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Location of radiosensitive organs inside pediatric anthropomorphic phantoms: Data required for dosimetry

Stephen Inkoom [a], Maria Raissaki [b], Kostas Perisinakis [a], Thomas G. Maris [a], John Damilakis [a, *]

[a] Department of Medical Physics, Faculty of Medicine, University of Crete, P.O. Box 2208, 71003 Iraklion, Crete, Greece
[b] Department of Radiology, Faculty of Medicine, University of Crete, P.O. Box 2208, Iraklion 71003, Crete, Greece

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ABSTRACT

Purpose: The aim of this study was to determine the location of radiosensitive organs in the interior of four pediatric anthropomorphic phantoms for dosimetric purposes.
Methods: Four pediatric anthropomorphic phantoms representing the average individual as newborn, 1-year-old, 5-year-old and 10-year-old child underwent head, thorax and abdomen CT scans. CT and MRI scans of all children aged 0–16 years performed during a 5-year-period in our hospital were reviewed, and 503 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 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 and 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 all radiosensitive organs were reproduced using the coordinates of each organ on corresponding phantoms' transverse images.
Results: The locations of the following radiosensitive organs in the interior of the four phantoms was determined: 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.
Conclusions: The production of charts of radiosensitive organs inside pediatric anthropomorphic phantoms was feasible and may provide users reliable data for positioning of dosimeters during direct organ dose measurements.

Introduction

Medical procedures involving radiation exposure constitute the main contributor of human exposure to ionizing radiation from artificial sources [1] resulting in constantly increasing anxiety regarding the potential radiation risks to the general population. In particular, the radiation dose delivered to the examined patient during high-dose procedures such as routine computed tomography (CT) examinations and image-guided interventional procedures may result in an increased risk of radiation-induced carcinogenesis [2]. The risk of manifesting potential radiation damage is considerably higher in pediatric patients due to their increased radiosensitivity, longer life expectancy and increased possibility of repeated examinations [1,3–5].

Direct radiation dose measurements can be carried out by placing dosimeters on patients undergoing a radiological procedure. However, only entrance or/and exit skin dose can be directly determined while internal organ doses are commonly derived from skin dose data. Direct radiation dose measurements can be also carried out experimentally using physical phantoms representing the actual patient [6]. To minimize discrepancies due to different shape, size and composition these phantoms are commonly constructed to be anthropomorphic i.e. to represent the shape, size and anatomy of an average-sized individual. Pediatric anthropomorphic phantoms have been widely used in medical dosimetry [7–30]. Experimental direct dose measurements on anthropomorphic

* Corresponding author. Tel.: +30 2810 392569; fax: +30 2810 542095.
E-mail address: John.Damilakis@med.uoc.gr (J. Damilakis).

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phantoms may be considered more accurate than other methods that use simple phantoms such as a cylinders or sets of slabs [31].

Determination of effective dose through organ doses associated with a medical radiation exposure may be considered as the first step in optimizing the dose and comparison with diagnostic reference levels. Moreover, accurate assessment of organ doses may also be used to assess the level of radiation risk associated with the medical exposure [8]. Knowledge of the exact position/size of each organ in the phantoms is a prerequisite for the appropriate placement of dosimeters in order to minimize inaccuracies regarding organ localization and extent. Previous investigators have provided data on the location and extent of radiosensitive organs inside the Rando anthropomorphic phantom which simulates the average adult individual [19–21]. However, to our knowledge, there are no data in the literature regarding the location of radiosensitive organs inside pediatric anthropomorphic phantoms.

The aim of this study was to determine the location of all radiosensitive organs in the interior of the four pediatric anthropomorphic phantoms commonly used for dosimetry and provide practical data for the placement of dosimeters.

Materials and methods

Phantoms

Four commercially available pediatric anthropomorphic phantoms (ATOM Phantoms, CIRS, Norfolk, Virginia, USA) representing the average individual as newborn, 1-year-old, 5-year-old and 10-year-old child were studied (Fig. 1). These physical phantoms consist of 25-mm thick sections. Drilled in a 1.5 × 1.5 cm and 3 × 3 cm arrays, there are holes 5-mm in diameter that can accommodate dosimeters. The phantoms are constructed from radiologically tissue-equivalent materials that simulate soft, bone, brain and lung tissues. Therefore, among all radiosensitive organs only the outlines of brain, skeleton, and lungs are visible on phantom slices.

Phantom scans and measurements

Each phantom was subjected to standard brain, thorax and abdominal CT, with anterior-posterior (AP) and lateral (LAT) scout views taken prior to spiral scans. Brain scans extended from the skull base to the vertex, thoracic scans from the lung apices to the costophrenic angles and abdominal scans from the hemi-diaphragm's domes to the symphysis pubis.

The maximum fronto-occipital diameter of phantom's head and the cranio-caudal distance from the skull base to the vertex were measured on the lateral (LAT) scout view while the maximum lateral head dimension was measured on the transverse reconstructed CT image at the level of the third ventricle just above the orbits (Fig. 2).

The cranio-caudal distance from the level of the lung apices to the level of the costophrenic angles was measured on the AP scout view of thorax. The maximum lateral and AP dimensions of thorax were determined and measured on the transverse reconstructed CT image at the level of the base of heart (Fig. 3).

The distance from the hemi-diaphragm's domes to the symphysis pubis was measured on the AP scout view and considered the dimension along z-axis of the abdominal region of phantom. The maximum LAT and AP dimensions of abdomen were determined and measured on the transverse reconstructed CT image at the level of the mid upper abdomen, the same way as for thorax.

Patient CT and MR examinations

Case histories and reports of 589 consecutive pediatric patients aged 0–16 years who underwent a CT or MR diagnostic examination in our hospital within a 5-year period were reviewed. Examinations of patients with conditions that could potentially distort normal anatomy were excluded using the criteria shown in Table 1. Overall, 40 MR and 46 CT examinations were excluded.

The CT images obtained from a 16-slice CT scanner (Sensation 16, Siemens, Germany) and the MR images obtained from

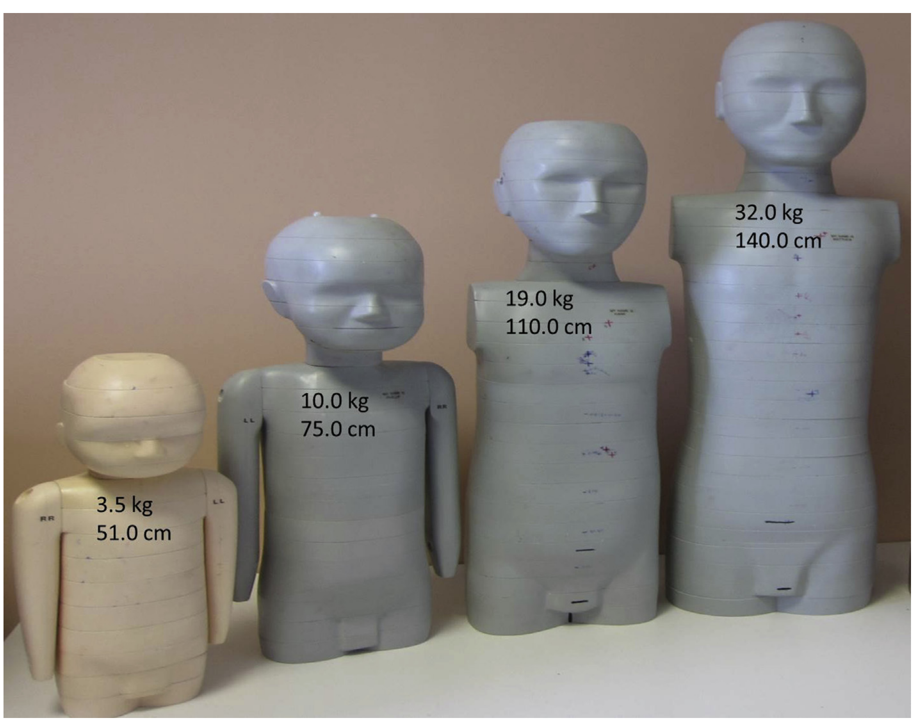

Figure 1. Pediatric anthropomorphic phantoms representing the average individual as newborn, 1-year-old, 5-year-old and 10-year-old child, from left to right. Data on their weights (kg) and heights (cm) are displayed for each phantom.

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