Chest Circumference as a Predictive Parameter of Computed Tomography Coronary Angiography Radiation Doses from Dual-Source Computed Tomography

Çift Kaynaklı Bilgisayarlı Tomografide Koroner Anjiografi Radyasyon Dozlarını Belirlemek için Göğüs Çevresinin Parametre Olarak Kullanılması

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Abstract

Objective: Our aim in this study was to determine the relationship between chest circumference and the radiation doses received by breast tissues during Dual-Source Computed Tomography (DSCT) cardiac scans.

Materials and Methods: Routine cardiac DSCT examinations with similar exposure lengths were applied to 30 female patients. The scanogram image, multi-slice helical scan x-ray tube voltage and anode-cathode current were adjusted automatically according to attenuation for each patient during the scanogram acquisition. The standard protocol was otherwise applied to all patients. The 30 patients had an average weight of 67.8±15.3 kg, and the average length of the scanned region was 278.0±11.6 mm. Radiation doses were calculated from the dose-length product (DLP) and the computed tomography dose index (CTDI) scanner data values. The correlations between radiation dose and chest circumference were investigated. The level of significance was set at $p<0.05$.

Results: For routine cardiac DSCT scans, the average values were as follows: total DLP: 715.54±317.01 mGycm, CTDIvol: 40.79±19.41 mGy, and effective dose (ED): 17.89±7.93 mSv. The chest circumference of patients correlates well with their radiation exposure ($p<0.01$).

Conclusion: The distribution of different tissues throughout the human body may vary among races and genders. Because of this, many researchers use body mass index (BMI) to set image quality and predict the radiation dose distribution from general computed tomography (CT) examinations. Additional anthropomorphic phantom studies should be conducted to determine more accurate conversion factors and, hence, better ED predictions.

Key Words: Breast, Cardiac, DSCT, Radiation dose

Özet

Amaç: Bu çalışmadaki amacımız göğüs çevresi ve Dual-Source Bilgisayarlı Tomografi (DSCT) kardiyak taramaları sırasında meme dokusu tarafından alınan radyasyon dozları arasındaki ilişkiyi belirlemektir.

Gereç ve Yöntem: Benzer tarama uzunluklarına sahip rutin kardiyak DSCT incelemeler 30 kadın hastaya uygulandı. Spot görüntü, çok kesitli helikal tarama x-ışını tüpü gerilim ve anot-katot akımı spot görüntü alınması sırasında belirlenerek her hasta için azaltma miktarına göre otomatik olarak ayarlandı. Aksi belirtilmedikçe standart protokol tüm hastalara uygulandı. 30 hastanın, ortalama ağırlığı 67.8±15.3 kg'dı ve taranan bölgenin ortalama uzunluğu 278.0±11.6 mm idi. Radyasyon dozları doz uzunluk çarpımı (DLP) ve bilgisayarlı tomografi doz indeksi (CTDI) tarayıcı verilerinden hesaplandı. Radyasyon dozu ve göğüs çevresi uzunluğu arasındaki ilişki araştırıldı. Anlamlılık düzeyi $p<0.05$ olarak tespit edildi.

Bulgular: Rutin kardiyak DSCT taramaları için ortalama değerler şöyleydi: Toplam DLP: 715.54±317.01 mGycm, CTDIvol: 40.79±19.41 mGy ve etkin doz (ED): 17.89±7.93 mSv. Radyasyona maruz kalma miktarı hastaların göğüs çevresi ile doğru orantılıdır. ($p<0.01$).

Sonuç: İnsan vücudu boyunca farklı dokuların dağılımı ırklar ve cinsiyetler arasında farklılık gösterebilmektedir. Bu sebeple, birçok araştırmacı görüntü kalitesini ayarlayabilmek ve genel bilgisayarlı tomografi (BT) incelemelerinde soğrulan radyasyon doz dağılımını tahmin etmek için vücut kitle indeksini (BMI) kullanmaktadır. Daha iyi ED tahminleri ve daha doğru dönüşüm faktörleri belirlemek amacıyla ek antropomorfik fantom çalışmalarının yapılması gerekmektedir.

Anahtar Kelimeler: Meme, Kardiyak, DSCT, Radyasyon dozu

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Introduction

The radiation dose received by radiosensitive organs, such as the breasts, in computed tomography coronary angiography (CTCA) is a critical concern for women because of the increased incidence of breast cancer in the population [1]. Higher effective doses from CTCA examinations have been reported in females than in males [2-5].

Using breast shields such as bismuth may significantly decrease the radiation dose to the breasts, but these types of shields also cause image artifacts that reduce diagnostic accuracy [1, 6]. The imaging quality with shielded coronary arteries produces inconclusive results [1, 7, 8].

Radiation exposure to the heart is lower than that of tissues and organs closer to the skin (e.g., breasts) because of the dose absorption. Therefore, damage to the organs closer to the skin might be underestimated [9].

Some new techniques are being used to reduce radiation exposure. One such technique, sinogram-affirmed iterative reconstruction (SAFIRE), was compared with standard-dose CTCA using filtered back-projection (FBP) in a study of female patients. In that study, in the scanning field of cardiac CT, the non-uniform adiposity of breast tissue, and thus its attenuation of radiation, resulted in absorbed dose variability that could not be predicted using only body mass index (BMI) [10]. The distribution of different tissues throughout the human body may also vary among races and genders. Because of this, many researchers use BMI to set image quality and predict the radiation dose distribution from general CT examinations [4, 11-15].

It has been shown that the radiation dose to the breasts could be reduced up to 76% with the use of prospective electrocardiography (ECG) triggering [16]. This is because only a small amount of the radiation is absorbed in the breast tissue when using prospective ECG-triggered scanning [11].

The introduction of DSCT changed cardiac imaging, resulting in a greater than 100-ms increase of the temporal resolution, which facilitates CT coronary angiography (CTCA) imaging independent of the patient's heart rate (HR). In a study examining dual-source CTCA with high HR and correspondingly larger pulsing windows, higher computed tomography dose index (CTDI) values were found because of the longer radiation pulses. In DSCT examinations with increasing heart rates, the radiation doses are decreased [14].

The CTDI of the patients can be calculated from the dose-length product (DLP), which is obtained from the scanner's dose data divided by the scan length. The effective dose (ED) can be calculated from the product of the dose-length product and a conversion coefficient for the chest expressed in terms of the irradiated anatomic area ($k=0.025$ mSv · mGy^{-1}· cm^{-1}) to estimate the real patient dose exposure [17, 18]. Similarly, the DLP can be defined as the product of the volume CTDI and the irradiated scan length.

$DLP=CTDI_{vol} \cdot$ irradiated length where $CTDI_{vol}$ is the volume of the CTDI, and the DLP is determined according to International Electro-technical Commission standards with proper electometers and cylindrical phantoms [19]. The conversion factor relating the DLP to effective dose was determined by dividing the effective dose by the DLP [20].

Materials and Methods

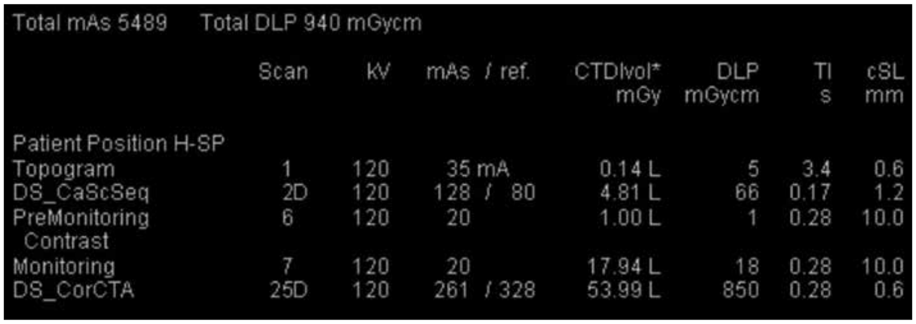
Thirty female patients with a coronary deficiency prognosis underwent routine CTCA between July and October 2012. Their radiation dose reports were examined. Four patients were excluded because of additional examination exposures. Routine cardiac DSCT examinations were performed using a Siemens Somatom Definition CT (Siemens Medical Solutions, Forchheim, Germany). Data acquisition was performed in a supine position. Both anterior-posterior and lateral topograms were taken to determine the examination scan range. For the dual-source CT angiography (DSCTA), the following settings were used: 0.6 mm collimation (cardiac mode), retrospective ECG gating, and 120 kV tube voltage. The examinations were performed with ECG triggering. The tube current was modulated with ECG data. The current was halted during the systolic phases and set to maximum values during the diastolic phase of the cardiac cycle.

All patients in our hospital have examination records that are controlled by a radiology specialist, and the preliminary patient diagnoses and demographic information are stored in computer-based electronic records. In addition, each patient signed an informed consent form prior to scanning that informed them about the data to be collected and how it would be used.

The total DLP, Ca scoring and coronary CTA exposure values for each patient were determined from scanner exposure reports (Figure 1). Patient chest circumference at the arcus aortic level was measured. The correlation coefficient between the circumference and total DLP, Ca Scoring exposure and coronary CTA exposure were evaluated. The statistical analysis was conducted with IBM SPSS Statistics Edition 20.0 (NY, USA).

Results

The 26 post-exclusion patients had an average weight of 67.8±15.3 kg, and the average length of the scanned region was 311.7±31.6 mm. The radiation doses were calculated from the DLP and CTDI values of scanner data. The level of significance was set to $p<0.05$.



Total mAs 5489 Total DLP 940 mGycm

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	TI s	cSL mm
Patient Position H-SP							
Topogram	1	120	35 mA	0.14 L	5	3.4	0.6
DS_CaScSeq	2D	120	128 / 80	4.81 L	66	0.17	1.2
PreMonitoring	6	120	20	1.00 L	1	0.28	10.0
Contrast							
Monitoring	7	120	20	17.94 L	18	0.28	10.0
DS_CorCTA	25D	120	261 / 328	53.99 L	850	0.28	0.6

Figure 1. *Exposure values reported by CT scanner.*

Table 1. CT coronary angiography exposures

	Total DLP (mGycm)	CTCA dose (mGy)	ED (mSv)	CC (mm)
Mean	715.54	40.79	17.89	1028.23
Std Dev	317.01	19.41	7.93	131.73

DLP: dose-length product, CTCA: CT coronary angiography, ED: effective dose, CC: chest circumference

Table 2. The correlation coefficients calculated using Pearson's test

		CC	DLP	CTCA
CC	Pearson Correlation	1	0.749	0.682
	r^2	1	0.561	0.465
DLP	Pearson Correlation	0.749	1	0.958
	r^2	0.561	1	0.918
CTCA dose	Pearson Correlation	0.682	0.958	1
	r^2	0.465	0.918	1

P<0.01 (2-tailed)
DLP: dose-length product, CTCA: CT coronary angiography, CC: chest circumference

Using the Kolmogorov-Smirnov test, all numerical parameters, i.e., chest circumference, total DLP and CT coronary angiography exposure, were found to normally distributed (p>0.05). The total DLP, ED, and $CTDI_{vol}$ for CT coronary angiography exposures are listed in Table 1. The correlation coefficients were calculated according to Pearson's test and are listed in Table 2.

Discussion

Coronary CTA does not examine the whole chest but does examine the lower chest and upper abdomen, thus causing breast tissue irradiation. The conversion factor used to calculate the effective dose from CT coronary angiography was 0.025. This value was upgraded from 0.014 to 0.028 in the recent International Commission on Radiological Protection (ICRP) documentation [11, 19]. For this reason, the effective doses from coronary CT angiography may be underestimated because of the use of an incorrect cardiac specific conversion factor.

In patients undergoing CT coronary angiography, tube current modulation should be used. In addition to the ECG-triggering of radiation exposure, automatic pitch selection should also be used with dual-source CT-scanners. Radiation exposure is an important issue in coronary CT examinations. However, compared to phantom measurements, radiation exposure is increased because of variable BMI and scan length [14]. Chest circumference is a more reliable parameter than BMI because tube current is modulated according to the attenuation of radiation at the level of heart, which is covered by breast tissue. As indicated in Table 2, the chest circumference is more effective in predicting the total DLP value (56.1%). This may be due to ECG monitoring stand-by doses. High heart rate variability (HRV) produces monitoring doses such the total DLP is increased, as the tube time intervals during stand-by are based on a 20-mA current, which, given heart rate, is convenient for acquisition. This may cause variations in CT coronary angiography exposure values.

In conclusion, additional anthropomorphic phantom studies should be conducted to determine more accurate conversion factors and, hence, to produce more accurate predictions of effective doses. HRV data should also be explored for to determine more precise dose predictions. In addition, BMI should be investigated together with CC measurements.

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