°. We also performed measurements for 40°, unless rendered unfeasible by the geometric setting circumstances. We accordingly performed for 164 ([21 × 7] + 17) individual tube angulations measurements of fluoroscopic DAP/s and a total of 1,640 (164 × 10) local measurements of operator dose. We finally calculated the operator’s mean personal dose per DAP, applied to the Alderson-Rando phantom (Table 3). Primary and secondary scatter radiation depends directly on DAP, applied to the phantom. However, DAP depends on tube angulation. The personal dose to DAP ratio enables characterization of the additional occupational operator stray radiation risk due to certain tube angulations (26).

RESULTS

Phantom radiation exposure. Fluoroscopic DAP/time was lowest (12 mGy × cm²/s) for the RAO 20°/0° tube angulation and highest (31 mGy × cm²/s) toward the lateral LAO 60°/0° and RAO 90°/0° angulations (Table 1,

Table 1. Time-Adjusted Radiation Exposure (mGy × cm²/s) to an Alderson-Rando Phantom in Dependency on Tube Angulation

<table>
<thead>
<tr>
<th>Tube Angulation</th>
<th>RAO</th>
<th>PA 0°</th>
<th>LAO</th>
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<tbody>
<tr>
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<td>43</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>90°</td>
<td>54</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>80°</td>
<td>54</td>
<td>17</td>
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<td>30° Caudal</td>
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<td>10° Caudal</td>
<td>71</td>
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<tr>
<td>0° Caudal</td>
<td>80</td>
<td>31</td>
<td>34</td>
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</tbody>
</table>

*Boldface characters indicate range of typically used tube angulations.
LAO = left anterior oblique; PA = posteroanterior; RAO = right anterior oblique.

Figure 2. Calculated isodose lines in a three-dimensional graph of time-adjusted fluoroscopic dose-area product (DAP) (DAP F/time [mGy × cm²/s]), as a function of tube angulation. LAO = left anterior oblique; RAO = right anterior oblique.
The mean radiation exposure values for all cranio-caudal tube angulations along the table (cranial 0°/30°–30°/H11001 projection) continuously rose to 3.7 times that of the PA baseline values toward both the respective mean RAO 100° and LAO 100° angulation planes. The mean radiation exposure values for all 21 tube angulations at right angles around the phantom (RAO 100°/0° to LAO 100°/0° projection) continuously rose to 2.6 times that of the baseline values toward 30° craniocaudal angulation planes. Further craniocaudal tube angulation toward an angle of 40° creates even more radiation exposure to the phantom. Consequently, fluoroscopic DAP/time is highest for extreme oblique tube angulations >50°, which are angulated ≥20° toward cranial and caudal, respectively (Fig. 2).

Fig. 2). The mean radiation exposure values for all cranio-caudal tube angulations along the table (cranial 0°/30°+ to caudal 0°/30°− projection) continuously rose to ~3.7 times that of the PA baseline values toward both the respective mean RAO 100° and LAO 100° angulation planes. The mean radiation exposure values for all 21 tube angulations at right angles around the phantom (RAO 100°/0° to LAO 100°/0° projection) continuously rose to ~2.6 times that of the baseline values toward 30° cranio-caudal angulation planes. Further craniocaudal tube angulation toward an angle of 40° creates even more radiation exposure to the phantom. Consequently, fluoroscopic DAP/time is highest for extreme oblique tube angulations ≥50°, which are angulated ≥20° toward cranial and caudal, respectively (Fig. 2, Table 1).

Operator occupational dose. The mean local scatter dose in the operator position—measured from 20 to 200 cm body height—was lowest for the RAO 20°/0° tube angulation: 80 μSv/h. It increased to mean peak levels of 730 μSv/h toward LAO tube angulations between 50°/0° and 100°/0° (Table 2, Fig. 3) and of 190 μSv/h toward the RAO 90°/0° tube angulation. The operator’s mean personal dose during fluoroscopy of all seven tube angulations along the table between cranial 30°+ and caudal 30°− continuously rose to ~10.6 times PA baseline values toward the LAO 90° tube

Table 2. Mean Operator Radiation Exposure (μSv/h) During Fluoroscopy at a Rando Phantom as a Function of Tube Angulation

<table>
<thead>
<tr>
<th>Tube Angulation</th>
<th>RAO 100°</th>
<th>LAO 100°</th>
<th>PA 0°</th>
</tr>
</thead>
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<tr>
<td>0°</td>
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<td>10°</td>
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<td>500</td>
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</tr>
<tr>
<td>40°</td>
<td>400</td>
<td>700</td>
<td>400</td>
</tr>
</tbody>
</table>

Table 2 indicates range of typically used tube angulations.

Abbreviations as in Table 1.

Figure 3. Calculated isodose lines in a three-dimensional graph of the operator’s mean personal dose per time (μSv/h), as a function of tube angulation. LAO = left anterior oblique; PA = posteroanterior; RAO = right anterior oblique.
angulation and merely to 2.4 times toward the RAO 90° angulation. The mean radiation exposure values for all 21 tube projections in the plane at right angles around the phantom continuously rose up to \(2.4\) times toward 30° craniocaudal angulations. Scatter radiation to the operator during fluoroscopy is consequently highest—up to 2,500 μSv/h—in extreme diagonal LAO tube angulations (Fig. 3, Table 2).

In Tables 1 and 2, we have highlighted in boldface the data for radiation exposure produced by the range of tube angulations typically used in clinical routine. A typical standard view for the left coronary main stem is the caudal LAO 60°/20° angulation (Fig. 4), which, however, generates a 2.6-fold increase in the DAP/s level and a 7.6-fold increase in the operator radiation level from caudal PA 0°/30° angulation, respectively. Documentation of an ostial lesion of the left coronary main stem in the cranial PA 0°/0° and PA 0°/0° angulation will likewise significantly reduce the patient and operator dose to even lower levels (Figs. 2, 3, and 4, Tables 1 and 2). The same applies to the typical cranial LAO 60°/20°+ angulation for visualization of the bifurcation into the left anterior descending coronary artery (LAD) and diagonal artery. This angulation in comparison to the cranial PA 0°/30°+ view produces a 2.5-fold increase in DAP/s to the phantom and a fivefold increase in DAP/s.

Table 3. Dose-Corrected Operator Scatter Exposure (μSv/Gy × cm²) During Fluoroscopy as a Function of Tube Angulation.

<table>
<thead>
<tr>
<th>RA0</th>
<th>PA 0°/30°+</th>
<th>PA 0°/0°</th>
<th>LAO 60°/20°+</th>
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<td>100°</td>
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<td>1.7</td>
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</tbody>
</table>

*Boldface characters indicate range of typically used tube angulations.*

Abbreviations as in Table 1.

Figure 4. Ostial lesion of the left coronary main stem (arrowhead): cranial posteroanterior (PA) 0°/30°+ and PA 0°/0° angulations enable personal dose levels much lower than those obtained with the typical caudal left anterior oblique (LAO) 60°/20°– angulation.

In Tables 1 and 2, we have highlighted in boldface the data for radiation exposure produced by the range of tube angulations typically used in clinical routine. A typical standard view for the left coronary main stem is the caudal LAO 60°/20°– angulation (Fig. 4), which, however, generates a 2.6-fold increase in the DAP/s level and a 7.6-fold increase in the operator radiation level from caudal PA 0°/30°– angulation, respectively. Documentation of an ostial lesion of the left coronary main stem in the cranial PA 0°/30°+ and PA 0°/0° angulation will likewise significantly reduce the patient and operator dose to even lower levels (Figs. 2, 3, and 4, Tables 1 and 2). The same applies to the typical cranial LAO 60°/20°+ angulation for visualization of the bifurcation into the left anterior descending coronary artery (LAD) and diagonal artery. This angulation in comparison to the cranial PA 0°/30°+ view produces a 2.5-fold increase in DAP/s to the phantom and a fivefold
increase in the scatter radiation dose level to the operator (Fig. 5, Tables 1 and 2). Neither of these unconventional angulations are, to be sure, typically practiced in invasive cardiology. For the same reason, the RAO 30°/0° angulation should be favored over the cranial RAO 30°/30° angulation for documentation of the LAD.

The ratio between the mean scatter radiation dose in the operator position and the DAP applied to the phantom characterizes the particular additional occupational operator stray radiation risk for certain radiation intensive tube angulations (Table 3). It significantly increases to three- to fourfold levels toward steep LAO angulations, owing to the considerable backscatter radiation from the patient's right side toward the operator, up to 8.0 μSv/Gy × cm² for the caudal LAO 70°/20° tube angulation. Conversely, in efforts toward operator radiation protection, the RAO 90°/0° angulation enables much lower operator radiation
exposure than does the typical LAO 90°/0° view (i.e., the
LAD will be documented 180° around the patient), without
any loss of diagnostic information (Fig. 6). Furthermore,
RAO angulations ≥40° enable very low absolute and
DAP-corrected operator radiation exposure levels (Tables 2
and 3). It is, however, precisely these angulations that are
unconventional in clinical routine (Fig. 7).

**DISCUSSION**

This study clearly reveals that mapping of the time-adjusted
fluoroscopic DAP, applied to an Alderson-Rando phantom,
and of mean personal dose in the operator’s position, in
accordance with all tube angulations feasible in invasive
cardiology, enables identification of projections for coronary
procedures that in clinical routine promise significant re-
duction of radiation exposure to patients and staff.

Tube angulation, likewise, considerably influences patient
and operator radiation exposure in invasive cardiology (i.e.,
steep LAO tube angulations are most radiation intensive for
the patient [5,17,24] and operator [24,25,28]). These data,
however, cannot be considered representative. Indeed, fa-
vored tube angulations for special investigations in invasive
cardiology vary extensively among catheterization laborato-
ries and even among experienced individual operators.
For the first time, the present experimental approach (i.e.,
mapping the time-corrected fluoroscopic DAP and time-
corrected mean personal operator dose for each conceivable
tube angulation) provides a representative and valuable data
tool for every interventionist to examine the possibility of
less radiation-intensive angulations in clinical routine.

In the context of this objective, the few existing clinical
studies corroborate our experimental setting. Employing the
caudal RAO 10°/30° – instead of the former LAO 60°/0°
view reduced the fluoroscopic operator dose by 75%, a level
obtained by averaging readings from five body points (eye,
thyroid, chest, gonads, and knees). Additionally, a 43% re-
duction was seen by favoring the LAO 30°/0° over the
LAO 45°/0° angulation for percutaneous transluminal coro-
nary angioplasty of the left circumflex and right coronary
artery (28). The dose reductions derived by simulation of
these improved angulations in our experimental approach
were highly comparable (i.e., 75% and 44%, respectively).
Furthermore, in accordance with the aforementioned exper-
imental results, our previous clinical data have shown that
the cranial RAO 30°/30° angulation for exact documenta-
tion of the right coronary bifurcation at the crux occasions
greater radiation intensity than does the RAO 30°/0° view
(5,17).

The present analysis disclosed numerous additional de-
tails (Table 4). Interventionists, for example, should avoid
the typical caudal LAO spider view for documentation of
the left main stem, in favor of the cranial PA view for its
proximal region and the caudal PA view for its distal
bifurcation. The panoramic lateral LAO 90°/0° view of the
LAD allows significant radiation benefits over the typical
LAO 90°/0° projection (Fig. 6). For its mid and peripheral
segments, the RAO 30°/0° angulation should be favored
over the cranial RAO 30°/30° angulation. For example,
fluoroscopy in the course of a percutaneous coronary inter-
vention of the bifurcation into the LAD and diagonal artery
(Fig. 5) in the PA cranial 0°/30° + view for 49 s will provide
the same exposure as the cranial LAO 60°/20°+ angulation
for 19 s (Table 1). It is evidently meaningful to establish left
ventriculography in the LAO 40°/0° or, even more effective
in reducing operator stray radiation, in the steep lateral
RAO 100°/90° instead of the LAO 60°/70° angulation for
assessment of septal and lateral wall motion. The same
applies for documentation of the right coronary main stem
up to the crux and the right posterolateral branch (Fig. 7).
From the viewpoint of radiation protection of patients and
staff, interventionists should avoid steep LAO tube angula-
tions whenever possible. The LAO views ≥60° with cranial
or caudal angulation ≥20° are unjustifiable and obsolete; it
is precisely those views which imply a longer SID and,
consequently, more radiation exposure to patients and staff.
From the viewpoint of interventional routine, however, the
best views are those that demonstrate the particular coro-
nary lesion with the least overlap of other structures and in
its “worst stenosis” view. If some radiation intensive angu-
lations are unavoidable, the interventionist should, as far as

**Table 4. Occupational Operator Dose Reduction by Less Irradiating Tube Angulations in Invasive Cardiology**

<table>
<thead>
<tr>
<th>Target Structure</th>
<th>Typical Angulation</th>
<th>Recommended Angulation</th>
<th>Patient (Table 1)</th>
<th>Operator (Table 2)</th>
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<td>LAO 60°/0°</td>
<td>LAO 40°/0°</td>
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<td>−60</td>
</tr>
<tr>
<td>Left main stem bifurcation</td>
<td>LAO 60°/0°</td>
<td>LAO 40°/0°</td>
<td>−2</td>
<td>−74</td>
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<td>Left main stem orifice</td>
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<td>PA 0°/30° (caudal)</td>
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<td>−87</td>
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<td>LAD panoramic view</td>
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<td>−79</td>
<td>−94</td>
</tr>
<tr>
<td>Mid/peripheral LAD</td>
<td>RAO 30°/30°</td>
<td>RAO 30°/0°</td>
<td>−57</td>
<td>−63</td>
</tr>
<tr>
<td>LAD/D bifurcation</td>
<td>LAO 60°/20°</td>
<td>PA 0°/30° (cranial)</td>
<td>−60</td>
<td>−81</td>
</tr>
<tr>
<td>Cx</td>
<td>LAO 60°/0°</td>
<td>LAO 10°/30° (caudal)</td>
<td>−28</td>
<td>−75</td>
</tr>
<tr>
<td>RCA</td>
<td>LAO 60°/0°</td>
<td>LAO 30°/0°</td>
<td>−40</td>
<td>−66</td>
</tr>
<tr>
<td>RCA</td>
<td>LAO 60°/0°</td>
<td>RAO 100°/0°</td>
<td>−2</td>
<td>−74</td>
</tr>
</tbody>
</table>

+ = cranial; − = caudal; Cx = circumflex artery; D = diagonal artery; LAD = left anterior descending coronary artery; RCA = right coronary artery.
possible, minimize lengthy cinegraphic documentation and should increase the SOD.

Another topic needs to be discussed. Given the inverse-square law, any experienced interventionist will wonder why the caudal LAO view results in much occupational radiation exposure as the cranial LAO view. The logical explanation might be as follows: while caudalization of angulation indeed will cranially distance the undercouch tube as well as the patient’s skin entrance site from the operator position, the operator dose will nevertheless not decrease, for a greater proportion of the scatter radiation will be directed from that entrance site caudally toward him or her.

A few limitations of our experimental approach are worthy of mention. Firstly, our conclusions in their quantitative aspects are dependent on the X-ray system used and its setting in a particular center. Secondly, it is not possible to transfer our data on patient exposure during angiography of the right coronary artery without reservation; because for this vessel, it is difficult to identify PA and RAO projections that rotate out the spine. Not least, our experimental approach recorded an over-apron operator radiation dose in the course of invasive cardiac procedures without table-attached and personal radiation protection devices. With use of 0.5- and 1.0-mm overcouch and undercouch shielding, it was possible to reduce the mean operator radiation exposure to 14% and 6% of baseline, respectively. Closure of radiation leakage at 80 to 105 cm of height was achieved by an additional 1.0-mm lead-equivalent undercouch-top and overcouch-flap, adjacent to the table, and resulted in a reduction of radiation exposure levels down to 1% of baseline. Such new, state-of-the-art table-attached lead protection enabled fluoroscopic radiation exposure levels in the operator’s position from 3 (PA 0°) to 16 μSv/h (caudal LAO 60°/20°) and from 60 to 180 nSv/h above and beneath 0.5-mm lead apron, collar, glasses, helmet, and foot-switch shield (24,25). Baseline levels for these reference angulations were 100 and 1,600 μSv/h, respectively. In consequence, the better fixed and personal radiation protection devices are, the less important will be tube angulation with respect to operator radiation exposure. In clinical routine, however, as emphasized recently, measured occupational over-apron doses differed due to the irregular use of thermoluminescence dose meters and film badges (21), and the protective overcouch screen was, “when used, . . . appropriate only occasionally” (11).

The present experimental approach provides the first available mapping of the DAP-corrected mean local scatter dose to the operator for each conceivable tube angulation and offers a representative data tool for every cardiology interventionist to check his or her own occupational radiati

REFERENCES