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European Journal of Radiology 69 (2009) 473–477

EJR
EUROPEAN JOURNAL OF RADIOLOGY

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Comparison of the image quality of various fixed and dose modulated protocols for soft tissue neck CT on a GE Lightspeed scanner

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Received 10 March 2007; received in revised form 13 November 2007; accepted 14 November 2007

Abstract

Purpose: Up-to-date CT scanners provide high quality soft tissue imaging of the neck, but scanning protocols often are not optimized regarding radiation dose. Thus, we tried to find a dose-optimized protocol for soft tissue imaging of the neck.
Material and methods: 70 patients were scanned with a 16-row CT-scanner (Lightspeed, GE) with seven different protocols. We used four fixed tube current settings (225, 200, 175 and 150 mA; corresponding $CTDI_{vol}$ = 10.6, 9.5, 8.3 and 7.1 mGy) and three *z*-axis dose modulations with a relatively high, moderate and low dose (calculated $CTDI_{vol}$ = 10.5, 9.1, 7.7 mGy). Representative slices of seven anatomical regions (from the nasopharynx to the aortic arch) were subjectively judged by two radiologists with respect to image quality (five-point rating scale for noise and sharpness). For each protocol and for each judged anatomical region we determined and compared mean values regarding image quality and local tube current. For each protocol, mean values regarding the volume CT dose index ($CTDI_{vol}$) and the dose-length product (DLP) were statistically compared. Moreover, using the software CT-Expo the respective effective doses and the cumulative organ doses of the thyroid gland were compared.
Results: For a fixed tube current of at least 200 mA ($CTDI_{vol}$ = 9.5 mGy) and for dose modulations with a moderate or high dose adjustment (calculated $CTDI_{vol}$ = 9.1 and 10.5 mGy) the image quality was sufficient to excellent. As compared to a fixed tube current of 200 mA, dose modulation with a moderate dose adjustment improved the image quality in regions more vulnerable to noise-related artifacts such as at the level of the shoulder, without a noteworthy difference regarding the DLP. However, the cumulative organ dose of the thyroid gland was 17% lower using dose modulation with a moderate dose adjustment as compared to the fixed tube current of 200 mA. Thus, for a comparison with other scanners, we recommend dose modulation and an averaged $CTDI_{vol} < 9$ mGy (or a DLP < 250 mGy cm).
Conclusion: A combination of dose modulation and an averaged $CTDI_{vol} < 9$ mGy or a DLP < 250 mGy cm yields sufficient image quality for soft tissue CT-imaging of the neck.

Keywords: Computed tomography (CT); Radiation exposure; Dose optimization; Head and neck

1. Introduction

Computed tomography (CT) is regarded to be responsible for 30–50% of the public diagnostic radiation exposure [1,2]. Thus, a big effort to minimize the radiation exposure caused by CT-examinations can be noted and dose modulation techniques developed by the vendors are increasingly in use [3]. In the future, the main goal should not be the best image quality but an acceptable signal to noise ratio [3,4].

Especially for high contrast imaging of lung and bones, low dose techniques are commonly used [5–7]. As a consequence, it is increasingly interesting to establish appropriate low dose protocols for soft tissue imaging as well [5,8]. Recently, Namasivayam et al. compared *z*-axis automatic exposure control and fixed tube current technique for CT evaluation of the neck and published initial data [8].

The aim of our study was to find reasonable dose settings for routine CT of the neck. Here we compare various dose modulation settings with various fixed dose settings, providing additional data for general use.

2. Material and methods

70 patients with a median age of 49 (23–76) years (31 females, 39 males) were examined after informed consent was attained. The clinical diagnoses were either inflammation (mostly tonsillitis or paratonsillar abscess) or neoplasia (mostly

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doi:10.1016/j.ejrad.2007.11.027

laryngopharyngeal squamous cell cancer, medullary or anaplastic carcinoma of the thyroid gland and lymph node metastases).

All patients were examined with a 16-row spiral CT-scanner (Lightspeed, GE, USA). At the beginning and during the examination the shoulders were moved downwards as far as possible. After a start delay of 60 s 100 ml contrast medium (Iomeprol 350 IU, Altana, Germany) was injected at a flow rate of 3 ml/s. During quiet breathing, data acquisition from the aortic arch to the skull base was performed in a caudocranial scan direction (120 kV, scan-FOV 500 mm, 16 mm × 1.25 mm collimation, increment 1.0 mm, pitch 1.375, rotation time 0.7 s, constant scan length 250 mm, reconstruction filter GE Standard).

Dose modulation was performed with the help of *z*-axis automatic exposure control (AutomA, GE Healthcare Technologies), which evaluates the attenuation of the different body parts on the localizer radiograph. Our GE Lightspeed CT-scanner does not apply angular dose modulation (for a detailed discussion of the different dose modulation techniques see Kalra et al. [9]). The user can specify the minimum and maximum current thresholds (mA range) and the noise index (NI). The NI corresponds to the standard deviation of the CT-values in a homogeneous region and represents the quantum noise (resulting in image noise) based on which the automatic exposure control modulates the dose. The scanner display shows the resulting $CTDI_{vol}$, calculated from the actual mAs of the individual slices.

The 70 patients were divided into seven groups of ten patients. Each group was examined with a different tube current setting: four fixed settings (225, 200, 175 and 150 mA; corresponding $CTDI_{vol}$ = 10.6, 9.5, 8.3 and 7.1 mGy) as well as three dose modulation settings. The dose modulation settings had either a relative high image noise (high noise index with a vendor-specific value of 26 and corresponding low dose; calculated $CTDI_{vol}$ = 7.7 mGy) or a medium image noise (value of 22 and corresponding medium dose; calculated $CTDI_{vol}$ = 9.1 mGy) or a relative low image noise (value of 18 with corresponding high dose; calculated $CTDI_{vol}$ = 10.5 mGy). The mentioned dose modulation settings were chosen based on prior unpublished examinations in our department. Regarding the tube current, no maximum (or minimum) limits were given, because we wanted to get an appropriate image quality in noisier regions such as the supraclavicular region (and the lower thyroid gland) as well.

For retrospective image analysis, we chose seven representative 3 mm-slices for each patient: Axial slices at the level of the fossa of Rosenmuller of the nasopharynx, the floor of the mouth (with the mandible), the arytenoid cartilage, the lower thyroid gland (at the level of the clavicles), the pathological finding, and the aortic arch; an additional coronal 3mm-MPR through the arytenoid cartilage was reconstructed. After removal of all annotations, two CT-experienced radiologists analysed the images in consensus on a PACS-monitor. Window settings were 300/70HU and the display-FOV 250 mm.

The images were judged with respect to subjective image quality based on possible anatomical differentiation of soft tissues and pathology (inflammation and malignancy): five-point rating scales for subjective image noise (5 = very low, 4 = low, 3 = medium, 2 = high, 1 = very high) and sharpness (5 = very good, 4 = good, 3 = medium, 2 = bad, 1 = very bad). Based on the mean of both criteria the (overall) image quality was calculated (5 = very good, 4 = good, 3 = sufficient, 2 = bad, 1 = very bad). If the mean was exactly between two integer numbers, image noise was weighted stronger and the result was rounded up or down accordingly. A mean image quality of <3 in any of the anatomic regions was not tolerated. The local tube current was noted for each rated slice and averaged for each patient group. Moreover, the volume CT dose index ($CTDI_{vol}$ [mGy]) and the dose-length

Table 1
Image quality, depending on anatomic level and various fixed tube currents (or corresponding $CTDI_{vol}$ [mGy])

mA/$CTDI_{vol}$	150/7.1	175/8.3	200/9.5	225/10.6
Nasopharynx	3.8	4	4.4	4.4
Floor of the mouth	3.8	4	4.6	4.6
Arytenoid cartilage	4.1	4.3	4.4	4.6
Lower thyroid gland	2.7	2.7	3.6	3.8
Aortic arch	2.9	3.3	3.7	3.8
Pathological finding	3.7	3.7	4.5	4.8
Coronal MPR	3.7	3.7	4.3	4.2
DLP	196	218	246	279
Calculated dose with CT-Expo:				
$CTDI_{vol}$	7.2	8.4	9.6	10.8
DLP	202	236	269	303
Effective dose	2.1	2.4	2.8	3.1

Moreover, the respective dose-length products (DLP [mGy cm]) as given by the scanner are shown. The respective $CTDI_{vol}$ and DLP as calculated with the CT-Expo software correspond well to the latter (divergence <10%). The effective dose is displayed [mSv]. Compare with Table 2.

Table 2
Image quality, depending on anatomic level and three different dose modulation settings (low, medium and high dose)

Dose modulation setting	Low	Medium	High
Nasopharynx	2.8	3.6	3.9
Local current	56	153	204
Floor of the mouth	3.5	3.8	3.9
Local current	99	161	161
Arytenoid cartilage	4	4.2	4.3
Local current	115	163	173
Lower thyroid gland	3.5	3.8	3.9
Local current	219	231	263
Aortic arch	3.5	3.8	3.9
Local current	167	212	281
Pathological finding	3.5	4	3.9
Local current	101	162	173
Coronal MPR	3.8	4.2	4.3
DLP	212	245	277
$CTDI_{vol}$, averaged	7.6	8.9	10.1
Calculated dose with CT-Expo:			
$CTDI_{vol}$	7.7	9.1	10.5
DLP	216	256	297
Effective dose	2.2	2.6	3.1

Moreover, the respective dose-length products (DLP [mGy cm]) and averaged $CTDI_{vol}$ as given by the scanner are shown. The respective $CTDI_{vol}$ and DLP as calculated with the CT-Expo software correspond well to the latter (divergence <5 and <10%, respectively). The effective dose is displayed [mSv]. Compare with Table 1.