EXPERIMENTAL STUDY: EFFECTS OF GANTRY TILTING ON RADIATION DOSE TO EYE LENS DURING HEAD CT AT A HOSPITAL IN PENANG, MALAYSIA

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Abstract

Computed Tomography (CT) plays an increasingly vital role in the field of neuroradiology. However, the high radiation dose of CT has always been a concern. The radiosensitive eye lens is of particular concern when it is included in the scan field during a CT examination of the head. This study measured the radiation dose of eye lenses at different gantry angulations and determined the relationship between gantry angulations and the lens dose. The anthropomorphic head phantom was scanned at different gantry angulations with increments of 4°. The lens doses were measured using thermoluminescent dosimeter (TLD) chips and T-test was used to determine if there is a significant difference in the dose at different gantry angulations relative to the non-tilted scan. By comparing the dose with the 0° reference scan, the dose was found to be significantly reduced starting from the angulation of 16°. The lens dose was reduced up to approximately 78 % at the gantry angulation of 23.5° as the lenses are excluded from the primary beam and avoided direct exposure. It was shown that the dose of the eye lens decreased with the increase of gantry tilting angles. With the significant dose reduction, the cumulative dose of multiple or repeated CT examinations of the head may not be a cause of concern. It was proven that the lens dose can be greatly reduced when the eye lenses are avoided from direct exposure in the use of gantry tilting.

Keywords: Computed Tomography, Radiation Dose, Eye Lens, Gantry Tilting, Dose Reduction

Introduction

Since its introduction in the 1970s, Computed Tomography (CT) has played an increasingly vital role in the diagnosis, evaluation, and monitoring of numerous disorders or diseases. This is especially true in the field of neuroradiology, where CT is used nearly three times more frequently than magnetic resonance imaging as it is less sensitive to patient movement, has faster image acquisition, and is more readily available. A head CT examination is also known as brain CT, CT scan skull, and cranial CT. It is usually performed to demonstrate the anatomy and pathology of the brain and associated soft tissues (Jibiri & Adewale, 2014; Lampignano & Kendrick, 2020).

The risks of the radiation exposure of computed tomography could be a cause of concern as it has a much higher radiation exposure than conventional X-ray, not to mention the cumulative radiation dose for repeated CT studies over the course of the disease. Particularly, the lens of the eye is widely recognized as a highly radiosensitive organ of the body, and cataract formation is a well-documented outcome of the radiation effect (Barabanova et al., 2019; Poon &Badawy, 2019). However, the eye lenses are often included in the scan field during a CT examination of the head while it is barely the area to be examined. The threshold dose for lens opacification was estimated in the range of 0.5 to 2 Gy whereas the threshold for cataract formation or visual impairment was 5 Gy as suggested by the International Commission on Radiological Protection (ICRP) Publication 103 in 2007. However, ICRP Publication 118 in 2012 has lowered the threshold dose to 0.5 Gy for both acute and fractionated exposures. In recent years, it is suggested that the eye lens is more sensitive to ionizing radiation than previously considered and the risk is proven to increase with the repeated CT imaging of head and neck regions (Ainsbury et al., 2016; Yuan et al., 2013). Even though the lens dose from a head CT examination is lower than the threshold value, multi-phase contrast examinations or multiple repeated CT could be required in some cases thus the cumulative dose is believed to be potentially close to the threshold (Roslee et al., 2020; Wang et al., 2012).

In light of the substantially increased utilization of CT imaging, an investigation is warranted to determine the radiation dose delivered to the eye lens and evaluate the dose reduction technique.

According to the European Guidelines, a certain degree of gantry angulations above the orbitomeatal line may exclude the eye lens from the primary beam and avoid direct exposure. It is believed to be a simple, inexpensive, and approachable method for lens dose reduction (Nikupaavo et al., 2015). Therefore, this study intended to determine the dose of eye lenses with different levels of gantry angulations and identify the most appropriate tilting angle thus further encouraging the use of gantry angulation in routine examinations in clinical practices.

Materials and methods

This study was carried out on an anthropomorphic head phantom using the Siemens SOMATOM Definition AS+ CT scanner at the Advanced Medical and Dental Institute (AMDI), Universiti Sains Malaysia. It was set up in accordance with the standard protocol of a clinical CT examination of the head. The head phantom was positioned to assure the median sagittal plane (MSP) was parallel to the vertical laser beam and the table height was adjusted until the side laser beam passed through the external auditory meatus (EAM). The landmark was aligned above the vertex.

First, the phantom was scanned at 0° gantry angulation as a reference scan. Then it was followed by different gantry angulations with an increment of 4° until the maximum tilting angle allowed by the protocol was reached, which was 23.5°. A total of seven scans were performed with the same acquisition parameters of 120 kVp, slice thickness of 5 mm, and the scan range included the whole brain. This acquisition protocol used adhered to the guidelines and protocol of the hospital for clinical head CT. The radiation doses of eye lenses at different gantry angulations were measured using the thermoluminescent dosimeter 100 (TLD-100) chips placed on the phantom at both left and right eye lenses. The sensitivity test of TLD was performed prior to the calibration process in order to select the TLD chips with optimal sensitivity. The selected TLD chips were irradiated along with the Unfors dosimeter to obtain the calibration factor and the dose readings were then determined using the interpolated data acquired from the TLD calibration curve and equation as shown in Figure 2.

The study determined the radiation dose of eye lenses at different gantry angulations and the relationship between gantry angulations and the dose. The data collected in this study were analyzed using the GNU PSPP Statistical Analysis Software. The percent change in the eye lens dose relative to the non-tilted scan was calculated for each gantry angulation. In addition, the Pearson Correlation test was used to determine the relationship between the gantry tilting angle and the lens dose.

Results

The mean absorbed dose of this study varied from 6.248 mGy to 28.386 mGy. The gantry angulation of 4° gave the highest reading compared to other angulations, which recorded 28.386 mGy. It was found that the dose of the eye lenses was significantly reduced starting from the angulation of 16 °. Meanwhile, the maximum gantry angulation reached under the CT head protocol in this study was 23.5 ° and it recorded the lowest reading of the dose at 6.248 mGy, representing a dose reduction of 77.87% to the lens of the eye. Additionally, the result showed that there was a strong negative correlation between the gantry angulation and the readings of lens dose (r-value =0.909). The greater the gantry angulation, the lesser the dose delivered to the eye lens.

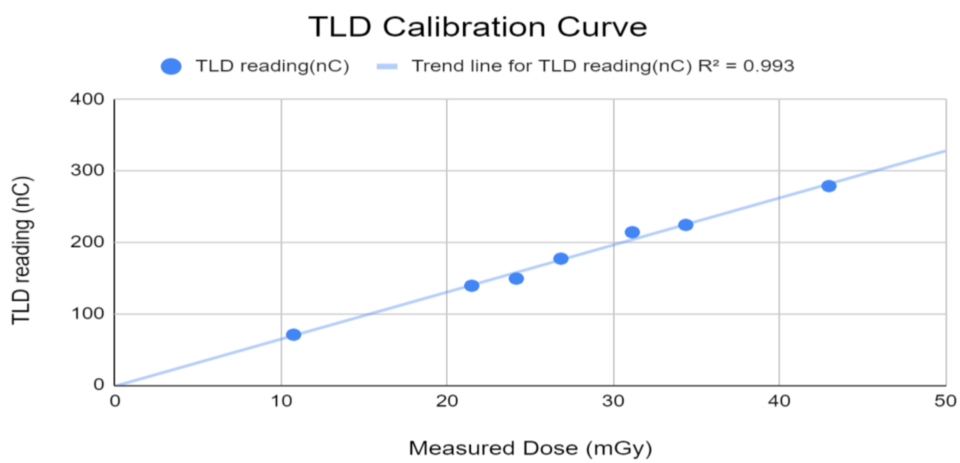

Figure 1: The graph of the calibration curve for TLD-100 chips

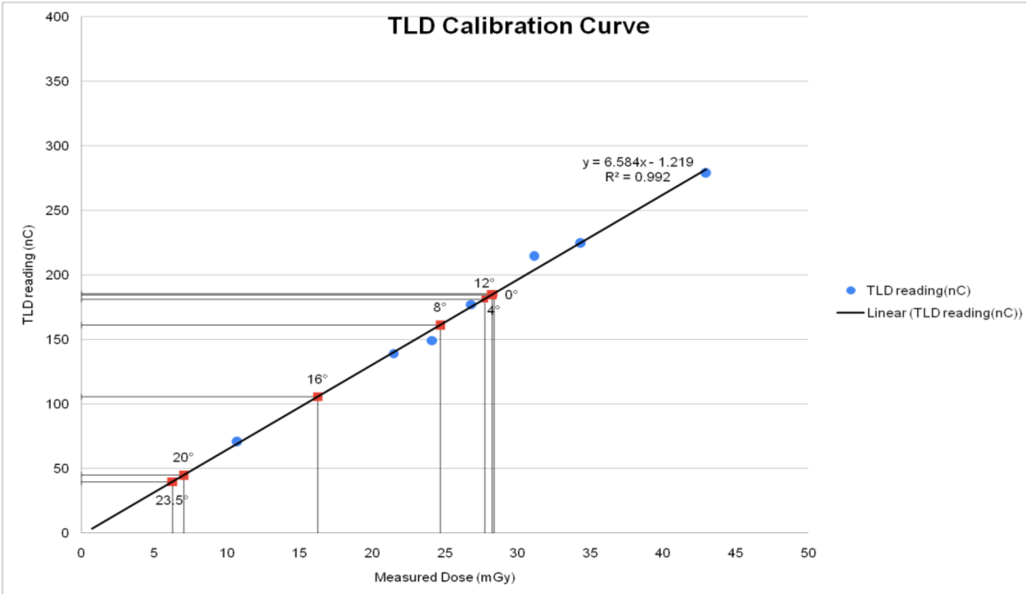

Figure 2: The interpolated graph of the TLD calibration curve

Table 1. The absorbed dose at different gantry angulations

Gantry Angulation	Absorbed Dose(mGy)		
	Right Lens	Left Lens	Mean dose
0 °	27.163	29.315	28.239
4 °	29.436	27.335	28.386
8 °	23.700	25.685	24.693
12 °	27.609	27.872	27.740
16 °	16.061	16.448	16.255
20 °	6.885	7.192	7.039
23.5 °	7.052	5.443	6.248

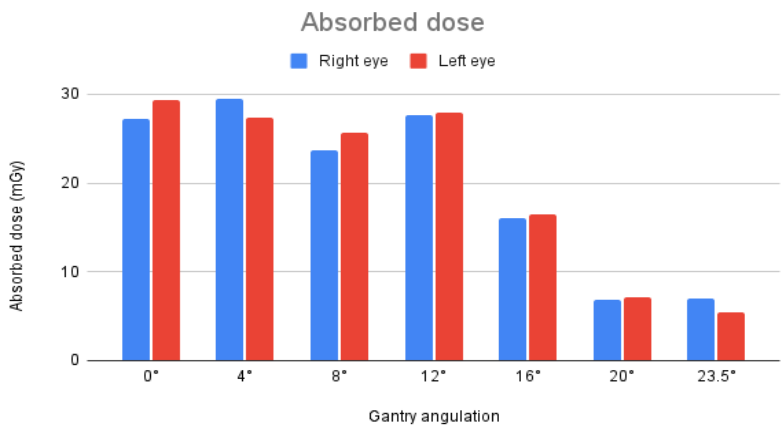

Figure 3: The graph of absorbed dose to the lens at different gantry angulations

Discussion

During routine head CT examination, radiation exposure of the eye lens is unavoidable due to its superficial position to direct exposure in the primary beam field. In fact, the lens of the eye is considered highly sensitive to radiation which is a known risk factor for cataract formation and vision impairment effect (Barabanova et al., 2019; Poon & Badawy, 2019). In this study, the doses of the eye lens at different gantry angulations were determined.

From the findings, the dose of the eye lens could be reduced up to 77.87% in the use of gantry angulation during a CT examination of the head. This result is in line with those of previous studies. The significant dose reduction is primarily because the tilting is mainly comparable to the supraorbital baseline in which the eye lenses are excluded from the primary beam when the gantry is angled to a certain degree (Tarkiainen et al., 2022). When the gantry angulation could avoid irradiating the eye lens with the primary beam, the dose to the eye lens will be solely from scattered radiation. Therefore, the dose of the eye lens is significantly reduced. By comparing the dose with the 0° reference scan, the dose of the eye lens was found to be significantly reduced starting from the angulation of 16°. It is found that the level of eye inclusion decreases with increasing tilting angle. Along with the increasing tilting angle, the anatomy of the brain and associated soft tissues including sella turcica, temporomandibular joints, and more are still included in the scan field and well visualized in the images. The image quality parameters were found not to be significantly different and acceptable at a diagnostic level (Ebrahiminia et al., 2020).

On the other hand, there was an unanticipated finding that the lens dose is slightly reduced at 8° angulation but then increases over again at the gantry angulation of 12°. A possible explanation for this result could be due to the thermoluminescent dosimeter (TLD) response. Variable factors such as energy, dose rate, and the time-temperature profile are essential in the optimization of the reading result (Paige et al., 2018; Sadeghi et al, 2015). Additionally, TLDs do not provide immediate reading as the TLD could only be read out 24 hours after the irradiation (Toossi, 2017). Therefore, fading of the TLD response may occur. Furthermore, prolonged exposure to ultraviolet light may also lead to the response fading. However, a brief exposure to the room fluorescent lights for a short period of time shall not significantly affect the TLD response. Nonetheless, the possibility of the fading of TLD response or changes in its sensitivity might not be ruled out. TLDs have to be handled with care as any minor variations could affect the optimization of TLD responses.

Furthermore, the relationship between the gantry angulation and the received lens dose was determined in this study to provide further insight into the impact of gantry angulation on the patient dose. There was a strong negative correlation between the gantry tilting angles and the lens dose. It can be concluded that the eye lenses are likely to be fully excluded in greater gantry angulation. The maximum gantry tilting angles involved in this study were only 23.5°. However the reality remains that the maximum tilting angle allowed by the Siemens SOMATOM AS+ Definition CT scanner is 30°. In this study, this maximum angle could not be reached due to the specific protocol applied by the hospital. It is believed that a lower reading of the lens dose could be achieved at a greater tilting angle above 23.5°. A phantom study by Lai et al. (2015) reported the dose of the eye lens region could be reduced up to 92.5% at the gantry angulation of 30°. Hence, it is important to note that the inability to reach the maximum tilting angle may have implications for the dose reduction potential of gantry tilting and warrants further investigations. Further studies could be done with different protocol settings or CT scanners to determine the feasibility of the gantry angulation of 30° in routine head CT in clinical practice.

In ICRP Publication 118 in 2012, the threshold dose of cataracts for acute and protracted exposure is 0.5 Gy. Typically, the radiation dose delivered to the eye lens during a head CT is approximately 30-50 mGy (Lai et al., 2015; Harbron et al., 2019) and yet the repeated CT examinations may lead to a higher accumulated radiation dose. According to a study by Roslee et al. (2020) at Hospital Universiti Sains Malaysia (HUSM) and Advanced Medical and Dental Institute (AMDI), the number of repeated head CTs could range from 3 to 14. The authors reported that 4% of the population received more than ten CT exposures due to traumatic injuries and the follow-up for progress assessment. Based on the result of this study as shown in Table 1, the dose delivered to the eye lens was substantially lowered with the use of gantry tilting. With the reduction of the lens dose to approximately 6.248 mGy, the cumulative dose of multiple CT examinations of the head may not exceed the threshold levels that could cause deterministic effects. It was proven that the lens dose can be greatly reduced when the eye lens avoided from the direct exposure in the use of gantry tilting. In addition, the use of gantry angulation may also reduce the scan length of the CT examination and lead to a corresponding decrease in the overall radiation dose delivered to patients (Nikupaavo et al., 2015). In short, the gantry tilting technique may reduce the direct exposure of the eye lens as well as the scan length resulting in significant dose reduction.

In conclusion, a better understanding and awareness of dose reduction is crucial in radiation protection and dose optimization. The gantry tilting technique is an easier and more approachable method for lens dose reduction during head CT without an extra running cost compared to other dose reduction approaches such as bismuth or lead eye shielding, organ-based tube current modulation (TCM) and more (Mosher et al., 2018; Zakariaee et al., 2017). Hence, it is encouraged that the gantry angulation technique could be employed during routine CT examinations in clinical practices.

Conclusion

The result of the study has shown that the lens dose is hugely reduced in the use of gantry tilting. From the findings, gantry tilting angulation may contribute to the significant reduction of the lens dose in head CT examinations when it excludes the lens from the primary beam and avoids direct exposure. In addition, it is found that the dose of the eye lens decreases with increasing gantry tilting angles. The greater the tilting angle, the greater the effectiveness in the lens dose reduction. The objectives of this study are met. Further studies could be conducted to compare the effect of gantry tilting in different patient conditions. Greater gantry angulations could also be tried with different protocols or CT scanners to determine the optimal use of this technique with regard to dose reduction and image quality.

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