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# *Air kerma area product in cone beam computed tomography*

## Produto kerma área no ar em tomografia computadorizada de feixe cônico

Marcus Vinicius Linhares de Oliveira[1*], Wilson Otto Gomes Batista[2], Maria Rosângela Soares[3], Paulo Sergio Flores Campos[4]

*[1*]Professor do Curso de Tecnologia em Radiologia. IFBA. Doutorando do Programa de Pós-Graduação Processos Interativos dos Órgãos e Sistemas. UFBA; [2]Doutor em Física. UFS. Professor Adjunto. IFBA; [3]Doutoranda do Programa de Pós-Graduação de Física. UFS. Professora Substituta. IFBA; [4]Professor Titular de Radiologia da Faculdade de Odontologia e do Programa de Pós-Graduação Processos Interativos dos Órgãos e Sistemas. UFBA*

**Abstract**
***Objective:*** *to evaluate the influence of FOV in air kerma-area product (KAP) and the constancy of exposure parameters on cone beam computed tomography equipments.* ***Methodology****: Two cone beam CT (GENDEX CBX 500 and i-CAT Classic) were used and seven exposures with the following FOVs were performed: (A) 14cm x 8,5cm, (B) 14cm x 6cm, (C) 8,5cm x 8.5cm e (D) 8,5cm x 6cm, for CBX 500; and (E) 14cm x 6.cm, (F) 14cm x 8cm e (G) 14cm x 13cm, for the i-CAT. The technical exposure factors (kV, mA, mAs and voxel), remained constant. The dosimetric evaluation was performed with air KAP meter manufactured by IBA dosimetry, model kerma X plus TinO, positioned at the output of the X-ray beam. To evaluate the constancy of the exposure parameters a semiconductor (Radcal, Rapidose) fixed in front of the tomography image receptor was used.* ***Result:*** *The KAP values obtained ranged between 360.1 mGy.cm² and 1031.2 mGy.cm². The FOV height had a substantial influence on the radiation dose. Repeatability and accuracy of the tube voltage varied less than 10%.* ***Conclusion****: The radiation dose is directly related to the height and inversely related with the FOV diameter; even within the recommended limits, the percentage variation of repeatability and accuracy of kV, for the tomography equipments tested, points to the regular equipment calibration, in order to reduce radiation dose to the patient to a minimum.*
***Keywords****: Cone beam computed tomography. Radiation. Dosimetry.*

***Resumo***
**Objetivo:** avaliar a influência do FOV no produto kerma-área ($P_{KA}$) no ar e a constância dos parâmetros de exposição em equipamentos de tomografia computadorizada feixe cônico. **Metodologia:** Foram utilizados dois tomógrafos de feixe cônico (GENDEX CBX 500 e i-CAT Classic) e foram realizadas sete exposições com os seguintes FOVs: (A) 14cm x 8,5cm, (B) 14cm x 6cm, (C) 8,5cm x 8.5cm e (D) 8,5cm x 6cm, para o CBX 500; e (E) 14cm x 6.cm, (F) 14cm x 8cm e (G) 14cm x 13cm, para o i-CAT. Os fatores técnicos de exposição (kV, mA, mAs e voxel), permaneceram constantes. A avaliação dosimétrica foi realizada com um medidor do produto kerma-área no ar fabricado pela *IBA dosimetry,* modelo *kerma X plus TinO*, posicionado na saída do feixe de raios X. Para a avaliação da constância dos parâmetros de exposição foi utilizado um multimedidor do tipo semicondutor, *Radcal,* modelo *Rapidose* fixado na entrada do receptor de imagem do tomógrafo*.* **Resultados:** Os valores de $P_{KA}$ obtidos variaram entre 360,1 mGy.cm² e 1.031,2 mGy.cm². A altura do FOV teve influência substantiva na dose de radiação. A repetibilidade e exatidão da tensão do tubo variaram abaixo dos 10%. **Conclusões**: a dose de radiação tem relação direta com a altura e inversa com o diâmetro do FOV; embora dentro das margens recomendadas, a variação dos percentuais de repetibilidade e exatidão do kV, para os tomógrafos testados, aponta para a calibragem periódica dos equipamentos, com vistas a reduzir ao mínimo necessário a dose de radiação para o paciente
**Palavras-Chave**: Tomografia Computadorizada de Feixe Cônico. Radiação. Dosimetria.

### *INTRODUÇÃO*

*The air kerma-area product (KAP) is a quantity often used in complex procedures that are sometimes not classified as conventional radiology. The KAP is defined as the air kerma product by the radiation field area at the detector level.[1]*

*The applicability and advantage of using the KAP for exposure evaluation in intraoral and panoramic techniques in dentistry have been demonstrated[1], and the use of this quantity in the dosimetry of cone beam computed tomography equipments is considered easy to implement and it is useful for dose evaluation, establishment of reference levels and comparison with other imaging techniques in dentistry. For these reasons, when KAP meters are positioned at the beam output, it is possible to obtain air kerma-area product values to all exposure possibilities and CBCT (Cone Beam Computed Tomography) equipment configurations. However, comparison studies of radiation doses between dental imaging techniques and several CBCT technologies are still in small number in the literature[2,3,4].*

*Another important point is the need for quality control tests, although they haven't been well established for CBCT yet. The SENDENTEXC[5] project and the British Health Protection Agency[6] (HPA) have started the first steps to*

Correspondente/ ***Corresponding***: *****Marcus Vinicius Linhares de Oliveira. Instituto de Ciências da Saúde. Universidade Federal da Bahia. Endereço: Av. Reitor Miguel Calmon, s/n, Vale do Canela, Salvador, Bahia, Brasil, CEP: 40.110-902. Tel:(71)3283-8959. E-mail: marcusradiology@gmail.com

*establish quality control tests and reference levels in cone beam computed tomography[7]. The latter suggests the KAP as a useful quantity in the evaluation of procedures involving CBCT.*

*Thus, this study aims to assess the FOV's influence on KAP and the constancy of exposure parameters in CBCT.*

## *MATERIALS E METHODS*

*Two CBCTs were used: GENDEX CBX 500 (Gendex Dental Systems, Pennsylvania, USA) and i-CAT Classic (Imaging Sciences International, Hatfield, Pennsylvania, USA). Four different exposure protocols were evaluated at GENDEX, varying the available dimensions of FOVs (14 x 8,5cm, 14 x 6cm, 8,5 x 8,5cm e 8,5 x 6cm) for tomographic acquisitions of the maxillofacial region. For the i-CAT, three FOVs were evaluated varying only the height (14 x 6 cm, 8 cm and 14 x 14 x 13cm) (Table 1). In these equipments, the applied voltage is established by the manufacturer and set at 120 kV. Furthermore, voxel dimensions, exposure time and the current x time product (mAs) were kept the same for all exposures for each manufacturer.*

**Table 1** – *Protocols for each tomography analyzed*

| | Protocol | FOV (cm) | kV nominal | Voxel (mm) | mAs | Exposure time (s) |
|---|---|---|---|---|---|---|
| GENDEX CBX 500 | A | 14 x 8,5 | 120 | 0.2 | 30 | 23 |
| | B | 14 x 6 | 120 | 0.2 | 30 | 23 |
| | C | 8,5 x 8,5 | 120 | 0.2 | 30 | 23 |
| | D | 8,5 x 6 | 120 | 0.2 | 30 | 23 |
| i-CAT Classic | E | 14 x 6 | 120 | 0.25 | 36.12 | 40 |
| | F | 14 x 8 | 120 | 0.25 | 36.12 | 40 |
| | G | 14 x 13 | 120 | 0.25 | 36.12 | 40 |

*The dosimetric evaluation was performed using an air kerma-area product meter manufactured by IBA dosimetry (GmbH, Schuarzenbruck, Germany), model KermaX® plus TinO, positioned at X-ray beam output, which informs the dose and kerma-area product simultaneously and instantly. To evaluate the constancy of exposure parameters a semiconductor multimeter manufactured by Radcal (Corp., Monrovia, CA, USA), model rapidose and positioned on the tomography image receptor surface was used. Both measuring instruments were previously calibrated.*

## *RESULTS*

*The equipment's performance evaluation is shown in Table 2, which indicates, voltage values, time, number of pulses, the constancy of exposure through voltage repeatability and voltage accuracy applied to the X-ray tube. The KAP values obtained for the selected protocols and for the two manufacturers can also be seen.*

**Table 2** – *Equipments Performance*

| | Protocol | kV measured | Number of pulses | Time measured | Pulse duration | KAP (mGy. cm²) | Repeatability kV | Accuracy kV |
|---|---|---|---|---|---|---|---|---|
| GENDEX CBX 500 | A | 122,4 | 620 | 22,93 | 15,3 | 478,5 | 7,42% | 2% |
| | B | 121,8 | 620 | 22,93 | 15,2 | 360,1 | | 1,50% |
| | C | 118,4 | 620 | 22,93 | 15,2 | 507,8 | | 1,33% |
| | D | 127,5 | 620 | 22,93 | 15,2 | 385 | | 6,25% |
| i-CAT Classic | E | 125,1 | 621 | 41,34 | 17,4 | 571,4 | 1,03 % | 4,25% |
| | F | 126,2 | 620 | 41,33 | 17,3 | 718,2 | | 5,16% |
| | G | 126,4 | 621 | 41,34 | 17,3 | 1.031,2 | | 5,33% |

## DISCUSSION

*The British Health Protection Agency[8] (HPA, 2010) suggests regular quality control tests and establishes tolerance limits. CBCT equipments evaluated in this study showed a repeatability deviation and voltage accuracy below 10%, showing stability in its exposures, following the HPA recommendations which states that the difference between the nominal and the measured voltage may not exceed 10%. On the other hand, the wide percentage variation of the deviation between the nominal and the measured voltage shows the need for periodic evaluation of the equipment regarding exposure factors stability. This same agency also suggests that the voltage should not be smaller than 60 kV. In this experiment, voltages smaller than 60 kV were not used.*

*When comparing the same diameter and different height protocols of Gendex CBX 500 equipment, the KAP showed a dependence on the FOV's height. Then, for the 8.5 cm x 8.5 cm FOV protocol, the KAP was 507.8 mGy.cm ² and for the 8.5 cm x 6cm FOV protocol the KAP was 385.00 mGy.cm². This same behavior was observed for 14cm x 8.5 cm (478.5 mGy.cm ²) and 14cm x 6cm (360.1 mGy.cm ²) FOV protocols.*

*However, an opposite relation was observed when assessing the influence of larger or smaller diameters (14cm x 6cm x 8,5 cm and 6 cm and 14cm x 8.5 cm and 8.5 cm x 8.5 cm), being the KAP 360.1 mGy.cm², 385 mGy.cm², 478.5 mGy.cm ² and 507.8 mGy.cm², respectively. This is because the Gendex CBX 500 tomography uses a geometric maneuver characterized by the collimator lateral-side displacement, which allows an enlargement of the FOV using small detectors and reducing equipment costs[9].*

*The relation between KAP and the FOV's size was also verified by Han et al. (2012)[10], who tested equipments with large, medium and small FOVs, by Xu et al. (2012)[11] who suggested that KAP may vary depending on the equipment's brand, and by Andrade et al. (2013)[12], which also tested the i-CAT tomography.*

*Besides the appropriate FOV, optimized exposure parameters lead to reduced patient dose exposure. Vassileva and Stoyanov (2012)[13] evaluated the doses in adults and children with specific protocols and recorded 185 mGy.cm² and 54 mGy.cm², respectively. Thus, the need of appropriate protocols to each patient, as well as the stabilization of exposure parameters, ensured by a periodic equipment evaluation becomes evident.*

*The KAP enables, in an easy and practical way, the evaluation and comparison of exposure protocols However, it is limited to estimate the effective dose for the patient, since it requires a conversion factor, which varies according to the anatomical region studied. On the other hand, the KAP can be measured in different CBCT equipments, regardless the beam geometry variation of the equipment and also the distance between the X-ray source and the detector[3]. Furthermore, the KAP is an efficient way to monitor the repeatability and accuracy of radiation dose during image acquisition.*

## CONCLUSION

*The radiation dose is directly related to the height and inversely related to the FOV's diameter. Although the repeatability and accuracy percentage variation of kV for the tested equipments was kept within acceptable margins by international organizations of health protection, periodic equipment calibration is essential in order to reduce radiation dose to the patient to a minimum necessary.*


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