

## ORIGINAL ARTICLE

# Associated with Excess Chest CT Scan Length: A Single-Centre Retrospective Analysis

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## ABSTRACT

**Introduction:** Computed tomography (CT) develops into a rapid and precise screening tool in the medical field. Over-scanning in the z-axis of CT examinations contributes significantly to increased radiation exposure. The aim of this study was to determine the factors associated with excess chest CT scan length. **Materials and methods:** One hundred data on the patient's age and gender, chest CT scans, radiographers in charge, day and time of examination performed, and dose length product (DLP) were obtained from the Picture Archiving and Communication System (PACS). **Results:** The mean excess scanning length below and above the lungs were  $15.69 \pm 6.11$  cm ( $p < 0.001$ ), and  $4.32 \pm 2.65$  cm ( $p < 0.001$ ) respectively. There was also a significant association between the total excess scanning length with patient age, radiographers' experience level and day of the week ( $p < 0.05$ ). The total excessive scanning length shows a significant correlation with the dose length product (DLP) ( $p < 0.001$ ). **Conclusion:** The findings demonstrated that the excess scans performed have exposed patients to more radiation, emphasising the need to minimise the scanning lengths by optimising the workflow, awareness of the radiation dose in CT scans, and radiographers' skills and training ought to be strengthened.

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## INTRODUCTION

Chest CT, or also known as thorax CT, have been increasingly performed as lung cancer screening is indicated with the increase trend of smoking history (1) with estimation of approximately 238,340 new lung cancer cases in 2023 (2). As CT develops into a rapid and precise screening tool in the medical field, its use rises. About 2% of cancers are thought to arise, with a 0.4% increase attributed to CT radiation exposure (3). Chest CT was reported to be the highest over-scanned, as much as 88% in the overall study done by Yar et al. (4). A study done by Karim et al. (5) in evaluating organ dose and radiation risk of routine CT examinations in a state in Malaysia, found that lungs having the highest cancer risk during CT chest examinations. It was also found that approximately 98% of chest CT scans were performed excessively, beyond their scan protocols, which are beyond the lung apices and the lowermost

portion of the lung parenchyma (6).

Excess scanning is defined as scanning coverage in the z-axis that extends beyond the limits of the requested scan, as well as any scans performed more than 2 cm from standard reference points on both the cranial and caudal sides (7) considering patient motion, patient non-compliance with breathing instructions, and technologist-related factors (1, 7-8). Excess scanning in chest CT is determined by the excess scan length of more than 2 cm above or below the lungs (9).

Contributory factors to the excess scanning length in CT performed may vary significantly by patient age and gender, radiographers' experience level and the day and time of the CT performed, as carried out by previous studies (7, 9-10). The dose length product (DLP) is important to be determined as it associates directly with the radiation dose exposed, as included in the study done by Liao et al. (10), to enable future improvement in minimising radiation exposure.

This study aims to identify and evaluate the contributing factors leading to excessive scanning lengths during chest CT examinations and their impact on radiation exposure,

focusing on patient demographics, radiographers' expertise and examination time in a one of the largest Malaysian government-owned public hospital in Kuala Lumpur.

**MATERIALS AND METHODS**

**Study design**

This retrospective study was conducted by reviewing adult chest CT images dated from January 2021 until May 2023 in the Radiology Department, Hospital Kuala Lumpur, Malaysia. Only adult patients with completed chest CT scans within the study period were included. Chest CT images which did not include the lung apices and lung bases were excluded from the review. CT examination information such as day and time of examination, radiographer in-charged, and the DLP were collected.

**Excess scan length measurement on chest CT scans**

The excess scan length was defined as scanning more than 2cm above the lung and below the costophrenic angle (Fig. 1).



Fig. 1: Excess scanning length was measured above the lung and below the lung (red arrow)

**Radiographers' experience**

The radiographers' experience was categorised into three categories based on years of experience working in CT. Category 1, less experienced (less than five years). Category 2, moderately experienced radiographers (6 to 9 years). Category 3, highly experienced radiographers (more than ten years).

**Statistical analysis**

The normality test was done using the Kolmogorov-Smirnov test. The mean of excess scanning length for all the chest CT scan images was tested using a one-sample t-test. The Kruskal-Wallis test was employed because the data did not follow a normal distribution, as determined by the Kolmogorov-Smirnov test, necessitating the use of non-parametric method for analysing categorical variables. The Pearson correlation test was used to determine the correlation between the total excess scanning length and DLP. All analyses were performed using SPSS version 28.0. A p-value ≤ 0.05 was considered statistically significant.

**Ethics approval**

Ethical approvals were obtained from both Faculty Ethics Research Committee (FREC) of Faculty of Health Sciences, UiTM (FERC/FSK/MR/2023/00077) and Medical Research and Ethics Committee (MREC) (NMRR ID-23-01324-0KM). The study was registered through National Medical Research Register (NMRR) and Clinical Research Centre (CRC), Hospital Kuala Lumpur, Malaysia.

**RESULTS**

This study evaluates patient age, radiographer experience and examination timing to determine their association with excess scanning lengths and radiation exposure.

**Characteristics of chest CT scan examinations**

One hundred adult chest CT images were included in our analysis. The characteristics of included chest CT images are tabulated in Table I. The patients' mean age was 63 years (range 55 to 62). Fifty-nine patients (59%) were male. Forty-three (43%) less experienced radiographers performed most of the chest CT examinations.

Table I: Characteristics of chest CT scan examinations

Scan characteristics	Frequency	Percentage (%)
<b>Demographic</b>		
N = 100		
Patient age, mean (range)	63	63
< 60	42	42
> 60	58	58
Patient gender, N (%)		
Male	59	59
Female	41	41
Radiographers' experience level, N (%)		
Less experienced	43	43
Moderate experienced	27	27
High experienced	30	30
CT scans by day of week, N (%)		
Monday	7	7
Tuesday	67	67
Wednesday	8	8
Thursday	4	4
Friday	14	14
CT scans by time of day, N (%)		
AM	68	68
PM	32	32

**Excess of scanning length**

The mean excess scanning length below the lungs was 15.69 cm (SD: 6.11), while the mean excess scanning length above the lungs was 4.32 cm (SD: 2.65). Both measurements were statistically significant more than the cut-off value of 2cm (Table II).

Table II: Descriptive analysis of the presence of excess scanning length

Excess scanning length	Mean	Standard deviation	p-value
Above lungs <sup>a</sup>	4.32	2.65	<0.001*
Below lungs <sup>a</sup>	15.69	6.11	<0.001*
Total <sup>b</sup>	20.01	7.11	<0.001*

<sup>a</sup> Test value = 2.0

<sup>b</sup> Test value = 4.0

\*p <0.001 is considered statistically significant

### Factors contributing to the excess scanning length

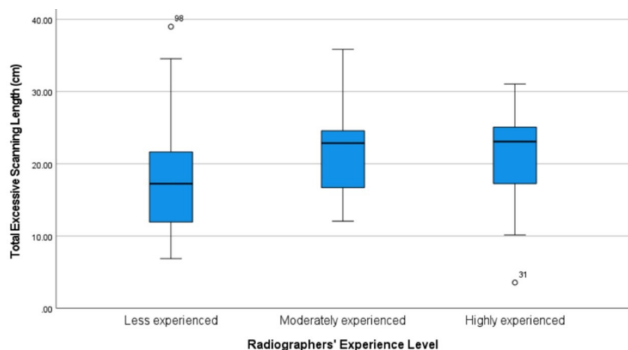
Factors that were significantly associated with excess scanning length were patients' age ( $p$ -value = 0.015), radiographers' experience level ( $p$ -value = 0.026), and examination day ( $p$ -value = 0.045) (Table III). The median excessive scanning length was significantly greater in patients younger than 60 years old compared to patients aged more than 60 years old ( $p$ -value = 0.015). The median excessive scanning length was significantly greater in the highly experienced radiographers than in the less experienced radiographers as shown in Fig. 2 ( $p$ -value = 0.039).

Fig. 3 shows that Friday was the most significant day with a median value of 25 cm (IQR 20–29) total excessive scanning length than the other workdays ( $p$ -value = 0.004).

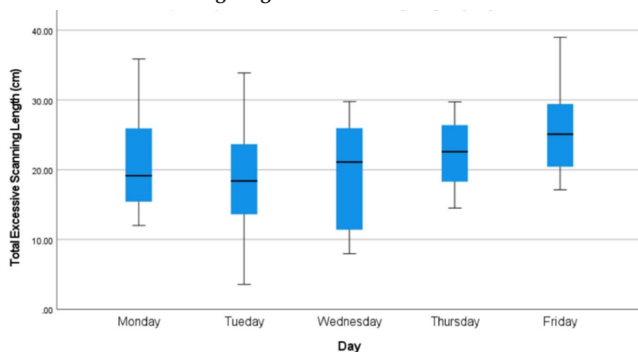
The median total excessive scanning length for Chest CT examination conducted in the morning (AM) was 20.18 cm (IQR: 15.63 – 25.04) compared to those performed in the evening (PM) ( $p$ -value = 0.206).

**Table III: The association between the variables with the excess scanning length**

Variables	$p$ -value
Patients' age	0.015*
Patients' gender	0.077
Radiographers' experience level	0.026*
Examination day	0.045*
Time of day	0.199



**Fig. 2: Association between radiographers' experience level with total excessive scanning length.**

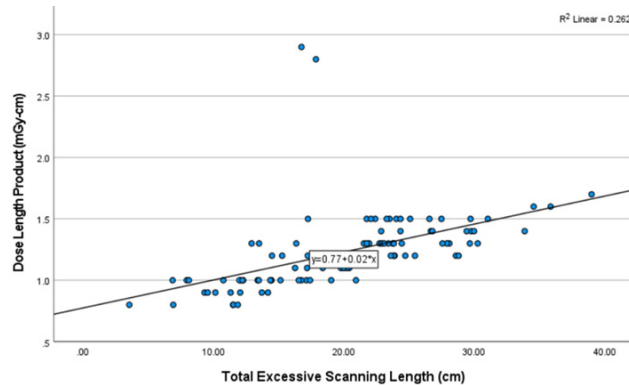


**Fig. 3: Association between days of the week with the total excessive scanning length.**

### Association between DLP and the total excess scanning length

The dose length product (DLP), representing patient

radiation exposure, was analysed in relation to excess scanning lengths. The mean (SD) DLP across all chest CT scans was 1.73 mGy·cm (0.91). A significant moderate positive linear relationship was identified between DLP and total excess scanning length ( $r = 0.511$ ,  $p < 0.001$ ), indicating that increased scanning lengths corresponded to higher radiation doses. (Fig. 4).



**Fig. 4: The association between the dose length product (DLP) with total excess scanning length.**

### DISCUSSION

This study builds upon existing research by Cohen et al. (9) with detailed categorization of radiographer experience levels. By focusing on one of the busiest hospitals in Malaysia, the study reflects unique CT practices that may differ from those observed in other settings, adding valuable context to the global understanding of this issue. Additionally, the imaging approach in this study highlights the routine chest CT examinations conducted using local protocols, which may differ from other literatures.

The extent of excess scanning length in chest CT scans. The radiation dose exposed excessively above the lung apices could contribute to additional radiation dose to the thyroid gland, a radiosensitive organ. In contrast the excess scanning below the lowermost portion of the lung parenchyma contributes to the additional radiation dose to the upper abdominal structures (6). Thus, most patients who underwent the CT chest scans in this study may have been exposed to the additional radiation dose on the lower part of the lung region.

Cohen et al. (9), also presented similar findings with excess scan length below the lungs being greater than above the lungs. It was assumed that this was due to the increased difficulty in acquiring the lower lungs due to diaphragm movement between the scout image and the actual CT (9). Besides that, one of the possible reasons for the excess scans below the lungs in this study was that the examination was performed with a thorax-abdomen protocol but registered under a routine chest CT protocol in the system, which usually has a more extensive scanning FOV.

The excess scanning length can be reduced by using an automated scan range delimitation as suggested

by Demircioglu et al. (11). Their study compared an automated software in determining the scan length in 1149 chest CT images using deep learning as compared with the radiographers' scan range delimitation. The application of an automated scan range could reduce total radiation exposure by 6% with a scan range of 2.9cm above the lung apices and below the costophrenic angle.

### **The influence of variable factors on excess scanning length in chest CT scans**

This study showed that the excess scanning length was significant in patients younger than 60 years old. This may be attributed to the ability of younger patients to hold their breathing and have bigger lung expansion during chest CT examinations (12). In contrast, older patients may have difficulties in complying with the breathing commands due to the degradation in cognitive abilities, affecting their lung volume expansion (7,9). Thus, the differences in patient age may contribute to the significant excess scanning as the inspiration level of the chest differs during the end of the scanned region. Another contributing factor to excessive scanning length was radiographers' experience in performing chest CT examinations. Our study found that highly experienced radiographers performed the most scans with excess scanning length. Our study contradicted a study by Yar et al. (7), which concluded that less experienced radiographers need to have continuous training and thus were cautious in performing CT scan examinations (7). Experienced radiographers may face difficulties in adapting the CT scan protocol and have a fear of strictly minimizing the scanning region that may exclude the region of interest, especially in a situation where they are pressured with the request to not exclude any lung region (9).

However, the varying levels of certification and qualifications among radiographers represent a potential source of bias in this study. Radiographers with advanced certifications of post-basic CT training may approach scanning protocols differently, potentially affecting the scanning length and radiation dose outcomes. While this study categorise radiographers based on years of experience, it did not account for specific qualifications or additional training, which could influence their decision-making during CT examinations.

The day of examination was also a contributing factor to excessive scanning length. Our findings showed that Friday was the day with the most excessive scan lengths performed. This could be attributed to the more chest CT examination requested during the day. Our findings were consistent with Cohen et al. (9), who found that Monday to be the day with the most excessive scan length performed due to the most chest CT scans performed (9). However, the day of chest CT scans performed may differ from one hospital to other hospitals, depending on the study protocols assigned. In

a multivariable analysis, Smith-Bindman et al. (13) found that institutional characteristics such as examination workloads and specialised centres were significant predictors of chest CT mean doses. Thus, radiographers need to be more alert during the days which have more chest CT requested.

However, it is worth to note that the distribution of CT scans across the days of the week in this study was imbalanced with most scans performed on certain days, such as Tuesday. This uneven distribution may introduce bias into the statistical analysis, as the excess scanning lengths observed could be influenced by the factors unique to those specific days, such as higher workloads or differences in staffing.

### **The association between the total excess scanning length and dose length product (DLP)**

Excessive effective radiation dose and increased individual organ effective doses rise because of excessive z-coverage in 36% of chest CT exams (1). The excess scanning has been proven to contribute to the increase of DLP values (7,10) in CT examinations.

The study's finding shows that there is a highly statistically significant moderate positive relationship between the total excess scanning length and dose length product. Thus, the radiographers need to minimize the scanning length to reduce the unnecessary radiation exposure towards patients.

Narendran et al. (14) reported that long-term radiosensitivity in females is higher than in males receiving a comparable radiation dose. As much as excessive scanning theoretically raises the radiation dose, it should be lower in younger patients as radiation risk exposure at later ages mainly contributes to the promotion of premalignant cells that have already been present (15).

Tailoring the chest CT protocol according to patients' size could reduce the radiation dose delivered to patients. Radiographers need to properly identify proper anatomical landmarks on scout chest CT images in optimizing CT scan length across the z-coverage (16).

### **Limitations**

The limitation of this study was that the height, body surface area, and body mass index (BMI) of patients were not obtained due to the unavailability of the data in the CT record. As suggested by Cohen et al. (9), scanning length can be affected directly by the patient's height and body surface area. Taller patients may require a longer scan length and more significant adjustment for costophrenic angle position than morbidly obese patients (9). Thus, this factor should be taken into consideration in future studies.

While one hundred adult chest CT images were

included in this study is smaller compared to previous studies, it is sufficient to provide robust statistical power for the analysis of the specific variables under investigation. The focused nature of this study, which are patient demographics, radiographer experience, and examination timing, ensures that meaningful conclusions can be drawn from the available data. Furthermore, the study's methodological design was carefully tailored to maximize the insights gained from the selected sample.

## CONCLUSION

This study found that the excessive scanning length in chest CT scans was presented, possibly contributed by factors such as different patient age and gender, radiographers' experience level, and day and time of the CT scan examinations.

As a recommendation, proper supervision and training are much needed as the unnecessary excessive radiation exposed to patients may not contribute to additional diagnosis information but increase in radiation dose. Achieving a precise minimised scanning region may be challenging due to various factors, such as patient condition, and avoiding excluding the anatomical region. However, reducing the amount of excessive scanning in most chest CT scans may be possible if the radiographers' skills improve. In addition, the awareness of CT radiation dose in the CT department should be improved by printing out infographics at the operating unit to remind the radiographers performing.

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