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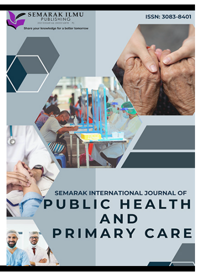

Assessment of Scattered Radiation Dose for Different CT Imaging Protocols in 128-slice and 512-slice Multi-detector Computed Tomography (MDCT) Scanners

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ABSTRACT

Computed Tomography (CT) has become the primary diagnostic tool among imaging devices, driven by continuous advancements in technology. Hospitals are increasingly adopting the latest Multi-detector Computed Tomography (MDCT) scanners to take advantage of their enhanced imaging capabilities. However, these advancements raise concerns about scattered radiation due to higher x-ray output. This study aims to compare scattered radiation dose levels between 128-slice and 512-slice MDCT scanners across different CT imaging protocols and evaluates the effectiveness of radiation shielding in a CT suite of a hospital in Kedah. Using a RaySafe 452 survey meter and a PMMA phantom, scattered radiation was measured during CT brain, thorax, and abdomen scans at both controlled and uncontrolled areas. There is a significant difference ($p = 0.029$) in scattered radiation dose for different CT imaging protocols between 128-slice and 512-slice MDCT scanners at various locations. The main door exhibited the highest radiation for the 128-slice MDCT, while the corridor had the lowest levels for both scanners. This study highlights the varying radiation exposure between different MDCT technologies and underscores the importance of effective radiation shielding in minimizing exposure.

1. Introduction

Computed Tomography (CT) is a non-invasive imaging modality that combines x-rays and computer technology to generate detailed cross-sectional images of the body's internal structures, essential for diagnosing conditions and guiding procedures. The development of Multi-Detector Computed Tomography (MDCT) scanners, which feature two-dimensional arrays of detector elements, has revolutionized CT technology by enabling faster and more efficient image acquisition through multiple slices per rotation [1]. Modern MDCT scanners now offer slice counts ranging from 16 up to 640.

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However, the use of MDCT introduces concerns about scattered radiation—a secondary type of radiation that occurs when the x-ray beam interacts with an object, potentially increasing exposure risks to medical personnel. Despite technological advancements, there is limited research comparing scattered radiation exposure between different MDCT systems, particularly between newer, higher-slice scanners and older models. This study addresses this gap by comparing scattered radiation dose levels between 128-slice and 512-slice MDCT scanners across various imaging protocols and evaluating the effectiveness of radiation shielding in controlled and uncontrolled areas of the CT suite. The findings aim to improve the understanding on radiation safety practices and contribute to more effective shielding strategies. This research is crucial in ensuring that technological advancements in CT imaging enhance diagnostic capabilities without increasing occupational risks.

2. Methodology

2.1 Research Design

An experimental study was conducted at the CT facility of the Radiology Department in a hospital in Kedah, from 1st April to 7th June 2024. The study focused on four specific locations in the CT suite: the control panel, control room door, main door (entrance), and corridor behind the main door. The locations outside of the Radiology Department were excluded.

2.2 Research Materials

In this study, data were collected using two MDCT scanners: the 128-slice Philips Ingenuity Elite and the 512-slice GE Revolution, both located at the CT facility. Each CT scanner is housed in a separate examination room, and both rooms share the same layout. Besides, a PMMA phantom, designed to mimic the radiological properties of human tissue, was used for all CT imaging protocols. The phantom features a 16 cm diameter head and a 32 cm diameter body, made from solid acrylic. Furthermore, scattered radiation was measured by using a RaySafe 452 survey meter, a portable and lightweight (0.8 kg) handheld device.

2.3 Data Collection

For data collection, measurements of scattered radiation doses were taken during normal working hours (8 a.m. to 5 p.m.) at four locations within each MDCT room. The assessment involving three CT imaging protocols: plain CT brain, CT thorax (HRCT), and CT abdomen (Urography), was tested three times on both scanners using constant scanning parameters shown in Table 1. Data were recorded and analyzed to determine average scattered radiation doses.

Table 1
Scanning parameters for different CT imaging protocols

Types of CT Imaging Protocol	Exposure Factor
CT Brain	120 kVp, 300 mAs
CT Thorax	80 kVp, 20 mAs
CT Abdomen	80 kVp, 30 mAs

2.4 Data Analysis

Data analysis was performed using IBM-SPSS. Normality tests were conducted to assess whether the scattered radiation dose levels from 128-slice and 512-slice MDCT scanners followed a normal distribution. However, since the data did not meet the normality criteria ($p < 0.05$), the non-parametric Mann-Whitney U Test was used to compare scattered radiation doses instead. A significant difference was identified ($p = 0.029$) across all three CT imaging protocols with a 95% confidence interval.

3. Results

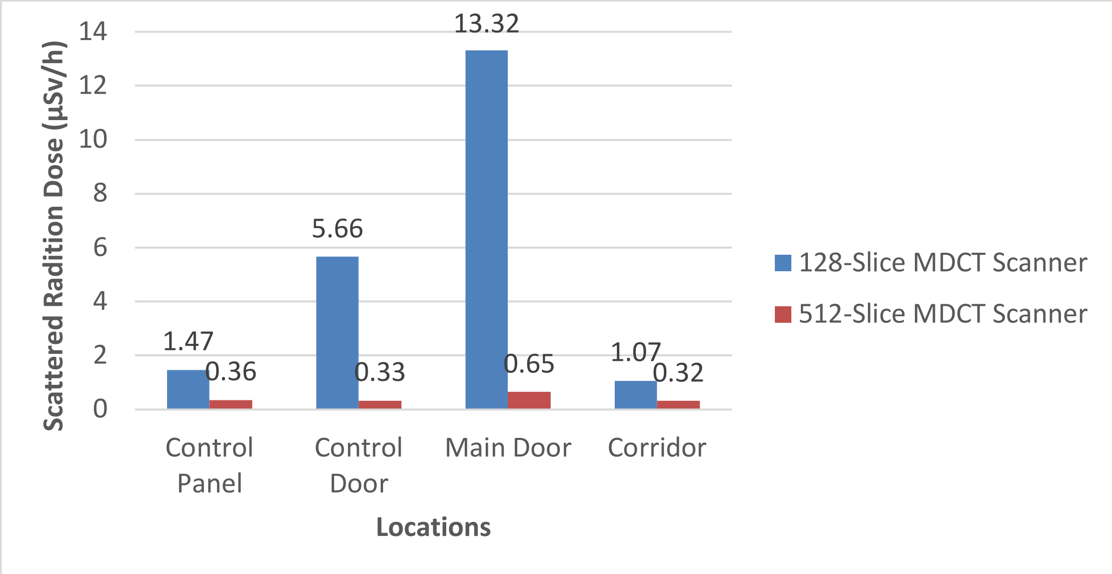

Fig. 1. Scattered radiation dose levels for CT brain imaging protocols at various locations in CT suite

Based on Figure 1, the highest scattered radiation doses were observed at the main door for both scanners, with 128-slice MDCT scanner producing an extremely high dose of 13.32 µSv/h and 512-slice MDCT scanner producing 0.65 µSv/h. The lowest scattered radiation dose recorded at the corridor, with 1.07 µSv/h for 128-slice MDCT scanner and 0.32 µSv/h for 512-slice MDCT scanner. Overall, the 128-slice MDCT scanner generally produced higher scattered radiation dose compared to 512-slice MDCT scanner.

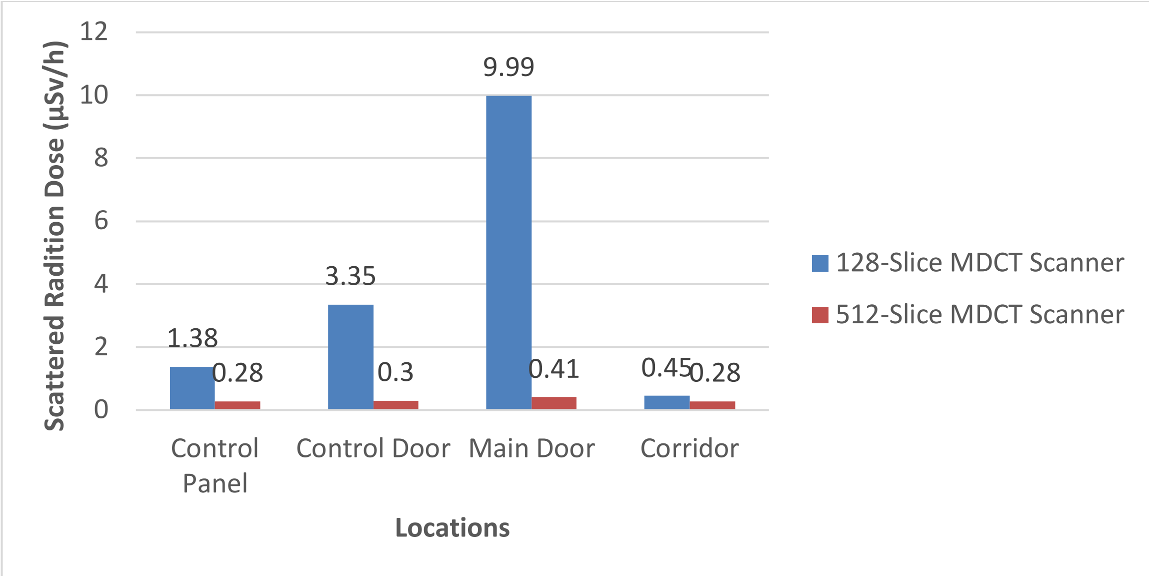

Fig. 2. Scattered radiation dose levels for CT thorax imaging protocols at various locations in CT suite

Based on Figure 2, 128-slice scanner recorded the highest dose at the main door (9.99 µSv/h), while 512-slice scanner produced 0.41 µSv/h. The lowest dose for the 128-slice was 0.45 µSv/h at the corridor, and for 512-slice, it was 0.28 µSv/h at both the control panel and corridor. Overall, the 128-slice MDCT scanner generally produced higher scattered radiation dose compared to 512-slice MDCT scanner.

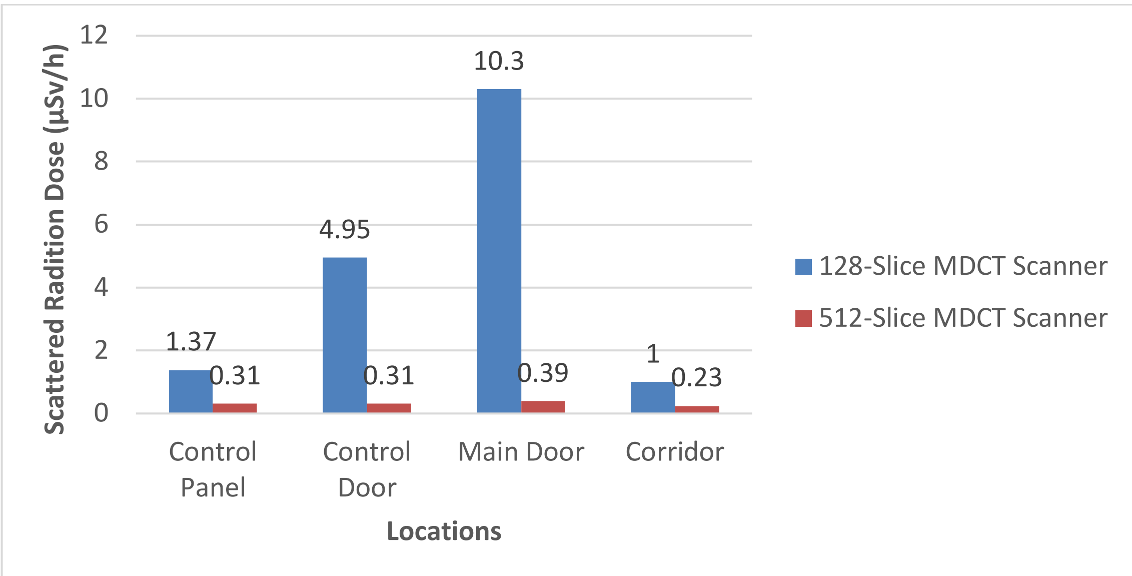

Fig. 3. Scattered radiation dose levels for CT abdomen imaging protocols at various locations in CT suite

Based on Figure 3, the 128-slice MDCT showed higher doses, with a peak of 10.30 µSv/h at the main door and a lowest dose of 1.00 µSv/h in the corridor. The 512-slice MDCT had lower doses, peaking at 0.39 µSv/h at the main door and a minimum of 0.23 µSv/h in the corridor. Overall, the 128-slice MDCT scanner generally produced higher scattered radiation dose compared to 512-slice MDCT scanner.

4. Discussion

With the evolution of CT imaging technologies, the introduction of higher slice MDCT scanners has significantly advanced clinical applications by offering larger volume coverage, shorter scanning times, and improved spatial resolution. However, these benefits come with a trade-off in terms of increased x-ray tube output, leading to higher scattered radiation. Scattered radiation poses significant health risks, including DNA damage and elevated cancer risk over time. To mitigate these risks, the ICRP has established dose limits for occupational exposure and the general public. According to these guidelines, the effective dose should not exceed 100 mSv over five years, and the effective dose in a single year should not exceed 50 mSv, as well as 5 mSv for public area [2]. Studies done by Walden [3] and Tam *et al*., [4] have identified scattered radiation as the major source of occupational dose for radiographers.

Based on the results of this study, 128-slice MDCT scanner consistently produced higher scattered radiation doses compared to 512-slice MDCT scanner for three CT imaging protocols measured at the four locations. For example, 128-slice scanner recorded significantly higher doses at the main door location for CT brain, thorax, and abdomen protocols, with doses reaching up to 13.32 µSv/h, 9.99 µSv/h, and 10.30 µSv/h respectively, compared to 512-slice scanner which recorded substantially lower doses. Consistent with previous studies, this research confirmed that 128-slice MDCT scanner produced higher scattered radiation doses across all protocols and locations compared to 512-slice MDCT scanner [5-8]. Therefore, higher number of detectors generally produced lower levels of scattered radiation.

The reduction in scattered radiation with 512-slice MDCT scanner can be attributed to its wide-detector array, which enables larger z-axis coverage and faster scan times, thereby reducing the overall radiation dose required for imaging [9]. The wide-detector CT scanner markedly reduces the image acquisition time to less than 1 seconds, thereby reducing radiation dose required for the examination [10]. This advanced scanner design significantly reduces the need for multiple passes and lowers radiation exposure. Additionally, 512-slice scanner incorporates various dose optimization strategies, such as Automatic Tube Potential Selection (ATPS) and z-axis Automated Tube Current Modulation (ATCM), which further minimize radiation exposure by adjusting the tube current and potential in real-time based on patient size and anatomy [11-13]. Innovations in iterative reconstruction (IR) algorithms also play a crucial role in reducing radiation dose while maintaining image quality. Unlike traditional filtered-back projection (FBP) techniques, IR algorithms reduce image noise and allow for lower radiation doses, which in turn decreases scattered radiation [14-15]. These advancements align with regulatory guidelines, such as the ALARA principle, emphasizing the importance of minimizing radiation exposure wherever possible.

Beside evaluating the scattered radiation profile, this study assessed the effectiveness of radiation shielding within the CT suite. The results revealed that the main door location, particularly in 128-slice MDCT scanner room, recorded the highest scattered radiation levels across all protocols, due to direct alignment with the primary beam and potential weakness in the current shielding design. Over time, improper installation, wear and tear, can reduce the effectiveness of these shields, allowing more scattered radiation to pass through. Conversely, the corridor consistently recorded the lowest levels of scattered radiation, likely due to its greater distance from the radiation source and the application of the inverse-square law, which reduces radiation intensity with increasing distance [16-17]. These findings highlight the importance of proper shielding, strategic suite design, and consistent monitoring to protect both healthcare workers and the public from the risks associated with scattered radiation. The study also highlights the need for continuous advancements in CT technology and the implementation of robust safety protocols to minimize radiation exposure in clinical settings.

5. Conclusion

The primary purpose of this study is to determine the significant difference in scattered radiation dose levels between 128-slice and 512-slice MDCT scanners across various CT imaging protocols at various locations in CT suite. The 512-slice MDCT consistently produced significantly lower scattered radiation doses due to advanced technologies such as ATCM and IR. The findings emphasize the need for improved radiation shielding, particularly at the main door location where 128-slice MDCT scanner showed high scattered radiation levels. This study provides valuable insights into the scattered radiation doses associated with different CT imaging protocol, specifically by comparing 128-slice and 512-slice MDCT devices. By gaining a comprehensive understanding of scattered radiation profile, radiologists and technologists can optimize imaging protocols to maintain diagnostic image quality while minimizing radiation exposure to both patients and radiological professionals. It raises awareness regarding the extent of scattered radiation exposure associated with CT imaging. Future research should continue to explore and refine these technologies to further optimize radiation protection in medical imaging.

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