Paediatric organ and effective doses in dental cone beam computed tomography

Theodorakou C[1,2], Horner K[2], Howard K[1], Walker A[1], The SEDENTEXCT Project Consortium[3]

[1]North Western Medical Physics, The Christie NHS Foundation Trust, Manchester, UK; [2]School of Dentistry, University of Manchester, UK; [3]Listing of partners on www.sedentexct.eu

Introduction

Cone Beam Computed Tomography (CBCT) imaging is accomplished by using a rotating gantry to which an x-ray source and an imaging detector are attached. A pyramidal or cone-shaped x-ray beam is used instead of the conventional CT fan beam. The x-ray source and the detector perform a full or half rotation around a point fixed within the centre of region of interest. During the rotation multiple planar projections of the field of view are acquired and reconstructed.

Three dimensional imaging

CBCT offers three-dimensional images with high level of diagnostic accuracy. Dental CBCT has been associated with higher radiation risk compared to conventional dental imaging and lower radiation risk compared to multi-slice CT (MSCT). Several studies have reported on radiation doses for dental CBCT examinations [1-2] but none has reported on paediatric organ and effective doses.

Dental CBCT unit

Accuitomo 170, Morita

The majority of the studies have used thermoluminescent dosimeters (TLDs) in tissue-equivalent anthropomorphic phantoms. For most of the studies the number of TLDs used for measuring the average organ doses was rather limited. For organs such as the brain or for small organs such as the salivary glands which are positioned along several phantom slices, a large number of TLDs should be placed to ensure that the mean absorbed dose is accurately measured.

Aim

The aim of this study was to estimate average absorbed organ and effective doses to two paediatric anthropomorphic phantoms for a range of CBCT units and imaging protocols using a large number of TLDs.

Methods and Materials

Two tissue-equivalent anthropomorphic phantoms (ATOM Model 702-C and ATOM Model 706-C, Computerized Imaging Systems, Inc, USA) were used in the measurement of radiation absorbed doses. Models 702-C and 706-C simulate an adult female and a 10 year old child respectively. An adult female phantom was used to simulate an adolescent patient as there are no commercially available teenager tissue equivalent anthropomorphic phantoms.

Adolescent/Female ATOM phantom

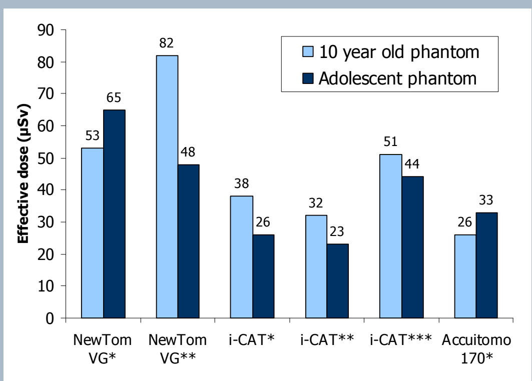
10 year old ATOM phantom

The dose measurements were performed using thermoluminescent dosimeters chips TLD-100H, LiF:Mg,Cu,P (Harshaw Thermo Fisher Scientific Inc, USA). The TLDs were calibrated free in air against an ionisation chamber with calibration traceable to national standards. A flat energy TLD response was observed from 60 kV to 100 kV. Chips with an uncertainty of less than 10% were used.

Absorbed doses were measured in the brain, salivary glands, thyroid gland, red bone marrow, bone surface, skin and lungs as these are the most radiosensitive organs in the head, neck and shoulders according to ICRP 103 [3]. The absorbed doses to bone surface, oesophagus, lungs and oral mucosa were too small to be reported. The bone surface dose was taken into account for the effective dose calculations.

On average, 120 TLDs were uniformly positioned in the small phantom and 160 TLDs in the adolescent phantom. Correction factors were applied to the skin, bone surface and red bone marrow doses for each phantom slice to account for the fraction of the total mass of the specified organ in the phantom [4]. The effective doses were calculated using the ICRP 103 tissue equivalent factors. Measurements were made on three dental CBCTs for a range of imaging protocols.

Results and Discussion



NewTom VG*=Maxillofacial, NewTomVG**=Dento-alveolar, i-CAT*=16Øx6 Mandible, i-CAT*=16Øx6 Maxilla, i-CAT***=16Øx10 Dento-alveolar, Accuitomo 170*= 4Øx4 molar

Figure 1. Effective doses for the two phantoms

Figure 1 shows that the effective doses range from 26 µSv to 82 µSv for the 10 year old phantom and from 23 µSv to 65 µSv for the adolescent phantom. The maxilla imaging protocol of the Next Generation i-CAT unit and the 3D Accuitomo gave the lowest effective doses for the two phantoms. The highest effective doses for both phantoms were observed for the NewTom VG unit because of its fixed large field of view. The effective doses for the 10 year old phantom are higher than these for the teenager phantom for most of the CBCT units and imaging protocols.

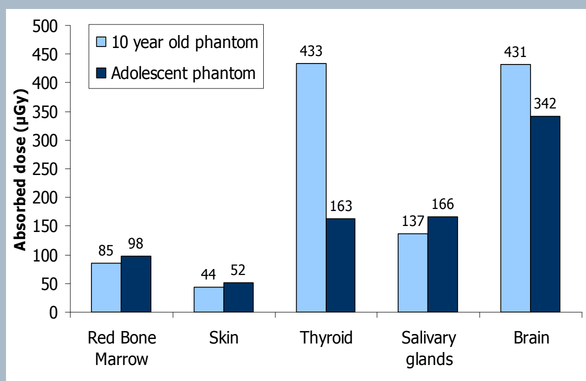


Figure 2. Absorbed organ doses for the two phantoms

This is mainly due to the positioning of the thyroid, salivary glands and brain with respect to the primary beam. In addition, the thyroid and the salivary glands are the main contributors to the effective dose for the 10 year old phantom but for the adolescent phantom, the salivary glands contribute the most. Figure 2 shows that the thyroid dose for the 10 year old phantom is four times higher than the one for the teenager phantom and the salivary glands are almost equal between the two phantoms.

Figure 2 shows that the red bone marrow and skin have received lower doses than the other three organs. Although the contribution of the brain to the effective dose was lower than the thyroid and the salivary glands, the doses to the brain are significantly higher or equal to the thyroid and salivary glands doses.

The average effective dose was 43 µSv which is one-twentieth of published MSCT radiation doses [5] but four times higher than the average panoramic dose (10µSv) [6]. The % radiation-induced fatal cancer risk for a 10 year old child undergoing a dental CBCT exam is 0.0005% and for a teenager is 0.0004%.

Conclusions

This study has estimated the organ and effective doses to two paediatric tissue-equivalent anthropomorphic phantoms for three dental CBCT units. It was found that the radiation doses to patients are significantly higher than the traditional x-ray imaging. As children are more radiation sensitive than adults it is essential that the dental CBCT use is fully justified over conventional dental imaging techniques.

References

1. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol 2006; 35: 219-26.
2. Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. Br J Radiol 2009; 82: 35-40
3. International Commission on Radiological Protection ICRP Publica-tion 103 (2007) Recommendations of the International Commission on Radiological Protection. Annals of the ICRP. Elsevier Ltd.
4.Huda W and Sandison (1984) Estimation of mean organ doses in diagnostic radiology from Rando phantom measurements. Helth Physics 47:463-467
5. Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, Marchal G, Sanderink G, Jacobs R. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol. 2008; Jul 16.
6. NRPB-W4, Radiation Exposure of the UK Population from Medical and Dental X-ray Examinations, National Radiological Protection Board, 2002

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Contact: Dr Christie Theodorakou, christie.theodorakou@physics.cr.man.ac.uk