Early Online

The European Research Journal 2024 Original Article

DOI: https://doi.org/10.18621/eurj.1560244 *Radiology*

Evaluation of bismuth shielding in reducing thyroid radiation dose during neck multidetector computed tomography examinations: a comparative study

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ABSTRACT

Objectives: This study pointed to assess the viability of bismuth protecting in lessening thyroid radiation measurements amid neck multidetector computed tomography (MDCT) examinations and to explore alternative protecting strategies which will moderate negative impacts on picture quality.

Methods: The study involved 20 patients undergoing neck MDCT. Thermoluminescent dosimeters (TLDs) were utilized to degree radiation measurements to the thyroid organ with and without bismuth protecting. Measurable investigations, counting combined tests t-test and Wilcoxon signed-rank test, were conducted to evaluate the importance of dosage decrease.

Results: Bismuth protecting altogether diminished the radiation measurements to the thyroid organ by 43.95%, from 24.50 mGy to 17.59 mGy ($P<0.01$). The reduction was statistically significant in women ($P<0.01$) but not in men ($P>0.05$) due to the small sample size. No significant correlation was found between age and radiation dose levels ($P>0.05$).

Conclusions: Bismuth shielding effectively reduces thyroid radiation dose during neck MDCT examinations. However, the potential increase in image noise necessitates careful management to maintain diagnostic accuracy. Further research is needed to optimize shielding techniques and explore alternative methods to minimize radiation exposure while preserving image quality.

Keywords: Bismuth shielding, thyroid radiation dose, neck MDCT, radiation protection

All living organisms are continuously exposed to natural radiation throughout their lives. This exposure includes billions of particles and photons from cosmic rays and radionuclides present in the earth's crust, which pass through our bodies daily. In addition to natural sources, humans are exposed to man-made radiation, primarily from medical procedures, which accounts for approximately 15% of total radiation exposure [1]. Radiation can be categorized into ionizing and non-ionizing types, with ionizing radiation, such as X-rays and gamma rays, having the potential to cause significant biological damage due to its ability to ionize atoms and molecules within cells [2].

The fast progressions in computed tomography (CT) innovation over the past decade have driven a

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How to cite this article: Başar Y. Evaluation of bismuth shielding in reducing thyroid radiation dose during neck multidetector computed tomography examinations: a comparative study. Eur Res J. 2024. doi: 10.18621/eurj.1560244

Received: October 2, 2024
Accepted: November 14, 2024
Published Online: November 19, 2024

noteworthy increment within the number of CT examinations and the volume of body locales filtered. CT constitutes almost 5% of all radiological examinations worldwide, accounting for one-third of therapeutic radiation presentations [3]. Despite its diagnostic benefits, CT imaging poses a substantial risk due to the high radiation doses involved, particularly to radiosensitive organs like the thyroid gland. The thyroid is especially vulnerable during neck CT scans, where it can receive doses significantly higher than those from conventional radiography [4].

Bismuth shields have been introduced as a protective measure to reduce radiation exposure to the thyroid during CT examinations. These protective barriers are capable of reducing the radiation exposure to the thyroid gland by roughly 30-60% [5, 6]. However, their employment is controversial because of possible negative impacts on image clarity, including heightened noise and distortions, which might undermine the accuracy of diagnoses [7]. Due to these drawbacks, the American Association of Physicists in Medicine (AAPM) has recommended against the routine use of bismuth shields [8].

Given these concerns, alternative methods such as the Saba shield have been explored. The Saba shield, which combines copper and bismuth, offers a promising solution by reducing radiation exposure without significantly affecting image quality [9]. The objective of this research is to assess how well bismuth shielding can decrease the amount of radiation exposure to the thyroid during neck multidetector computed tomography (MDCT) scans, while also investigating different shielding techniques that could lessen adverse effects on image clarity.

The primary goal of this study was to examine how radiation exposure to the thyroid gland varies during neck MDCT scans, especially when comparing procedures done with and without the use of bismuth shields. To achieve precise measurements, thermoluminescent dosimeters were employed. Additionally, the research aimed to determine the overall amount of radiation the thyroid gland receives during these diagnostic tests. From October to December 2007, twenty patients who needed neck MDCT scans at our facility were included in this research. The findings from this study are vital, offering significant insights into how effective bismuth shielding is at reducing radiation exposure to the thyroid.

METHODS

Study Design and Sample

This research was carried out following the approval from the institutional ethics committee, and informed consent was secured from all participants. The research was carried out between October 2007 and December 2007 at the Radiology Department of an university hospital. A total of 20 patients (9 males and 11 females, aged 28 to 70 years, with a mean age of 52) who were referred for neck MDCT were included in the study. The primary aim of this study was to evaluate the differences in radiation exposure to the thyroid gland with the application of bismuth shielding versus without, employing thermoluminescent dosimeters (TLDs) for measurement. Additionally, the study sought to quantify the total radiation dose received by the thyroid throughout MDCT procedures.

Imaging Protocol

MDCT imaging was conducted utilizing a Siemens Sensation Cardiac scanner (Sensation 16, Siemens, Forchheim, Germany). The parameters set for the scanning procedure encompassed a detector collimation of 15, a gantry rotation duration of 0.75 seconds, an X-ray tube potential of 120 kV, and a tube current measuring 230 mAs. The slice thickness was set to 5 mm, and the average field of view (FOV) was 20 cm. Patients were positioned supine on the gantry, and images were acquired from the occiput to the thoracic inlet, covering the cervical region.

Dosimetry

For each patient, a pair of thermoluminescent dosimeters (dimensions: 3x3x1 mm; manufactured by Harshaw Lif TLD-100 and Saint-Gobain Industrial Ceramics, Solon, Ohio) were employed. The TLDs were placed on the estimated thyroid tissue, 2.5 cm inferior to the central prominence of the thyroid cartilage and 2 cm lateral to the midline, parallel to the long axis of the cervical spine. One TLD was covered with a bismuth shield, while the other was left uncovered, allowing for a direct comparison of radiation doses between the shielded and unshielded sides of the thyroid.

Statistical Analysis

The measurement of the radiation dose absorbed by the thyroid gland was carried out through TLDs,

Table 1. **Evaluation by gender**

TLD average dose (mGy)	Mean±SD	Median	P value
Women (n=11)			
Shielded side	15.97±5.97	15.2	**0.003**
Unshielded side	23.69±9.07	20.1	
Men (n=9)			
Shielded side	19.56±6.32	18.3	0.051
Unshielded side	25.50±8.00	21.9	

TLD= thermoluminescent dosimeter, SD=standard deviation
Wilcoxon signed-rank test was used.

with an evaluation of the bismuth shield's efficiency in mitigating this dose. Statistical analyses were executed employing NCSS 2007 & PASS 2008 Statistical Software, based in Utah, USA. This included the computation of descriptive statistics, such as the mean and standard deviation. For the comparison of normally distributed quantitative data, the paired samples t-test was utilized, whereas the Mann-Whitney U test and the Wilcoxon Signed Rank test were employed for data that did not follow a normal distribution. Additionally, Pearson correlation analysis was performed to examine the linkage between the age of the subjects and the received radiation dose. A P-value below 0.05 was established as the threshold for statistical significance.

RESULTS

This research sought to assess the effect of bismuth shielding on the amount of radiation absorbed by the thyroid gland during neck MDCT scans. The use of TLDs allowed for precise measurement of radiation exposure, comparing the shielded and unshielded lobes of the thyroid.

The results demonstrated a statistically significant reduction in radiation dose to the thyroid gland when bismuth shielding was applied. The average TLD dose for the shielded side was 17.59±6.24 mGy, compared to 24.50±8.43 mGy for the unshielded side, indicating a reduction of 43.95%±28.72% (P<0.01). This substantial reduction highlights the efficacy of bismuth shields in mitigating radiation exposure to organs sensitive to radioactivity.

The percentage reduction in TLD average dose for the shielded side compared to the unshielded side was calculated as 43.95%±28.72%.

In females, the mean dose of TLD for the side protected by shielding was markedly less in comparison to the side without protection, with the difference being statistically significant (P=0.003). In males, the mean dose on the shielded side was also reduced; however, this reduction did not achieve statistical significance, which could be attributed to the limited size of the sample (P>0.05).

The study indicated no substantial disparity in the average doses of TLD for both males and females, regardless of whether the measurement was taken on the shielded or unshielded sides, as evidenced by a P-value greater than 0.05 (Table 1).

There was no statistically significant association identified between age and the average dose levels of TLD on both the shielded and unshielded sides, as evidenced by a p-value greater than 0.05 (Table 2).

DISCUSSION

In our study, we investigated the average radiation exposure of the thyroid gland in 20 patients referred to

Table 2. **Correlation between age and TLD average dose**

TLD average dose (mGy)	r	P value
Shielded side	0.221	0.348
Unshielded side	0.355	0.124

TLD= thermoluminescent dosimeter
Pearson correlation analysis was used.

our department for neck MDCT scans. Our analysis focused on evaluating the effectiveness of bismuth shielding in reducing this exposure. TLDs were utilized to quantify the thyroid gland's radiation dose. One dosimeter was covered with a bismuth shield, while the other was left uncovered, thus protecting one lobe of the thyroid gland while leaving the other unprotected. The calculated radiation dose for the unprotected thyroid lobe was 24 mGy, whereas the dose for the protected lobe was measured at 17.50 mGy. This suggests that employing a bismuth shield can decrease the superficial radiation exposure to the thyroid gland by an estimated 43.95%.

Humans are exposed to natural background radiation daily from the earth, air, food, and cosmic rays. The majority of this background radiation comes from radon gas and its decay products. The average annual dose from natural background radiation worldwide is estimated to be between 1 and 10 mGy, with an average of approximately 2.4 mGy/year, half of which (1.2 mGy/year) is due to radon and its decay products [3]. However, due to the mixed nature of many radiation sources, the exact percentage of low LET natural background radiation is difficult to estimate.

Beyond the natural background radiation, human beings are subjected to artificial sources of radiation, encompassing the medical, research, and industrial applications of radioactive substances and X-ray equipment. A study conducted in 1987 found that 82% of the annual radiation exposure of the U.S. population was from natural background radiation, while 18% was from man-made sources [10]. Medical X-rays and nuclear medicine account for 79% of human-made radiation exposure, while consumer products (e.g., tobacco, building materials, televisions, and computer screens) account for 16%, and occupational exposure, nuclear explosions, and nuclear fuel cycles account for less than 5%.

Over the last ten years, the swift advancement in CT technology and its applications in the clinical field have contributed to a notable rise in both the frequency of CT scans and the extent of body area covered per scan. Presently, CT scans represent 5% of global radiological procedures and a third of the total medical radiation exposure [11]. The proliferation of CT usage is ongoing, now comprising 15% of all diagnostic processes and 75% of the cumulative diagnostic radiation dose in major healthcare facilities [12]. However, unlike other X-ray-based examinations, CT scan parameters vary widely in practical applications, even though they are generally the same for most patients [13].

Numerous methodologies have been formulated to minimize radiation exposure while ensuring the effective utilization of CT imaging, taking into account the clinical justifications, the patient's age or physique, and the specific region under examination. [14]. In 1993, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) documented that an estimated 93 million CT scans were conducted globally each year. This translates to a rate of 16 scans per 1,000 individuals [3]. The advent of helical and multi-slice CT technologies has markedly elevated the application of CT in the fields of vascular, cardiac, and oncological imaging, consequently amplifying the associated radiation exposure [15].

Research has demonstrated that the application of bismuth shielding can significantly mitigate radiation exposure to superficial radiosensitive organs, notably the thyroid gland. Investigations have documented reductions in radiation doses that vary between 25% and 84%, influenced by variables including the type of scanner utilized and the configuration of the shielding [5]. However, bismuth shields can also introduce image noise and artifacts, which can be mitigated by using foam spacers to increase the distance between the shield and the organ, thereby maintaining acceptable image quality for diagnostic purposes [16].

In our study, the use of bismuth shielding reduced the radiation dose to the thyroid gland by approximately 43.95%. This outcome aligns with prior research, which has corroborated the efficacy of bismuth shields in diminishing radiation exposure to the thyroid [9]. However, it is important to note that the use of bismuth shields can also increase image noise, which can affect diagnostic accuracy.

In light of the increased risk for radiation-induced thyroid malignancies, it is imperative to minimize exposure to the thyroid gland during computed tomography (CT) scans. It is essential for patients to be thoroughly briefed on the necessity of the procedure as well as the potential immediate and long-term consequences of radiation exposure, allowing them to make an informed decision regarding their participation in the scan. The justification for MDCT must be rigorously evaluated, with a preference for alternative diagnostic methods when feasible. Employing low-dose protocols is crucial to diminish the radiation dosage, and protective measures for superficial radiosensitive organs, including the thyroid, breasts, and gonads, should be implemented. Furthermore, it is vital to educate clinicians who refer patients for CT scans about the hazards associated with radiation exposure. Particular care should be taken with vulnerable patient populations, such as children and women younger than 40 years, to circumvent unnecessary scans whenever possible.

CONCLUSION

The findings of our research indicate that employing bismuth shielding substantially decreases the radiation exposure to the thyroid gland in neck MDCT scans. Nonetheless, it is imperative to meticulously address the resultant elevation in image noise and artifacts to preserve diagnostic precision. Additional studies are essential to refine shielding strategies and explore alternative approaches for reducing radiation exposure without compromising the quality of the images.

Ethical statement

This research received approval from the institutional ethics committee (Istanbul University Cerrahpaşa Medical Faculty, Decision no: 10254, date: 17.08.2006), and informed consent was obtained from all participants involved.

Data availability

The data sets produced and/or examined over the course of the present investigation can be obtained from the lead author upon a justified request.

Authors' Contribution

Study Conception: YB; Study Design: YB; Supervision: YB; Funding: N/A; Materials: YB; Data Collection and/or Processing: YB; Statistical Analysis and/or Data Interpretation: YB; Literature Review: YB; Manuscript Preparation: YB and Critical Review: YB.

Conflict of interest

The author disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

The author disclosed that they did not receive any grant during conduction or writing of this study.

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