Strategies for optimal occupational radiation protection during vascular intervention

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Cook Medical: Proctoring, Speaker’s fees, Grant support
Long-Term Low-Dose Radiation Exposure May Increase Leukemia Risk

Leukemia was already known to be caused by exposure to high doses of radiation, like that released by the atomic bombs dropped on Japan in 1945.
Low Dose Risk Theories

McLean AR et al. Proc. R. Soc. 2017
Factors dictating incidence of cancer:

- Years employment
- Cumulative air hours
- Total radiation dose
- Cumulative radiation dose up to 40 yrs age

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancers</td>
<td>2.4 [1.5-3.92]</td>
</tr>
<tr>
<td>Prostate</td>
<td>9.88 [1.57-190.78]</td>
</tr>
<tr>
<td>Melanoma</td>
<td>3.61 [1.64 to 8.48]</td>
</tr>
<tr>
<td>Basal Cell</td>
<td>6.65 [1.61 to 44.64]</td>
</tr>
</tbody>
</table>
Real time dose feedback
Real time dose feedback

Cardiac Catheterization

Effect of a Real-Time Radiation Monitoring Device on Operator Radiation Exposure During Cardiac Catheterization

The Radiation Reduction During Cardiac Catheterization Using Real-Time Monitoring Study

GEORGIOS CHRISSAKOULIS, MD, ARISTIDIS C. PAPAGIANNIS, MD, MOHAMMAD ALIYARI, MD, ATSU KEKUI, MD, TEODORI T. MIHALIS, MD, BARAN A. KAMAN, BDS, MPH, MICHIGA BODA, MD, BHUNI, DEBORAH SHORELLO, LORRAINE MULLEN, RCSI; RONALD LEWIS, BS; REBECCA GEORGIANNI, BS; DONALD HAUGEN, BCS; SPYROS MANGONAULAS, MD; ADIF MOHAMMAD, MD, KAREN SANDS, MA; DARIA C. GIVENS, BBS; CHARLES E. CHAMBERS, MD; SELDAH BANGALE, MD, EMMAUSSA L. EHAKAH, MD, PHD

Background: The Radiation Reduction During Cardiac Catheterization Using Real-Time Monitoring study sought to examine the effect of a real-time radiation detector that provides real-time operator dose reporting through an audio feedback (i.e., real-time radiation reduction device). The device was compared with the standard radiation protection protocol in two groups: the experimental group using the device and the control group using the standard protocol.

Methods: Patients were assigned to the experimental or control group based on availability and consent. The experimental group received an audio feedback system during the procedure, while the control group received the standard protocol. The audio feedback provided real-time radiation exposure data to the operator, allowing for adjustments to radiation exposure strategies.

Results: The audio feedback system was well-received by operators in both groups and was found to be effective in reducing radiation exposure. The data collected during the procedure was analyzed to compare the radiation exposure between the two groups. The audio feedback system was found to significantly reduce the radiation exposure in the experimental group compared to the control group.

Conclusion: The use of an audio feedback system during cardiac catheterization procedures can significantly reduce radiation exposure. Further studies are needed to confirm these findings and to determine the optimal implementation of real-time radiation monitoring devices in clinical practice.

Key Words: cardiac catheterization • quality improvement • radiation
## Exposures during standard and complex aortic repair

<table>
<thead>
<tr>
<th></th>
<th>Median (IQR) (n=24)</th>
<th>Standard EVAR/TEVAR (IQR) (n=13)</th>
<th>Complex Cases Branched/Fenestrated (IQR) (n=11)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Operating Time (mins)</strong></td>
<td>178 (10-164)</td>
<td>117 (105-147)</td>
<td>232 (217-282)</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Total Fluoroscopy Time (mins)</strong></td>
<td>40 (22-68)</td>
<td>22 (21-36)</td>
<td>71 (205-293)</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Total DAP (mGy.m²)</strong></td>
<td>135,369 (74440-201708)</td>
<td>98236 (38106-168855)</td>
<td>194839 (104525-239903)</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Primary Operator Dose (µSv)</strong></td>
<td>57 (10.3-124.9)</td>
<td>41.4 (22.3-85.3)</td>
<td>69.9 (48.9-111)</td>
<td>NS</td>
</tr>
</tbody>
</table>
Lowest dose that allows adequate image quality

X-ray tube:
- Copper filtration
- Tube potential (kV)
- Pulse duration (ms)
- Tube current (mA)

<table>
<thead>
<tr>
<th>Setting</th>
<th>Dose (mGy/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoflavor 1 (Low)</td>
<td>0.076</td>
</tr>
<tr>
<td>Fluoflavor 2 (Medium)</td>
<td>0.113</td>
</tr>
<tr>
<td>Fluoflavor 3 (Normal)</td>
<td>0.267</td>
</tr>
</tbody>
</table>

Localisation vs Characterisation
Active management of field of view: Collimation

25% collimation \approx 25\% \text{ reduction DAP}
Reduce scatter
Reduce exposure surrounding tissues

Haqqani et al. JVS 2012
Majority of radiation exposure occurs during DSA runs

**Occupational Radiation Exposure During Endovascular Aortic Procedures**

A.P. Patel 1, D. Geallacher 1, R. Dourado 1, O. Lyons 1, A. Smith 1, H. Zayed 1, M. Waltham 1, T. Sabharwal 1, R. Bell 1, T. Carrell 1, P. Taylor 2, B. Modarai 2

1 Vascular Unit, Guy’s & St Thomas’ NHS Foundation Trust and King’s College London, Cardiovascular Clinical Academic Group, King’s Health Partners, United Kingdom
2 Department of Medical Physics, Guy’s & St Thomas’ NHS Foundation Trust, United Kingdom

**WHAT THIS PAPER ADDS**

The dangers of radiation exposure while performing endovascular operations are not well recognised by vascular interventionists. The present study assesses the radiation dosage received by the operating team during endovascular aortic procedures and demonstrates that particular behaviours increase this dose considerably. A greater awareness of these behaviours would help to reduce the amount of radiation to which patients and members of the operating team are exposed.

**Objectives:** To measure the radiation exposure of the operating team during endovascular aortic procedures, and to determine factors that predict high exposures.

**Materials and methods:** Electronic dosimeters placed over and under protective lead garments, were used to prospectively record radiation exposure during endovascular aortic repairs performed in a designated interventional radiology suite. Univariate and multivariate linear regression analyses of predictors of radiation exposure were performed.

**Results:** A total of 26 infra-renal and 10 thoracic endovascular cases were studied. Median (IQR) patient age and body mass index were 76.0 (70.0–81.8) years and 26.2 (23.9–28.9) kg/m² respectively. Over-lead exposure to the operator was higher for thoracic than for infra-renal procedures (421.0 [233.8–597.8] μSv vs. 52.5 [27.8–179.8] μSv, p < 0.0003), reflecting a significant exposure to unprotected parts of the body. Under-lead exposures for operator and assistant were 5.5 (2.0–14.2) μSv and 1.0 (0.0–2.3) μSv respectively, which for an average caseload would comply with total body effective dose limits. Type of case and percentage of digital subtraction angiography (DSA) time in left anterior oblique angulations predicted dose to the operator (p < 0.0001).

**Conclusions:** Thoracic procedures, DSA runs and obliquity of the C-arm are strong predictors of radiation exposure during endovascular aortic repairs. Understanding scatter radiation dynamics and instituting measures to minimise radiation exposure should be mandatory.

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Article history: Received 27 February 2013, Accepted 29 May 2013, Available online XXX

**Keywords:** Occupational radiation exposure, Dosimetry, Endovascular, Aortic repair

**Average patient DAP = 170.6 Gycm²**

- **22.1%** DSA runs
- **77.9%** Background Fluoroscopy
Predictors of operator dose during DSA: Operator position

*P=0.021
**P=0.014

<table>
<thead>
<tr>
<th>Position</th>
<th>Median (IQR)</th>
<th>IEVAR / TEVAR (IQR)</th>
<th>BEVAR / FEVAR (IQR)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tableside</td>
<td>24 (11-106)</td>
<td>14 (8-18)</td>
<td>28 (23-31)</td>
<td>0.001</td>
</tr>
<tr>
<td>1-2m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;2m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No of DSA runs PO stepped back (% of runs)

<table>
<thead>
<tr>
<th>Position</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tableside</td>
<td>80 (17%)</td>
</tr>
<tr>
<td>1-2m</td>
<td>49 (26%)</td>
</tr>
<tr>
<td>&gt;2m</td>
<td>31 (11%)</td>
</tr>
</tbody>
</table>
Predictors of operator dose during DSA: Angulation of C-arm
Angulation of C-arm and head exposure

![Graph showing radiation dose and head dose with LAO angle](image)

- Left graph: Comparison of radiation dose for primary and assistant operators under different measured areas (Under, Over, Head).
  - Significant difference for the Head area with p < 0.001.
  - p = 0.014 for Over area.
  - p = 0.022 for Under area.

- Right graph: Scatter plot showing head dose (in μSv) against LAO angle (in degrees).
  - p = 0.004.
  - rho = 0.656.

Albayati, Modarai et al. EJVES 2015
Predictors of operator dose during DSA: Source to image distance

$P < 0.000$, $R^2 = 0.066$
Radiation-Induced DNA Damage in Operators Performing Endovascular Aortic Repair.

El-Sayed T¹, Patel AS¹, Cho JS¹, Kelly JA¹, Ludwinski FE¹, Saha P¹, Lyons OT¹, Smith A¹, Modarai B²; Guy's and St Thomas' Cardiovascular Research Collaborative.

Radiation → Double Stranded DNA Break → H2AX → Gamma H2AX

![Pre-op](image1.png) ![Post-op](image2.png)

![Graph](image3.png)

*P<0.05
Effects of ionising radiation on micronucleus formation and chromosomal aberrations in Chinese radiation workers

Qing-Zeng Qian,¹, Xiang-Ke Cao,² Fu-Hai Shen,¹ and Qian Wang¹

<table>
<thead>
<tr>
<th>Groups</th>
<th>Cases (N)</th>
<th>MN Numbers (N)</th>
<th>MN numbers (N)</th>
<th>MN rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed group</td>
<td>1392</td>
<td>1 392 000</td>
<td>3395</td>
<td>2.44⁴</td>
</tr>
<tr>
<td>Control group</td>
<td>143</td>
<td>143 000</td>
<td>246</td>
<td>1.72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exposure time (y)</th>
<th>Cases (N)</th>
<th>MN number (N)</th>
<th>MN rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>723</td>
<td>1597</td>
<td>2.21</td>
</tr>
<tr>
<td>10–20</td>
<td>532</td>
<td>1316</td>
<td>2.47⁴</td>
</tr>
<tr>
<td>&gt;20</td>
<td>137</td>
<td>482</td>
<td>3.52</td>
</tr>
</tbody>
</table>
“Genetic susceptibility to radiation-induced cancer involving strongly expressed genes is judged to be too rare to appreciably distort estimates of population risk; the potential impact of common but weakly expressing genes remains uncertain”
Cancer staging: 99mTc MDP bone scans

Anti-oxidant formulation:
- 1.2g N-acetylcysteine,
- 600mg lipoic acid
- 30mg betacarotene

Reduction in DNA damage (gamma H2AX)
Leg lead shielding is protective

Without leg pads (n=10)
With leg pads  (n=10)

* P<0.05

% γH2AX

Pre | Post | Pre | Post
Towards X-ray free endovascular interventions – using HoloLens for on-line holographic visualisation

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✉E-mail: kuhlmann@rob.uni-luebeck.de

Published in Healthcare Technology Letters; Received on 24th July 2017; Accepted on 24th July 2017
As Low As Reasonably Achievable

- Intermittent fluoroscopy
- Reduce pulse rate
- Reduce frame rate
- Limit number of DSA runs
- Step away during DSA runs
- Magnification
- Collimation
- Avoid angulation C-arm
- Reduce “air gap”

• Elevated markers of DNA damage after EVAR
• Know your dose
• Real time dosimetry +/- alert
• Role for “spotter” in theatre
• Insist on maximal shielding