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PAPER

Study of attenuation characteristics for novel neonatal head phantom in diagnostic radiology using Monte Carlo simulations and experiments

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Abstract

This study presents the design and validation of a neonatal head phantom using innovative heterogeneous composite materials customized to replicate the x-ray attenuation properties of neonatal cranial structures. Analysis of Hounsfield Unit (HU) data from 338 neonatal head CT scans informed the design of epoxy resin-based composites with additives such as sodium bicarbonate, fumed silica, and acetone to simulate bone, brain matter, cerebrospinal fluid (CSF) and hyperdense abnormalities. The cranial bone substitute (60% epoxy resin, 40% sodium bicarbonate) achieved a density of 1.60 g cm⁻³, with HU values (574.67–608.04) closely matching clinical ranges. Brain matter (95% epoxy resin, 5% acetone) achieved HU values (35.27-43.61), aligning with clinical means, while the CSF-equivalent material (80% epoxy resin, 15% furned silica, 5% acetone) matched neonatal CSF HU values (14.53-17.02). A mass substitute for hyperdense abnormalities exhibited HU values (56.16-61.07), enabling differentiation from normal brain. Validation included Monte Carlo simulations and experimental CT imaging, showing close agreement in linear attenuation coefficients, with deviations below 11% across energy levels. Mass attenuation coefficients from simulations and XCOM software were consistent, with deviations under 0.7%, confirming the materials dosimetric reliability. The phantom, with a cylindrical geometry (9 cm diameter, 10 cm length), provides accurate attenuation properties across 80-120 kVp energy levels, with deviations below 5% between experimental CT numbers and simulation data. This phantom offers a robust platform for neonatal imaging research, enabling impactful dose optimization and imaging protocol adjustment and supports improved diagnostic accuracy in pediatric imaging.

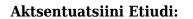
1. Introduction

Pediatric radiology plays a fundamental role in the diagnosis, treatment, and follow-up care for children, with CT (Computed Tomography) scans being particularly effective but delivering notably higher radiation doses than conventional radiography techniques as demonstrated by previous studies [1–3], therefore, optimizing imaging protocols that balance lower radiation doses with high diagnostic quality is essential. The use of specialized phantoms can support this effort by providing a controlled means to evaluate various protocol settings. For accurate dose assessment, these phantoms should mimic the radiological properties of pediatric tissues. While current standard CT dose measurements are typically based on polymethyl methacrylate (PMMA) phantoms designed to represent adult anatomy, such measurements often fail to account for the significant variations in body composition and size among pediatric patients [4, 5].

Pediatric exposure to ionizing radiation poses particular concerns due to children's longer life

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Aktsentuatsiini Etiudi Book Review: Unveiling the Power of Words

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RIGGING FORCES AND ... MODULE 4 - LIFTING AND RIGGING Dunderstand the proper use of wire ropes, wire rope fittings, end terminations, and tighteners.

Explain the use of slings and sling arrangements.

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