Conversion factors for determining organ doses received by paediatric patients in high-resolution single slice computed tomography with narrow collimation☆

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Abstract

Estimations of organ doses D_T received during computed tomographic examinations are usually performed by applying conversion factors to basic dose indicators like the computed tomography dose index (CTDI) or the dose-length-product (DLP). In addition to the existing conversion factors for beam apertures of 5 mm or 10 mm, we present new DLP-D_T conversion factors adapted to high-resolution CT (HRCT) examinations of infants and young children with beam apertures of the order of 1 mm and under consideration of bow tie filtration. Calculations are performed on mathematical MIRD phantoms for an age range from 0, 1, 5, 10, 15 up to (for comparison) 30 years by adapting PCXMC, a Monte Carlo algorithm originally developed by STUK (Helsinki, Finland) for dose reconstructions in projection radiography. For this purpose, each single slice CT examination is approximated by a series of corresponding virtual planar radiographies comprising all focus positions. The transformation of CT exposure parameters into exposure parameters of the series of corresponding planar radiographies is performed by a specially developed algorithm called XCT. The DLP values are evaluated using the EGSRay code. The new method is verified

Konversionsfaktoren zur Ermittlung von Organdosen bei pädiatrischen Patienten in der hochauflösenden Einzelschicht-Computertomographie mit enger Kollimation

Zusammenfassung

Die Abschätzung der vom Patienten im Rahmen computertomographischer Untersuchungen in einzelnen Organen aufgenommenen Strahlendosen (D_T) erfolgt üblicherweise durch die Anwendung von Konversionsfaktoren, wobei der Computertomographie-Dosis-Index (CTDI) oder das Dosis-Längen-Produkt (DLP) als Ausgangsdosisgrößen dienen. In dieser Arbeit werden zusätzlich zu den bereits für Schichtkollimationen von 5 mm und 10 mm existierenden Konversionsfaktoren neue DLP-D_T-Konversionsfaktoren unter Zugrundelegung einer Schichtkollimation von 1 mm und unter Berücksichtigung der Fächerstrahlfilterung für hochauflösende CT-Untersuchungen (HRCT) von Säuglingen und Kleinkindern bestimmt. Die Berechnung der Organdosen D_T wurde an mathematischen MIRD-Phantomen der Altersstufen 0, 1, 5, 10, 15 und (zum Vergleich) 30 Jahre durch Adaptation des von

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at a beam aperture of 10 mm by comparison with formerly published conversion factors. We show that the higher spatial resolution leads to an enhanced DLP-D_T conversion factor if a small organ (e. g. thyroid gland, mammae, uterus, ovaries, testes) is exactly met by the chosen CT slice, while the conversion factor is drastically reduced if the chosen CT slice is positioned above or below the organ. This effect is utilized for dose-saving examinations with only a few single slices instead a full scan, which technique is applied in about 10% of all paediatric chest CT examinations.

Keywords: High-resolution CT, organ doses, dose length product, CTDI, computed tomographic dose index, conversion factors, fan beam filter

der finnischen Strahlenschutzbehörde STUK (Helsinki, Finnland) ursprünglich für Dosisrekonstruktionen in der konventionellen Projektionsradiographie entwickelten Monte-Carlo-Algorithmus PCXMC an die in der Computertomographie herrschenden Expositionsbedingungen durchgeführt. Jede CT-Einzelschichtuntersuchung wurde dabei durch eine Serie entsprechender, sämtliche Fokuspositionen erfassender planarer Radiographien approximiert. Zur Transformation der CT-Expositionsparameter in die Expositionsparameter einer entsprechenden Serie planarer Radiographien wurde der XCT-Algorithmus entwickelt. Die DLP-Werte wurden mit dem EGSRay-Algorithmus ermittelt. Zur Verifikation der neuen Methodik dient ein Vergleich der für eine Schichtkollimation von 10 mm ermittelten Konversionsfaktoren mit Literaturwerten. Es wird gezeigt, dass die höhere Ortsauflösung bei einem kleinen Organ (z. B. Schilddrüse, Brustdrüsen, Uterus, Ovarien, Testes) zu einem erhöhten DLP-D_T-Konversionsfaktor führt, falls die gewählte CT-Schicht genau dieses Organ erfasst, dass der Konversionsfaktor jedoch drastisch erniedrigt ist, wenn die gewählte CT-Schicht oberhalb oder unterhalb des Organs angeordnet wird. Dieser Effekt wirkt sich vor allem bei der dosissparenden Untersuchungstechnik der bei etwa 10% aller pädiatrischen CT-Thorax-Untersuchungen angewandten hochauflösenden Einzelschicht-CT aus, bei welcher nur wenige dünne Einzelschichten mit vergleichsweise hohem Schichtabstand angefertigt werden.

Schlüsselwörter: HRCT, Organdosen, Dosis-Längen-Produkt, CTDI, Konversionsfaktoren, Fächerstrahlfilter

1 Introduction

Computed tomography (CT) is a radiological procedure ranking in the upper sector of the required doses to the examined regions of the body [1]. With increasing availability of age-specific low-dose protocols, CT has come to be used more frequently in paediatric radiology [2]. On the other hand, the radiation sensitivity of children must be estimated considerably higher than that of adults [3–10]. Recently, direct epidemiologic proof has been given of a heightened risk for neoplastic diseases after CT examinations in the age range under 22 years [11,12]. Against that background, the possibility of the retrospective reconstruction of organ doses administered in a long-years practice of paediatric CT examinations - the aim of the present paper - is of significant importance for radiation safety and radiation epidemiology. The organ dose D_T is defined as the absorbed dose in an organ or tissue T, averaged over the mass of that organ or tissue. This definition is equivalent to the quotient of the energy imparted to the matter of the organ or tissue and its mass.

In paediatric radiology, CT beam apertures of about 1 mm, as implemented, e.g., in the CT scanner *Philips Aura*, have been used for a long time since this narrow collimation is necessarily adapted to the small sizes of anatomical structures in neonates and infants. In the literature of paediatric radiology [13], this narrow collimation approach, combined with the application of high-resolution reconstruction filters, is usually referred to as "high-resolution computed tomography" (HRCT). Moreover in some paediatric radiology departments, about 10% of all chest CT examinations are performed with a small set of narrow single slices with beam apertures of about 1 mm and - as a low-dose procedure – with relatively large gaps between the single slices instead of continuous CT series [14–16]. Another feature of the narrow collimation single slice HRCT is the general choice of a relatively high tube voltage such as 120 kV [14], whereas low tube voltages such as 80 kV are normally applied in paediatric radiology. Relatively high tube voltages are used as an auxiliary means to obtain the high radiation output required to produce sufficiently low-noise detector signals in