ORIGINALARBEIT

Optimizing radiation exposure for CT localizer radiographs

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Abstract

Introduction: *The trend towards submillisievert CT scans leads to a higher dose fraction of localizer radiographs in CT examinations. The already existing technical capabilities make dose optimization of localizer radiographs worthwhile. Modern CT scanners apply automatic exposure control (AEC) based on attenuation data in such a localizer. Therefore not only this aspect but also the detectability of anatomical landmarks in the localizer for the desired CT scan range adjustment needs to be considered.*

Materials and methods: *The effective dose of a head, chest, and abdomen-pelvis localizer radiograph with standard factory settings and user-optimized settings was determined using Monte Carlo simulations. CT examinations of an anthropomorphic phantom were performed using multiple sets of acquisition parameters for the localizer radiograph and the AEC for the subsequent helical CT scan. Anatomical landmarks were defined to assess the image quality of the localizer. $CTDI_{vol}$ and effective mAs per slice of the helical CT scan were recorded to examine the impact of localizer settings on a helical CT scan.*

Results: *The dose of the localizer radiograph could be decreased by more than 90% while the image quality remained sufficient when selecting the lowest available settings (80 kVp, 20 mA, pa tube position). The tube position during localizer acquisition had a greater impact on the AEC than the reduction of tube voltage and tube current. Except for the use of a pa tube position, all changes*

Optimierung der Strahlenbelastung von CT-Übersichtsaufnahmen

Zusammenfassung

Einleitung: *Der Trend zu dosisoptimierten CT-Scans bis in den Submillisievert-Bereich führt zu einem höheren relativen Dosisanteil der Übersichtsaufnahmen bei CT-Untersuchungen. Dies macht eine Dosisoptimierung der CT-Übersichtsaufnahmen erstrebenswert. Moderne CT-Geräte verwenden eine Belichtungsautomatik mit Röhrenstrommodulation (AEC) die auf den Schwächungswerten der Übersichtsaufnahme basiert. Daher muss dieser Aspekt ebenso berücksichtigt werden, wie die Erkennbarkeit von anatomischen Landmarken in der Übersichtsaufnahme.*

Material und Methoden: *Die effektive Dosis einer Kopf-, Thorax- und Abdomen-Becken-Übersichtsaufnahme wurde bei Standardeinstellungen und anwenderbezogenen Einstellungen mit einer Monte-Carlo-Software berechnet. An einem anthropomorphen Phantom wurden CT-Untersuchungen durchgeführt. Dabei wurden verschiedene Aufnahmeparameter für die Übersichtsaufnahme und die Belichtungsautomatik für den Spiral-CT-Scan verwendet. Um die Bildqualität der Übersichtsaufnahme zu beurteilen, wurden anatomische Landmarken definiert. $CTDI_{vol}$ und effektive mAs pro Schicht wurden aufgenommen um die Auswirkung der optimierten Übersichtsaufnahmen auf den Spiral-CT-Scan zu untersuchen.*

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of acquisition parameters for the localizer resulted in a decreased total radiation exposure.

Conclusion: *A dose reduction of CT localizer radiograph is necessary and possible. In the examined CT system there was no negative impact on the modulated helical CT scan when the lowest tube voltage and tube current were used for the localizer.*

Keywords: Localizer radiograph, Tube current modulation, Automatic exposure control, Monte Carlo simulation, Computed tomography, Dose reduction

Ergebnisse: *Die effektive Dosis der CT-Übersichtsaufnahme konnte mit ausreichender Bildqualität um mehr als 90% reduziert werden, wenn die niedrigsten wählbaren Einstellungen (80 kV, 20 mA, pa-Röhrenposition) verwendet wurden. Die Röhrenposition in der Übersichtsaufnahme zeigte eine größere Auswirkung auf die Röhrenstrommodulation des Spiral-CT-Scans, als die Reduzierung der Röhrenspannung und des Röhrenstroms. Außer bei der Verwendung einer pa-Röhrenposition führten alle veränderten Aufnahmeparameter der Übersichtsaufnahme zu einer Verringerung der Dosis des Spiral-CT-Scans.*

Schlussfolgerung: *Eine Dosisreduzierung bei der Übersichtsaufnahme ist notwendig und möglich. Bei dem untersuchten CT-System gab es keine negative Auswirkung auf den röhrenstrommodulierten Spiral-CT-Scan, wenn geringste Röhrenspannung und geringster Röhrenstrom für die Übersichtsaufnahme verwendet wurden.*

Schlüsselwörter: Übersichtsaufnahme, Röhrenstrommodulation, Belichtungsautomatik, Monte Carlo Simulation, Computertomographie, Dosisreduzierung

1 Introduction

The scientific community is aware that patient exposure in computed tomography can reach high dose levels and makes a substantial contribution to the collective effective dose [1,2]. Up to now great effort has been made to minimize the dose of CT scans. Available techniques such as automatic exposure control (AEC) could decrease the dose up to 60% [3–6]. Also iterative reconstruction decreased the dose up to 74% [7–9] and *z*-axis collimation up to 55% [10,11]. Tube potential selection and beam shaping filters are further dose reduction techniques, each with a reduction potential up to 50% [12,13]. Taking all these techniques into account, the dose of a single-phase abdomen/pelvis CT scan could be minimized up to 70% to 2.8 mSv [14], for example. Further new technical advances show the potential to achieve submillisievert CT scanning for routine CT examinations [14]. In optimized CT scanning, doses below 1 mSv are already achievable [15–19].

Frequently in reports and studies about dose and dose-reduction capabilities in computed tomography the localizer dose is disregarded [17,20–23].

However, Schmidt et al. showed that the effective dose of localizer radiographs reaches values up to 0.12 mSv (head), 0.39 mSv (chest), and 0.42 mSv (abdomen-pelvis) [24]. Compared to typical doses for routine head (2.3 mSv), chest (8 mSv), and abdomen-pelvis CT scans (10 mSv), the localizer dose is about 4–5% of the related CT scan dose [25]. Considering lung cancer screening protocols with an effective dose lower than 1 mSv [26], the localizer dose could be more than 40% of the CT scan dose. Furthermore, optimized axial/helical CT scans with a short scan range such as cardiac imaging with a dose lower than 0.1 mSv [17] the localizer dose is higher than the axial/helical CT scan dose. This is due mainly to a longer scan length of the localizer radiograph.

As vertical centering becomes more widely recognized as being critical for the AEC function to work properly (by avoiding magnification and reduction effects) [27,28], we can expect more repeated localizers to be obtained. This also adds to the justification of understanding the dosimetry effects of localizers.

Former studies about the localizer radiograph recommend a lower tube current, tube voltage, and a posterior-anterior (pa) tube position for the localizer radiograph, especially for children due to their smaller body size and higher radiosensitivity [24,29–31]. Incident air kerma on central beam [29], effective dose [24,30,31], and image quality [31] of the localizer radiograph have been examined in former studies. However, to the best of our knowledge a complete investigation of the effective dose and optimization capabilities of a modern CT scanner with the tube current modulation technique has not been done. CT manufacturers use automatic exposure control (AEC) techniques that are essentially based on the attenuation recorded in the localizer radiograph. Therefore, the impact of the localizer acquisition parameters on the AEC must be considered before implementing radical localizer dose reductions.

These findings encourage the investigation of dose-optimization capabilities for the CT localizer radiograph. In this study, the effective dose of localizer radiographs for head,

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