Assessment of trigger levels to prevent tissue reaction in interventional radiology procedures

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In fluoroscopy-guided interventional radiology (IR) procedures the extensive exposure to x rays often provides high radiation doses to patient’s skin.

Several radiation-induced skin injuries were described in the 1990s. This injuries vary from erythema to ulceration and necrosis (Koenig et al., Skin injuries from fluoroscopically guided procedures. *Am J Roentgenol*, 2001, *177*:3–20).

Even with contemporary state-of-the-art dose-reducing x-ray systems and appropriate training of the physicians, radiation-induced skin injuries still can occur, due to the complexity of these procedures.
As stated by the ICRP, skin dose should be estimated for each patient in order to provide an adequate follow-up and eventual treatment for patients whose skin dose has been 3 Gy or greater.

Skin dose cannot be directly measured. Therefore procedures for estimating and monitoring skin dose in daily practice need to be developed and *on line* dose indicators that could alert the physician about radiation risk should be individuate.

**Trigger level**, defined as the level that indicate skin exposures requiring medical follow-up for possible radiation injuries, has to be defined.
KAP is the quantity recommended by ICRU to monitor patient doses in IR. KAP is defined as the integral of air kerma across the entire X-ray beam emitted from the X-ray tube.

Cumulative KAP does not provide a direct indication of the possibility of skin injury: the same KAP is observed with large fields and low skin doses as with small fields and high skin doses.

For that reasons the CK at the IRP has been introduced for the purpose of limiting the maximum patient’s skin dose.
Aim

- To investigate the relationships between the measured skin dose and CK at IRP and KAP respectively and their usefulness as on-line indicators.

- To evaluate the possibility to define a trigger level which can help operators to identify situations with high probability to exceed the threshold for deterministic effects.
Material and Methods

- Maximum skin dose (MSD) has been measured in a sample of patients using radiochromic films (Gafchromic XR-typeR, IPS, USA) placed between patient and couch during the procedure.

- Calibration has been performed on the same angiographic equipment used for the interventional procedure (Axiom Artis dFa, Siemens, Germany).

- The film has been cut in small pieces (3x3 cm²) and irradiated to different amount of dose measured with an ion chamber (Radcal, Model 2026C 6cc)
<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>No.</th>
<th>FT (min)</th>
<th>KAP (Gycm²)</th>
<th>CK (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebral Angiography</td>
<td>197</td>
<td>6.1 ± 8.2</td>
<td>71.1 ± 49.2</td>
<td>770.9 ± 887.4</td>
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<tr>
<td>Aneurysm Embolization</td>
<td>76</td>
<td>26.6 ± 13.5</td>
<td>135.4 ± 60.8</td>
<td>2153.7 ± 1345.3</td>
</tr>
<tr>
<td>Chemo-embolization</td>
<td>144</td>
<td>14.1 ± 7.7</td>
<td>210.5 ± 138.6</td>
<td>1136.3 ± 767.9</td>
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<tr>
<td>Embolizations</td>
<td>57</td>
<td>26.2 ± 41.6</td>
<td>269.7 ± 320.8</td>
<td>1384.7 ± 1472.0</td>
</tr>
<tr>
<td>Peripheral Angiography</td>
<td>145</td>
<td>1.4 ± 1.9</td>
<td>43.4 ± 29.3</td>
<td>154.5 ± 106.1</td>
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<td>Lower limb Angioplasty</td>
<td>44</td>
<td>15.6 ± 9.9</td>
<td>24.7 ± 37.6</td>
<td>149.0 ± 237.6</td>
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<td>Carotid Angioplasty</td>
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<td>9.4 ± 5.5</td>
<td>53.7 ± 26.0</td>
<td>247.3 ± 135.7</td>
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<td>Iliac Angioplasty</td>
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<td>11.4 ± 9.8</td>
<td>80.5 ± 69.5</td>
<td>401.9 ± 293.5</td>
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<td>Below-knee Angioplasty</td>
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<td>17.9 ± 10.4</td>
<td>8.9 ± 14.3</td>
<td>101.6 ± 326.0</td>
</tr>
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<td>Renal Angioplasty</td>
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<td>7.7 ± 3.5</td>
<td>48.6 ± 54.3</td>
<td>308.6 ± 270.3</td>
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<td>AAA/AAT</td>
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<td>11.6 ± 5.1</td>
<td>87.6 ± 50.3</td>
<td>495.7 ± 248.6</td>
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<td>Brachytherapy</td>
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<td>22.6 ± 19.8</td>
<td>16.4 ± 14.6</td>
<td>104.1 ± 94.5</td>
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<td>Cavography</td>
<td>7</td>
<td>7.5 ± 6.5</td>
<td>66.1 ± 53.3</td>
<td>273.3 ± 216.4</td>
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<td>Fibrinolysis</td>
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<td>19.9 ± 11.0</td>
<td>28.1 ± 29.5</td>
<td>113.2 ± 102.9</td>
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<td>Caval Filter</td>
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<td>64.1 ± 98.3</td>
<td>236.7 ± 282.7</td>
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<td>4.5 ± 14.6</td>
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<td>Flebography</td>
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<td>HVPG measurement</td>
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<td>29.2 ± 18.1</td>
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<td>TIPS</td>
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<td>20.5 ± 13.3</td>
<td>117.3 ± 74.1</td>
<td>827.5 ± 609.5</td>
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<td>Epiaortic trunk angiography</td>
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<td>40.9 ± 30.5</td>
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<td>Vertebroplasty</td>
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<td>51.4 ± 26.0</td>
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</tbody>
</table>
Material and Methods

- Images (48 bit colour) were read with a flatbed scanner (Epson Expression1680 pro) and the conversion of grey values in dose values has been done with an home-made Matlab routine.

- KAP and CK at IRP were measured with a transmission ionisation chamber place inside the tube environment (Diamentor PTW, Freiburg, Germany)

- KAP meter has been periodically calibrated in situ for different tube voltages, filtrations and modes (fluoroscopy and cineangiography) for comparison with the same ion chamber used for film calibration.

- A second level regression analysis has been performed to investigate the relation between MSD and CK and KAP respectively.
Results

- CALIBRATION CURVE
  Third order polynomial fit ($p<0.001$)

![Graph showing a third order polynomial fit](image)
The overall uncertainty associated with MSD measurement was estimated to be around 16%

It takes into account:

- Uncertainty on chamber reading
- Film dose response with (Blair et al., 2009):
  - Energy
  - Postexposure growth
  - Polarisation effect
  - Uniformity
- Scanner characteristic
  - Uniformity
  - Reproducibility
Aneurysm embolisation
Results

Chemoembolisation

p < 0.001

No. | MSD (mGy) | Range (mGy)
---|------------|------------
38 | 1343.8 ± 915.7 | 342.4 ÷ 4135.5
Results

Aneurism Embolisation

Chemoembolisation
CK appears to be a better dose indicator than KAP for the type of procedure analysed.

The relationship established between CK and MSD could be used to derive trigger levels. It doesn’t represent the general relationship between CK and MSD because is strictly dependant on:

- Procedure
- Physician
- Calibration and reading of films
- KAP meter calibration
In our centre, the trend line results in:

5.2 Gy for aneurism embolisation
2.6 Gy for chemoembolisation

for 3 Gy MSD levels.

The overall uncertainty associated to the predicted trigger level has been estimated with a second level regression taking into account both the uncertainties on MSD measure and on CK measure and the power of correlation. It was is about 27% for chemoembolisation and 30% for aneurysm embolisation.
As suggested by ICRP in the publication No. 85, a follow-up for patients whose estimated peak skin dose was 3 Gy or greater has been implemented as a routine practice for aneurysm embolisations and chemoembolisations.
CK is a good on-line dose indicator for skin dose, in particular for chemoembolisation procedure.

The relationship between CK and MSD could be used to establish trigger levels to alert the physician for high skin dose procedures.

CK trigger level is not a dose constraints or dose limit, but it’s an useful instrument for the identification of unusually high levels of radiation that require investigation if substantially exceeded.

Trigger levels are centre- and procedure-specific.
THANK YOU