DOSE PROFILE STUDY IN HEAD CT SCANS USING A MALE ANTHROPOMORPHIC PHANTOM

Álvaro M. L. Gómez¹, Priscila do C. Santana² and Arnaldo P. Mourão³

¹ Departamento de Engenharia Nuclear – Escola de engenharia
Universidade Federal de Minas Gerais
Avenida Presidente Antônio Carlos
31270-901 Belo Horizonte, MG
amlgphys@gmail.com

² Departamento de Engenharia Nuclear – Escola de engenharia
Universidade Federal de Minas Gerais
Avenida Presidente Antônio Carlos
31270-901 Belo Horizonte, MG
pridili@gmail.com

³ Centro Federal de Educação Tecnológica de Minas Gerais - CEFET
Departamento de Engenharia Biomédica – Campus I
Avenida Amazonas 5253
30480-000 Belo Horizonte, MG
apratabhz@gmail.com.br

ABSTRACT

Computed tomography (CT) test is an efficient and non-invasive method to obtain data about internal structures of the human body. CT scans contribute with the highest absorbed doses in population due X-ray beam attenuation and it has raised concern in radiosensitive tissues. Techniques for the optimization of CT scanning protocols in diagnostic services have been developing with the objective of decreasing the absorbed dose in the patient, aiming image quality within acceptable parameters for diagnosis by noise control. Routine head scans were performed using GE CT scan of 64 channels programmed with automatic exposure control and voltages of 80, 100 and 120 kV attaching the noise index in approximately 0.5%, using the tool of smart mA. An anthropomorphic adult male phantom was used and radiographic film strips were placed to measure the absorbed dose deposited in areas such as the lens, thyroid and pituitary for study of dose deposited in these important areas containing high radiosensitive tissues. Different head scans were performed using optimized values of mA.s for the different voltages. The absorbed dose measured by the film strips were in the range of 0.58 and 44.36 mGy. The analysis of noise in the images is within the acceptable levels for diagnosis, and the optimized protocol happens with the voltage of 100 kV. The use of other voltage values can allow obtain better protocols for head scans.

1. INTRODUCTION

The demand for images of diagnosis by CT in recent years has grown considerably, with the consequence that increases the radiation dose rates in the population. For this reason they seek and implement strategies to reduce the dose deposited in patients [1-3].

Automatic exposure control was introduced in tests by TC in mid-1990 for procedures in nuclear medicine and radiation therapy [4], which consists of modifying the levels of current that feeds the x-ray tube as soon as scanning takes place in proportion to the density of tissues which attenuate the beam of X rays. This type of control is used most frequently in chest routines.
In sensitive organs to radiation scans are research topics by risks and high chances of developing serious illnesses such as for example the lens that may develop cataracts to have exposure greater than 2 Gy according to ICRP [5, 6].

The objective of this study is to determine the rates of Air Kerma in lens, pituitary and thyroid using levels of power optimized voltage levels of the tube of 80, 100 and 120 kV, and perform analysis of image quality.

2. MATERIALS AND METHODS

Experiments were used a TC scanner multislice making helical acquisitions in a male adult anthropomorphic phantom. To study the distribution of doses in lens, thyroid and pituitary gland, were used strips of radiochromic film.

2.1. CT scanner and phantom

The CT scanner General Electric Discovery with 64 channels of radiology service was used. Equipment is of type multislices that enable explorations in helical mode.

The male anthropomorphic phantom, model Alderson rando, was used for conducting head and neck examinations. This phantom is constituted by human skeleton coated with a material possessing physical and chemical characteristics similar to those of the soft tissues of the body. The head and chest are structured in 34 slices of 2.5 cm thick, from which the first 17 slices were used for this experiment. In the interior of the phantom there are openings that allow the location of dosimeters for the recording of radiation. Fig. 1 show the phantom positioned in the isocenter of the gantry of the TC scanner [7].

![Figure 1. Phantom positioned in the gantry isocenter.](image)

Preliminary scans were carried out using the automatic exposure control for each voltage value in order to determine the average current value and then it was used these constant current values in the acquisition protocols. Fig. 2 represents the scout of the joint head, neck and part of the chest such as delimitation of the scanning volume. In preliminary scans were not placed the strips for Air Kerma recording. The protocols used in the exploration of the central region of the phantom in helical mode, are presented in tab. 1.
In 2017, Belo Horizonte, MG, Brazil.

**Figure 2.** Phantom Scout without radiochromic film strips.

**Table 1.** Helical mode acquisition protocols

| Voltage (kV) | Charge (mA.s) | wide beam (m.m) | Pitch |
|-------------|---------------|-----------------|-------|
| 80          | 450           |                 |       |
| 100         | 300           | 40              | 0.984 |
| 120         | 200           |                 |       |

With current optimized values, the equipment was programmed for further explorations, were located the strips of films being placed on the surface of the eye (left and right), throat and inside of the dummy where lens, the thyroid and pituitary gland would be located. Fig. 3 presents the location of radiochromic films on the surface of the phantom. Strip making the record of the pituitary gland is located in the interior of the phantom.

**Figure 3.** Film strips placed on the surface of the phantom

**2.2. Gafchromic XR-QA2 Film.**

Air Kerma measurements were performed using strips of radiochromic film GAFCRHOMIC XR-QA2 with dimensions of 0.5 x 2.5 cm². The film show a proportional browning to the amount of energy deposited when they are exposed to ionizing radiation.
This radiochromic film was developed as a tool for quality control of beams of ionizing radiation and are not sensitive to visible with light, the response in the range of 0.1 to 20 cGy dose record and can be used for X-ray beams on a supply voltage of X-ray tube ranging from 20 kV and 200 kV [8].

The strips were tagged and identified for each of the protocol, each film strip was radiated only once. It was considered a time of 24 h for the treatment of films post-irradiation [9, 10]. The film strips were scanned on a Hewlett Packard Scanjet G4050 model scanner at a resolution of 300 ppi image color and processed using ImageJ software performing RBG color separation for darkening on scale of intensity values by selecting the red channel.

From the curves of calibration of the films obtained for each voltage level, and corrected by the width of the X-ray beam, were calculated values of Air Kerma deposited in each strip.

1.3. Analysis of the image quality

For the analysis and validation of the quality of the image, the image of the central slice of the head region was selected with the purpose of studying the interference of the secondary radiation that it generates. For this, a region of interest (ROI) was defined in an image of each protocol to be compared within the parameters of diagnostic image quality.

3. RESULTS AND DESCUSSIONS

Air Kerma values reported by strips of radiochromic film for lens (left and right), the pituitary gland and the thyroid respectively are shown in figs 4, 5 and 6.

![Figure 4. Air Kerma recorded on the lens.](image)

Air Kerma values recorded by the film strips show higher values for the right lens for the three protocols used, with differences of 1.3% to 80 kV, 3.8% to 100 kV and 6.6% for 120 kV. Taking as a reference the values of Air Kerma for 120 kV, since that is the voltage used in the routines of skull in the service of radio-diagnostic, 80 kV voltage right lens recorded an increase of 7.7% and 17.10% left. For the voltage of 100 kV decreases of 62.20% and
61.06% were recorded respectively. As the Protocol for the 80 kV voltage who deposited the highest values of Air Kerma in the lens.

![Figure 5. Values of Air Kerma in the pituitary gland.](image)

Film strips located on the inside of the phantom near the region where it is located the pituitary gland recorded for the Protocol using a 80 kV voltage a decrease in values of Air Kerma of 28.94% and 115.89% for 100 kV in relation to the values recorded for the routine with 120 kV of voltage. The Protocol, which recorded higher values of Air Kerma for this organ was which used 120 kV of voltage.

![Figure 6. Air Kerma recorded on the thyroid.](image)

Thyroid region shows significant decreases in the values of Air Kerma for protocols using voltages of 80 and 100 kV in relation to the Protocol of routine, to 80 kV voltage is recorded a difference of 39.84% and for the voltage of 100 kV 167.77%. Showing for this organ, the protocol used by 120 kV of voltage was that recorded higher values of Air Kerma.

Analysis of quality of the images was performed using the RadiAnt software to obtain mean values of intensity scale Hounsfield and its standard deviation to calculate the percentage of noise that has images for each protocol used in this study. Tab. 2, shows the percentages for each value of voltage noise index.

INAC 2017, Belo Horizonte, MG, Brazil.
### Table 2. Percentages of noise index

| Voltage (kV) | Noise (%) |
|-------------|-----------|
| 80          | 0.716     |
| 100         | 0.495     |
| 120         | 0.366     |

The ROI selected to perform the analysis for three levels of tension are approximately in the central region of the phantom #3 slice. Using current values optimized for each of the protocols, there is that images have a noise close to 0.5% rate.

### 3. CONCLUSIONS

The values of Air Kerma in lens do not exceed levels recommended by the ICRP for a likely development of cataracts. However, the Protocol obtained higher concentrations of Air Kerma was 120 kV x-ray tube voltages.

The Protocol that used 80 kV of voltage, same as the value of charge (mA.s) was greatest in comparison to the three protocols, who recorded higher values of Air Kerma in the lens.

In the region marked for the thyroid, the Protocol which recorded lower rates of Air Kerma was that used 100 kV of voltage. It was therefore the optimized protocol which recorded the lowest values of Air Kerma in three regions at the same time.

The values of Air Kerma for the pituitary gland are significantly lower probably by X-ray filtration in the skull. The experiments for this organ will be performed again.

Found noise levels, are within the parameters established for images of diagnostics, to be about 0.5% indicates that three protocols generate images with similar qualities.

### ACKNOWLEDGMENTS

The authors are thankful to CAPES, FAPEMIG for their support in developing this study & CDTN/CNEN for the loan of the phantom.

### REFERENCES

1. Romano, R. F. T., Salvadori, P. S., Torres, L. R., Bretas, E. A. S., Bekhor, D., Caldana R. P., D'Ippolito, G. Readjustment of abdominal computed tomography protocols in a university hospital: impact on radiation dose. Radiologia brasileira, 48(5), 292-297. (2015).
2. Santana, P. D. C., Mourão, A. P., Oliveira, P. M. C. D., Bernardes, M. Mamede F. D., Silva, T. A. D. Dosimetry of patients submitted to cerebral PET/CT for the diagnosis of mild cognitive impairment. Radiologia brasileira, 47(6), 350-354. (2014).
3. Mourão, A. P., Silva, T. A., Alonso, T. C. O uso de protetor de olhos para redução da dose em varredura de TC de crânio. Sociedade Brasileira de Proteção Radiológica. (2013)
4. Gareth, R. I., Alexis, C. M., Elizabeth J. C. A routine quality assurance test for CT automatic exposure control systems. JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS. 17(4), 291-306 (2015)

5. Philomina, A., Arti, R. K., Shramika H. J., S. D. Sharma, Rajesh, K., D. Datta. Estimation of eye lens dose during brain scans using gafchromic xr-qa2 film in various multidetector CT scanner. Radiation Protection Dosimetry. 132, -6 (2016)

6. International Commission on Radiological Protection. ICRP Statement on tissue reactions/early and late effects of radiation in normal tissues and organs—threshold doses for tissue reactions in a radiation protection context. ICRP Publication 118. Ann. ICRP 41 (1/2) (2012).

7. Almeida, T. V. R., Cordova, A. L., Piedade, P. A., da Silva, C. M., Scheidegger, D. S, Et al. Analysis of translational errors in frame-based and frameless cranial radiosurgery using an anthropomorphic phantom. Colégio Brasileiro de Radiologia e Diagnóstico por Imagem. ;49(2):98–10398 (2016)

8. Ashland Inc. Gafchromic™ XR film. Gafchromic™ Radiology Films, [internet] Access Dec 10th 2015. <http://www.ashland.com/products/gafchromic-radiology-films>.

9. Tawfik, G., Yunfeng, C., James, G., Wenzhou, C., Yan, Y., Ying, X. Characteristics of Gafchromic XRQA2 films for kV image dose measurement. Med. Phys. 39 (2). 842-850. (2012)

10. Brady, S., Yoshizumi, T., Toncheva, G., Frush, D. Implementation of radiochromic film dosimetry protocol for volumetric dose assessments to various organs during diagnostic CT procedures. Med. Phys. 37(9), 4782–4792 (2010).