October 10, 2011

J.G. Blickman, Editor in chief
European Journal of Radiology

Dear Dr. Blickman,

The following is submitted as a letter to the editor:

I wish to congratulate Dr. Pauwels and his co-authors on their manuscript, “Effective dose range for dental cone beam computed tomography scanners,” which is at this time in-press in this journal. The authors have undertaken an impressive survey of the dosimetry of many of the currently available CBCT models for dentistry. Because this will be read by many who are interested in a better understanding of the risk of CBCT examinations, it is an important contribution to the literature. To place this work in the context of previously published studies it is important to understand differences in the methods that were used and the potential impact of the authors’ approach on the internal validity of the data and its extensibility to previous and future studies.

A large number of dosimeters (147 and 152) were employed for each of the 2 phantoms used in this study. The rationale for this was to insure an even spread over each of the radiosensitive organs in the head and neck area that are utilized in the 2007 ICRP calculation of effective dose. The intent was to produce dose estimates that were as accurate as possible. While this is a laudable goal, it is important to note that sampling strategy is just one of a number of factors that are important in measuring dose. Just as important are the actual location and extent of the radiosensitive organs that are being measured and the location of the field of view when exposing the phantom. Within patient populations, the location and size of tissues of interest can vary significantly. Positioning of patients for imaging is also subject to considerable variation depending on the operator and the positioning aids that are available with different units. While the current study attempted to position phantoms as closely as possible to a typical patient, use of different “local radiographic staff” for the different units may have resulted in inconsistent phantom positioning and important differences in dose measurements in some units. This is in fact suggested by an examination of the data for large FOV units. With large FOVs there is a more uniform distribution x-ray photons within the maxillofacial region than with smaller, regionally localized FOVs. When the same phantom is positioned at the same location in similarly sized large FOVs attenuation characteristics are similar regardless of the amount of radiation exposure. Because of this we can expect that the ratios of dose in different organs, for example, salivary glands and thyroid, to be similar from unit to unit, even when overall exposures may be higher or lower. For the most part that is true of the current study. Examination of the equivalent doses for these organs in the following table is revealing. A mean Salivary Gland/Thyroid dose ratio of 4.5 is seen for the 8 units that were measured in this study.
While ratios for 7 of the 8 units tested are within a standard deviation of that mean, the ratio for the NewTom VGi is 2.3 standard deviations below the mean. The thyroid dose (2045 µSv) is about 3 times the average thyroid dose for all machines. It is also more than 4 times greater than the dose found in my evaluation of the unit seen in the first column of data. This data is based on imaging geometry seen in the figure below. A likely reason for the difference in the estimate of dose between the two studies is a more caudal position of the FOV in the current study. It is also likely that the FOV is lower with the VGi than for the other units in the current study. Lower positioning of the FOV may result in direct exposure of the thyroid gland. Because this gland has a weighting factor of 0.04, it makes a significant contribution to the total effective dose calculation. Indeed, dividing the reported salivary gland dose by the mean salivary gland/thyroid ratio, we might estimate an expected thyroid dose of 640 µGy. The difference in expected and reported doses accounts for approximately 56 µSv of excess effective dose that is due to direct exposure of the thyroid in this case. This excess represents 29% of the reported total effective dose. While higher patient positioning in the FOV can occur during imaging, this is not an intrinsic property of the VGi unit which allows independent control of chin rest position and FOV location when positioning patients. The issue of susceptibility of measurement of thyroid dose to even subtle differences of phantom positioning has been discussed previously where it was shown that a rotation of even 10º of a RANDO phantom position can result in a 92% difference in thyroid dose for a large FOV. Because the current study seeks to report representative doses for the different units under comparison, it seems unfair to penalize an individual unit with a significantly different FOV location than other units.

In the current study a recalculation of organ doses using a subset of 24 dosimeters positioned similarly to protocols followed in our studies, demonstrated deviations in organ dose estimations by 18–28% with differences up to 80% in comparison to the full complement of dosimeters. The authors suggest that this finding of variability indicates that a large number of TLDs is needed for accurate effective dose estimation. However, the authors do not provide specific results of calculations of either equivalent doses or effective dose for the 24-dosimeter subset evaluations, so it is not possible to explore potential reasons for the observed variation. From the discussion of the above data, it is quite possible that some or even a large proportion of the variation is related to phantom position within the FOV rather than limited numbers of
dosimeters located in organs and tissues of interest. While use of additional dosimeters may increase the precision of calculation of organ dose, it does not guarantee an increase in the accuracy of calculation of effective dose.

Having made this argument I would like to suggest that future research in this field should be focused on the development of phantoms that can provide reasonable indicators of effective dose with fewer, rather than more dosimeters. Given the diversity of human craniofacial anatomy and the uncertainty of risk estimation of low dose exposures, the value of increased accuracy for a single anatomic representative must be considered in the context of the cost of time and resources needed to obtain a marginal increase in accuracy. Variation of around 25% between large and small numbers of dosimeters may be quite acceptable as long as reproducibility of phantom positioning within and across units is high. A simplified phantom should be easily manufactured and affordable allowing any researcher or clinician to readily quantitate doses associated with different imaging alternatives. Furthermore, as Dr. Pauwels and his co-authors suggest, while comparison of doses following “standard” exposure protocols is useful, dosimetry is more valuable when acquired in the context of an indication of image quality. Low dose imaging of insufficient diagnostic quality for the intended diagnostic task must be avoided just as excessively high dose imaging should be avoided. Calculation of effective dose is a best estimate of risk; however, risk estimation must also be applied over a ‘level playing field’ if it is to be of value in clinical decision-making.

Figure: location of RANDO phantom for dosimetry of NewTom VGi in Ludlow study. Position of FOV includes minimum amount of anatomy below soft tissue contour of chin. Location of thyroid dosimeters is below the lowest directly exposed level of the phantom.

1 Pauwels R, Beinsberger J, Collaert B, Theodorakou C, Rogers J, Walker A, Cockmartin L,

Ludlow JB. Effective doses of NewTom VG/i variable volume dental CBCT unit. Annual meeting of the American Association of Dental Research (AADR), Tampa, FL, Mar. 21-24 2012, In review
