Evidence of radiation induced cataracts and brain tumors

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Disclosures

- **Consultant**
  - Cook, Endologix, Gore, Medtronic

- **Research Grant**
  - Gore, Maquet, Medtronic, Siemens

- **Advisory Board**
  - Endologix, Gore, Maquet, Medtronic, Siemens

- **Paid Speaker**
  - Endologix, Gore, Maquet, Medtronic, Siemens

- **Major Stakeholder**
  - none
Radiation Protection becomes more important...

Patients, OR-Team, Anesthesiology, Scrub Nurses, Students, Visitors
More Endovascular > Increased Exposure

EVERY DAY HEALTHCARE PROFESSIONALS ARE EXPOSED TO THE HARMFUL EFFECTS OF RADIATION

NEARLY 40% OF THE INCREASED EXPOSURE IS RELATED TO CARDIOVASCULAR IMAGING AND INTERVENTION

Potential Harms of Radiation

Skin
Eye lens
Brain cancer
Treshold Values – Occupational Exposure

- Effective Dose < 20 mSv / year
- Occupational life dose < 400 mSv
- Treshold values for organ dosages (§ 55 StrlSchV)
  - Eye lens >20 mSv
  - Skin, hands, forearm, feet, ankle
  - Gonads
  - Thyroid gland, bones
  - Colon, stomach, lungs, liver
- Brain: unknown, not given

http://m.welt.de/gesundheit/article137871513/Grafik-Strahlenbelastung-Deutschland-DW-Wissenschaft-Berlin-der.jpg.html

University Hospital Heidelberg | 8th MAC 2018 | Prof. Dr. Dittmar Böckler
Potential Harms of Radiation

- Skin
- Eye lens
- Brain cancer
Evidence is increasing

Comparison of indirect radiation dose estimates with directly measured radiation dose for patients and operators during complex endovascular procedures

Giuseppe Panuccio, MD,* Ray R. Greenberg, MD,* Kevin Wunderle, MSc,* Tara M. Mastrocicco, MD,* Matthew G. Langston, MD,* and William Davros, PhD.* Cleveland, Ohio

Background: A great deal of attention has been directed at the necessity and potential for deleterious outcomes as a result of radiation exposure during diagnostic evaluations and interventional procedures. We embarked on this study in an attempt to accurately determine the amount of radiation exposure during complex endovascular aortic repair. These measured doses were then correlated with radiation dose estimates provided by the imaging equipment manufacturers that are typically used for documentation and analysis of radiation-induced risk.

Methods: Consecutive patients undergoing endovascular thoracoabdominal aortic aneurysm (TAAA) repair were prospectively studied with respect to radiation dose. Indirect parameters as cumulative air kerma (CAK), kerma area product (KAP), and fluoroscopy time (FT) were recorded concurrently with direct measurements of dose (peak skin dose [PSD]) and radiation exposure patterns using radiographic film placed in the back of the patient during the procedure. Simultaneously, operator exposure was determined using high-sensitivity electronic dosimeters. Correlation between the indirect and direct parameters was calculated. The observed radiation exposure pattern was reproduced in phantoms with over 200 dosimeters located in mock organs, and effective doses has been calculated in an in vitro study. Scatter plots were used to evaluate the relationship between continuous variables and Pearson correlations.

Surgeon radiation dose during complex endovascular procedures

Melissa L. Kirkwood, MD,* Jeffrey B. Guild, PhD,* Gary M. Arboigne, PhD,* Jon A. Anderson, PhD,* B. James Valentini, MD,* and Carlos Timuza, MD,* Dallas, Tex

Background: Surgeon radiation dose during complex fluoroscopically guided interventions (FGIs) has not been well studied. We sought to characterize radiation exposure to surgeons during FGIs based on procedure type, operator position, level of operator training, upper versus lower body exposure, and addition of passive shielding.

Methods: Optically readable, luminescent nanoDot (Landauer, Inc., Glenwood, IL) detectors were used to measure radiation dose prospectively to surgeons during FGIs. The nanoDot dosimeters were placed outside the lead apron of the primary and assistant operators at the left upper chest and left lower pelvis positions. For each case, the procedure type, the reference air kerma, the kerma area product, the relative position of the operator, the level of training of the fellow, and the presence or absence of external additional shielding devices were recorded. These positions were assigned on the right-hand side of the patient for decreasing relative protection (A, B, and C, respectively). Position A (main operator) was closest to the flat panel detector. Position D was on the left side of the patient at the brachial access site. The nanoDot data were read using a microRAI medical dosimetry system (Landauer, Inc.) after every procedure. The nanoDot dosimetry system was calibrated for scattered radiation in an endovascular suite with a National Institute of Standards and Technology traceable solid-state radiation detector (Pinnacle 720, RTI-Electronics, Fairfield, NJ). Comparative statistical analysis of nanoDot dose levels between categories was performed by analysis of variance with Tukey’s post hoc comparisons. Bonferroni correction was used for multiple comparisons.

Results: There were 415 nanoDot measurements with the following case distribution: 16 thoracic endovascular aortic
Radiation induces Cataract

Key findings:

- Lens changes 5 x higher in interventional cardiologist compared to controls.
- Cumulative effect > injuries result after years of practice.
Radiation exposure to eye lens in Hybrid - OR

- Prospective non-randomized trial
- 171 endovascular procedures
- Heidelberg & Nuremberg
- DAP, fluoro time, OR-time
- Radiation exposure to eye lens & hand
Radiation exposure to eye lens and operator hands during endovascular procedures in hybrid operating rooms

Nicolas Attigiah, MD; Kyriakos Okonomou, MD; Ulf Hinz, MS; Thomas Knoch, MS; Serdar Demirel, MD; Erik Verhoeven, MD, PhD; and Dittmar Böckler, MD; Heidelberg and Saarbrücken, Germany

Objective: The purpose of this study was to evaluate the radiation exposure of vascular surgeons' eye lens and fingers during complex endovascular procedures in modern hybrid operating rooms.

Methods: Prospective, nonrandomized multicenter study design. One hundred seventy-one consecutive patients (138 male, median age, 72.5 years [interquartile range, 65-77 years]) underwent an endovascular procedure in a hybrid operating room between March 2012 and July 2013 in two vascular centers. The dose-area product (DAP), fluoroscopy time, operating time, and amount of contrast dye were registered prospectively. For radiation dose recordings, single use dosimeters were attached at eye level and to the finger of the hand next to the radiation field of the operator for each endovascular procedure. Dose recordings were evaluated by an independent institution. Before the study, proprietary instruments were obtained to simulate the radiation dose to eye lens and fingers with an Alderson phantom (RAD, Long Beach, Calif.).

Results: Interventions were classified into six treatment categories: endovascular repair of infrarenal abdominal aneurysm (n = 65), thoracic endovascular aortic repair (n = 32), branched endovascular aortic repair for thoracoabdominal aneurysms (n = 17), fenestrated endovascular aortic repair for complex abdominal aortic aneurysms, (n = 25), iliac branched device (n = 8), and peripheral interventions (n = 24). There was a significant correlation in DAP between hands (P < .01; r = 0.53) and finger (P < .01; r = 0.56) doses. The estimated fluoroscopy time to reach a radiation threshold of 20 mSv/y was 1,404.10 minutes (90% confidence limit, 1,166.1,660 minutes). According to the correlation of the DAP and the estimated cumulative DAP of 932,000 mGy/m² (90% confidence limit, 822,000-1,089,000) would be critical for a threshold of 20 mSv/y for the eyes.

Conclusions: Radiation protection is a serious issue for vascular surgeons because most complex endovascular procedures are delivering measurable radiation to the eyes. With the correlation of the DAP obtained in standard endovascular procedures a critical threshold of 20 mSv/y to the eye can be predicted and thus as an estimate of a potential harmful exposure to the eyes can be obtained. (J Vasc Surg 2016;63:199-203.)
Radiation exposure to eye lens in Hybrid - OR

- Estimated fluoroscopy time to reach 20 mSV/y = 1404 minutes
- Estimated DAP to reach threshold of 20 mSv/y = 932,000 mGy/m²
Operator Eye Exposure depends on Working Position

femoral region, side, or head of patient

Radiation Eye Exposure increases with Angulation

When LAO/RAO angle are >30°, patient & operator dose rate increases exponentially. Same with CRA/CAU >15°

Haqqani J Vasc Surg 2012
Operator Eye Exposure – working position

Contrary to instincts, work closer to the side of the image intensifier rather than x-tube
Protect your Eye Lenses
## Differences between Lead Glasses

<table>
<thead>
<tr>
<th>Eyeglass</th>
<th>15-50%</th>
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<tbody>
<tr>
<td>9941 Ultralite ScanFlex</td>
<td></td>
</tr>
<tr>
<td>Eyeglass</td>
<td>10-15%</td>
</tr>
<tr>
<td>553 s Metallic Scanflex</td>
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<tr>
<td><strong>Fit over eyeglass</strong></td>
<td>80%</td>
</tr>
<tr>
<td>89 Fit over Scanflex</td>
<td></td>
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<tr>
<td><strong>Fit over + personal glasses under</strong></td>
<td>20-75%</td>
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<tr>
<td>89 Fit over Scanflex</td>
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<tr>
<td><strong>Visor - downward angled</strong></td>
<td>70-75%</td>
</tr>
<tr>
<td>BRV501 Mavig</td>
<td></td>
</tr>
<tr>
<td><strong>Visor - non-angled</strong></td>
<td>10-15%</td>
</tr>
<tr>
<td>BRV501 Mavig</td>
<td></td>
</tr>
<tr>
<td><strong>Ceiling mounted shield</strong></td>
<td>90-95%</td>
</tr>
<tr>
<td>OT 50001 Mavig</td>
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AN ASSESSMENT OF THE DOSE REDUCTION OF COMMERCIALLY AVAILABLE LEAD PROTECTIVE GLASSES FOR INTERVENTIONAL RADIOLOGY STAFF

Cat Rivett*, Matthew Dixon, Lucy Matthews and Nick Rawles
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In light of the proposal from the International Commission on Radiological Protection for a lowered eye dose limit, now adopted by a European Union Council Directive, lead glasses may be required for some staff in interventional radiology to ensure that occupational exposure is as low as reasonably practicable. To investigate the lens protection offered by various lead models of lead glasses exposed to X-rays coming from a source to the left and below, calibrated radiographic film was positioned in the lens area of a head phantom. When the source-to-eye angles were large, the dose reduction factors (the ratio of eye dose without protection to dose with protection) to the right lens area were much lower than to the left lens area, particularly with smaller-lensed glasses, due to gaps in protection between the face and the glasses. The results of this study reiterate the importance of employers providing eyewear based on the morphology of, and fit to, individual workers’ faces.

<table>
<thead>
<tr>
<th>Category</th>
<th>Transmission</th>
<th>DRF</th>
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<tr>
<td></td>
<td>81 kVp (%)</td>
<td>102 kVp (%)</td>
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<tr>
<td>A. Large flat lenses and side shields</td>
<td>0.4</td>
<td>1.1</td>
</tr>
<tr>
<td>B. Small flat lenses and side shields</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>C. Wraparound style with small curved lenses</td>
<td>0.4</td>
<td>1.1</td>
</tr>
<tr>
<td>D. Fitover style with large flat lenses</td>
<td>0.3</td>
<td>1.0</td>
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</table>
Potential Harms of Radiation

Skin

Eye lens

Brain cancer
Attention and Awareness

Edward Diethrich speaks about the impact of radiation on his health
Fri May 8, 2015 12:19 GMT

This video tells the story of one of the world’s most prominent heart surgeons, Edward Diethrich, and the career-altering health issues he has faced as a result of chronic, low-level exposure to ionising radiation through his work.

Invisible Impact: The Risk of Ionizing Radiation on Cath Lab ...
Attention and Awareness

Climbing Head and Neck Tumor Count in Interventional Cardiologists Prompts Calls for More Study

Shelley Wood
April 23, 2014
Cancer Risk for Aircrew - Natural Radiation Exposure

Systematic review (n= 65 publications)

- Increased incidence for breast cancer in women
- Increased risk for melanoma (ultraviolet rays)
- 50% elevated risk for prostatic cancer & brain tumors in pilots
- Overall low evidence and low correlation
DNA Changes in Operators
Aberrant cells and chromosome breaks

Individual Radiation Sensitivity

Circulation 2017
Radiation Induced Cancer = Latency of 10 years

<table>
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<tr>
<th>EXPOSURE</th>
<th>HEAD</th>
<th>LOWER BODY</th>
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<tbody>
<tr>
<td>Intensity</td>
<td>1,000 mSv</td>
<td>100 mSv</td>
</tr>
<tr>
<td>Equivalence(^6)</td>
<td>50,000</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>Chest x-rays</td>
<td>Chest x-rays</td>
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</table>

1,000 mSv correlated to a 5% risk of cancer\(^7\)
Angulation of C-ARM Increases Radiation Exposure to the Head

Editor’s Choice — Angulation of the C-Arm During Complex Endovascular Aortic Procedures Increases Radiation Exposure to the Head


Angulation of C-ARM Increase as Radiation Exposure

WHAT THIS PAPER AIMS
Increasing complexity of endovascular procedures can expose the vascular interventionist to higher levels of radiation, particularly to areas of the body not shielded by lead. This study directly measures radiation exposure to the operator’s head during complex endovascular aortic procedures and demonstrates that exposure is considerably higher with angulation of the C-arm. This knowledge will help operators to minimize C-arm angulation during procedures with the aim of reducing radiation exposure.

OBJECTIVES/BACKGROUND
The increased complexity of endovascular aortic repair necessitates longer procedure time and higher radiation exposure to the operator, particularly to exposed body parts. The aim was to measure direct exposure to radiation of the body and heads of the operating team during endovascular repair of thoracoabdominal aortic aneurysms (TAAA) and to identify factors that may increase exposure.

METHODS
This was a single-centre prospective study. Between October 2016 and July 2017, consecutive elective branchless and fenestrated TAAA repairs performed in a hybrid operating room were shielded.Dosimeter discs were used to measure direct radiation exposure to the primary (PO) and assistant (AO) operator in three different areas (under, head, over, and lead). Fluoroscopy and digital subtraction angiography (DSA) acquisition times, C-arm angulation, and patient height were recorded.

RESULTS
Seventeen cases were analysed (Crawford II–IV), with a median procedure time of 200 minutes (interquartile range 202–300 minutes). Median age was 76 years (range 51–85 years), median body mass index was 27 kg/m² (28–32 kg/m²), and all were operated on under general anesthesia. A total of 21 branches and 36 fenestrations were surrogated and identified. Head dose was significantly higher in the PO compared with the AO (median 54 μSv [range 24–130 μSv] vs. 15 μSv [range 7–48 μSv], respectively, p = 0.02); it was also higher than lead body dose (median 80 μSv [range 37–164 μSv] vs. 32 μSv [range 0–48 μSv], respectively, p = 0.08). Corresponding under-lead doses were similar between operators (median 64 μSv [range 27–177 μSv] vs. 62 μSv [range 1–316 μSv], respectively, p = 0.22). Primary operator height, DSA acquisition time in left anterior oblique (LAO) position, and degree of CAA angulation were independent predictors of PO head dose (p < 0.05).

CONCLUSIONS
The head is an unprotected area receiving a significant radiation dose during complex endovascular aortic repair. The deleterious effects of exposure to this area are not fully understood. Vascular Interventionists should be cognizant of head exposure increasing with C-arm angulation, and limit this maneuver.

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Keywords: Aortic repair; Endovascular; Occupational; Radiation protection

Hirntumore & Strahlenexposition, 6. Frühjahrestagung der DGG, Berlin April 2018
Radiation Head Exposure

Figure 1: Scatter plot showing the relationship between LAO angle (degrees) and head dose (μSv). The correlation coefficient (rho) is 0.656, and the p-value is 0.004.

Figure 2: Box plot illustrating the distribution of head dose (μSv) across different PO heights (cm). The p-value for the comparison is 0.009.
Is there an association?

Brain cancer & radiation exposed staff performing interventions
Selected Literature
Retrospective Study

- 110.297 MTRA
- Mean cumulative brain dose 12 mGy
- Mean follow up: 26.7. years
- 193 developed brain tumors (0.17%)
- Conclusion: no association

Kitahara et al. AJR 2017; 208:1278-84
Case control study

- 31 cases
  - 23 intervent. cardiologists
  - 6 intervent. radiologists
  - 2 electro-physiologists

- Tumor
  - 55% Glioblastoma multiforme
  - 16% Meningeoma
  - 7% Astrozytome

- 85% left sided
  - “possibility of causal relation”
  - raises concern
Nationale US- Survey

84.966 MTRA (radiological technologists)

- Increased incidence for melanoma (OR 1,3)
- Breast cancer (OR 1,16)
- No data on brain tumors
- 2x increased mortality risk (OR 2,55)
- Limitation: pot. Non radiogenic factors

„future epidemiological studies needed“

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Incidence&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mortality&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Cases</td>
<td>Hazard Ratio&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Ever Worked With</td>
<td>Never Worked With</td>
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<tr>
<td>All cancers excluding nonmelanoma skin cancer</td>
<td>900</td>
<td>2431</td>
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<tr>
<td>Brain cancer</td>
<td>26</td>
<td>34</td>
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<tr>
<td>Female breast cancer</td>
<td>324</td>
<td>962</td>
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<tr>
<td>Melanoma</td>
<td>141</td>
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<tr>
<td>Basal cell carcinoma</td>
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<td>1427</td>
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<tr>
<td>Squamous cell carcinoma</td>
<td>144</td>
<td>418</td>
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<tr>
<td>Thyroid cancer</td>
<td>32</td>
<td>96</td>
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<tr>
<td>Prostate cancer</td>
<td>114</td>
<td>211</td>
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<tr>
<td>Lung cancer</td>
<td>19</td>
<td>70</td>
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<tr>
<td>Colorectal cancer</td>
<td>48</td>
<td>159</td>
</tr>
<tr>
<td>Leukemia other than chronic lymphocytic leukemia</td>
<td>6</td>
<td>19</td>
</tr>
</tbody>
</table>

Effect of ceiling mounted shields

6.95 mSv

0.08 mSv

Factor 4000

0.0017 mSv
Reeves et al., JACC 2015;8:1197-1201

Benefit of lead caps?

Prospektive Single Center Study

- N= 11 cardiologists carried lead caps
- Interv. cardiologists are exposed to greater left sided radiation
- 5 x greater left > right sided radiation exposure
- 16 x higher radiation outside the cap than inside
Benefit of lead caps?

0.08 mSv

0.005 mSv

factor 16

Reeves et al., JACC 2015;8:1197-1201
Summary

- Evidence for radiation induced cataracts is relatively high (2a and b)
- Evidence for radiation induced brain tumors is low (3b)
Conclusion

Radiation protection of thyroid, eyes & head makes sense

2010-2016  Since 2017  ?