# Uniformisation of the anode heel effect and image quality

**Poster No.:** B-1021  
**Congress:** ECR 2015  
**Type:** Scientific Paper  
**Authors:** A. F. Abrantes, J. Aleixo, L. P. V. Ribeiro, S. Rodrigues, P. Sousa, J. Pinheiro, R. P. P. A. Almeida, O. Lesyuk; Faro/PT  
**Keywords:** Radioprotection / Radiation dose, Professional issues, Radiation physics, Digital radiography, Conventional radiography, Radiation safety, Diagnostic procedure, Experimental investigations, Occupational / Environmental hazards, Patterns of Care, Quality assurance  
**DOI:** 10.1594/ecr2015/B-1021

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Purpose

This paper aims to promote health and improve radiological protection, handling and controlling the anode heel effect for more positive results of image quality and doses delivered to patients.

The patient exposure to ionizing radiation is not uniform, with the anatomical area positioned on the side of the cathode receiving higher radiation intensity in relation to the anatomical region situated on the anode side. This event is called anode heel effect. This inhomogeneity of the radiation beam may not be positive in the image quality, making it more hyper or hypo exposed in certain areas. On the other hand, placing the thicker region of the anatomical area in the cathode side we can optimize the anode heel effect and use it to our advantage.

This research aims to improve and add a few variables to a previous study entitled "Attenuation of the Anode Heel Effect with Aluminum Filter" made by Dores et all (2012)\(^1\), among which the use of a phantom to better rebuild a patient undergoing such examination, and give greater importance to the quality of image produced with aluminum filter.

Thus, our purpose was to study the anode heel effect behaviour with and without aluminium filters and their influence in image quality.

Methods and materials

This study was conducted in a public radiology department in a regional Hospital. The sample was composed by the number of images made with anthropomorphic phantom (n=30) and with volunteers (n=8). The total number of queries made to health professional was 75, and the number of exposures made over the entire study was 174. The instruments used were: General radiology equipment, Raysafe base unit with detector Raysafe Xi R / F; aluminum filters; anthropomorphic phantom AR10A; electrometer, flat ionization chamber; Pehamed Digrad phantom; Questionnaire assessment of image quality;

Aluminum filters
Two aluminum filters were used (filter 1 and filter 2), both to standardize the anode heel effect with wedge-shaped.

The filter 1 has a wedge-shaped square, 169 mm long and 169 wide, 3.6 mm thick on the cathode side and 1 mm thickness on the anode side.

The filter 2 also has an identical shape to filter 1, 169 mm long and 169 mm wide, 2.6 mm thick on the cathode side and 1 mm thickness on the anode side.

**Questionnaires for assessing image quality**

The criteria used for this review were defined based on anatomical structures in the region under study and based on anode heel effect.

This questionnaire was first directed to evaluate images produced using a phantom, having a total of five pages and twenty-four questions, three assessment points for each type of examination.

It was later adapted to new radiograms produced from volunteers that were exposed to ionizing radiation, having a total of four pages, twenty questions, three assessment points for each type of examination and a final choice for the best image for diagnostic purposes.

**Measuring the difference in intensity along the cathode-anode axis.**

The anode heel effect was measured using the Raysafe XI detector and a millimeter scale for accurate measurements.

The detector was placed with a spacing of 1 cm between each measurement, these being recorded only in the longitudinal axis (cathode-anode), moving the detector in a total of 20 cm for the cathode side and 20 cm for the anode side, from the center of the field of exposure (point 0). The procedure was then repeated with the filter 1 and filter 2.

**Percentage reduction measurement of the entrance surface dose of the phantom**

In order to assess the radiation levels in the air at the entrance of the phantom with and without filters, we proceeded to some exposures with the automatic exposure control and the standard parameters of this institution for each type of exam. Thus, producing three images for each anatomic region of the phantom, one unfiltered, one with the filter 1 and
another one with the filter 2. In total were made 6 exposures by anatomic region, one for each picture, and another 3 for measuring exposure in the air at the entrance of the phantom, using an electrometer with a flat ionization chamber coupled.

The verification of dose values received by the phantom are posted on ESD or air Kerma, to be measured and accurate, not as the absorbed dose and effective dose values that are calculated. The diagnostic reference levels (DRLs) are dose values, measured on entrance skin, and not calculated or estimated. The NRD are intended to prevent exposure of patients of radiation doses which do not contribute to the clinical imaging and diagnosis \(^{(2)}\).

**Volunteers**

There were also some radiograms made using a few individuals who voluntarily participated in this study. This was made in order to more accurately assess the quality of the image produced by the x-rays with aluminum filters.

According to the portuguese Law No. 222/2008, examinations to 'Members of the public' which among others include "(...) individuals who voluntarily participate in programs of medical and biomedical research," respecting the dose limits for this category are allowed \(^{(3)}\).

**Results**

**Results:**

**Assessment of the anode heel effect behavior, without and with each of the filters**

The parameters used were constant, a voltage of 85 kVp, focus - field distance of 100 cm, field length, 52.8 x 52.1 cm, an intensity of 1 mAs and focus thick, the center of the field is considered the "0" point.

In figure 1 we can observe the variation in exposure as a function of position in the anode-cathode axis in case of absence of filter, with the filter 1 and filter 2.
Concerning the behavior of anode heel effect, using both filters, we can observe a standardization, although it has not eliminated completely, but only partially.

**Evaluation of the ESD reduction in phantom, with and without aluminum filters**

With regard to the phantom doses the following results were obtained, listed in table 1, figures 2 and 3, referring to doses measured at the entrance to each phantom exam as well as the percentage reduction achieved with the use of filters.

**Table 1 - Values of ESD**

<table>
<thead>
<tr>
<th>Exam</th>
<th>ESD (µGy)</th>
<th>ESD reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No filter</td>
<td>Filter 1</td>
</tr>
<tr>
<td>Lumbar spine AP</td>
<td>67,6</td>
<td>36,9</td>
</tr>
</tbody>
</table>
It is possible to observe a reduction in the ESD values in all tests, using both filters over the exams performed without a filter. Taking as an example that the greatest reduction was in the exam of the pelvis of about 54% (55.1 µGy) with filter 1, and in the examination of the abdomen of 39% (41.7 µGy) with the filter 2.
Fig. 2: ESD values on the phantom surface for each type of radiological examinations performed with and without aluminum filters

References: Radiology Department, School of Health - University of Algarve - Faro/PT

Fig. 3: Percentage of ESD reduction in each test

References: Radiology Department, School of Health - University of Algarve - Faro/PT

The results prove that the use of these filters effectively reduces the entrance surface dose in the phantom on any exam made, the filter 1 produces a greater reduction than the filter 2 due to its greater thickness.

To further highlight this reduction, estimates were made of the percentage reduction in dose for each type of the volunteers examination, it was possible using the parameters used in each case through a few calculations, getting the results obtained in table 2 and figure 4.

Table 2- ESD values of each exam and dose percentage reduction using the filter 1

<table>
<thead>
<tr>
<th>Exam</th>
<th>ESD (mGy)</th>
<th>% ESD reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>No filter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volunteer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phantom</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>% ESD Reduction</td>
<td>% ESD Reduction</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Skull PA AP</td>
<td>0,82</td>
<td>0,44</td>
</tr>
<tr>
<td>Cervical spine AP</td>
<td>0,50</td>
<td>0,30</td>
</tr>
<tr>
<td>Abdomen AP</td>
<td>6,41</td>
<td>3,92</td>
</tr>
<tr>
<td>Pelvis AP</td>
<td>0,72</td>
<td>0,44</td>
</tr>
</tbody>
</table>

**Fig. 4:** Comparison of the ESD percentage reduction

**References:** Radiology Department, School of Health - University of Algarve - Faro/PT

**Evaluation of image quality**

First it was evaluated the results of the questionnaire of the phantom, which were not very positive, as were obtained opposite results to the desired results, results that do not support the use of any filters to a gain in image quality. A total of 30 questionnaires and 720 responses, of which 279 (39%) favor not using any filter, 158 (22%) using the filter 1, 86 (12%) the filter 2 and 197 (27%) reveal indifference between the use of filters or not.
Analyzed these results and previous concerning radiation doses, we focused on using only the filter 1, to produce new images with volunteers, in order to reanalyze the image quality of the exams, with the least amount of radiation possible.

Finished collecting all the questionnaires for the second evaluation of image quality, the results obtained were a total of 45 questionnaires and 900 responses (675 for the assessment of image quality and 225 for the diagnostic quality). It is confirmed then, the increase in image quality in radiographs produced using the aluminum filter with a set of 331 (49%) responses to favor the filter, 151 (22%) do not favor the use the filter, and 193 (29 %) to equate the two previous hypotheses.

As for the quality of diagnosis, also had positive results on the aluminum filter, with the majority of health professionals questioned preferring the images produced with filter for the realization of medical diagnosis, with a total of 156 responses in favor of images with filter and 69 in favor of images without the aluminum filter.

These results can be confirmed and visualized in figures 5 and 6.
Fig. 5: Results of the questionnaires of the evaluation of image quality on the radiograms made from volunteer individuals

**References:** Radiology Department, School of Health - University of Algarve - Faro/PT

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Fig. 6: Results of questionnaires for the assessment of the diagnostic quality of the radiographs

**References:** Radiology Department, School of Health - University of Algarve - Faro/PT

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Images for this section:
Fig. 6: Results of questionnaires for the assessment of the diagnostic quality of the radiographs
Conclusion

It has been proved that both aluminum filters standardize largely the anode heel effect. As the radiation dose was also proved that the use of both filters is beneficial in decreasing the dose received by the patients, although with the filter 1 better results have been obtained.

The results obtained with the first questionnaires regarding the x-rays produced images from the anthropomorphic phantom, weren’t very positive, that due to the composition and characteristics of the phantom. Although in the following review, with images produced from volunteers, we obtained satisfactory results, which demonstrate improved image quality with the use of aluminum filters.

In summary, it is concluded that the use of aluminum filters is advantageous in performing conventional radiological examinations.

Personal information

A.F. Abrantes. PhD, Member of the Research Center of Sociologic Studies of Lisbon’s Nova University (Cesnova), Director of the Radiology Department, Professor and Member of the Center for Health Studies (CES) of Health School - University of Algarve (ESSUALG), Faro, Portugal.

J. Aleixo. Radiology student at Health Shcool - University of Algarve (ESSUALG), Faro, Portugal.

L.P.V. Ribeiro. PhD, Member of the Research Center of Sports and Physical Activity (CIDAF) of Coimbra University, Professor and Member of the Center for Health Studies (CES) of Health Shcool - University of Algarve (ESSUALG), Faro, Portugal.

S. Rodrigues. MSc. Professor and Member of the Center for Health Studies (CES) of Health Shcool - University of Algarve (ESSUALG), Faro, Portugal.
P. Sousa. PhD, Professor at Health School - University of Algarve (ESSUALG), Faro, Portugal.

J. Pinheiro. PhD student. MSc. Professor and Member of the Center for Health Studies (CES) of Health School - University of Algarve (ESSUALG), Faro, Portugal.

R.P.P. Almeida. MSc student at University of Murcia. Professor and Member of the Center for Health Studies (CES) of Health School - University of Algarve (ESSUALG), Faro, Portugal.

O. Lesyuk. Professor and Member of the Center for Health Studies (CES) of Health School - University of Algarve (ESSUALG), Faro, Portugal.

Images for this section:

Fig. 7: Health School - University of Algarve
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