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Individually adapted kilovoltage for oncologic chest CT: Levels of radiation dose in clinical practice

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Abstract

Purpose: The main purpose of this study was to verify the adequacy of dose levels of irradiation in oncologic chest CT obtained in our daily practice with the recommendations of the existing referral guidelines. The secondary objective was to evaluate the effect on radiation dose of individual adjustment of kilovoltage in thoracic multidetector row computed tomography (MDCT) images acquired with single and dual-source technology. The impact of lowering the kilovoltage in the diagnostic quality of these studies was also evaluated.

Methods: Ninety-seven patients were included in the study. CT examinations were performed using two different equipments: a conventional CT scanner (SOMATOM Emotion 6), and a dual-source computed tomography (DSCT) system (SOMATOM Force), (Siemens Medical System, Forchheim, Germany), with the following parameters. Emotion 6: collimation 6×1.0 , slice thickness 1.25 mm, 110/130 kV, 48-107 mAs. FORCE: collimation 64×0.6 , slice thickness 1 mm, 100-150 kV, 65-300 mAs. Dose levels of the CT scans were recorded digitally. The levels of DLP (Dose Length Product) obtained, as well as the existing noise in the acquired images, was evaluated.

Results: The average DLP of the protocols was as follows. Emotion 6, 130 kV: 336.3 mGy (5.72 mSv). Emotion 6, 110 kV: 209 mGy (3.55 mSv). FORCE, 150 kV: 183.3 mGy (3.11 mSv). FORCE, 100 kV: 49.4 mGy (0.84 mSv). The values of effective dose were obtained using the conversion factor described by the European Guidelines for Computed Tomography for chest CT (0.017 mSv/mGy/cm). The levels of noise did not rise significantly in the lower kV group.

Conclusions: The average values of DLP obtained in our daily practice meet the recommendations of the existing referral guidelines. Lower values can be achieved through individual adjustment of kilovoltage and using CT scanners with dual-source technology, maintaining the diagnostic quality of these studies.

Keywords

Multi detector row computed tomography, Thoracic CT, Lung cancer, Radiation dosage, Low dose, Dose Length Product

1 Introduction

Multidetector-row computerized tomography (MDCT) is at the moment the best method to detect pulmonary nodules (potential lung cancers) and to follow up oncologic patients. As a result, the number of MDCT exams for these purposes

has increased exponentially in the last years, generating a large volume of images, working hours, and also higher levels of radiation dose.

There is a growing concern among health professionals as well as in general population about radiation dose in CT and its carcinogenic risks. Nowadays, there are many scientific articles that refer to it, and the field of management of radiation dose has grown as well, significantly ^[1-3].

It has been pointed out that the diagnostic accuracy of CT could be maintained while reducing the radiation exposure; as a result, it has been claimed about the need of lowering the radiation dose “as low as reasonably achievable” (the ALARA principle) ^[1].

Different approaches have been proposed in order to reduce the dose, including adjustments of the milliamperage (automatic milliamperage modulation) ^[2], and adjustments of kilovoltage depending on the patient morphotype (as long as the radiation dose varies approximately with the square of the kilovoltage, it has been pointed out that reducing the kilovoltage is a potentially more efficient way to lower the radiation dose than reducing the milliamperage) ^[3].

As a result of using these reduction dose strategies, the noise also increases in the images and this could hamper diagnostic purposes. Recently, several investigators have proposed iterative techniques for dose reduction, which are designed to reduce radiation dose maintaining a good image quality ^[1].

Following the recommendations of the existing referral guidelines, we designed this study, its objectives being twofold. Firstly, to determine the radiation doses delivered at the moment at our diagnostic imaging department in daily clinical practice, comparing them with the current recommendations; and secondly, to evaluate the effect on radiation dose of individual adjustment of kilovoltage in thoracic MDCT images acquired with single and dual-source technology.

2 Materials and methods

2.1 Study design and CT technique

Examinations were performed in Santiago de Compostela and Lille, with a 6-slice CT scanner “SOMATOM-Emotion 6”, and a third generation dual-source computed tomography (DSCT) scanner “SOMATOM-Force” (Siemens Medical System, Forchheim, Germany). The study was approved by the ethics committee. Informed consent from patients was also required in agreement with national regulations.

The CT protocol consisted on non-gated acquisitions over the entire thorax, obtained in a cranio-caudal direction, with the patients scanned in the supine position and after deep inspiration. In all cases, the injection protocol consisted on the administration of an iodinated contrast medium, and the acquisition was always with the arms above the head.

The acquisition parameters were as follows. Emotion 6: collimation 6×1.0 , slice thickness 1.25 mm, 110/130 kV, 48-107 mAs. FORCE: collimation 64×0.6 , slice thickness 1 mm, 100-150 kV, 65-300 mAs.

Data were reconstructed at 1.25 mm (Emotion 6) and 1 mm (Force) contiguous transverse CT scans of the entire thorax, viewed in both the mediastine (window width, 450 HU, window center, 50 HU), soft reconstruction kernel and lung parenchyma (window width, 1600 HU; window center, -600 HU); high spatial frequency algorithm) window settings. The images were obtained in DICOM file formats directly from the CT modality. All patient data were removed from the images.

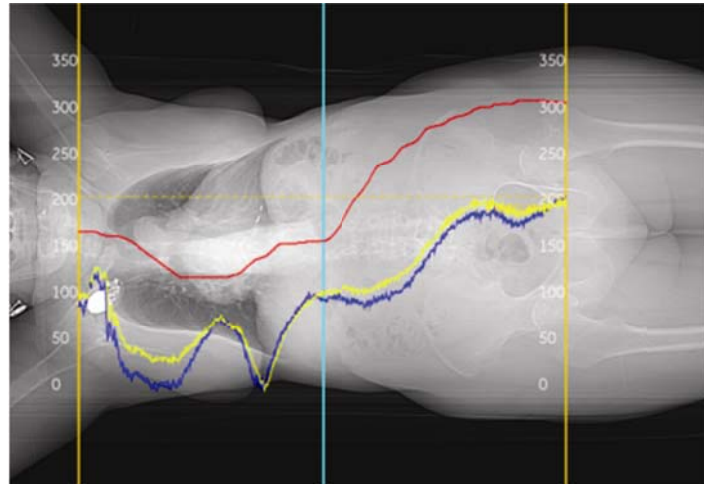


Figure 1. Automatic milliamperage modulation. Both MDCT scanners have this system

The protocol was applied on CT scans performed in ninety-seven patients. The database consisted on 47 patients scanned with the 130 kV protocol (those with a Body Mass Index [BMI] > 23), 30 patients scanned with the 110 kV protocol (patients with a BMI < 23), and 20 patients scanned using the dual-source MDCT. The criteria to determine whether a CT scan was eligible for inclusion in the database were as follows:

- The scans were performed by an experienced chest radiologist from the different institutions that collaborated in the project;
- All the acquisitions included kilovoltage selection depending on the weight and automatic milliamperage modulation.

2.2 Statistical analysis

An estimated minimal number of patients were necessary to detect a difference for the means of DLP values. Statistical analysis was performed and results were expressed by means, standard deviations, and as frequencies, percentiles and percentages. Comparative analysis was obtained using Microsoft Excel®.

3 Results

The average DLP of the protocols was as follows (see Table 1):

Table 1. Radiation dose parameters (DLP) using 130 kV, 110 kV, and dual-source technology

	EMOTION		FORCE
	130 kV	110 kV	100-150 kV
MEAN (mGy*cm)	336.2553	209.0333	69.462
SD	89.27083	72.25505	58.3973
MAX (mGy*cm)	578	404	190
MIN (mGy*cm)	177	129	23
p25 (mGy*cm)	268.3	166	26.75
p50 (mGy*cm)	324	184.5	36.4
p75 (mGy*cm)	384.5	209	94.275
N	47	30	20

Note. EMOTION 6, 130 kV: 336.3 mGy (5.72 mSv);
 EMOTION 6, 110 kV: 209 mGy (3.55 mSv);
 FORCE (100-150 kV): 69.5 mGy (1.18 mSv).

The values of effective dose were obtained using the conversion factor described by the European Guidelines for Computed Tomography for chest CT (0.017 mSv/mGy/cm).

All protocols resulted in mean doses of radiation that were lower than those recommended by European experts (for a typical chest scan performed with a single detector scanner, the recommended DLP is 375 mGy*cm).

Using the standard 130 kV single-source protocol, we obtained mean radiation doses below the recommended levels (since the mean DLP, 336.26 mGy*cm, it means 10% better). However, we have found that more than 25% of patients with the 130 kV protocol were in fact receiving radiation doses that exceeded the recommendations.

On the other hand, we found that by lowering the kV from 130 to 110 kV the mean DLP lowered by 37.8%. Furthermore, with this protocol nearly every patient received a radiation dose below the recommended levels.

The lower dose values were obtained by using the dual-source scanner, with this protocol the mean DLP being reduced by nearly 80% in comparison with the 130 kV single-source protocol. Moreover, none of the patients approached the recommended level, and the maximum value was 180 mGy.

The dual-source MDCT scanner protocol can be used in every patient, being able to achieve doses even lower than 37.5 mGy in thinner patients.

We have also evaluated the levels of noise existing in the studies acquired using the Somatom Emotion MDCT.

The level of noise measured as Standard Deviation (*SD*) of the HU at the tracheal lumen was significantly higher in the 110 kV group (18.17 vs. 22.5).

The contrast-to-noise ratio was slightly higher in the 110 kV group (3.77 vs. 3.85).

The diagnostic quality was similar in both groups of the study, but it has to be taken into the consideration the fact that the BMI was different, and as a result, the quality probably would be significantly lower if we used the 110 kV protocol in patients with a BMI > 23.

Table 2. Comparison of the levels of noise obtained using Somatom Emotion with 110 kV and 130 kV protocols (CTR = VHU-MHU/VN)

	130 kV (mean)	130 kV (SD)	110 kV (mean)	110 kV (SD)
Tracheal noise (ROI <i>SD</i>)	18.17	2.86	22.5	2.78
Vessel HU (ROI mean)	313.33	103.15	361.75	80.2
Vessel noise (ROI <i>SD</i>)	67.98	44.66	78.67	15.73
Muscle HU (ROI mean)	57.17	7.26	58.5	5.85
CTR ratio	3.77		3.85	

4 Discussion

Lung cancer is a leading cause of cancer-related deaths in the world. Accurate diagnosis and staging are critical factors in order to choose the best treatment, as well as in the evaluation of prognosis of patients with bronchogenic carcinoma^[4]. As a result, the total amount of chest CT performed for these purposes will probably rise significantly. It is therefore necessary to develop strategies to keep the radiation values well below the recommended dosimetric levels.

Exposure to diagnosis procedures using ionizing radiation, mainly CT, represents a significant part of total exposure. The contribution of CT represents about 41% of total radiation dose in medical procedures^[5]. Also, over the last years there has

been a great increase in the use of CT, to a point in which individual patient radiation dose through repeated procedures may fall to within the range of dozens of mSv of effective dose, therefore, becoming a growing preoccupation about the carcinogenic risks of ionizing radiation. As a result, the idea of tracking the radiation exposure history of patients is gaining momentum^[6,7].

In this work, we have described and validated our experience in daily practice. We have used the results of dosimetric measurements to estimate the radiation dose at our hospital and compared them with those from another radiology department, therefore evaluating different MDCT scanners. In our results, we found that we can significantly reduce the radiation dose delivered to the patients during the CT exam of the chest with weight adapted low kilovoltage protocols. And, nonetheless, this weight adapted low kilovoltage protocol was fully compatible with the diagnostic task of CT examinations.

It is difficult to establish comparison among protocols obtained and tested over different databases. Comparing with the reference values from the recommendations of the expert group of the European Commission, our results (5.72 and 3.55 mSv)^[8] are in good agreement with the accepted values, and they are lower than the reference dose value defined by the European Communities for routine chest CT^[9]. Our values are also lower than the reference effective dose for CT scans reported from the Fleishner Society^[10]. Our results are also in good agreement with those of Salmerón *et al.*^[11], and Broucker *et al.*^[1].

This study suffers from several limitations. Firstly, the study population was limited. In addition, the examinations were chosen at random and might not reflect a perfect average type of routine examination. And yet something more should have been taken into consideration: it would be interesting to study the impact of the system on a general population.

Besides, another relevant aspect would be to calculate their consecutive doses (for comparative studies). In fact, it is advisable to monitor the studies for temporal changes; therefore, we should analyze the variations on these radiation doses. This will be the objective of our future investigations.

No quantitative definition exists to indicate how low the dose in CT must be. Likewise, no precise definition of the term standard dose exists. In fact, the meaning of low dose is subject to considerable variation over time: the currently considered low dose will become the clinical standard in a very foreseeable future^[12], considerable variation that can also be related to the different equipments and techniques that can be utilized. In this study we have pretended to acquire a better knowledge about the radiation doses delivered at our departments, from different equipments, in order to improve our daily practice, trying to reduce them as low as possible, and, also, evaluating the possibilities offered by the new generation MDCT scanners.

We will continue to explore different ways of combining the appropriate techniques for our acquisition protocols, exploiting all the options to allow the doses to be reduced. Of interest of this is that RECIST (response evaluation criteria in solid tumors) requires follow-up studies of every other cycle of chemotherapy. As a result, the CT effectiveness in patient management in combination with its technological advances resulted in an increased in the frequency of these types of examinations, rendering the CT the modality with the highest radiation burden among most diagnostic examinations^[13]. But the ALARA principle should always be applied, and radiologists must take the lead in promoting this principle^[14,15].

5 Conclusions

The average values of DLP obtained in our daily practice meet the recommendations of the existing referral guidelines. We can obtain lower values through individual adjustment of kilovoltage, maintaining the diagnostic quality of our

studies. The best results require MDCT scanners with automatic kilovoltage selection and methods for iterative image reconstruction.

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