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Original Article

# Could the thorax CT protocol be designed based on neck circumference?

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**Abstract**

**Aim:** To evaluate whether neck circumference (NC) is an appropriate somatometric parameter for determining tube voltage of thorax CT for avoiding unnecessary radiation dose.

**Matetial and Methods:** One hundred sixty-three patients who underwent unenhanced thorax CT were included in the study. The NC, body weight and height were measured and the body mass index (BMI) was calculated. The patients were divided into two groups before CT examination: In group 1, the different kV values based on neck circumferences were used on CT protocol, however the same kV value was used for all patients in group 2. Both group CT images were evaluated visually and numerically.

**Results:** The effective dose showing radiation received by the patient was lower in Group 1 than the Group 2 ($p<0.001$). However, the aorta noise value as reducing the image quality was higher in Group 1 ($p<0.001$). The visual image quality score was lower in group 1 than group 2 ($p=0.002$).

**Conclusion:** Even though some clinical studies focus on the NC which reflects the thorax fat tissue, our study concludes that it is not a suitable anthropometric parameter in designing an individual-specific dose protocol for thorax CT.

**Keywords:** Individual dose control; computed tomography; ALARA; tube voltage; neck circumference; body mass index.

## INTRODUCTION

The multislice computed tomography (MDCT) using the state-of-the-art technology provides to get the images with 0.5 mm thickness of a high spatial resolution. The software of cardiovascular, visual endoscopy and 3D images are great values enabling us to process diagnostic images in medical, dental, veterinary domains as well as in the field of engineering. But the radiation exposure from computed tomography (CT) is a key point that raises concern for patients (1-3).

The popular and reliable application among all CT dose reduction strategies is automatic exposure control (AEC) systems (4-6). The tube current (milliampere, mA), one of the parameters that related the amount of X-ray, is automatically determined by the AEC system but the tube voltage (kilovolt, kV), which is the second parameter determining the radiation output of the CT, is still performed manually by the radiology technician. The automatic systems for determining patient-specific kV is not widespread in our country today. So, according to what the kV is determined? In daily practice, the tube voltage is generally determined on the basis of the weight and the body mass index (BMI) (7,8). The BMI is the parameter most frequently used in the diagnosis of obesity and also frequently preferred in low dose MDCT protocols (9-11). But BMI does not define a specific body region. It refers to the average mass of the body. The most appropriate anthropometric parameter of the thorax is thorax circumference and diameter (12,13).

Clinical researches report that neck circumference (NC) can easily be measured and reflects the risk of coronary artery disease and it is emphasized NC can predict the mass index of the thorax (14-18). The present study aimed to create a thorax CT protocol by using kV values adapted in accordance with NC value.

## MATERIAL and METHODS

### Study Population

The study was cross-sectional, and case–controlled. The local ethical board consent for this prospective study was obtained from the Ethical Board of the Training and

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Research Hospital of Van on 21.4.2015 under decision number 2015/3. The study was undertaken between June and December in 2015. Before the CT scanning, the consent form containing information about the biological effects of the radiation was given to all the patients, and signed consent was obtained from the patients or their family members. Those excluded from the study were the patients under 18 years of age, those who were pregnant, the ones who could not give written consent and patients with incomplete data. The final sample consisted of 163 patients fulfilling the above criteria, who were referred to the clinic for CT examination for hemoptysis, dyspnea, and infection. All the patients were subjected to MDCT examination of thorax without contrast. Prior to the CT examination, the neck circumference of each patient was measured at the level of the cricoid cartilage by a tape measure by two radiology technicians. The body height and weight were measured by a semi-automatic stadiometer, and patients' BMI was calculated by the physician by dividing the weight (kg) by the square of the height (m) [Body Mass Index= patient's body height (m) / (patient's body weight (kg))$^2$]

The patients were divided into two groups: Group 1 different kV values were used on the basis of neck circumferences and Group 2 examined by fixed kV values. First, Group 1 was formed, and then the patients in Group 2 were examined. Before the CT examination, both groups were divided into three subgroups by neck circumferences. The first subgroup was composed of patients with a neck circumference lower than 37 cm, the second subgroup of those with a neck circumference between, and including, 37 and 39 cm, and the third subgroup of the patients with a neck circumference over 39 cm.

**MDCT Protocol**

All the examinations were undertaken by a 64-slice CT scanning device (Brilliance 64; Philips Healthcare, Cleveland, Ohio, USA). The patients in the sub-groups of Group 1 were examined on the basis of their neck circumferences, namely the patients in the sub-group with the thinnest neck by 1; 80 kV, the ones in the sub-group with medium neck thickness by 2; 100 kV and the sub-group 3 with the thickest neck circumference by 120 kV. The fixed value of 100 kV was used in Group 2. Both groups were examined through the AEC system. Other parameters of the CT protocol of thorax without contrast are a helical mode, rotation time of 0.6 seconds, collimation 64×0.625 mm, pitch 0.98, and a slice thickness of 5 mm was chosen to reduce the noise value. The imaging field was planned to be between 300 and 350 mm from the lung apex to the left adrenal gland level on the basis of the patients' body height. The patients were positioned with the arms up, at the middle of the gantry, deep inspiration in the supine position.

**Calculation of the estimated dose amount**

Before the research, the CT machine was duly controlled and calibrated by the authorized service provider in terms of the reliability of the DLP (dose length product) value. The effective dose (ED) of a patient in mSv was calculated by multiplying the DLP value automatically calculated by the CT machine with the k constant value (k=0.017 mSv/mGy.cm) available in the literature (13).

**Image analysis**

All the images were transferred to an external workstation for evaluation (Extended Brilliance Workspace (Version 4.0); Philips Healthcare, Cleveland, Ohio, USA). The images were reviewed by one radiology specialist (F.C) with at least five years of experience in thorax CT interpretation with lung window settings [WW (window width), 1200 / 1500 HU, WL (window level) -550 /-700 HU] and mediastinal window settings (WW=350 HU; WL=40 HU). In CT scanning three anthropometric parameters of the thorax were calculated on the basis of the image on the axial plane. The chest anteroposterior (AP) and lateral (L) diameters were measured from skin-to-skin at the nipple level. As the third measurement, the arithmetic mean of the AP and L was obtained (AP+L/2).

The image quality was evaluated in two ways (Figure 1):

1. In calculating "the image noise" that is an objective value, the standard deviation value of the round sample area of 75-100 mm$^2$ placed at the ascending aorta was accepted as noise.

2. On the other hand, "the subjective image quality" was determined by two radiologists as a subjective value by using a scoring system from 0 to 4. The subjective image quality was evaluated by using a five-point scale based on the distinction of anatomical details of the lung interstitial anatomy and mediastinal structures. 0: image with no diagnostic quality, 1: image of weak quality, 2: image of medium quality, 3: image of good quality, 4: image of very good quality.

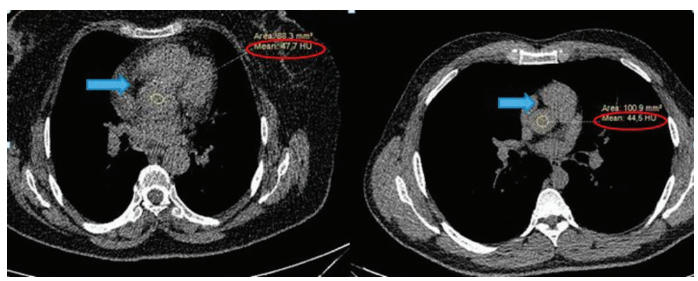


**Figure 1.** Evaluation of CT image quality of two different patients.

1. Objective scoring: Aorta noise was calculated by ROI on the ascending aorta(red circle). (Left 47.7, right 44.5)

2. Subjective scoring: Vascular interface acuity with mediastinal adipose tissue(blue arrow) (left 1 point, right 3 points)

**Statistical Analysis**

All the data were first combined in a common database and then subjected to statistical analysis. The identifying statistical data were expressed as a mean ±standard deviation for continuous variables and as a percentage (%) for discrete data. Parametric tests were used for continuous data with normal distribution and non-parametric tests for data with non-normal distribution. In the case where non-parametric tests were used, the differences between groups were tested by Mann Whitney U-Test in non-dependent groups. In the case when parametric tests were used, Independent Sample T-Test was used. The relationship between variables taken into account was tested by Pearson Correlation Test. The confidence interval for the differences between groups was accepted as 95%, with p<0.05 value that was considered as statistically significant. SPSS 22.0 package program (IBM Corp. Released 2013; IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp) was used for statistical analyses.

## RESULTS

The study sample consisted of 163 patients. Of the participants, 76 were in Group 1 (46.6%) and 87 in Group 2 (53.4%). Both groups were divided into three subgroups according to the neck circumferences. In Group 1, the subgroup 1 was 23.7% (n=18), the subgroup 2 was 59.2% (n=45) and the subgroup 3 was 13% (n=17.1) of the total patients. In Group 2, the subgroup 1 was 34.5% (n=30), the subgroup 2 was 36.8 % (n=32) and the subgroup 3 was 28.7% (n=25) of the total patients. There was no statistically significant difference in demographic data (gender, age, height, weight, BMI, NC) between Group 1 and 2 (Table 1).

**Table 1. Comparison between Group 1 and 2 in terms of demographic data**

| Demographic data | Group (G) | Parameters | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Standard Deviation | Median | Minimum-maximum | p* |
| Age | G1 | 29.7 | 13.8 | 24 | 16-76 | 0.150 |
| | G2 | 29.4 | 15.7 | 21 | 20-85 | |
| Weight | G1 | 75.5 | 12.9 | 72.5 | 45-112 | 0.570 |
| | G2 | 73.8 | 11.2 | 73 | 50-100 | |
| Height | G1 | 174.1 | 8.2 | 175 | 150-195 | 0.660 |
| | G2 | 173.6 | 8.7 | 174 | 150-195 | |
| BMI | G1 | 26.4 | 4.5 | 25 | 19-39 | 0.451 |
| | G2 | 25.8 | 4.3 | 25 | 19-40 | |
| NC | G1 | 37.8 | 2.4 | 38 | 31- 45.5 | 0.906 |
| | G2 | 37.9 | 2.5 | 38 | 31-44 | |
| | | | n | % | p** | |
| Gender | G1 | Male | 69 | 90.8 | 0.634 | |
| | | Female | 7 | 9.2 | | |
| | G2 | Male | 77 | 88.5 | | |
| | | Female | 10 | 11.5 | | |

*Chi-Square test, **Independent samples T-Test , BMI: Body mass index, NC: Neck circumference

The comparison between the subgroups of Group 1 and Group 2 revealed no statistically significant difference between the demographic data (gender, age, height, weight, BMI, NC) of the subgroup 1 (NC< 37 cm) and sub-group 2 (NC=37-39 cm). The comparison between the subgroups 3 (NC>39 cm) revealed no statistically significant difference between the data regards to gender, age, height, and NC; on the other hand, a significantly higher difference was found between weight and BMI values in the subgroup 3s of Group 1 and Group 2 (respectively; p=0.011 and p=0.043).

The comparison of the aorta noise and the scores of image quality between Group 1 and 2 revealed a higher value of aorta noise in Group 1 (p<0.001); higher values were found in Group 2 with respect to patients' ED (mSV) and image scores (respectively; p=0.001 and p=0.002) (Table 2).

The comparison of anthropometric measurements (AP, L, AP+L/2), ED and image quality between all subgroups are shown in Table 3. No statistically significant difference was found in AP, L and AP+L/2 values in the comparison of the subgroups 1, 2 and 3 of the Groups 1 and 2. The comparison of the subgroup 1's revealed a higher aorta noise rate in the subgroup of Group1 (p=0.254) and higher ED and image scores in the subgroup of Group 2 (respectively; p<0.001 and p=0.045). The comparison of subgroups 2's revealed a higher aorta noise rate in the subgroup of Group 1 (p<0.001) and statistically significant higher patient ED and image scores in the subgroup of Group 2 (respectively p<0.001, p<0.001). The comparison of the subgroups 3's, we found a statistically significant higher value of aorta noise only in the subgroup of Group 1 (p=0.004). No significant difference was found between both subgroups 3 between the ED and image scores (p=0.685, p=0.737).

The correlation of the anthropometric parameters in the groups revealed there was a positive and moderate correlation between NC and AP, L and AP + L \ 2 and the correlation between BMI and AP, L, was positive and strong (p <0.005) in Group 2. In group 1, there was a positive and moderate correlation between NC and AP, L and AP+L/2 and the correlation between BMI and L, AP+L/2 was also positive and strong (Table 4 and 5).

**Table 2. Comparison of Group 1 and 2 in terms of image quality and patient dose**

| Demographic data | Group (G) | Parameters Mean | Standard Deviation | Median | Minimum-maximum | p* |
|---|---|---|---|---|---|---|
| **AP** | G1 | 222.4 | 25.2 | 218.4 | 169.3-286.9 | 0.320 |
| | G2 | 218.8 | 21.5 | 214.4 | 160.2-269.4 | |
| **Lateral (L)** | G1 | 317.2 | 35.8 | 312.3 | 224.2-434.2 | 0.574 |
| | G2 | 314.1 | 36 | 311.4 | 200.2-386.1 | |
| **AP+L/2** | G1 | 269.1 | 27.5 | 263.8 | 222.4-354.8 | 0.432 |
| | G2 | 265.8 | 25.3 | 260.5 | 188.8-325.6 | |
| **Noise of aorta** | G1 | 30 | 6.4 | 30.2 | 16.2-41.8 | <0.001 |
| | G2 | 22.2 | 6.1 | 20.6 | 6.4-41.7 | |
| **Dose (mSv)** | G1 | 1.4 | 0.8 | 1.2 | 0.5-4.1 | 0.001 |
| | G2 | 1.9 | 0.9 | 1.7 | 0.9-3.8 | |
| **Score** | G1 | 1.9 | 0.7 | 2 | 1-3 | 0.002 |
| | G2 | 2.3 | 0.6 | 2 | 1-3 | |

*Independent samples T- Test, AP: Anteroposterior, G1: Group 1 (n=76, 46.6%), G2: Group 2 (n=87, 53.4%)

**Table 3. Comparison of subgroups in terms of image quality and patient dose**

| Demographic data | | Group (G) | Parameters Mean | Standard Deviation | Median | Minimum-maximum | p* |
|---|---|---|---|---|---|---|---|
| **AP** | Subgroup 1 | G1 | 214.8 | 21.5 | 209.2 | 187.7-275.4 | 0.139 |
| | | G2 | 206 | 18.4 | 209.2 | 160.2-254.4 | |
| **Lateral (L)** | Subgroup 1 | G1 | 301.3 | 40.8 | 297.2 | 236.4-434.2 | 0.936 |
| | | G2 | 300.4 | 36.4 | 303.7 | 200.2-367.0 | |
| **AP+L/2** | Subgroup 1 | G1 | 259 | 29.9 | 254.1 | 222.4-354.8 | 0.532 |
| | | G2 | 253.2 | 24 | 256.6 | 188.8-293.7 | |
| **Noise of aorta** | Subgroup 1 | G1 | 24.4 | 5.8 | 24 | 16.2-37.1 | 0.254 |
| | | G2 | 22.1 | 7.2 | 20.7 | 6.4-41.7 | |
| **Dose (mSv)** | Subgroup 1 | G1 | 0.7 | 0.1 | 0.7 | 0.5-0.8 | <0.001 |
| | | G2 | 0.9 | 0.2 | 0.9 | 0.9-2.4 | |
| **Score** | Subgroup 1 | G1 | 1.7 | 0.6 | 2 | 1-3 | 0.045 |
| | | G2 | 2.1 | 0.7 | 2 | 1-3 | |
| AP | Subgroup 2 | G1 | 219.1 | 23.3 | 218.3 | 169.3-286.9 | 0.682 |
| | | G2 | 217.1 | 18.1 | 212.4 | 172.1-255.9 | |
| Lateral (L) | Subgroup 2 | G1 | 311.6 | 28.1 | 309.9 | 224.2-370.7 | 0.474 |
| | | G2 | 307 | 26.6 | 304.1 | 266.3-367.1 | |
| AP+L/2 | Subgroup 2 | G1 | 264.1 | 20.6 | 261.2 | 230.1-305.7 | 0.664 |
| | | G2 | 262.1 | 20.6 | 259.2 | 226.8-306.5 | |
| Noise of aorta | Subgroup 2 | G1 | 32.3 | 5.3 | 32.7 | 18.9-41.8 | <0.001 |
| | | G2 | 21.3 | 5.9 | 20.2 | 14.4-37.2 | |
| Dose (mSv) | Subgroup 2 | G1 | 1.2 | 0.2 | 1.2 | 0.7-1.9 | <0.001 |
| | | G2 | 1.8 | 0.3 | 1.7 | 1.0-3.7 | |
| Score | Subgroup 2 | G1 | 1.84 | 0.6 | 2 | 1-3 | 0.034 |
| | | G2 | 2.19 | 0.6 | 2 | 1-3 | |
| AP | Subgroup 3 | G1 | 244.8 | 25.7 | 249.6 | 201.6-282.5 | 0.355 |
| | | G2 | 236.4 | 17.2 | 233.6 | 200.5-269.4 | |
| Lateral (L) | Subgroup 3 | G1 | 358.7 | 19.5 | 360 | 328.5-390.0 | 0.061 |
| | | G2 | 339.6 | 30.1 | 341.6 | 297.0-386.1 | |
| AP+L/2 | Subgroup 3 | G1 | 301.7 | 21.6 | 308.2 | 265.0-336.2 | 0.064 |
| | | G2 | 285.9 | 21.8 | 278.3 | 256.3-325.6 | |
| Noise of aorta | Subgroup 3 | G1 | 29.9 | 6.1 | 29.1 | 18.1-38.3 | 0.004 |
| | | G2 | 23.4 | 5.1 | 21.8 | 16.1-33.4 | |
| Dose (mSv) | Subgroup 3 | G1 | 3.1 | 0.6 | 3 | 2.2-4.1 | 0.685 |
| | | G2 | 3.2 | 0.6 | 3.4 | 1.7-3.8 | |
| Score | Subgroup 3 | G1 | 2.7 | 0.4 | 3 | 2-3 | 0.737 |
| | | G2 | 2.6 | 0.4 | 3 | 2-3 | |

*Independent samples T- Test, AP: Anteroposterior, G1: Group 1, G2: Group 2

**Table 4. The correlation of demographic data and other parameters in Group 1**

| Group(G) | Demographic data | Parameters | r | p |
|---|---|---|---|---|
| **G1** | **Age** | **AP** | **0.344** | **0.002** |
| | | Lateral (L) | 0.338 | 0.003 |
| | | AP+L/2 | 0.367 | 0.001 |
| | | Noise of aorta | 0.092 | 0.427 |
| | | Dose mSv | 0.107 | 0.359 |
| | | Score | 0.069 | 0.551 |
| **G1** | Weight | AP | 0.625 | <0.001 |
| | | Lateral (L) | 0.646 | <0.001 |
| | | AP+L/2 | 0.686 | <0.001 |
| | | Noise of aorta | 0.298 | 0.009 |
| | | Dose mSv | 0.802 | <0.001 |
| | | Score | 0.444 | <0.001 |
| **G1** | Height | AP | 0.065 | 0.580 |
| | | Lateral (L) | -0.086 | 0.460 |
| | | AP+L/2 | -0.054 | 0.641 |
| | | Noise of aorta | -0.160 | 0.167 |
| | | Dose mSv | 0.128 | 0.270 |
| | | Score | 0.139 | 0.233 |
| G1 | BMI | AP | 0.578 | <0.001 |
| | | Lateral (L) | 0.745 | <0.001 |
| | | AP+L/2 | 0.752 | <0.001 |
| | | Noise of aorta | 0.448 | <0.001 |
| | | Dose mSv | 0.739 | <0.001 |
| | | Score | 0.324 | 0.004 |
| G1 | NC | AP | .481** | <0.001 |
| | | Lateral (L) | .561** | <0.001 |
| | | AP+L/2 | .572** | <0.001 |
| | | Noise of aorta | 0.357 | 0.002 |
| | | Dose mSv | 0.836 | <0.001 |
| | | Score | 0.430 | <0.001 |

**AP: Anteroposterior, BMI: Body mass index, NC: Neck circumference**

Table 5. The correlation of demographic data and other parameters in Group 2

| Group(G) | Demographic data | Parameters | r | p |
|---|---|---|---|---|
| **G2** | **Age** | **AP** | **0.203** | **0.059** |
| | | Lateral (L) | 0.380 | <0.001 |
| | | AP+L/2 | 0.341 | 0.001 |
| | | Noise of aorta | 0.263 | 0.014 |
| | | Dose mSv | 0.092 | 0.399 |
| | | Score | 0.013 | 0.903 |
| **G2** | Weight | AP | 0.780 | <0.001 |
| | | Lateral (L) | 0.687 | <0.001 |
| | | AP+L/2 | 0.774 | <0.001 |
| | | Noise of aorta | 0.381 | <0.001 |
| | | Dose mSv | 0.653 | <0.001 |
| | | Score | 0.145 | 0.181 |
| **G2** | Height | AP | 0.088 | 0.419 |
| | | Lateral (L) | -0.130 | 0.229 |
| | | AP+L/2 | -0.023 | 0.835 |
| | | Noise of aorta | -0.311 | 0.003 |
| | | Dose mSv | 0.140 | 0.195 |
| | | Score | 0.203 | 0.059 |
| G2 | BMI | AP | 0.693 | <0.001 |
| | | Lateral (L) | 0.741 | <0.001 |
| | | AP+L/2 | 0.757 | <0.001 |
| | | Noise of aorta | 0.557 | <0.001 |
| | | Dose mSv | 0.544 | <0.001 |
| | | Score | 0.007 | 0.948 |
| G2 | NC | AP | 0.587 | <0.001 |
| | | Lateral (L) | 0.454 | <0.001 |
| | | AP+L/2 | 0.515 | <0.001 |
| | | Noise of aorta | 0.159 | 0.140 |
| | | Dose mSv | 0.820 | <0.001 |
| | | Score | 0.269 | 0.012 |

AP: Anteroposterior, BMI: Body mass index, NC: Neck circumference

## DISCUSSION

CT imaging with inadequate dose can cause undesirable consequences, such as noise and non-diagnostic images (5). Noise emerging in radiology is an undesired effect that creates a fuzzy image of poor quality. The principle in X-ray imaging is to get an image of the best quality with the lowest possible ED and lowest possible noise (8). In our study lower ED, but in turn higher noise and poor-quality image in Group 1 yielded an undesired result. We attributed this result to an insufficient exposure or to be an anthropometric parameter of the NC that might have not reflected the thorax region.

Most of the studies investigating individual specific dose administration to avoid unnecessary radiation are about CT coronary angiography (10, 11). Previous research reports that the most appropriate parameter reflecting the thorax region is thorax circumference and diameter (12, 13). Ghoshhajra et al. report that patients receive 27.4% more dose when cardiac CT tube voltage (kV) is planned on the basis of BMI (12). Li et al. reported that the correlation between BMI and image noise was weak when compared to thorax circumference (13). BMI did not reflect the body shape, but defined the general fat and muscle mass. It is reported that the thorax circumference reflects more accurately than BMI. In patients with central obesity and different body shape, it is estimated that overdose will be given if the BMI is taken as basis in the planning of CT exposure. On the other hand, several clinical studies demonstrated that the local visceral fat tissue was rather correlated with physiological or pathological processes when compared with the total fat tissue (BMI) in the body (19). NC measurement shows the amount of subcutaneous fat tissue in the neck; it might be correlated with mediastinal visceral fat tissue. Therefore the NC is used to detect the visceral fat amount in some clinical practices such as the one in coronary heart disease (20).

In our study we found a medium correlation between the thorax parameters of AP, L, AP+L/2, and NC. Unlike the literature, the correlation between BMI and thorax parameters was higher than the NC. We concluded that the higher consistency of BMI with thorax parameters compared with NC could be attributed to our patient profile mainly comprised of younger and men patients. The fact that our patients had relatively lower fat tissue at the abdomen and waist might have led to a consistent correlation between BMI and thorax parameters.

Our second result, the aortic noise associated with image quality indicated moderate to high correlation with BMI and moderate correlation with NC. A similar condition was seen in the study of Li et al. , and correlation between chest circumference length (measurement was made based on image) and aorta noise was highest; on the other hand, the correlation between the manually measured chest circumference value and aorta noise was defined as weak. Similarly, in our study, the NC measurement is more practical but it is measured manually by the technician. The measurements made over image like scout image could be more accurate and practical than manual (13).

Our study has shown that NC is not a suitable parameter to show the thorax region when compared with BMI.

The limitations of our study were the patient profile consisting mainly of younger and men patients and an insufficient number of patients.

## CONCLUSION

Even though some clinical studies argue that neck circumference reflects the thorax fat tissue, our study concludes that it is not a suitable anthropometric parameter in designing an individual-specific dose protocol for thorax CT.

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