PhD Thesis Title: 'Location of Radiosensitive Organs, Measurement of Absorbed Dose to Radiosensitive Organs and use of Bismuth Shields in Paediatric Anthropomorphic Phantoms'

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ABSTRACT:

The aim of this study was to investigate: (1) the location of radiosensitive organs in the interior of four pediatric anthropomorphic phantoms for dosimetric purposes, and (2) the effect of bismuth shielding on thyroid dose and image quality in paediatric neck multidetector computed tomography (MDCT) performed with fixed tube current (FTC), and automatic exposure control (AEC). For the study on the location of radiosensitive organs four pediatric anthropomorphic phantoms representing the average individual as a newborn, 1-year-old, 5-year-old, and 10-year-old child were used. They underwent head, thorax, and abdomen computed tomography (CT) scans. CT and magnetic resonance imaging scans of all children aged 0–16 years performed during a 5-year-period were reviewed. 503 children were found to be eligible for normal anatomy. Anterior-posterior, and lateral dimensions of twelve of the above children closely matched that of the phantoms' head, thoracic, and abdominal region in each one of the four phantoms. The mid-sagittal, and mid–coronal planes were drawn on selected matching axial images of patients, and phantoms. Multiple points outlining large radiosensitive organs in patient images were identified at each slice level. Their orthogonal distances from the mid-sagittal, and mid–coronal planes were measured. In small organs, the coordinates of organs' centers were similarly determined. The outlines, and centers of radiosensitive organs (brain, eye lenses, salivary glands, thyroid, lungs, heart, thymus, esophagus, breasts, adrenals, liver, spleen, kidneys, stomach, gallbladder, small bowel, pancreas, colon, ovaries, bladder, prostate, uterus, and rectum) were reproduced using the coordinates of each organ on corresponding phantoms' transverse images. To investigate the effect of bismuth shielding on thyroid dose, and image quality, each of the four phantoms were subjected to neck CT, using a 16-slice MDCT system. Each scan was performed without, and with single-, and double-layered bismuth shield placed on the skin surface above the thyroid. Thyroid dose was measured with thermoluminescent dosemeters. The location of the thyroid within the phantom slices was determined by anthropometric data from patients' CT examinations whose body stature closely matched the phantoms, as described above. Effective dose (*E*) was estimated using the dose–length product (DLP) method. Image quality of resulted CT images was assessed through the image noise metric. Image noise was measured as the standard deviation of the mean

Hounsfield unit value in circular regions of interest (ROI, 1 cm^2). A total of five ROIs were separated into two groups on the basis of three ROIs in the anterior area closer to the thyroid glands, and two ROIs in the posterior area beneath the surface of the phantom slice. The ROIs were placed so that only soft tissue was included, excluding the predrilled holes, TLDs chips, and vertebrae from assessment. Scans were repeated with cotton spacers of 1, 2 and 3 cm thick placed between the skin and shield, to study the effect of skin-to-shielding distance on image noise. Activation of AEC was found to decrease the thyroid dose by 46 % to the 10-y-old phantom subjected to neck CT. When FTC technique is used, single-, and double-layered bismuth shielding was found to reduce the thyroid dose to the same phantom by 35 and 47 %, respectively. The corresponding reductions in AEC-activated scans were 60 and 66 %, respectively. The use of single and double bismuth shields caused an increase in the noise up to a factor of 22, and 34 respectively, for the 1-year-old phantom during FTC scans. Similarly, the noise increased by a factor of 17 and 32 for single and double shields upon activation of AEC. Elevation of shields by 1-, 2- and 3-cm cotton spacers decreased the image noise by 69, 87 and 92 %, respectively, for single-layered FTC, without considerably affecting the thyroid dose. The artefacts that were seen upon the use of the shields also disappeared with the introduction of the cotton spacers. In conclusion, data on location of radiosensitive organs inside pediatric anthropomorphic phantoms was produced and may provide users reliable data for positioning of dosimeters during direct organ dose measurements. AEC was more effective in thyroid dose reduction than in-plane bismuth shields. Application of cotton spacers had no significant impact on thyroid dose, but significantly decreased the image noise.

References to author publications that relate specifically to the dissertation:

1. **Stephen Inkoom**, Antonios E. Papadakis, Maria Raissaki, Kostas Perisinakis, Cyril Schandorf, John J. Fletcher and John Damilakis, "Paediatric Neck Multi-Detector Computed Tomography: The Effect of Bismuth Shielding on Thyroid Dose and Image Quality." Radiation Protection Dosimetry. 2016 Feb 17. pii: ncw007. [Epub ahead of print].

2. **Stephen Inkoom**, Maria Raissaki, Kostas Perisinakis, Thomas G. Maris and John Damilakis, "Location of radiosensitive organs inside pediatric anthropomorphic phantoms: Data required for dosimetry." European Journal of Medical Physics (Physica Medica). 2015;31(8):882-8.