Acta Clin Croat 2022; 61:257-264

doi: 10.20471/acc.2022.61.02.12

Original Scientific Paper

EFFICIENCY OF BREAST SHIELDING DEVICE IN OUT-OF-PLANE COMPUTERIZED TOMOGRAPHY IMAGING OF THE ABDOMEN – PRELIMINARY RESULTS

Nikola Ivan Leder[1], Jelena Popić[1], Željka Knežević[2] and Vinko Vidjak[1]

[1]Merkur University Hospital, Zagreb, Croatia;
[2]Ruđer Bošković Institute, Zagreb, Croatia

SUMMARY – The dose absorbed by sensitive breast glandular tissue in abdominal computed tomography examinations, even when the breasts are outside the primary imaging beam, is still significant. Several studies have explored using breast shielding with a protective lead sheet or a bra. Since the source of radiation in computed tomography rotates by 360° around the patient, we made a custom-tailored shielding device that wraps around the entire thorax. The hypothesis is that such a custom-tailored breast shielding device provides significantly better dose reduction. Study participants were female patients with no anatomic anomalies. Entrance surface doses were measured using thermoluminescence dosimeters placed on the skin of the breast in the control group without shielding and on the surface and below the shielding device in the group with anterior shielding and the group with the new device. As expected, according to literature data, doses measured at breast level were above the threshold that epidemiological studies determine as an increased risk of breast cancer development although they were not in the primary imaging plane. Preliminary results of our study showed that average dose reduction was 42% with conventional anterior shielding and 57% with wrapped shielding compared to the doses measured with no shielding.

Key words: *Breast; Multidetector computed tomography; Radiation protection; Radiation dose; Thermoluminescent dosimetry*

Introduction

Rapid development of computerized tomography (CT) made great advances in the quality of diagnostic information over the last couple of decades. The introduction of multi-slice devices, the ability of multiplanar reconstruction, as well as the introduction of automatic contrast medium injectors has enabled multi-phasic imaging, which resulted in a significantly higher quality of diagnostic imaging and consequently in more precise diagnoses. As a result, modern imaging of various pathologic conditions and diseases of the abdominal region, aside from the conventional x-ray imaging and ultrasound scanning, require increasing usage of CT scanning. According to modern diagnostic guidelines, CT imaging is often the first choice method in initial evaluation of several abdominal entities and the first method of choice in the follow up of most oncologic patients[1-6]. However, increasing the quality of diagnostic information has also set a trend of increasing radiation doses in the domain of diagnostic radiology, especially from CT scanning. According to literature data, approximately 50% of the entire population dose by sources of medical radiation is due to CT scanning[7-9].

Correspondence to: *Nikola Ivan Leder, MD,* Merkur University Hospital, Zajčeva 19, HR-10000 Zagreb, Croatia
E-mail: nikola.leder@gmail.com

Received October 6, 2020, accepted January 14, 2021

A large number of literature data are available on the irradiation of tissues and organs within the imaging plane[2-4,10-15]. Numerous techniques and methods are used with the goal of dose reduction, the so-called CT imaging optimization techniques. By modulating the x-ray tube current and voltage[4,10,16-20], as well as the application of various software solutions used in image post processing and algorithms such as iterative reconstruction[21-28], it is possible to adjust the imaging technique to the specific diagnostic requirements and anthropometric characteristics of individual patient with reduction of radiation dose to organs and tissues within the primary imaging plane.

Unlike the well-researched dose reduction techniques within the imaging plane, a persisting issue is the dose to the organs and tissues outside the primary imaging plane, when these organs are not of any diagnostic interest, and especially if they are radiosensitive organs and tissues.

According to literature data, the dose absorbed by breast tissue in thoracic imaging when it is within the primary radiation beam ranges from 14 to 89.1 mGy. In different studies, large differences were found in the measured doses between various scanners and different imaging protocols[11,12,29-33]. The absorbed doses measured on the breasts are also higher during imaging other regions of the body, where the breasts are outside the primary imaging beam (out-of-plane). These doses are caused by scatter and secondary radiation and range from 0.15 to 28 mGy[34-39]. As demonstrated by multiple authors, even in out-of-plane imaging, there is still a significant dose to breasts[31,34,35,37,38], even when compared to 1.86 to 3 mGy in a regular mammography examination[40-42]. Literature data show that a dose of 0.01 mGy on the breast tissue of a young, 35-year-old female, increases the risk of breast cancer approximately by 14% compared to the basis risk[14]. Therefore, breast dose, even outside the primary imaging beam, is significant and not to be disregarded.

Most of recent literature data demonstrate that the application of anterior breast shielding device is useful for dose reduction. The data showed that the doses measured on the breast surface were lower in both cases, i.e., when the breasts were within the primary beam, as well as when they were out of the plane. Measurements of the effectiveness of breast shielding demonstrated dose reduction by 16.2% to 76%, depending on the protocol used[11,29-35,37,39,43,44]. It is important to note that the application of shielding devices inside the primary imaging beam (i.e., breast shielding in thoracic imaging) inherently reduces the quality of images achieved, due to a significant impact on the visibility of the thoracic structures scanned. When performing in-plane shielding, the shielding device needs to be applied after performing the initial topogram scan to avoid overcompensation by CT automatic tube modulation. This is a problem because it further increases imaging time[31]. Available data on the use of breast shielding when breasts are within the primary imaging beam are contradictory[31,45], which is why breast shielding, when breasts are within the primary imaging beam, has never been included in standard clinical practice.

On the other hand, the role of shielding devices applied to the organs outside the primary imaging beam to absorb scatter and secondary radiation is well established (except for the scatter radiation formed within the patient's body, which we cannot influence with this method nor measure with *in vivo* study)[31,34-39,46,47]. A shielding device used in this way does not influence the quality of the images acquired and does not increase imaging time.

There is a lack of available literature data on the application of breast shielding device in out-of-plane imaging. In all published papers[31,34,35,37,38], research was based on using a shielding device covering breasts only from the front side of the body. Considering the operating technique of a CT scanner where the x-ray tube, as a source of radiation, rotates 360° around the patient's body, the hypothesis in our work was that the application of a shielding device that envelops the entire circumference of the patient's thorax should be significantly more effective. Better results were expected in dose reduction for breasts during abdominal imaging (when breasts are outside the primary imaging plane) as compared with frontal shielding. While reviewing the available literature, the authors did not find any data on using this kind of shielding. As far as the authors are aware, this is the first paper describing the efficiency of a shielding device by wrapping the shielding device around the entire thorax during abdominal CT imaging.

The aim of our work was to test the efficiency of custom-made breast shielding device during CT examination of the abdomen. The doses were measured with thermoluminescence (TL) dosimeters positioned on the surface of the breasts.

Patients and Methods

Patients

Preliminary measurements in this study were performed in 28 patients randomly divided in three groups, as follows: (A) no protection; (B) frontal protection only; and (C) new shielding device enveloping the entire thorax. All study patients had regular appointments for CT imaging of the abdominal region in Merkur University Hospital. The study included female patients older than 18 years. Exclusion criteria were as follows:

- any anatomical anomaly (e.g., mastectomy, previous surgical interventions, severe scoliosis),
- breast implants,
- any foreign bodies in thoracic or abdominal region (e.g., osteosynthetic materials),
- presence of contrast medium within gastrointestinal tract from previous imaging,
- patients with severe clinical status where manipulating with dosimetry would increase the time spent at the radiology department, or enveloping the thorax might cause difficulty breathing or hinder emergency medical procedures in critically ill patients, and
- adverse reactions to contrast medium.

All patients were included in the study after providing their consent by signing the informed consent form and approval from the Merkur University Hospital Ethics Committee and University of Zagreb School of Medicine Ethics Committee.

Materials

The breast shielding device was specifically tailored for this study, with the protection equivalent of a 0.5 mm lead layer, providing shielding in the entire circumference of the thorax (Fig. 1). This lead shielding differs from other devices described in the available literature, as well as from commercially available shielding devices, since they only offer protection to the front of the body. The quality of our custom shielding device was tested at the Department of Medical Physics, Zagreb University Hospital Center, in accordance with the manual for control of lead aprons in diagnostic and interventional radiology, and passed all testing.

Fig. 1. Our custom tailored shielding device.

One important role of the device was also to physically reposition large or ptotic breasts. These breasts were firmly positioned upward, away from the primary imaging plane. Proper use of the device is to firmly adhere to the breasts and thorax and keep the breasts firmly pressed upwards using a thick Velcro pad. In this way, the device itself, as well as the breasts are always outside the primary imaging plane. This prevents interference with automatic tube modulation system of the x-ray tube. In case where the device was marginally included in the primary imaging plane due to increased patient movement after positioning, patients were excluded from the study.

The imaging was performed on a multi-detector, 64 slice CT scanner, Toshiba Aquilion TSX 101A with OptiVantage DH contrast medium power injector system. All imaging was performed with a standard protocol of the Department of Diagnostic and Interventional Radiology, Merkur University Hospital for abdominal and pelvic examination (Table 1). Our standard protocol includes acquisition of two pre-scan topograms, spiral acquisition mode, and automatic tube current modulation. Every acquisition was performed with all 64 detectors (64x0.5 mm). In case of multiphasic studies, dosimetry for this study was done only during the initial, pre-contrast series.

Tissue equivalent TL dosimeters based on LiF: Mg, Ti (TLD-100) were used for entrance surface dose

Table 1. Scan protocol used in the study

Tube voltage (kV)	Standard deviation	Rotation time (s)	Beam collimation (mm)	Image slice thickness (mm)	Pitch
120	10	0.57	64x0.5	3.0	0.828

measurements. The holder of TL dosimeters was dark polyethylene foil without any filter. Control and calibration dosimeters were used for every round of measurement. Calibration dosimeters were packed exactly in the same way as those used for measuring and irradiated at ^{137}Cs source with a dose of 5 mGy expressed as air kerma. Detailed characterization and description of dosimetry system is given in papers by Knežević *et al*. and Miljanić *et al*.[48,49]. From the practical point of view, the dosimeters were numbered and sorted in individual envelopes. Each envelope was unsealed before imaging and contained 8 dosimeters. These were placed at pre-determined locations on the patient (left and right breast, above and below the shielding device, xiphoid, thyroid, eye lens plus the control dosimeter). After usage, the exposed dosimeters were placed back in the envelope, sealed and returned to Ruđer Bošković Institute for analysis.

Dosimeters placed on the breast were at the height of the upper lateral breast quadrant (one on each breast), which is the point of highest density of breast parenchyma. Dosimeters were positioned on the body surface in control group, where the entrance dose with no shielding was measured (today's standard practice), and above and below the shielding device at the same height in other study groups.

One of the well-established dose estimation methods for CT is based on CT dose index and dose length product[50]. This method is using parameters from the CT scanner itself, but can only be used for in-plane dose estimation, so it was not used in our study.

Results

Upon preliminary data collection, the normality of distribution of measured doses was tested with Kolmogorov-Smirnov and Shapiro-Wilks tests. Considering significant scatter of the measured values from normal distribution, data were analyzed with appropriate nonparametric methods (Kruskal Wallis to analyze the significance of differences among the three groups and Mann-Whitney to compare the groups with frontal and enveloping shielding, and for post hoc analysis of the Kruskal Wallis test results).

After review of the acquired images, four participants were excluded from the study due to either pre-existing anatomic anomalies or displacement of the dosimeter because of excessive patient movement during exposure. The preliminary results are shown in Table 2. The doses measured on the breast for each series were in the range of 0.97-17.42 mGy with no shielding, 1.53-13.43 mGy for frontal shielding, and 0.81-7.57 mGy with enveloping shielding (Table 2). The efficiency of dose reduction was analyzed by comparing the measured values for each breast individually.

Table 2. Measured entrance surface dose values according to patient groups

		Min (mGy)	Max (mGy)	M	SD	Med
Group A	Left breast	0.97	17.425	5.778	5.765	2.5625
	Right breast	1.365	14.47	6.349	5.098	4.407
	Xiphoid	9.49	54.25	26.629	15.992	20.79
Group B	Left breast	1.695	13.43	5.285	4.13	3.98
	Right breast	1.535	10.89	4.001	3.177	3.26
	Xiphoid	16.93	57.24	32.782	16.022	28.95
Group C	Left breast	0.865	5.8	2.737	1.7	2.207
	Right breast	0.815	7.57	2.975	2.322	2.37
	Xiphoid	9.955	58.98	28.497	18.117	23.0475

A = no protection; B = frontal protection only; C = new shielding device enveloping the entire thorax; M = mean; SD = standard deviation; Med = median

Discussion

Despite the small sample size, preliminary data confirmed the hypothesis that a significantly greater dose reduction was possible using breast shielding by enveloping the entire thoracic circumference as compared with using only frontal protection. Comparison of the values measured in our study showed a 23% dose reduction on average when using frontal shielding and 53% when using enveloping protection. To reduce the impact of variation in anthropometric characteristics and differences in imaging protocols, we can also display the values of dose reduction by the ratio of dose measured with dosimeter placed on the breast and the one placed on the xiphoid process of the sternum, which is always within the primary imaging plane. By this analysis, we recorded a 42% dose reduction when applying only frontal shielding device and 57% when using enveloping shielding device. These results are in accordance with the available literature data which demonstrate a 26%-50% entrance skin dose reduction with breast shielding during abdominal CT scans[31,37], as well as an average 50% dose reduction during abdominal fluoroscopic examinations[38]. When performing out-of-plane breast shielding during CT examination of the head, the dose reduction ranges from 33.5% to 76%[34,35,37].

As previously stated, these are preliminary findings based on a very small sample study that was performed to test our hypothesis and calculate an adequate sample size. We analyzed data in this pilot study with the NCSS/PASS (PASS 11. NCSS, LLC, Kaysville, Utah, USA; www.ncss.com) software package. By using the methodology described by Machin *et al.* and Zar[51,52], with 90% power (1-β) and a statistical significance level (α) of 0.05, the required sample size is 21 patients *per* group. By observing the less favorable case at the right breast, where the average values are closer together and standard deviation larger, using the identical methodology the required sample size is 28 patients (Fig. 2).

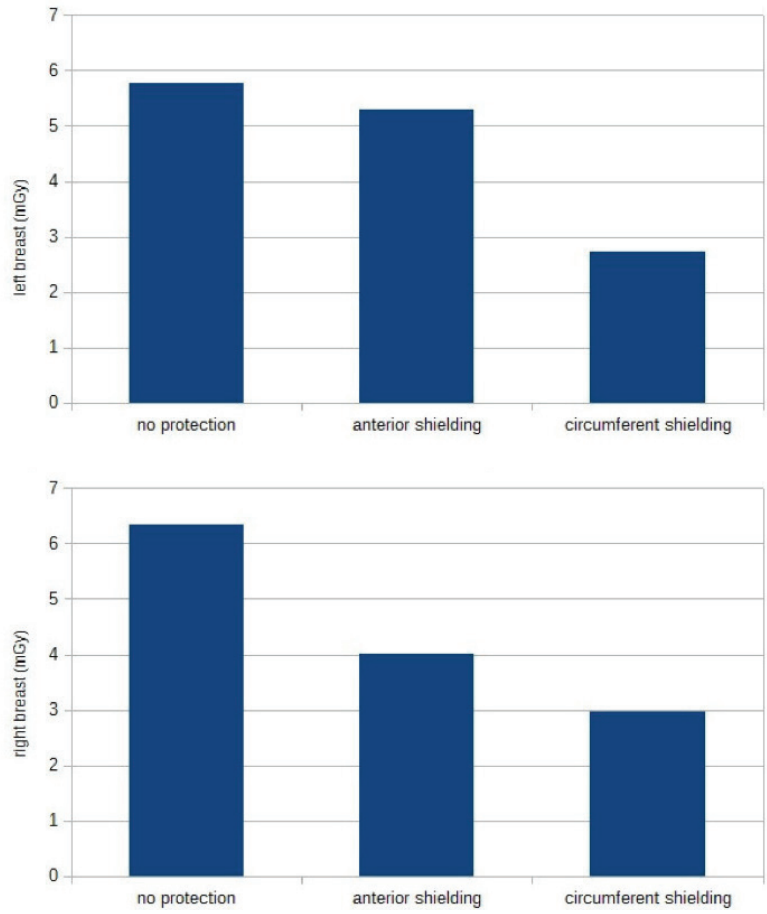

Fig. 2. Average entrance surface dose values according to patient groups.

Limitations of the study were as follows: all measurements were performed on one CT scanner at a single institution and patients were not allocated to particular groups according to their anthropometric characteristics (body mass index, breast size, breast glandular percentage), which leaves options for further studies. This study did not take into account whether the source of radiation to the breast was from the patient's body or from outside the body, which we are investigating *in vitro* by measurements on anthropomorphic phantoms.

Conclusion

Preliminary study results confirmed the hypothesis that using a new custom-made breast shielding device wrapping around the entire thorax significantly reduced radiation dose to the breast tissue during abdominal (out-of-plane) imaging. Dose reduction is significant even when the breasts are completely outside the primary imaging plane. As our initial measurements confirmed the hypothesis, we are continuing this study on a larger sample size.

References

1. Amis ES, Butler PF, Applegate KE, Birnbaum SB, Brateman LF, Hevezi JM, *et al*. American College of Radiology White Paper on Radiation Dose in Medicine. J Am Coll Radiol [Internet]. 2007 May;4(5):272-84. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1546144007001081 DOI: 10.1016/j.jacr.2007.03.002
2. Jarry G, DeMarco JJ, Beifuss U, Cagnon CH, McNitt-Gray MF. A Monte Carlo-based method to estimate radiation dose from spiral CT: from phantom testing to patient-specific models. Phys Med Biol [Internet]. 2003 Aug 21;48(16):2645-63. Available from: https://iopscience.iop.org/article/10.1088/0031-9155/48/16/306 DOI: 10.1088/0031-9155/48/16/306
3. ICRP. ICRP PUBLICATION 87: Managing patient dose in computed tomography. Ann ICRP. 2000;30(4):7-. DOI: 10.6009/jjrt.kj00000922565
4. ICRP. ICRP PUBLICATION 102: Managing patient dose in multi-detector computed tomography (MDCT). Ann ICRP. 2007;37(1). DOI: 10.1016/j.icrp.2007.09.001
5. Smith-Bindman R, Miglioretti DL, Larson EB. Rising use of diagnostic medical imaging in a large integrated health system. Health Aff. 2008 Nov;27(6):1491-502. DOI: 10.1377/hlthaff.27.6.1491
6. Brenner DJ, Hricak H. Radiation exposure from medical imaging: time to regulate? JAMA. 2010;304:208. DOI: 10.1001/jama.2010.973
7. UNSCEAR 2000 report. Sources and effects of ionizing radiation [Internet]. Vol. I. [cited 2017 Jul 20]. Available from: https://www.unscear.org/unscear/en/publications/2000_2.html DOI: 10.1088/0952-4746/21/1/609
8. Thomton FJ, Paulson EK, Yoshizumi TT, Frush DP, Nelson RC. Single *versus* multi-detector row CT: comparison of radiation doses and dose profiles. Acad Radiol. 2003;10(4):379-85. DOI: 10.1016/s1076-6332(03)80026-0
9. Mettler FA, Bhargavan M, Faulkner K, Gilley DB, Gray JE, Ibbott GS, *et al*. Radiologic and nuclear medicine studies in the United States and worldwide: frequency, radiation dose, and comparison with other radiation sources – 1950-2007. Radiology. 2009 Nov;253(2):520-31. DOI: 10.1148/radiol.2532082010
10. Mehnati P, Ghavami M, Heidari H. Reducing radiation doses in female breast and lung during CT examinations of thorax: a new technique in two scanners. J Biomed Phys Eng [Internet]. 2017 Sep [cited 2019 Sep 20];7(3):217-24. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29082213
11. Yilmaz MH, Albayram S, Ya?ar D, Ozer H, Adaletli I, Selcuk D, *et al*. Female breast radiation exposure during thorax multidetector computed tomography and the effectiveness of bismuth breast shield to reduce breast radiation dose. J Comput Assist Tomogr. 2007;31(1):138-42. DOI: 10.1097/01.rct.0000235070.50055.e6
12. Parker MS, Hui FK, Camacho MA, Chung JK, Broga DW, Sethi NN. Female breast radiation exposure during CT pulmonary angiography. Am J Roentgenol. 2005;185(5):1228-33. DOI: 10.2214/AJR.04.0770
13. Franck C, Smeets P, Lapeire L, Achten E, Bacher K. Estimating the patient-specific dose to the thyroid and breasts and overall risk in chest CT when using organ-based tube current modulation. Radiology. 2018 Jul 1;288(1):164-9. DOI: 10.1148/radiol.2018170757
14. Remy-Jardin M, Remy J. Spiral CT angiography of the pulmonary circulation. Radiology. 1999;212(3):615-36. DOI: 10.1148/radiology.212.3.r99se02615
15. Costello JE, Cecava ND, Tucker JE, Bau JL. CT radiation dose: current controversies and dose reduction strategies. AJR Am J Roentgenol. 2013;201(6):1283-90.
16. Ramac JP, Knezevic Z, Hebrang A, Kristo DR, Vidjak V, Slavica M, *et al*. Radiation dose reduction by using low dose CT protocol of thorax. Radiat Meas. 2013;55(0):46-50. DOI: http://dx.doi.org/10.1016/j.radmeas.2012.07.012
17. Lee CH, Goo JM, Ye HJ, Ye SJ, Park CM, Chun EJ, *et al*. Radiation dose modulation techniques in the multidetector CT era: from basics to practice. Radiographics. 2008;28(5):1451-9. DOI: 10.1148/rg.285075075
18. Zhao YX, Zuo ZW, Suo HN, Wang JN, Chang J. A comparison of the image quality and radiation dose using 100-kVp combination of different noise index and 120-kVp in computed tomography pulmonary angiography. J Comput Assist Tomogr. 2016;40(5). DOI: 10.1097/RCT.0000000000000488
19. Fu W, Tian X, Sturgeon GM, Agasthya G, Segars WP, Goodsitt MM, *et al*. CT breast dose reduction with the use of breast positioning and organ-based tube current modulation. Med Phys. 2017;44(2). DOI: 10.1002/mp.12076
20. Franck C, Smeets P, Lapeire L, Achten E, Bacher K. Estimating the patient-specific dose to the thyroid and breasts and overall risk in chest CT when using organ-based tube current modulation. Radiology. 2018;288(1). DOI: 10.1148/radiol.2018170757
21. Hara AK, Wellnitz CV, Paden RG, Pavlicek W, Sahani DV. Reducing body CT radiation dose: beyond just changing the

numbers. AJR Am J Roentgenol. 2013;201(1):33-40. DOI: 10.2214/AJR.13.10556

22. Litmanovich DE, Tack DM, Shahrzad M, Bankier AA. Dose reduction in cardiothoracic CT: review of currently available methods. Radiographics. 2014;34(6):1469-89. DOI: 10.1148/rg.346140084
23. Sodickson A. Strategies for reducing radiation exposure in multi-detector row CT. Radiol Clin North Am. 2012;50(1):1-14.
24. Smith EA, Dillman JR, Goodsitt MM, Christodoulou EG, Keshavarzi N, Strouse PJ. Model-based iterative reconstruction: effect on patient radiation dose and image quality in pediatric body CT. Radiology. 2014 Feb;270(2):526-34. DOI: 10.1148/radiol.13130362
25. Raman SP, Johnson PT, Deshmukh S, Mahesh M, Grant KL, Fishman EK. CT dose reduction applications: available tools on the latest generation of CT scanners [Internet]. J Am Coll Radiol. 2013 Jan;10(1):37-41. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23290672 DOI: 10.1016/j.jacr.2012.06.025
26. Sauter A, Koehler T, Brendel B, Aichele J, Neumann J, Noël PB, *et al*. CT pulmonary angiography: dose reduction *via* a next generation iterative reconstruction algorithm. Acta Radiol. 2018 Apr 1;478-87. DOI: 10.1177/0284185118784976
27. Padole A, Khawaja RDA, Kalra MK, Singh S. CT radiation dose and iterative reconstruction techniques. Am J Roentgenol. 2015;204(4). DOI: 10.2214/AJR.14.13241
28. Nagayama Y, Oda S, Nakaura T, Tsuji A, Urata J, Furusawa M, *et al*. Radiation dose reduction at pediatric CT: use of low tube voltage and iterative reconstruction. Radiographics. 2018;38(5). DOI: 10.1148/rg.2018180041
29. Parker MS, Kelleher NM, Hoots JA, Chung JK, Fatouros PP, Benedict SH. Absorbed radiation dose of the female breast during diagnostic multidetector chest CT and dose reduction with a tungsten-antimony composite breast shield: preliminary results. Clin Radiol. 2008;63(3):278-88. DOI: 10.1016/j.crad.2007.07.029
30. Yilmaz MH, Yaşar D, Albayram S, Adaletli I, Özer H, Ozbayrak M, *et al*. Coronary calcium scoring with MDCT: the radiation dose to the breast and the effectiveness of bismuth breast shield. Eur J Radiol. 2007;61(1):139-43. DOI: 10.1016/j.ejrad.2006.08.012
31. Catuzzo P, Aimonetto S, Fanelli G, Marchisio P, Meloni T, Mistretta L, *et al*. Dose reduction in multislice CT by means of bismuth shields: results of *in vivo* measurements and computed evaluation. Radiol Med. 2010;115(1):152-69. DOI: 10.1007/s11547-009-0469-4
32. Einstein AJ, Elliston CD, Groves DW, Cheng B, Wolff SD, Pearson GD, *et al*. Effect of bismuth breast shielding on radiation dose and image quality in coronary CT angiography. J Nucl Cardiol. 2012;19(1):100-8. DOI: 10.1007/s12350-011-9473-x
33. Colletti PM, Micheli OA, Lee KH. To shield or not to shield: application of bismuth breast shields. AJR Am J Roentgenol. 2013;200(3):503-7. DOI: 10.2214/AJR.12.9997
34. Beaconsfield T, Nicholson R, Thornton A, Al-Kutoubi A. Would thyroid and breast shielding be beneficial in CT of the head? Eur Radiol. 1998;8(4):664-7. DOI: 10.1007/s003300050456
35. Brnić Z, Vekić B, Hebrang A, Anić P, Brnic Z, Vekić B, *et al*. Efficacy of breast shielding during CT of the head. Eur Radiol. 2003;13(11):2436-40. DOI: 10.1007/s00330-003-1945-1
36. Hurwitz LM, Yoshizumi TT, Reiman RE, Paulson EK, Frush DP, Nguyen GT, *et al*. Radiation dose to the female breast from 16-MDCT body protocols. Am J Roentgenol. 2006;186(6):1718-22. DOI: 10.2214/AJR.04.1917
37. Chung JJ, Cho ES, Kang SM, Yu JS, Kim DJ, Kim JH. Usefulness of a lead shielding device for reducing the radiation dose to tissues outside the primary beams during CT. Radiol Med. 2014;119(12):951-7. DOI: 10.1007/s11547-014-0421-0
38. Fordham LA, Brown ED, Washburn D, Clark RL. Efficacy and feasibility of breast shielding during abdominal fluoroscopic examinations. Acad Radiol. 1997;4(9):639-43. DOI: 10.1016/s1076-6332(05)80269-7
39. Gunn ML, Kanal KM, Kolokythas O, Anzai Y. Radiation dose to the thyroid gland and breast from multidetector computed tomography of the cervical spine. J Comput Assist Tomogr. 2009;33(6):987-90. DOI: 10.1097/rct.0b013e3181a776ff
40. Liu B, Goodsitt M, Chan HP. Normalized average glandular dose in magnification mammography. Radiology. 1995;197(1):27-32. DOI: 10.1148/radiology.197.1.7568836
41. Hendrick RE, Pisano ED, Averbukh A, Moran C, Berns EA, Yaffe MJ, *et al*. Comparison of acquisition parameters and breast dose in digital mammography and screen-film mammography in the American College of Radiology imaging network digital mammographic imaging screening trial. AJR Am J Roentgenol. 2010;194(2):362-9. DOI: 10.2214/AJR.08.2114
42. Gennaro G, di Maggio C. Dose comparison between screen/film and full-field digital mammography. Eur Radiol. 2006;16(11):2559-66. DOI: 10.1007/s00330-006-0314-2
43. Wang J, Duan X, Christner JA, Leng S, Yu L, McCollough CH. Radiation dose reduction to the breast in thoracic CT: comparison of bismuth shielding, organ-based tube current modulation, and use of a globally decreased tube current. Med Phys. 2011;38(11):6084-92. DOI: 10.1118/1.3651489
44. Foley SJ, McEntee MF, Rainford LA. An evaluation of in-plane shields during thoracic CT. Radiat Prot Dosimetry. 2013;155(4). DOI: 10.1093/rpd/nct030
45. Geleijns J, Salvado Artells M, Veldkamp WJ, Lopez Tortosa M, Calzado Cantera A. Quantitative assessment of selective in-plane shielding of tissues in computed tomography through evaluation of absorbed dose and image quality. Eur Radiol. 2006;16(10):2334-40.
46. Iball GR, Brettle DS. Organ and effective dose reduction in adult chest CT using abdominal lead shielding. Br J Radiol [Internet]. 2011 Nov [cited 2020 Apr 7];84(1007):1020-6. Available from: www.impactscan.org/ctdosimetry.htm DOI: 10.1259/bjr/53865832
47. Iball GR, Kennedy E V, Brettle DS. Modelling the effect of lead and other materials for shielding of the fetus in CT pulmonary angiography. Br J Radiol [Internet]. 2008 Jun [cited 2020 Apr 7];81(966):499-503. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18487390 DOI: 10.1259/bjr/66819221
48. Miljanić S, Ranogajec-Komor M, Knežević Z, Vekić B. Main dosimetric characteristics of some tissue-equivalent TL detectors. Radiat Prot Dosimetry [Internet]. 2002 [cited 2019 Oct 1];100(1-4):437-42. Available from: http://www.ncbi.nlm.

nih.gov/pubmed/12382916 DOI: 10.1093/oxfordjournals.rpd.a005908

49. Knežević Z, Beck N, Milković D, Miljanić S, Ranogajec-Komor M. Characterisation of RPL and TL dosimetry systems and comparison in medical dosimetry applications. Radiat Meas. 2011;46(12):1582-5. DOI: 10.1016/j.radmeas.2011.05.042
50. Martin CJ. Effective dose: how should it be applied to medical exposures? Br J Radiol. 2007;80(956):639-47. DOI: 10.1259/bjr/25922439
51. Machin D, Campbell MJ, Tan SB, Tan SH. Sample Size Tables for Clinical Studies, 3rd Edition. Malden, MA: Blackwell Science, 2009. DOI: 10.1002/9781444300710
52. Zar JH. Biostatistical Analysis (2nd Edition). Englewood Cliffs, New Jersey: Prentice-Hall, 1984.

Sažetak

UČINKOVITOST ZAŠTITE DOJKE OMATANJEM PRSIŠTA U SLIKOVNOJ DIJAGNOSTICI ABDOMENA KOMPJUTORIZIRANOM TOMOGRAFIJOM

N. I. Leder, J. Popić, Ž. Knežević i *V. Vidjak*

Doza koju apsorbira osjetljivo žljezdano tkivo dojke prilikom pregleda abdomena kompjutoriziranom tomografijom značajna je čak i kad su dojke izvan primarnog polja snimanja. Brojne studije istraživale su primjenu olovne plahte ili „grudnjaka" za zaštitu dojki. S obzirom na to da se izvor zračenja prilikom kompjutorizirane tomografije rotira 360° oko bolesnika izradili smo vlastitu zaštitnu pregaču koja se omata oko cijelog opsega prsišta. Naša hipoteza je da tako skrojena pregača pruža značajno bolju zaštitu. U istraživanje su bile uključene bolesnice bez anatomskih anomalija. Ulazne doze na površini kože mjerene su putem termoluminiscentnih dozimetara koji su postavljeni na kožu dojke u kontrolnoj skupini bez zaštite, na površinu i ispod površine pregače u skupini s prednjom zaštitom i u skupini s novom pregačom. Prema očekivanjima i u skladu s literaturnim podacima, izmjerene doze na razini dojke su bile iznad granice koju epidemiološke studije označuju kao povišeni rizik za razvoj karcinoma dojke, iako su bile izvan primarnog snopa snimanja. Preliminarni rezultati naše studije pokazuju prosječno smanjenje doze uz konvencionalnu prednju zaštitu za 42% te uz obuhvatnu novu pregaču za 57% u usporedbi s dozama izmjerenima bez zaštite.

Ključne riječi: *Dojka; Multi detektorska kompjutorizirana tomografija; Zaštita od zračenja; Doza zračenja; Termoluminiscentna dozimetrija*