Radiation Exposure During Endovascular Procedures: Methods to Protect Patients, Physicians and OR Personnel

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Objectives

- Define commonly used Dose Metrics
- Discuss different forms of Radiation Injury
- Describe the types of Operator Exposure
- Identify which Endovascular Procedures are high dose
- Review best operating practice to limit dose
- Introduce new advances to lower dose
Complex Endovascular Procedures

The National Council on Radiation Protection and Measurements threshold for substantial radiation dose level is $\geq 5$ Gy.

The Joint Commission defines a sentinel event for any endovascular procedure that reaches 15 Gy.
Fluoroscopy Dose Metrics

- **Fluoroscopy Time**
  - Poor indicator
  - Omits all doses from digital acquisitions

- **Dose Area Product**
  - Dose $\times$ beam cross-sectional area
  - Reflects total radiation beam output from the x-ray tube
  - Better indicator for cancer risk and operator exposure

- **Reference Air Kerma**
  - Best approximation of patient skin dose
Reference Air Kerma

- Interventional reference point is 15 cm along the beam axis toward the focal spot from iso-center
- Intended to reflect AK at the patient skin surface
- RAK does not account for angulation or table position
Where is RAK Displayed?

RAK is displayed as a rate during acquisitions and as a total dose when you are off the pedal.
Radiation Injury

• **Deterministic effects**
  - Skin Injury, Cataracts
  - Dose-related response with a threshold level

• **Stochastic Injury**
  - Cancer risk
  - Not dose dependent
  - Increasing exposure increases risk
# Radiation Skin Injury

<table>
<thead>
<tr>
<th>Skin dose (Gy)</th>
<th>Expected Injury Grade</th>
<th>Prompt/Early &lt; 8weeks</th>
<th>Midterm 6-52 weeks</th>
<th>Long Term &gt; 40weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-5</td>
<td>1</td>
<td>Erythema/Epilation</td>
<td>Recovery</td>
<td>No effects</td>
</tr>
<tr>
<td>5-10</td>
<td>1-2</td>
<td>Erythema/Epilation</td>
<td>Prolonged erythema, permanent epilation</td>
<td>Dermal atrophy, Induration</td>
</tr>
<tr>
<td>&gt;10</td>
<td>2-4</td>
<td>Erythema Epilation edema ulceration desquamation</td>
<td>Epilation Atrophy, necrosis, Ulceration</td>
<td>Telangiectasia induration</td>
</tr>
</tbody>
</table>

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From the Western Vascular Society

Radiation-induced deterministic effects after fenestrated endovascular aortic aneurysm repair

Melissa L. Kirkwood, MD, a Gary M. Arbique, PhD, b Jeffrey B. Guild, PhD, b Colleen Timmons, MD, a Jon A. Anderson, PhD, a

Background: Radiation-induced skin injury is a concern with all endovascular aneurysm repair (EVAR) procedures. Transient erythema occurs at doses above 2 Gy. We hypothesized that skin injuries would be detected in fenestrated EVAR (FEVAR) repair by using a threshold of 2 Gy.

Methods: All FEVARs during 2010-2012 were included for analysis. Estimated peak skin dose (PSD) was calculated for each procedure and recorded for all CEPs performed. Dose was calculated using input data from the radiologic equipment manufacturer, the patient’s body mass index, and the dose rate. The mean PSD for each patient was calculated and used for analysis. The frequency of PSD levels was determined by the Radiation Protection Officer (RPO) using a scoring system based on the Joint Commission guidelines.

Results: Twenty-two patients were included in the study with a total of 69 procedures. The mean PSD was 7.9 Gy with a range of 2.3-10.4 Gy. Sixty-one CEPs resulted in no skin injury. The remaining 8 CEPs had PSDs of 4.3-8.9 Gy. No skin injuries were reported.

Conclusions: This study represents the largest cohort of fenestrated EVARs to date. The results suggest that fenestrated EVARs are associated with a lower risk of skin injury compared to conventional EVAR. Further studies are needed to confirm these findings and to determine the optimal management of radiation-induced skin injury.
Surgeon Radiation Exposure

- Operator Radiation dose
  - Primary beam
  - Leakage radiation
  - Scatter radiation
Surgeon radiation dose during endovascular procedures.

Melissa L. Kirkwood, MD, Jeffrey J. Kachnoff, MD, and R. James Valentine, MD, and Carla

Background: Surgeon radiation dose during endovascular procedures was studied. We sought to characterize radiation exposure, operator position, level of operator training, and assist their radiation dose prospectively to surgeons. We used the primary and assistant operators at the beginning of the reference air kerma, the kerma-area product and the presence or absence of external shielding. Right-hand side of the patient in decreased Position A (main operator) was closest to the brachial access site. The nanoDots were mounted on the procedure. The nanoDot dosimetry system (National Institute of Standards and Technology, NJ). Comparative statistical analysis of the data was performed with Tukey pairwise comparisons. Bonferroni correction was applied.

Results: There were 415 nanoDot measurements during repairs/endovascular aneurysm repairs, lower extremity interventions, and femoral artery repairs. Operator effective dose for FEVARs was lower than position B. For all case types, position B (4 mSv) or position C (0 mSv) was not statistically different from that for position A (2 mSv). The total cumulative dose (33 ± 0.3 mSv to 63 ± 3.3 mSv) for operators with monitored shielding was not different from that for operators without monitoring.

Conclusions: Surgeon radiation dose during endovascular procedures is influenced by operator position and level of fellow training. On the basis of these data, we recommend operators have an annual dose <10 mSv, which would result in lower annual doses for operators with higher case loads, operator doses are relatively low.
Radiation dose with different pre-manufactured devices
Radiation dose and number of fenestrations during FEVAR
Applying basic techniques can lower radiation dose to yourself and your patients.
Be aware when you are on the fluoro pedal and use the lowest fluoro mode possible

<table>
<thead>
<tr>
<th>Mode</th>
<th>Vascular</th>
<th>Cardio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor 1</td>
<td>7.5 pps, 1.0/0.4 mm Al/Cu, LCC</td>
<td>15 pps, 1.0/0.4 mm Al/Cu, LCC</td>
</tr>
<tr>
<td>Flavor 2</td>
<td>7.5 pps, 1.0/0.1 mm Al/Cu, LCC</td>
<td>15 pps, 1.0/0.1 mm Al/Cu, LCC</td>
</tr>
<tr>
<td>Flavor 3</td>
<td>15 pps, 1.0/0.1 mm Al/Cu, LCC</td>
<td>15 pps, 1.0/0.1 mm Al/Cu, HCC</td>
</tr>
<tr>
<td>Angiography</td>
<td>3 fps, 0.0/0.0 mm Al/Cu, DSA</td>
<td>15 fps, 0.0/0.0 mm Al/Cu</td>
</tr>
</tbody>
</table>

Typical Philips Operating Parameters
DSA has an exponentially higher dose than fluoroscopy.

Medium Sized Patient Reference Air-Kerma
Typical dose rates for an abdomen protocol on a Philips Allura Exper FD-20 interventional system

Fluoroscopy (magnification and dose mode range)

Angiography (magnification and 3-6 fps range)

0.001 0.01 0.1 1.0 10.0

Gy/min

So try to limit DSA and use fluoro looping when possible.
Use Angio Multiphase

Reduced frame rate in later stages of an angiographic run
Limit Magnification

Use Collimation

If the goal is to restrict exposure area on the patient then collimate.

If the goal is to achieve increased spatial resolution use magnification.

Collimation: same resolution and RAK rate

Magnification: increased resolution and RAK rate

On image intensifier systems RAK increases in inverse proportion to square of field size (i.e., halve FOV, quadruple RAK rate)

On flat panel systems RAK increases in inverse proportion to field size (i.e., halve FOV, double RAK rate)
Principles to Remember..

- Dose rate at the Image receptor is maintained at a constant level to preserve image quality
- Compensates for variations in attenuation
- Radiation dose decreases as $1/distance^2$ from the source
  - Double the distance from the source and decrease radiation by a factor of 4
Raise the Angio Table
Minimize the Patient to Detector Distance

- AK at the patient decreases as a function of the:
  \[(\text{patient to source distance})^2\]
  So raise the angio table
- Minimize the source to image distance (SID)
  Drop the II close to the patient
- Overall result is a decrease in patient dose even though the RAK may increase because the RAK is registering the dose at the reference point and not the patient position
Avoid Steep Angulation

The attenuation is increased due to increased patient thickness, which leads to increased machine output to maintain constant AK at the detector.
Operator Position

Step Back!
Radiation falls off as $1/distance^2$ from the source. Double the distance, quarter the radiation level.

Stand on the opposite side of the X-ray tube!
Using Angulation and collimation to Spread Dose

Skin Dose Maps

No Angulation
PSD equally distributed over skin surface

Beam Angulation without Collimation does not decrease PSD

Angulation with collimation Can spread skin dose and lower PSD
New Software Developments

• AlluraClarity (Philips Healthcare)
  • New image technology that claims to reduce dose while maintaining image quality

• Adaptive Noise Reduction Algorithms
  • Motion compensation
  • Spatial noise and Temporal filtering
  • This allows for optimization of the image chain to maintain image quality and lower dose
Patient and Operator Dose was decreased by 60% with AlluraClarity.
Tips to Limit Dose

• Limit Fluoroscopy time
• Minimize frame rates
• Use low dose fluoroscopy modes when possible
• Minimize use of DA (use fluoro capture)
• Keep the table height high
• Keep the image receptor close to the patient
• Minimize steep angles (if necessary, Collimate)
• Vary imaging angle to spread skin dose
Tips to Limit Dose

• Keep patient extremities out of the beam
• Minimize use of Magnification
• Monitor RAK rate during the procedure
• Step back from the table
• If gantry is angulated stand on the opposite side of the X-ray tube
• Be Aware of new software developments that can lower dose