Open Journal of Emergency Medicine, 2023, 11, 115-125
https://www.scirp.org/journal/ojem
ISSN Online: 2332-1814
ISSN Print: 2332-1806

BMI-Adjusted Tube Current in Chest CT and Comparison of Lifetime Attributable Risk (LAR) of Breast Cancer in Two Different BMI-Based Protocols

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How to cite this paper: Akhtari, A.S., Heidariaghdam, B., Vahid, F., Oloumi, A., Gachkar, L., Taghizadeh, M. and Mousavipaak, S.H. (2023) BMI-Adjusted Tube Current in Chest CT and Comparison of Lifetime Attributable Risk (LAR) of Breast Cancer in Two Different BMI-Based Protocols. *Open Journal of Emergency Medicine*, **11**, 115-125.
https://doi.org/10.4236/ojem.2023.113013

Received: July 10, 2023
Accepted: September 22, 2023
Published: September 25, *2023**

Abstract

Possible strategies to reduce radiation dose during CT scanning have been investigated over recent decades; here the optimization of the tube current and its link with patient's cancer incidence are being evaluated. 154 consecutive trauma patients with the need for chest CT scan were included. Two different BMI-adjusted CT protocols at a fixed voltage tube and the same scan length were applied. Dose estimation parameters like CT dose index (CTDI), dose length product (DLP) and effective breast dose were calculated. Breast surface dose was obtained by using thermoluminescence dosimeters (TLDs) and eventually, the life attributable risk (LAR) of cancer incidence was estimated. The mean effective dose was 4.87 ± 2.3 mSv and 5.12 ± 2.8 mSv for patients who were scanned with tube currents of 120 mAs and 200 mAs, respectively. There was no significant difference between organ surface doses for females but in males it was notable. The risk of cancer incidence is lower for protocol 1 in comparison with protocol 2. Optimizing tube current of 120 mAs reduced breast surface dose up to 50% in comparison with the tube current of 200 mAs. In trauma patients, using lower tube current based on BMI has notable impact on the absorbed dose in the breast and can reduce the breast cancer risk by nearly 33.6% for women.

Keywords

Radiation Dose, Trauma Patients, Cancer Risk

1. Introduction

Multi-detector computed tomography (MDCT) benefits from multiple rows of CT detectors, while single-detector computed tomography (SDCT) has only one row of CT detectors. Due to the multiple rows of detectors and spiral scanning, MDCT technology offers higher spatial resolution along the longitudinal axis of the patient, greater coverage per rotation, faster scan time, faster patient throughput and thinner slices in comparison with SDCT scanners. Apart from the advantages of MDCT, there has been a concern about the higher radiation exposure in certain MDCT practices. In trauma patients, particularly in polytrauma cases, shorter scanning time can be a determining factor to make an early and accurate diagnosis of the injuries [1] [2]. According to Advanced Trauma Life Support guidelines, the chest imaging (chest radiography and chest computed tomography) is the most widely used imaging technique for the evaluation of adult patients with blunt trauma [3]. As mentioned before, despite diagnostic improvements, ionizing radiation doses can have undesirable effects on the exposed organs of patients. The radiation dose and its hazardous effects can be measured using different methods, while it is still challenging to measure radiation dose outcomes and decrease them during medical imaging procedures [4].

During the last decades, practical recommendations with respect to dose saving such as lowering tube voltage, modulation of tube current, adjustment of tube voltage, improving detection system efficiency and noise reduction algorithms have been introduced and evaluated by many reports [5]-[9]. Although the mentioned strategies are the most feasible dose reduction approaches, changing CT parameters like tube current and tube voltage has a direct impact on image quality. Therefore, optimizing tube current and tube voltage according to body type not only reduces radiation dose but also can keep diagnostic image quality. Some studies have reported that using automatic tube current modulation reduced the dose significantly [10]-[13]. The most typical calculation method is the determination of the effective dose (ED) using the measured dose of the CT console. However, *in vivo* dosimetry during the examination can estimate dose of exposed organs more accurately. Moreover, the estimation of LAR of cancer incidence and mortality using accurate organ dose value can result in improvements in dose saving protocols.

The main aim of this study was to evaluate the impact of changing tube current based on BMI on the breast surface dose during chest CT of traumatic patients.

Moreover, with respect to ionizing radiation-induced effects, LAR of cancer incidence and mortality were calculated utilizing BEIR VII report [14] and, ultimately, we assessed the importance of *in vivo* dosimetry to improve dose saving protocols in case of emergency patients.

2. Materials and Methods

2.1. Patients

In this study, we included all adult patients (≥18 years old). A total of 154 trauma patients attending emergency department at Loghman Hakim Hospital (Tehran, Iran) were enrolled from June to August 2021. Informed consent was obtained in all cases prior to the study. The height, weight, age and BMI were collected for each patient. All patients were examined for chest CT scans. Two different tube currents based on patients' BMI (120 mAs for BMI < 25 kg/m^2 and 200 mAs for BMI ≥ 25 kg/m^2) were used. The fixed tube voltage of 120 kVp was implemented and the scan length was the same. Radiation dose values called computed tomography dose index (CTDI) and dose length product (DLP) were derived from the CT console. Effective dose of the breast was calculated using chest conversion factor. Ten calibrated thermoluminescence dosimeters (TLDs) were placed on patient's breasts and the average of dosimeters' read-out was calculated to obtain breast surface dose. The radiation dose was used to estimate life attributable risk (LAR) of cancer incidence based on biological effects of ionizing radiation. We used the STROBE cross sectional reporting guidelines [15].

2.2. CT Protocol

All CT scans were performed with 16-slice CT scanner (Activion Toshiba, Japan) in emergency care department. The contrast agents were not used in all scans. Patients were examined via two different protocols based on patient's BMI as follows: pitch factor was set to 1, slice thickness was 2.5 mm, tube voltage was 120 kVp, slice collimation was 1.2 mm and slice interval was 1.5 mm. In protocol 1, the tube current was adjusted to 120 mAs and in protocol 2 was 200 mAs for BMI < 25 kg/m^2 and BMI ≥ 25 kg/m^2, respectively. The scanning range in chest CT was from the upper end of the lung apex to the base of the lungs.

2.3. Radiation Dose

Dose length product (DLP) and volumetric CT dose index ($CTDI_{vol}$) were obtained from each scan. Effective radiation dose was calculated by multiplying DLP by chest conversion factor based on the International Commission of Radiation Protection (ICRP103) report [11] [12]. The dose value of chest was measured by placing 10 thermoluminescence dosimeters (TLD) on patient's breasts; five TLDs on each breast were put. We used TLD-100 and all TLDs were calibrated at Secondary Standard Dosimetry Laboratory (SSDL), Karaj, Iran. After each scan, all TLDs were delivered to dosimetry laboratory at Shahid Beheshti University of Medical Sciences and were read by Fimel TLD reader. The average of five readings was obtained and used to calculate surface dose values. We calculated equivalent dose by multiplying the averaged TLDs' value by the breast tissue weighting factor (Wt = 0.12) based on ICRP 103.

2.4. Life Attributable Risk Estimation

The BEIR VII report provides a method that estimates LAR of cancer based on the radiation dose and a patient's age specified for each gender separately. For all patients, the LAR of breast cancer incidence was calculated from BEIR VII report.

2.5. Statistical Analysis

All statistical analyses were performed using SPSS software (16.0, SPSS Inc., USA). Our data showed a normal distribution. Continuous variables (normally distributed) were presented with mean ± standard deviation (mean ± SD). We used One-way analysis of variance (ANOVA) and one sample t-test to evaluate the possible differences between the two protocols. P value < 0.05 is considered statistically significant.

3. Results

A total of 154 patients (70 female/84 male) were examined in this study with a mean age of 50 ± 17 years old. The average age was 47.3 ± 14.1 for women and 52.7 ± 15.1 for men. Patients' demographic data and radiation dose values are presented in **Table 1** and **Table 2** respectively. LAR of breast cancer for two groups of people was presented in **Table 3**. **Figure 1** and **Figure 2** illustrate the comparison of mean radiation dose values between two protocols for males and females, separately.

There were no significant differences between two protocols for scan time and scan length (p-value 0.063 and 0.845, respectively). The mean BMI was 22.3 ± 2.7 and 27.6 ± 3.03 for protocol 1 and protocol 2, correspondingly. The value of radiation dose shows that the mean CTDI and the effective dose are slightly higher using tube current of 200 mAs in comparison with 120 mAs. Furthermore, the organ surface dose presents notable difference between two protocols. As can be seen in **Table 2** the organ surface dose is nearly doubled in protocol 2. In addition, the same trend was observed between two protocols for males while for females there was no obvious difference. (P-value = 0.001 and 0.359 for

Table 1. Patient demographic data.

	protocol 1 (mean ± SD)	protocol 2 (mean ± SD)	p-value
patient number	78	76	N/A
Age (Y)	48 ± 16	49 ± 19	0.49
BMI (kg/m^2)	22.3 ± 2.7	27.6 ± 3.03	N/A
Scan length (mm)	275.3 ± 15.4	274.5 ± 14.4	0.845
Scan Time (s)	16.1 ± 2.2	14.38 ± 2.24	0.063

SD, standard deviation; BMI, body mass index.

Table 2. Radiation dose values for two tube currents of 100 mAs and 200 mAs.

	protocol 1 (mean ± SD)	protocol 2 (mean ± SD)	p-value
CTDI (mGy)	12.4 ± 5.1	16.3 ± 7.8	0.11
DLP (mGy·cm)	297.4 ± 129.7	350.37 ± 126.8	0.533
ED (mSv)	4.87 ± 2.3	5.12 ± 2.8	0.533
Breast surface dose (mSv)			
left	9.41 ± 0.6	23.8 ± 1.2	0.027
right	10 ± 0.4	24.08 ± 0.7	0.026

SD, standard deviation; CTDI, computed tomography dose index; DLP, dose length product; ED, effective dose.

Table 3. LAR of cancer incidence.

	LAR of Breast cancer incidence		p-value
Age (Y)	protocol 1	protocol 2	
51 - 60	0.791	1.19	0.023
61 - 70	0.425	0.689	0.048

LAR, life attributable risk.

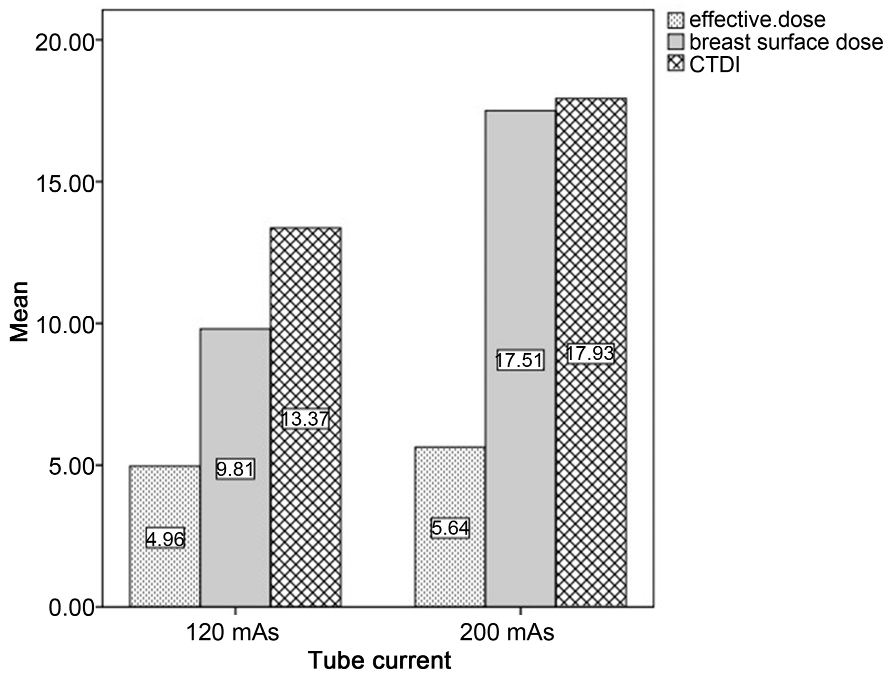

Figure 1. Radiation dose values-males.

males and females, respectively).

LAR of cancer incidence was lower for protocol 1 in comparison with protocol 2. This reduction was more noticeable for the age range from 51 to 60 years.

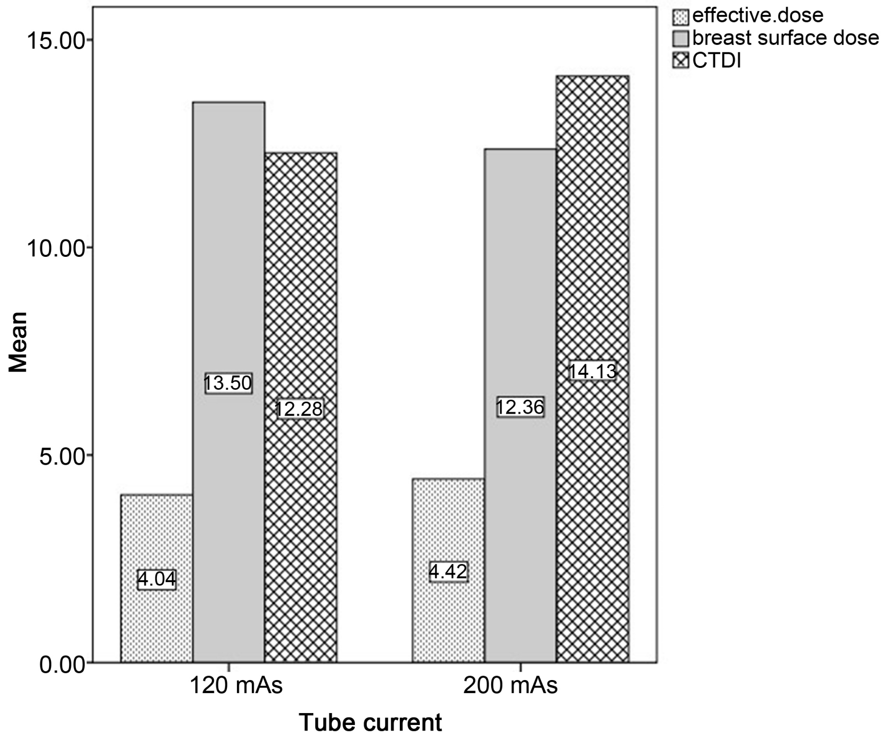

Figure 2. Radiation dose values-females.

4. Discussion

In recent years, attention has been focused on the biological effects of low-dose radiation induced by diagnostic imaging. As each person may have to receive radiation doses from different medical examinations through the life span, it is essential to keep radiation as low as reasonably achievable (ALARA) in medical imaging.

Multislice CT scanners, especially new generations (like Dual sources), are capable of capturing the specific organ at higher resolution and faster scan time. Many studies have reported the impact of new scanners on reducing radiation dose [16] [17] [18] [19]. Although new CT systems have automatic adjustment of parameters, medical imaging needs some methodological techniques that are more beneficial to different CT generations as a whole [20]. Several recent studies reported the dose reduction of up to 60% by tube current modulation [8] [21] [22]. In this study, we used two different tube currents based on the patient's BMI. Our result showed the effective dose was reduced approximately 10% when using tube current of 120 mAs. In Eller *et al.* study, they used automatic tube voltage adaptation (ranging from 80 to 100 kV) and consequently, the effective dose was lower compared with our study. They provided evidence for a 47% radiation dose reduction in patients examined at 80 kV with a 128-dual source CT. Different CT scanner models and similar but non-identical settings including tube current modulation and tube voltage adaptation combined with different iterative reconstruction algorithms may result in higher ED levels in our study [23].

In addition to ED; CTDI and DLP are two standard methods to compare radiation dose values among different CT scanners. Kidoh *et al*. [24] reported that much higher CTDI level in comparison with our study. The reason can be the different CT systems and also higher tube current which resulted in increasing CT dose index in their study.

Besides these comparable parameters, many studies tend to estimate and evaluate the specific organ dose during CT scanning by using anthropomorphic phantoms and by placing physical dosimeters on them [25] [26] [27]. In our study, we placed TLDs on patient's breasts to estimate the organ surface dose. As we expected the organ surface dose was much higher for protocol 2 in comparison with protocol 1. Since scan length and tube voltage were equal in the two protocols, we anticipate that different tube currents may cause dose reduction in protocol 1. This reduction was obviously can be seen in cancer risk estimation which is lower for protocol 1. Thus, we can anticipate that using this protocol not only reduces radiation dose for different age groups, but also can reduce the risk of breast cancer incidence for patients scanned with protocol 1. By decreasing tube current based on body mass index, lower radiation absorbed dose was obtained and the diagnostic image quality has also remained. In comparison with similar study, the breast surface dose was much lower in our study while both techniques were the same (nearly half of their report) [26]. It should be noted that in our study slice thickness and pitch factor were lower than in their study. Another investigation showed that the organ surface dose for chest CT is 22 mSv, their result is approximately similar to the amount of organ surface dose we derived and calculated from TLDs output in this study [5].

Earlier studies demonstrated that the incorporation of body size measures like height, weight, body circumference and body diameter into clinical imaging practice could be useful in order to optimize organ dose [28] [29] [30]. Hence, apart from the tube current modulation, modifying CT scan parameters based on size-specific dose estimate (SSDE) as the other effective dose reduction technique was reported by different research groups [24] [31] [32]. According to Bashier *et al*., there has been a relationship between CT dose and patient dimensions measured from scout and transverse CT images [31]. It has also been reported that reducing body size, about 4 cm, reduced radiation dose by up to 50% [33].

Higher values of dosimetric parameters including CTDI, ED and DLP were presented in a study conducted by Fujii and their colleagues due to their greater scan length in comparison with the present study. They applied the scan length of 300 mm which was greater than the scan length of our study which varied between 274 - 276 mm. On the other hand, they used Care Dose technique with a 64-slice CT scanner that has been equipped with longitudinal and angular tube current modulation [10]. In the present study, we limited scan range as minimum as possible to reduce the radiation dose to the breast and also to prevent unwanted radiation dose exposure to the other radiosensitive organs like the thyroid. The main limitation of this study was that our sample was relatively small. Despite this limitation, the research shed light on the significant dose reduction technique that can have a direct impact on improving patient safety and reducing potential long-term health risks associated with CT imaging.

Future Research Perspective

Implementing personalized CT scanning techniques that take into account factors like radiation reduction with tube current modulation for each case, the number of CT examinations a particular patient underwent during his/her lifetime, the patient's cumulative exposure and estimation of associated radiation-induced cancer risk and individual's clinical history can help physicians make more reasonable risk-benefit decisions in the future. From clinical point of view, this approach becomes even more important when a physician must decide about the necessity of recurrent CT imaging [34].

5. Conclusion

In this study, the feasible approach to reduce radiation dose in chest CT scan in trauma patients was presented. As patients may need to repeat medical imaging, using appropriate and practicable protocols has notable impact on patient dose. We used BMI as an essential factor to optimize tube current in chest CT and we obtained lower radiation dose value during CT scans examination. Optimizing tube current of 120 mAs can reduce breast surface dose by up to 50% in comparison with 200 mAs at the fixed tube voltage of 120 kVp and as a consequence, it could reduce the incidence of breast cancer by 33.6%.

Acknowledgements

The authors would like to thank the Clinical Research Development Unit (CRDU) of Loghman Hakim Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran for their support, cooperation and assistance throughout the research.

Author Contributions

Conceptualization, Amin Shams Akhtari; Data curation, Seyedeh Hedieh Mousavipaak; Fomal analysis, Latif Gachkar; Investigation, Alireza Oloumi; Methodology, Amin Shams Akhtari; Project administration, Babak Heidariaghdam; Resources, Alireza Oloumi; Software, Latif Gachkar; Supervision, Amin Shams Akhtari; Validation, Latif Gachkar and Mehrdad Taghizadeh; Writing-original draft, Alireza Oloumi; Writing-review and editing, Faeze Vahid.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data is unavailable due to ethical restrictions of the Clinical Research De-

velopment Unit (CRDU) of Loghman Hakim Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Cahir, J., Freeman, A. and Courtney, H. (2004) Multislice CT of the Abdomen. *The British Journal of Radiology*, **77**, S64-S73. https://doi.org/10.1259/bjr/31892755

[2] Goldman, L.W. (2008) Principles of CT: Multislice CT. J*ournal of Nuclear Medicine Technology*, **36**, 57-68. https://doi.org/10.2967/jnmt.107.044826

[3] The ATLS Subcommittee, American College of Surgeons' Committee on Trauma, and the International ATLS Working Group (2013) Advanced Trauma Life Support (ATLS®): The Ninth Edition. *Journal of Trauma and Acute Care Surgery*, **74**, 1363-1366. https://doi.org/10.1097/TA.0b013e31828b82f5

[4] Flammia, F., Chiti, G., Trinci, M., Danti, G., Cozzi, D., Grassi, R., Palumbo, P., Bruno, F., Agostini, A. and Fusco, R. (2022) Optimization of CT Protocol in Polytrauma Patients: An Update. *European Review for Medical and Pharmacological Sciences*, **26**, 2543-2555.

[5] Pantos, I., Thalassinou, S., Argentos, S., Kelekis, N.L., Panayiotakis, G. and Efstathopoulos, E.P. (2011) Adult Patient Radiation Doses from Non-Cardiac CT Examinations: A Review of Published Results. *The British Journal of Radiology*, **84**, 293-303. https://doi.org/10.1259/bjr/69070614

[6] Lahham, A., ALMasri, H. and Kameel, S. (2018) Estimation of Female Radiation Doses and Breast Cancer Risk from Chest CT Examinations. *Radiation Protection Dosimetry*, **179**, 303-309. https://doi.org/10.1093/rpd/ncx283

[7] Nazli, S.B., Aghamiri, S.M.R., Gholizadeh Sendani, N. and Shams Akhtari, A. (2017) Evaluation of Radiation Absorbed Dose and Image Quality in Different Retrospective-ECG Gating Acquisition Methods of Cardiac CT Angiography. *Radiation Protection Dosimetry*, **178**, 304-309. https://doi.org/10.1093/rpd/ncx111

[8] Kubo, T., Lin, P.J.P., Stiller, W., Takahashi, M., Kauczor, H.U., Ohno, Y. and Hatabu, H. (2008) Radiation Dose Reduction in Chest CT: A Review. *American Journal of Roentgenology*, **190**, 335-343. https://doi.org/10.2214/AJR.07.2556

[9] Park, H.J., Choi, S.Y., Lee, J.E., Lim, S., Lee, M.H., Yi, B.H., Cha, J.G., Min, J.H., Lee, B. and Jung, Y. (2022) Deep Learning Image Reconstruction Algorithm for Abdominal Multidetector CT at Different Tube Voltages: Assessment of Image Quality and Radiation Dose in a Phantom Study. *European Radiology*, **32**, 3974-3984. https://doi.org/10.1007/s00330-021-08459-8

[10] Fujii, K., Aoyama, T., Yamauchi-Kawaura, C., Koyama, S., Yamauchi, M., Ko, S., Akahane, K. and Nishizawa, K. (2009) Radiation Dose Evaluation in 64-Slice CT Examinations with Adult and Paediatric Anthropomorphic Phantoms. *The British Journal of Radiology*, **82**, 969-e260. https://doi.org/10.1259/bjr/13320880

[11] Papadakis, A.E., Perisinakis, K. and Damilakis, J. (2014) Automatic Exposure Control in CT: The Effect of Patient Size, Anatomical Region and Prescribed Modulation Strength on Tube Current and Image Quality. *European Radiology*, **24**, 2520-2531. https://doi.org/10.1007/s00330-014-3309-4

[12] Lambert, J.W. and Gould, R.G. (2016) Evaluation of a Net Dose-Reducing Organ-Based Tube Current Modulation Technique: Comparison with Standard

Dose and Bismuth-Shielded Acquisitions. *American Journal of Roentgenology*, **206**, 1233-1240. https://doi.org/10.2214/AJR.15.15778

[13] Law, W.Y., Huang, G.L. and Yang, C.C. (2022) Effect of Body Mass Index in Coronary CT Angiography Performed on a 256-Slice Multi-Detector CT Scanner. *Diagnostics*, **12**, Article 319. https://doi.org/10.3390/diagnostics12020319

[14] Council, N.R. (2006) Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. The National Academies Press, Washington DC.

[15] Von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C., Vandenbroucke, J.P. and Initiative, S. (2014) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *International Journal of Surgery*, **12**, 1495-1499. https://doi.org/10.1016/j.ijsu.2014.07.013

[16] Lim, H., Ha, H., Hwang, H. and Lee, K. (2016) Feasibility of High-Pitch Dual-Source Low-Dose Chest CT: Reduction of Radiation and Cardiac Artifacts. *Diagnostic and Interventional Imaging*, **97**, 443-449. https://doi.org/10.1016/j.diii.2016.01.007

[17] De Broucker, T., Pontana, F., Santangelo, T., Faivre, J.B., Tacelli, N., Delannoy-Deken, V., Duhamel, A., Remy, J. and Rémy-Jardin, M. (2012) Single-and Dual-Source Chest CT Protocols: Levels of Radiation Dose in Routine Clinical Practice. *Diagnostic and Interventional Imaging*, **93**, 852-858. https://doi.org/10.1016/j.diii.2012.07.009

[18] Hwang, H.J., Seo, J.B., Lee, J.S., Song, J.W., Kim, S.S., Lee, H.J. and Lim, C.H. (2012) Radiation Dose Reduction of Chest CT with Iterative Reconstruction in Image Space-Part I: Studies on Image Quality Using Dual Source CT. *Korean Journal of Radiology*, **13**, 711-719. https://doi.org/10.3348/kjr.2012.13.6.711

[19] Kim, M.C., Han, D.K., Nam, Y.C., Kim, Y.M. and Yoon, J. (2015) Patient Dose for Computed Tomography Examination: Dose Reference Levels and Effective Doses Based on a National Survey of 2013 in Korea. *Radiation Protection Dosimetry*, **164**, 383-391. https://doi.org/10.1093/rpd/ncu293

[20] Wati, A., Anam, C., Nitasari, A., Syarifudin, S. and Dougherty, G. (2022) Correlations between Body Weight and Size-Specific Dose Estimate on Thoracic Computed Tomography Examination. *Atom Indonesia*, **48**, 61-65. https://doi.org/10.17146/aij.2022.1114

[21] Martin, C. and Sookpeng, S. (2016) Setting up Computed Tomography Automatic Tube Current Modulation Systems. *Journal of Radiological Protection*, **36**, R74. https://doi.org/10.1088/0952-4746/36/3/R74

[22] Goo, H.W. (2012) CT Radiation Dose Optimization and Estimation: An Update for Radiologists. *Korean Journal of Radiology*, **13**, 1-11. https://doi.org/10.3348/kjr.2012.13.1.1

[23] Eller, A., Wuest, W., Saake, M., Ellmann, S., Kaemmerer, N., Hammon, M., Janka, R., Uder, M. and May, M.S. (2018) Extent of Simultaneous Radiation Dose and Iodine Reduction at Stable Image Quality in Computed Tomography of the Chest: A Systematic Approach Using Automated Tube Voltage Adaption and Iterative Reconstructions. *Medicine*, **97**, e0388. https://doi.org/10.1097/MD.0000000000010388

[24] Kidoh, M., Utsunomiya, D., Oda, S., Nakaura, T., Funama, Y., Yuki, H., Hirata, K., Namimoto, T., Sakabe, D. and Hatemura, M. (2017) Breast Dose Reduction for Chest CT by Modifying the Scanning Parameters Based on the Pre-Scan Size-Specific Dose Estimate (SSDE). *European Radiology*, **27**, 2267-2274.

https://doi.org/10.1007/s00330-016-4618-6

[25] Chae, I.H., Kim, Y., Lee, S.W., Park, J.E., Shim, S.S. and Lee, J.H. (2014) Standard Chest CT Using Combined Automated Tube Potential Selection and Iterative Reconstruction: Image Quality and Radiation Dose Reduction. *Clinical Imaging*, **38**, 641-647. https://doi.org/10.1016/j.clinimag.2014.04.004

[26] Shdeed, T.A., Nahili, M., Issa, N.A. and Bitar, A. (2016) Study of Absorbed Dose in Important Organs during Helical CT Chest Scan Using MCNP Code and MIRD Phantom. *The Egyptian Journal of Radiology and Nuclear Medicine*, **47**, 1649-1663. https://doi.org/10.1016/j.ejrnm.2016.09.004

[27] Hashim, S., Karim, M., Bakar, K., Sabarudin, A., Chin, A., Saripan, M.I. and Bradley, D.A. (2016) Evaluation of Organ Doses and Specific K Effective Dose of 64-Slice CT Thorax Examination Using an Adult Anthropomorphic Phantom. *Radiation Physics and Chemistry*, **126**, 14-20. https://doi.org/10.1016/j.radphyschem.2016.05.004

[28] O'Neill, S., Kavanagh, R.G., Carey, B.W., Moore, N., Maher, M. and O'Connor, O.J. (2018) Using Body Mass Index to Estimate Individualised Patient Radiation Dose in Abdominal Computed Tomography. *European Radiology Experimental*, **2**, Article No. 38. https://doi.org/10.1186/s41747-018-0070-5

[29] Alikhani, B., Getzin, T., Kaireit, T.F., Ringe, K.I., Jamali, L., Wacker, F., Werncke, T. and Raatschen, H.J. (2018) Correlation of Size-Dependent Conversion Factor and Body-Mass-Index Using Size-Specific Dose Estimates Formalism in CT Examinations. *European Journal of Radiology*, **100**, 130-134. https://doi.org/10.1016/j.ejrad.2018.01.027

[30] Kleinman, P.L., Strauss, K.J., Zurakowski, D., Buckley, K.S. and Taylor, G.A. (2010) Patient Size Measured on CT Images as a Function of Age at a Tertiary Care Children's Hospital. *American Journal of Roentgenology*, **194**, 1611-1619. https://doi.org/10.2214/AJR.09.3771

[31] Bashier, E.H. and Suliman, I. (2018) Multi-Slice CT Examinations of Adult Patients at Sudanese Hospitals: Radiation Exposure Based on Size-Specific Dose Estimates (SSDE). *La Radiologia Medica*, **123**, 424-431. https://doi.org/10.1007/s11547-018-0859-6

[32] Moore, B.M., Brady, S.L., Mirro, A.E. and Kaufman, R.A. (2014) Size-Specific Dose Estimate (SSDE) Provides a Simple Method to Calculate Organ Dose for Pediatric CT Examinations. *Medical Physics*, **41**, Article ID: 071917. https://doi.org/10.1118/1.4884227

[33] Li, J.L., Liu, H., Huang, M.P., Zhang, Z.L., Liu, H.J., Cui, Y.H., Xue, L. and Liang, C.H. (2014) Potentially Optimal Body Size to Adjust Tube Current for Individualized Radiation Dose Control in Retrospective ECG-Triggered 256-Slice CT Coronary Angiography. *Hellenic Journal of Cardiology*, **55**, 393-401.

[34] Sodickson, A., Baeyens, P.F., Andriole, K.P., Prevedello, L.M., Nawfel, R.D., Hanson, R. and Khorasani, R. (2009) Recurrent CT, Cumulative Radiation Exposure, and Associated Radiation-Induced Cancer Risks from CT of Adults. *Radiology*, **251**, 175-184. https://doi.org/10.1148/radiol.2511081296