http://www.cjmb.org

Open Access | Original Article

Crescent Journal of Medical and Biological Sciences
Vol. 6, No. 1, January 2019, 46–50
eISSN 2148-9696

Breast Conservation From Radiation Damage by Using Nano Bismuth Shields in Chest Computed Tomography Scan

Parinaz Mehnati[1], Mohammad Yousefi Sooteh[1,2*], Reza Malekzadeh[1], Baharak Divband[3,4], Soheila Refahi[5]

Abstract

Objectives: The present study aimed to calculate the efficiency of bismuth nanoparticles shield to protect the breast in chest computed tomography (CT) scan and investigate the alteration of image quality after using the shield.

Materials and Methods: Three groups were included in this experimental research in which phantom was scanned without using nano bismuth shield (group 1), using 0.5 mm nano bismuth shield (group 2), and employing nano bismuth shield with 1 mm thickness (group 3). The polymethyl methacrylate phantom was applied to present the main organ of the chest including the breast and lung. Multi-detector 6-slice CT scan system was utilized for the tests. In addition, the breast radiation dose was measured by ion-chamber which was placed at 12 o'clock position in the phantom according to dosimetry protocol. Further, chest CT image processing was performed once without shield and once in the presence of 10% nano bismuth shield with different thicknesses. Finally, image quality was compared by adding the shield for correct diagnosis. Tests were repeated three time and data were analyzed by ANOVA.

Results: Based on the results, using nano bismuth shields, breast dose reduced by 7.2% and 13.8% for 0.5 and 1 mm thickness of the shield, respectively. Furthermore, the CT number and noise increased from 121.3 to 126.36 HU and from 24.53 to 28.1 HU, respectively. Finally, the dose reduction ratio approximately doubled by increasing the thickness from 0.5 to 1 mm.

Conclusions: Generally, nano bismuth shields have a noticeable potential for reducing the breast dose with the smallest change in the noise.

Keywords: Nano bismuth, Shields, Dose reduction, Chest CT, Image quality

Introduction

Using new materials to protect the radiation, especially in the computed tomography (CT) plays a main role in reducing the dose of sensitive organs such as the breast. With the growing use of CT scans, concerns about the growing population-based dose have increased (1,2). In CT examination of the thoracic, the breast is involved in the examination field and straightly exposed to x-rays. However, it is not the diagnostically relevant organ in the imaging. In the females, radiation protection of the breast is essential for 2 main reasons. The glandular parts of the breasts are more radiosensitive. In addition, the breasts are superficial organs and thus lower energy photons are absorbed in their surface. However, they do not participate in image creation and only raise the breast dose (3-5). The high dose level of the glandular part can increase the risk of breast cancer so that this part receives a dose of 20-60 mGy in CT pulmonary angiography (6). Therefore, it is vital to decrease the dose received by the breast and the risk of breast cancer.

Using protective shields such as bismuth, lead, and tungsten–antimony is one of the effective strategies for reducing the breast dose (7,8). In-plane shields employed for CT scan are distinct from the lead shields which are used in radiographic tests. In conventional shields, the aim is to completely absorb the radiation exposure, however, in in-plane shields, x-rays with low energy are absorbed and high energy beams transmitted to produce a diagnostic image (9). Hopper et al. were the first ones to propose using the bismuth shield for in-plane radiation shield (10). The bismuth shield is normally placed above the breast sensitive organs in order to protect the breast. This shield reduces the radiation dose to the patients by attenuating the photons crossing through the shields (11). Further, the main concern regarding using the bismuth shields is that they be able to introduce image artifacts like beam hardening and increase the CT number values and noise chiefly proximity the shield itself (12). Several studies indicated that dose reduction can be increased by using nanoparticle instead of the microparticle (13,14).

Received 8 February 2018, **Accepted** 19 August 2017, **Available online** 2 October 2018

[1]Department of Medical Physics, School of Medicine, Tabriz University of Medical Sciences, Tabriz, Iran. [2]Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran. [3]Stem Cell Research Center, Tabriz University of Medical Sciences, Tabriz, Iran. [4]Infectious and Tropical Diseases Research Center, Tabriz University of Medical Sciences, Tabriz, Iran. [5]Department of Medical Physics, Faculty of Medicine, Ardabil University of Medical Sciences, Ardabil, Iran
*Corresponding Author: Mohammad Yousefi Sooteh, Tel: +989114124260, Email: myousefisooteh@gmail.com

Similarly, many studies examined using bismuth shields. For example, Alonso et al found that breast dose reduced by 37% at thoracic CT examination utilizing the bismuth shield (15). Furthermore, Noor Azman et al represented that the attenuation coefficient (μ) improves by altering the size of bismuth microparticles to nanoparticles (16). They understood that the attenuation of the bismuth oxide powder (Bi_2O_3) nanoparticles was about 2-3 times higher than that of the microparticles in low tube potential (17).

Covering of the breast by special-made shields such as bismuth shield during the chest CT scan is one important factor for breast cancer prevention. Therefore, this study mainly sought to investigate breast dose reduction by the new composite shields made of bismuth nanoparticles in the chest CT exam, especially for young women by evaluating the image quality potential for medical diagnosis.

Materials and Methods

This is experimental research in basic medical sciences which was approved by the Ethical Committee of Tabriz University of Medical Sciences. In the present study, Bi_2O_3 in nano size was purchased (UF Nano, China, 50 nm) and used for making the shields. Moreover, silicone rubber (density 1.11 g/cm^3 after curing) was used as the matrix material.

The composite shields were prepared by mixing nano Bi_2O_3 and the silicone rubber with 10-90%, respectively in 20×20 cm and 0.5 and 1 mm thickness.

The polymethyl methacrylate (PMMA) phantom was used for the purpose of the study. It is an accepted chest CT phantom for presenting the main organ of the chest including breast, lung, and heart. The special ionization chamber (Model 205-3 CT, Monrovia, USA) was put in the 12 o'clock position of the PMMA phantom (body phantom, 76-419-4150, Fluke Biomedical) in order to measure the breast radiation dose and then the phantom was scanned with Multi-detector 6-slice CT scan system (SOMATOM Emotion, model 03815300, Siemens). The experimental process encompassed three groups in which phantom was scanned with no nano bismuth shield at chest CT scan protocol (group 1), by using 0.5 mm nano bismuth shield (group 2), or nano bismuth shield with 1 mm thickness (group 3). All tests were repeated in triplicate and then dose reduction was measured.

The routine adult chest CT protocols with 110 kVp, 105 mAs, 1.8 pitch, and 5-mm slice thickness were used. Each nano bismuth shield was placed above the phantom by using 1 cm foam.

Additionally, CT number and the standard deviation were employed to calculate the image quality and noise in the region of interests (ROIs) within the area of 3 cm^2 on the PMMA phantom with and without nano bismuth shields. ROIs were defined in anterior, central, and posterior on seven consecutive slices (Figure 1) and all data were analyzed using the SPSS software by one-way ANOVA.

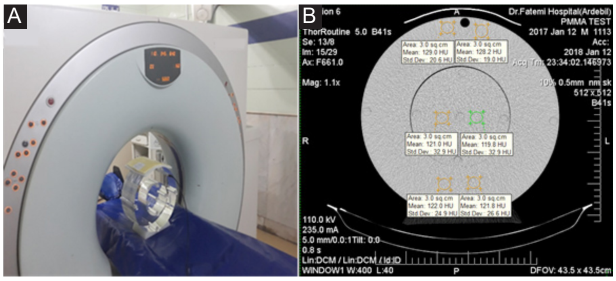

Figure 1. (A) Standard CT phantom covered by nano bismuth shield and 1 cm foam; (B) The image exhibited 3 regions for studying the image quality. In addition, the ROIs were defined in anterior, central, and posterior regions on the shield.

Results

The average breast dose was 8.65 mGy in the position of 12 o'clock without applying nano bismuth shields. After placing the nano shields with 0.5 and 1 mm thickness, the average breast doses reduced to 8.02 and 7.45 mGy. In addition, using these shields induced the breast dose reduction by about 7.2 (0.5 mm) and 13.8% (1 mm), respectively. The details of breast doses are represented in Figure 2 for each group with or without nano bismuth shields.

CT number and noise of the chest CT obtained from different ROIs for 2 thickness of nano bismuth shields are presented in Table 1. Statistical analysis demonstrated a significant difference in the CT number noise between 2 groups, namely, without-shield group and 1-mm shield group. In non-shield type, the mean of CT numbers and noise values were 121.3 and 24.53 HU. After using 0.5 and 1 mm nano bismuth shields, the mean CT numbers and noise raised to 124.5 and 26.23 HU, as well as 126.36 and 28.1 HU, respectively.

Further, the mean noise was 24.53 HU for the group without nano bismuth shield test. However, after applying the 0.5 and 1 mm nano bismuth shields, the mean noise changed to 26.23 and 28.1 HU. Furthermore, the mean

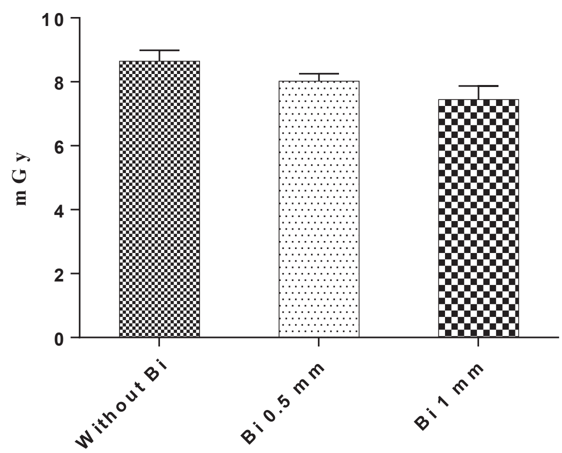

Figure 2. Recorded Dose Values of the Breast in Chest CT Scan With PMMA Phantom with and Without 10% Nano Bismuth.

Table 1. The CT Number and Noise Values for Different ROIs Achieved by CT Images of PMMA Phantom With and Without 10% Nano Bismuth Shields

Shields	Anterior Region		Central Region		Posterior Region		Mean	
	CT Number	Noise	CT Number	Noise	CT Number	Noise	CT Number	Noise
Reference	125.3 ± 2.30	19 ± 0.8	118.9 ± 2.92	32.4 ± 1.34	119.7 ± 2.14	22.4 ± 1.19	121.3	24.53
Bismuth Shield (0.5 mm)	128.5 ± 2.53	19.6 ± 1.0	122.3 ± 3.31	34.8 ± 1.86	122.7 ± 1.24	24.3 ± 1.51	124.5	26.23
Bismuth Shield (1 mm)	130.1 ± 2.33*	21.1 ± 1.4	124.2 ± 2.52*	36.2 ± 2.77*	124.8 ± 2.12*	27.2 ± 2.23*	126.36*	28.1*

Note. The symbol * denotes a significant difference between 1 mm Nano bismuth shield and the reference group.

noise in the central region of the phantom increased from 32.4 HU in the absence of the shield to 34.8 and 36.2 HU in the presence of 0.5 and 1 mm shields (Figure 3). Comparing the mean noise for nano bismuth shields with 0.5 and 1 mm thickness revealed that the value of noise in the anterior area raised to 3% and 11%. As regards the central area, this factor was 7% and 11% for 0.5 and 1 mm thickness. Finally, the value of noise was equal to 6% and 14% for the posterior region compared to the situation with no shield.

Discussion

In this study, a new nano bismuth oxide shield was applied for preserving the breast from cancer risk since it is a sensitive organ for radiation damage during the chest CT scan. Moreover, the result indicated that this new shield had considerable potential for preventing the sensitive organs from ionizing radiation damage in medical imaging. Additionally, the CT scan plays an important role in diagnosing the diseases. In recent decades, concerns regarding the dose which is received by the tissues and the risk for cancer induction through the organs in the image field has increased by an increase in CT scan tests (18).

Recent studies demonstrated that CT scan is responsible for 2% of the cancers in the United States (19). Breast cancer is one of the most common cancers among the Asian females (20) and a study reported that the incidence of cancer in Iranian women has risen from 22 per 100 000 in 2005 to 28 per 100 000 in 2009 (21). With the growing use of multi-detector CT, the possibility of patient dose raising and the increased risk of cancer, especially the breast cancer in women, the matter of radiation protection has gained more significance. In this respect, the lead shield is the normal protecting method. However, this method induces a lot of artifacts in CT image and is not used in CT scan while using bismuth shield, in addition to dose reduction of organ represents an acceptable image quality, especially for superficial tissues such as the breast in chest CT scan (22). One study indicated that by using the bismuth shield for eye shielding during the head CT scans, the dose of the lens reduced from 21 to 29% with no negative influence on the image quality (23).

A number of researchers compared the use of micro and nanoparticles in radiation protection and their efficacy in dose reduction and found that nanoparticles had a higher ability to absorb the radiation dose (24, 25). In the current study, employing nano bismuth shields with 0.5 mm thickness (10%) in the CT scan of the chest, the dose reduction for the breast was 7.2% while using 1 mm nano bismuth shield, dose reduction increased to 13.8%. In addition, image quality analysis indicated no significant change in CT image while using the shields. The greatest advantage of this shield is its non-toxicity and light characteristic when nanoparticle of bismuth is used in the silicon matrix. Further, these shields induce a significant dose reduction as a method for protecting the breast in

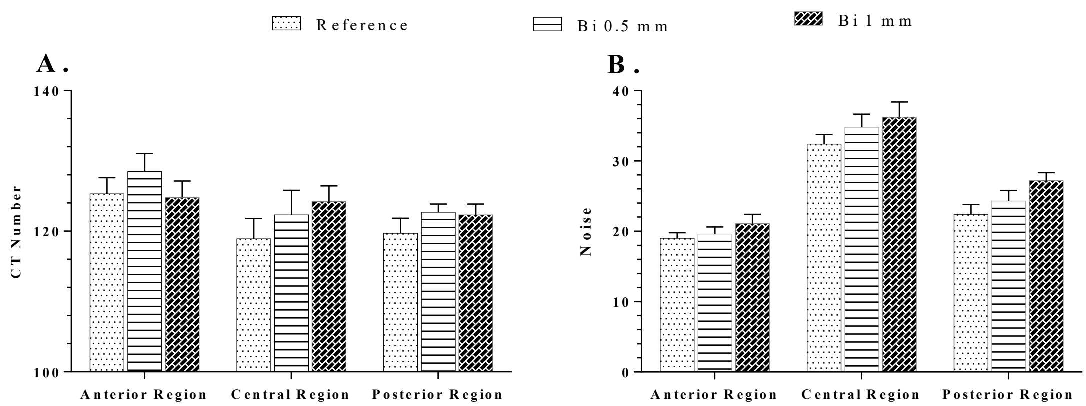

Figure 3. The CT number values (A) and image noise (B) in regions of the interest position in CT images from PMMA phantom under different Nano bismuth shields.

chest CT scan.

The nanoparticles have higher uniform distribution in the matrix due to their smaller size compared to the microparticles. Increasing the thickness leads to an increase in the number of bismuth nanoparticles inside the shield and helps raise the collision and protection. Furthermore, the results indicated that by increasing the thickness of the shield from 0.5 to 1 mm, a different ratio was observed on dose reduction (47%). Hopper et al found that the radiation dose reduced by 39.6%–52.8% by changing the bismuth shield thickness (26).

Various studies revealed that using bismuth shields increases the noise and artifacts in the image. However, a significant decrease is observed in artifacts by creating a gap between the shields and the superficial tissue. For example, in one study the noise reduction was 69% when the patient was separated from the shield by 1 cm (27). In this study, the CT number raised to 2 and 4% when nano bismuth shields were used with 1 mm foam compared to the no-shield situation (Table 1). Finally, the noise level increases by utilizing a shield which can be ignored and has no great effect on the image quality for 0.5 and 1 mm thickness of nano bismuth shields.

Conclusions

In general, based on the findings of this study, nano bismuth shields have a great potential for decreasing the breast dose with the minimum noise and therefore can be used to protect the breast in CT scan and reduce the probability of breast cancer.

Conflict of Interests

Authors have no conflict of interests.

Ethical Issues

This study was approved by the Ethical Committee of Tabriz University of Medical Sciences (IR.TBZMED.VCR.REC.1397.003).

Financial Support

This study was financially supported by Tabriz University of Medical Sciences.

References

1. Fu W, Sturgeon GM, Agasthya G, Segars WP, Kapadia AJ, Samei E. Estimation of breast dose reduction potential for organ-based tube current modulated CT with wide dose reduction arc. Medical Imaging 2017: Physics of Medical Imaging; 2017: International Society for Optics and Photonics. doi:10.1117/12.2255797
2. Dobbs M, Ahmed R, Patrick LE. Bismuth breast and thyroid shield implementation for pediatric CT. Radiol Manage. 2011;33(1):18-22; quiz 23-14.
3. Vollmar SV, Kalender WA. Reduction of dose to the female breast in thoracic CT: a comparison of standard-protocol, bismuth-shielded, partial and tube-current-modulated CT examinations. Eur Radiol. 2008;18(8):1674-1682. doi:10.1007/s00330-008-0934-9
4. 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):6084-6092. doi:10.1118/1.3651489
5. Akhlaghi P, Miri-Hakimabad H, Rafat-Motavalli L. Effects of shielding the radiosensitive superficial organs of ORNL pediatric phantoms on dose reduction in computed tomography. J Med Phys. 2014;39(4):238-246. doi:10.4103/0971-6203.144490
6. Colletti PM, Micheli OA, Lee KH. To shield or not to shield: application of bismuth breast shields. AJR Am J Roentgenol. 2013;200(3):503-507. doi:10.2214/ajr.12.9997
7. Papadakis AE, Perisinakis K, Oikonomou I, Damilakis J. Automatic exposure control in pediatric and adult computed tomography examinations: can we estimate organ and effective dose from mean MAS reduction? Invest Radiol. 2011;46(10):654-662. doi:10.1097/RLI.0b013e3182213c55
8. Papadakis AE, Perisinakis K, Damilakis J. Angular on-line tube current modulation in multidetector CT examinations of children and adults: the influence of different scanning parameters on dose reduction. Med Phys. 2007;34(7):2864-2874. doi:10.1118/1.2747048
9. Fricke BL, Donnelly LF, Frush DP, et al. In-plane bismuth breast shields for pediatric CT: effects on radiation dose and image quality using experimental and clinical data. AJR Am J Roentgenol. 2003;180(2):407-411. doi:10.2214/ajr.180.2.1800407
10. Hopper KD, King SH, Lobell ME, TenHave TR, Weaver JS. The breast: in-plane x-ray protection during diagnostic thoracic CT--shielding with bismuth radioprotective garments. Radiology. 1997;205(3):853-858. doi:10.1148/radiology.205.3.9393547
11. Coursey C, Frush DP, Yoshizumi T, Toncheva G, Nguyen G, Greenberg SB. Pediatric chest MDCT using tube current modulation: effect on radiation dose with breast shielding. AJR Am J Roentgenol. 2008;190(1):W54-61. doi:10.2214/ajr.07.2017
12. Lambert JW, Gould RG. Evaluation of a Net Dose-Reducing Organ-Based Tube Current Modulation Technique: Comparison With Standard Dose and Bismuth-Shielded Acquisitions. AJR Am J Roentgenol. 2016;206(6):1233-1240. doi:10.2214/ajr.15.15778
13. Aghaz A, Faghihi R, Mortazavi SMJ, Haghparast A, Mehdizadeh S, Sina S. Radiation attenuation properties of shields containing micro and Nano WO3 in diagnostic X-ray energy range. Int J Radiat Res. 2016;14(2):127-131. doi:10.18869/acadpub.ijrr.14.2.127
14. Noor Azman NZ, Siddiqui SA, Hart R, Low IM. Effect of particle size, filler loadings and x-ray tube voltage on the transmitted x-ray transmission in tungsten oxide-epoxy composites. Appl Radiat Isot. 2013;71(1):62-67. doi:10.1016/j.apradiso.2012.09.012
15. Alonso TC, Mourao AP, Santana PC, da Silva TA. Assessment of breast absorbed doses during thoracic computed tomography scan to evaluate the effectiveness of bismuth shielding. Appl Radiat Isot. 2016;117:55-57. doi:10.1016/j.apradiso.2016.03.018
16. Noor Azman NZ, Siddiqui SA, Haroosh HJ, et al. Characteristics of X-ray attenuation in electrospun bismuth oxide/polylactic acid nanofibre mats. J Synchrotron Radiat. 2013;20(Pt 5):741-748. doi:10.1107/s0909049513017871

17. Noor Azman NZ, Musa NFL, Nik Ab Razak NNA, et al. Effect of Bi2O3 particle sizes and addition of starch into Bi2O3–PVA composites for X-ray shielding. Appl Phys A. 2016;122(9):818. doi:10.1007/s00339-016-0329-8
18. Albert JM. Radiation risk from CT: implications for cancer screening. AJR Am J Roentgenol. 2013;201(1):W81-87. doi:10.2214/ajr.12.9226
19. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277-2284. doi:10.1056/NEJMra072149
20. Youlden DR, Cramb SM, Yip CH, Baade PD. Incidence and mortality of female breast cancer in the Asia-Pacific region. Cancer Biol Med. 2014;11(2):101-115. doi:10.7497/j.issn.2095-3941.2014.02.005
21. Taheri NS, Bakhshandehnosrat S, Tabiei MN, et al. Epidemiological pattern of breast cancer in Iranian women: is there an ethnic disparity? Asian Pac J Cancer Prev. 2012;13(9):4517-4520. doi:10.7314/APJCP.2012.13.9.4517
22. Ngaile JE, Uiso CB, Msaki P, Kazema R. Use of lead shields for radiation protection of superficial organs in patients undergoing head CT examinations. Radiat Prot Dosimetry. 2008;130(4):490-498. doi:10.1093/rpd/ncn095
23. Ciarmatori A, Nocetti L, Mistretta G, Zambelli G, Costi T. Reducing absorbed dose to eye lenses in head CT examinations: the effect of bismuth shielding. Australas Phys Eng Sci Med. 2016;39(2):583-589. doi:10.1007/s13246-016-0445-y
24. Verdipoor K, Alemi A, Mesbahi A. Photon mass attenuation coefficients of a silicon resin loaded with WO3, PbO, and Bi2O3 Micro and Nano-particles for radiation shielding. Radiat Phys Chem. 2018;147:85-90. doi:10.1016/j.radphyschem.2018.02.017
25. Mesbahi A, Ghiasi H. Shielding properties of the ordinary concrete loaded with micro- and nano-particles against neutron and gamma radiations. Appl Radiat Isot. 2018;136:27-31. doi:10.1016/j.apradiso.2018.02.004
26. Hopper KD, Neuman JD, King SH, Kunselman AR. Radioprotection to the eye during CT scanning. AJNR Am J Neuroradiol. 2001;22(6):1194-1198.
27. Inkoom S, Papadakis AE, Raissaki M, et al. Paediatric neck multidetector computed tomography: the effect of bismuth shielding on thyroid dose and image quality. Radiat Prot Dosimetry. 2017;173(4):361-373. doi:10.1093/rpd/ncw007