Optimization of the Image Quality and Radiation Dose in CT Chest Exposure Parameters

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Abstract—**Background: Chest computed tomography (CT) is a vital diagnostic tool, but it delivers one of the highest radiation doses among routine imaging examinations. Repeated exposure poses long-term risks, making optimization of scanning protocols essential. Adhering to the ALARA (As Low As Reasonably Achievable) principle while preserving diagnostic image quality is a key priority in medical imaging.**

Methods: This study investigated the optimization of chest CT exposure parameters, including tube voltage (kVp), tube current (mAs), pitch, and scan length. Data were collected and analyzed to compare standard protocols with optimized scanning techniques. Radiation dose indices—CTDIvol, dose-length product (DLP), and effective dose—were measured, while image quality was evaluated through radiologists' assessments of diagnostic adequacy.

Results: Optimization strategies demonstrated that radiation dose could be reduced by nearly 25% without compromising diagnostic quality. The most significant reductions were achieved through lowering tube current, selecting practical tube voltage values (100–120 kVp), and minimizing scan length to the diagnostic region of interest. Pitch adjustments showed minimal impact within the operational range studied. The optimized protocol yielded consistent reductions in CTDIvol, DLP, and effective dose across the patient population, with radiologists confirming image quality remained clinically acceptable.

Conclusion: Optimizing chest CT protocols can meaningfully lower radiation exposure while maintaining diagnostic adequacy. Simple measures—such as controlled tube current, disciplined scan length selection, and appropriate tube voltage—offer a safe and practical approach to dose reduction. These findings support the adoption of standardized, optimized protocols in routine clinical practice, aligning with international diagnostic reference levels and reinforcing radiation safety.

I. INTRODUCTION

Computed tomography (CT) is a noninvasive diagnostic imaging technique that employs X-rays & advanced computer processing to generate precise cross-sectional views of the body. It helps diagnose a large range of medical conditions, including boner, cancer, vascular diseases, and internal organ problems1. Using digital techniques, plane body can be visualized as (3D) lines of varying widths, divided into a square matrix of attenuation elements (pixels) with linear attenuation coefficients μ(x,y).

The matrix size is 256 × 256.or512 × 512 corresponds to a pixel size of 1 mm or 0.1 mm. The thickness of the Z-axis can vary between 1 mm and 10 mm.[2,3] The rise of CT imaging marked a significant leap in the understanding of complex anatomical structures, including those of the chest. This technology authorized non-invasive visualization of internal structures, greatly adding diagnostic accuracy. It also provided a new perspective on anatomical changes associated with aging, disease, and trauma.[4,5] The arrival of CT imaging marked a significant leap in the understanding of complex anatomical structures, including those of the chest. This technology enabled non-invasive dashboards of internal structures, substantially enhancing diagnostic accuracy. It also provided a new perspective on anatomical changes associated with fading, disease, and trauma.[6,7] The patient's effective dose for chest CT might exceed 100 mSv.[,8,]

History of Computed Tomography (CT) Imaging

X-rays were discovered in 1895 by the German physicist Wilhelm Conrad Röntgen, who was later awarded the Nobel Prize in Physics in 1901. From start, X-rays were confessed as important for diagnosing medical conditions. The first X-ray CT (Computed Tomography) scanner was determined by

Godfrey Hounsfield in 1972. Hounsfield, who won the Nobel Prize in 1979, developed a prototype for the 1st medical CT scanner, which dominant to the development of modern CT scans. CT scans were first used in hospitals in 1971 to help diagnose conditions like cysts and fracture. One of the 1st patients diagnosed using a CT scan was at Atkinson Morley Hospital in Wimbledon, where doctors found a brain tumor. Since then, CT scans have become a crucial tool in medical diagnosis and are considered one of the most important advances in diagnostic imaging.[10]

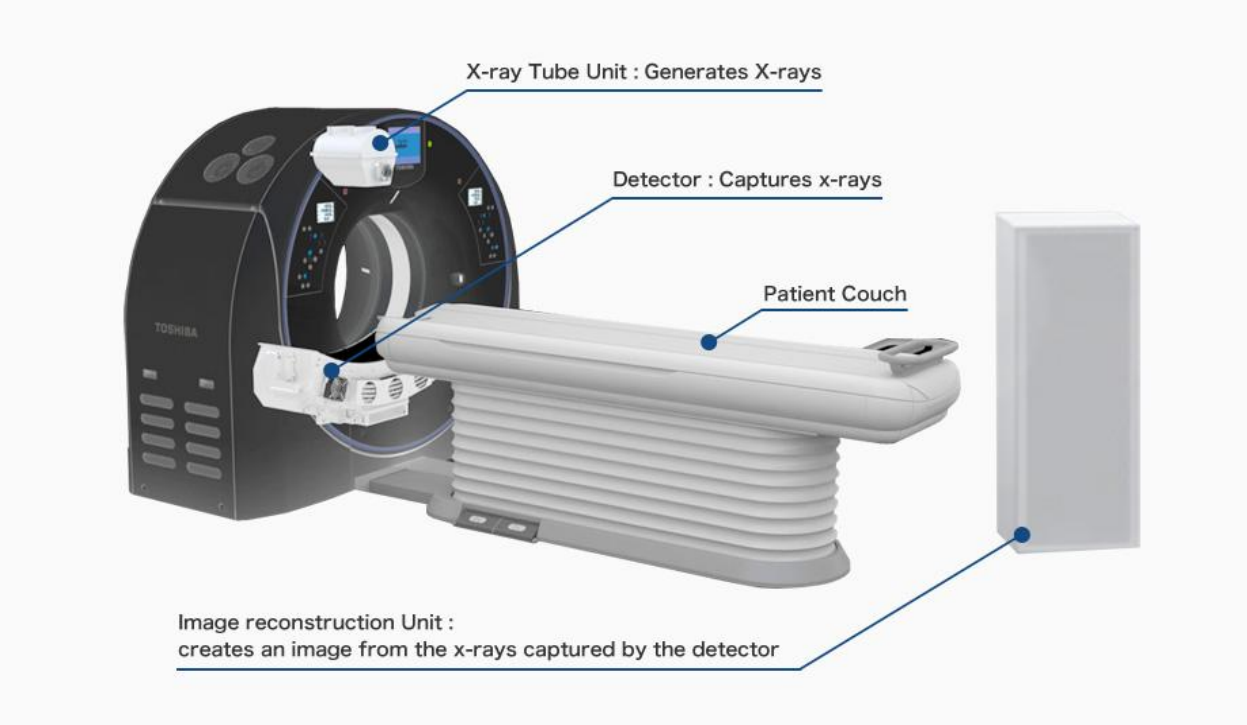


Fig.2 CT Machine[11]

Image Quality in CT Scanning: Essential Factors for Optimal Diagnostic

The choice of technique factors for performing a chest CT scan includes many important parameters that the CT operator controls are as follows:

CT Dose Index (CTDI):

The (CTDI) quantifies the amount of radiation absorbed by a patient during a CT examination, allowing comparison of dose levels across different scanners or protocols to minimize exposure while maintaining diagnostic image clarity.

The CTDI shows the radiation dose in the scanned body region, measured in milligray and influenced by different factors.

1. CT scanner Type: Different CT scanners may have differed radiation output based on their design and technology.
2. Scan Protocol: Parameters like slice thickness, tube current, and exposure time all affect the dose taken during a scan.
3. Scan Region: CTDI measurements can differ based on the area being scanned, as radiation dose distribution is not constant across the body.

CTDI is calculated in different ways depending on the specific scan area. The two most common types of CTDI are:

- CTDIvol (Volume CT Dose Index): This is the average dose per slice, taking into account the volume of tissue irradiated.
- CTDI100: This measurement represents the dose within a 100 mm length of the scanning region.

Formula: - CTDIVOL = (1/Pitch) × CTDI100

DLP

DLP is which is product of CTDIvol and CTscan length. Unit's measurement for CTDIvol is mGy.

CTDIvol represents the average radiation dose for a phantom, but can vary significantly between phantoms. It also does not vary with scan length, i.e., the scan range. DLP (Dose Length Product) takes scan length into account.

Formula[12]:- DLP =$CTDI_{VOL}$ × Scan Length

PITCH

Pitch refers to the proportion between the advancement of the patient table (or couch) and the width of the X-ray beam during helical (spiral) scanning.

Helical Pitch Ratio

Pitch = couch move each 3600 /Beam width

Rotation Time

Rotation time effect both how long the scan takes and the amount of radiation used. Faster rotations make the scan quicker and decrease radiation, but they can lower image quality, especially in studies that track changes over time. It's important to find the right balance to reduce radiation while still getting clear images for diagnosis. ,

The X-Ray Tube Voltage (kV)

The X-ray (kV) used in CT scan usually ranges from 80 to 140 kV. Expanding the voltage means more radiation is used during the scan, and the power of X-rays increases. This can lower the image contrast, but it also reduces image noise, making the image clearer. Higher voltages can also help reduce certain problems, like beam high density, which happens when low-energy X-rays are absorbed by denser tissues and cause distortions in the image. Adjusting the voltage properly is important to get good image quality while keeping the patient safe,

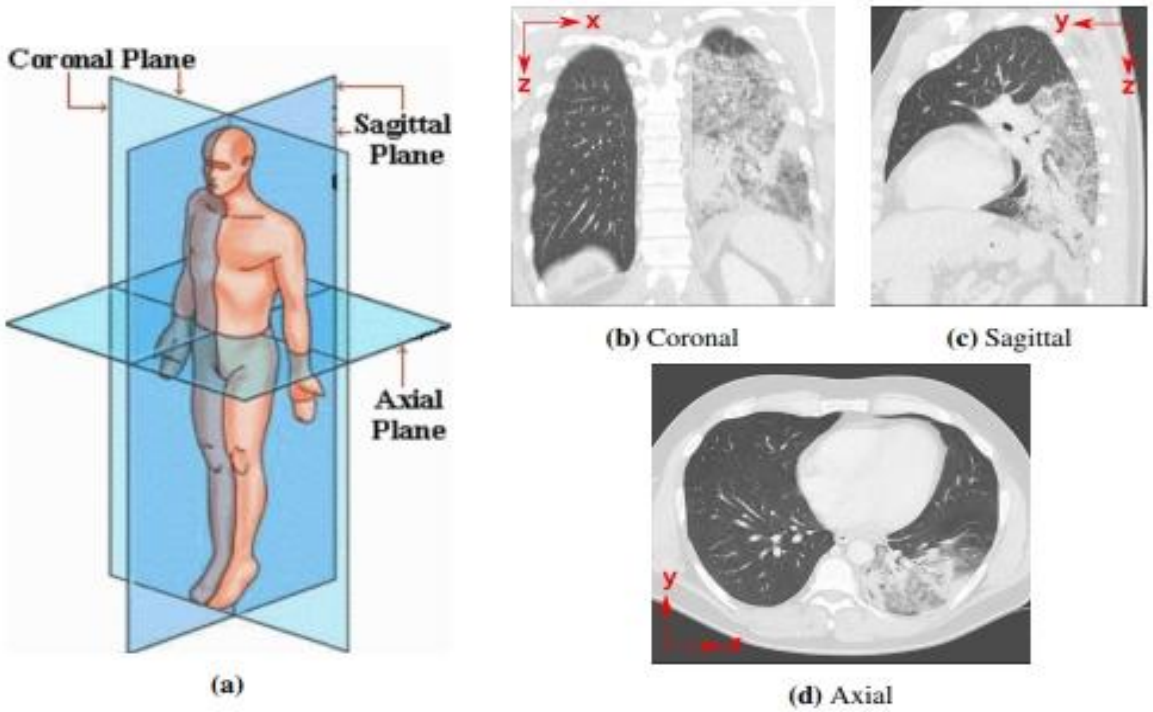


Fig3. (a) The anatomical planes, illustration from [22]. constructions along the (b) (frontal), (c) sagittal and (d) axial plane[13]

Image slice thickness

The slice thickness in CT determines the voxel depth, or its extension along the z-axis. When the slices are made thicker, the resolution along this axis decreases because each voxel covers a larger portion of tissue, which increases the risk of partial volume effects. Although thicker slices may still provide acceptable diagnostic quality in the axial plane, the resolution is often compromised when images are reconstructed in coronal or sagittal views. To maintain uniform image quality in all reconstruction planes, the data should ideally be captured with isotropic, or cubic, voxels—where voxel depth matches the in-plane pixel size. The depth of the voxel sets the minimum slice thickness, but thicker reconstructions can be generated by combining several voxels. This process boosts photon

counts per voxel, reducing image noise and lowering the number of slices a radiologist must review. This principle, often summarized as 'scan thin, view thick,' highlights the importance of acquiring thin slices for data collection while reconstructing thicker slices for practical interpretation

Radiation Hazards

Danger are related to the harmful effects of radiation on various parts of the body. Although the side effects of X-rays, radioactivity, and radium were known soon after their discovery, it was not at first clear that these effects were caused by radiation. This misreading was partly due to the delayed appearance of harmful effects over time. Early makers suspected that electrical factors, ultraviolet radiation, or platinum particles in the X-ray tube could be the cause. In the early period of X-ray use, radiologists often demonstrated the machine's operation by placing their hands in the beam and projecting the image onto a fluorescent screen. Such practices eventually caused chronic radiation-induced ulcers and, in some instances, even led to cancer. In some cases, prior radiologists and radiologist had to cut off part or all of their hands. In 1926, the first case of radiation-related cancer was identified in a factory worker producing X-ray tubes, who passed away two years after losing his arm to the disease. Later, scientists Pierre Curie and Henri Becquerel also suffered hand burns from radiation exposure. Eventually, it was discovered that certain alkaline earth metals released radiation similar to X-rays, and substances such as radium were officially categorized as radioactive.[16,17].

Radiation Protection

Radiation protection refers to the measures and planning used to safeguard people, the environment, and property from the damaging effects of ionizing radiation. These protections are essential in contexts like medical imaging, nuclear power generation, and industrial applications, where radiation exposure is innate. The main goal is to minimize exposure to ionizing radiation while ensuring the beneficial use of radiation, such as for medical treatments or energy production. The key principles of radiation protection are to prevent unnecessary exposure, limit dose, and ensure that exposure levels remain as low as reasonably achievable. To ensure safety from radiation, key measures include minimizing the time of exposure, keeping as much distance as possible from the source, and using protective barriers.[17,18,19,20,21].

Patient safety

Accurate calibration of imaging equipment is crucial for maintaining patient safety, as it ensures that radiation doses are delivered correctly and prevents both overexposure and unnecessary exposure. Another important guideline is the 'as low as reasonably achievable' (ALARA) principle, which aims to minimize radiation dose while preserving diagnostic value. A recent prospective study (2019) demonstrated that CT radiation dose can be reduced by more than 50% without affecting image quality. By comparing patients scanned with baseline protocols against those examined with optimized parameters, the study confirmed that significant dose reduction is possible while still maintaining reliable diagnostic outcomes25.

II. AIM AND OBJECTIVES

AIM: Optimization of the Image Quality and Radiation Dose CT Chest Exposure Parameters

OBJECTIVE:

1. To optimize the reduction of radiation dose by including the factor kVp, mAs, pitch, FOV in routine scanning protocols of chest CT examinations.
2. To determine the degree of dose reduction with changes in CT protocol parameters.
3. To investigate the optimization of exposure parameters in chest computed tomography (CT) to enhance image quality while minimizing radiation dose to patients..

NEED OF STUDY

1. The disparity between current practices in optimizing CT chest imaging and the potential benefits of advanced technologies and protocols.

2. Despite advancements in CT technology, many radiographers lack comprehensive knowledge of exposure parameters, limiting effective dose optimization strategies.

III. MATERIALS AND METHODS

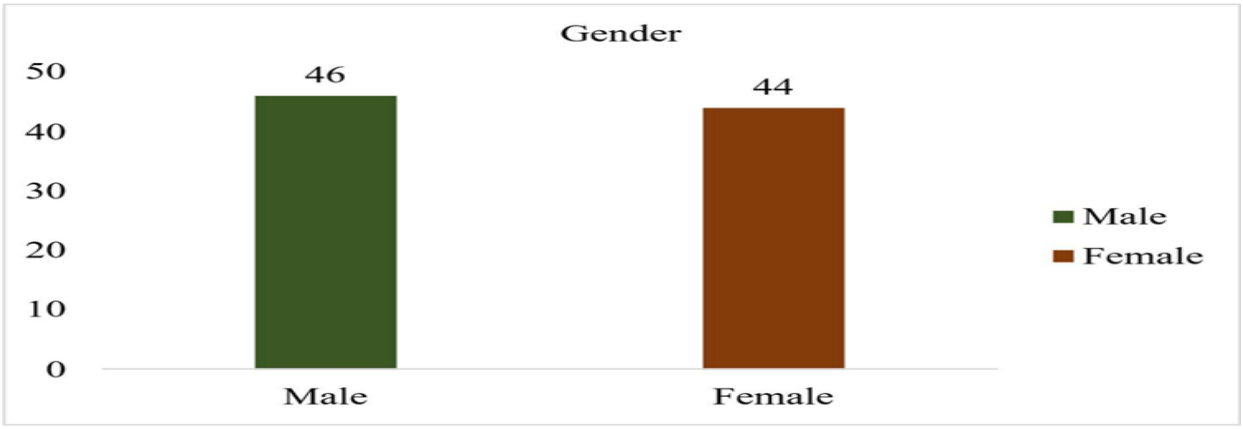
Study Design: Prospective Study Sample Size*: 90 Subjects				
Input Data				
Confidence Interval (2-sided)		95%		
Power		80%		
Ratio of sample size (Group 2/Group 1)		2		
	Group 1		Group 2	Difference*
Mean	2.02		3.18	-1.16
Standard deviation	1.71		2.1	
Variance	2.9241		4.41	
Sample size of Group 1		30		
Sample size of Group 2		60		
Total sample size		90		
*Difference between the means				

Place Of Study: Department of Radio-diagnosis Santosh hospital, Ghaziabad
Inclusion criteria: 1. Adults patients undergoing routine chest CT scans.
2. Age group-20yrs to 48yrs
Exclusion Criteria: Obese patients, above 50 yrs. and paediatric patients
Instrumentations: CT Siemens Healthineer, Slice: 128; Model: Somato Go Now
Ethical clearance: :
Ethical approval from the institution.

III. RESULTS

Out of a total of 90 participants, 44 (48.9%) were females and 46 (51.1%) were males. This indicates that the study sample had an almost equal distribution of males and females, with a slight predominance of males.

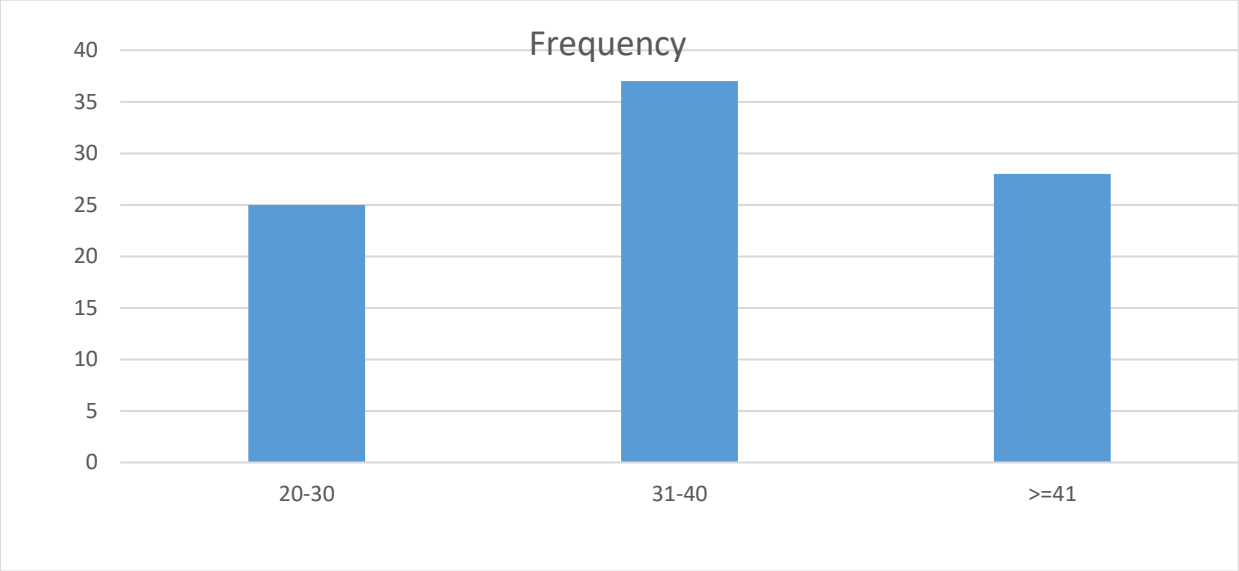
Sex					
Frequency			Percent	Valid Percent	Cumulative Percent
Valid	F	44	48.9	48.9	48.9
	M	46	51.1	51.1	100.0
	Total	90	100.0	100.0	



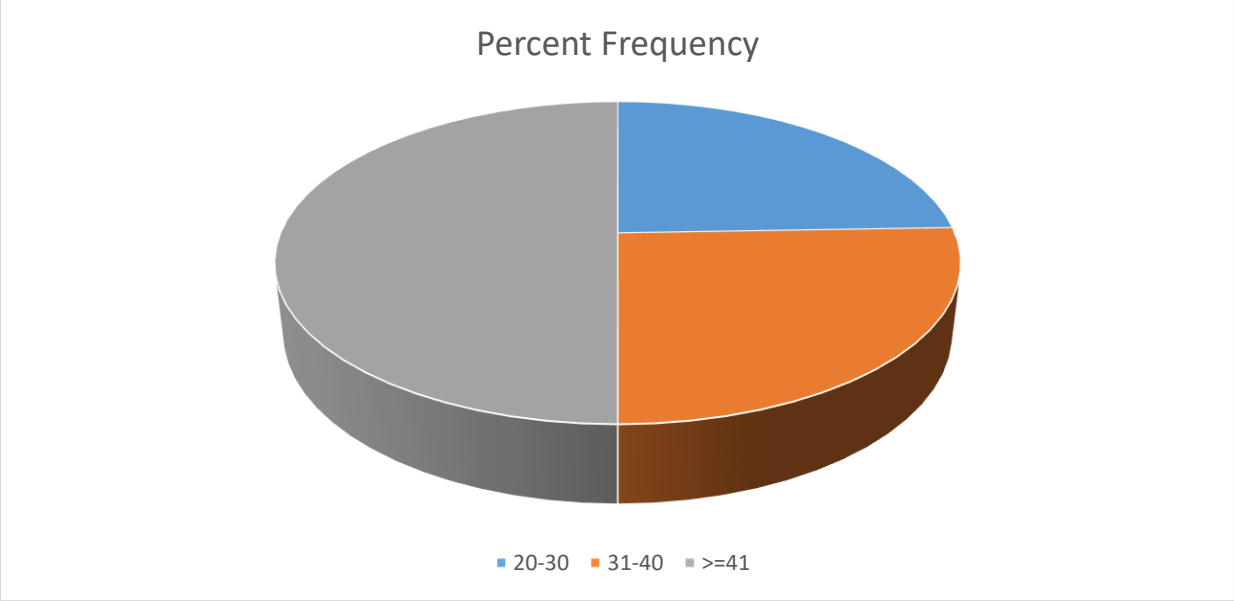
Graph: Gender wise Data

Out of a total of 90 participant 25 (27.8%) were in the age group 20–30 years, 37 (41.1%) were in the age group 31–40 years, and 28 (31.1%) were aged 41 years and above.
The largest proportion of participants belonged to the 31–40 years age group, followed by ≥41 years, while the smallest group was 20–30 years.
Age New

Frequency			Percent	Valid Percent	Cumulative Percent
Valid	20-30	25	27.8	27.8	27.8
	31-40	37	41.1	41.1	68.9
	>=41	28	31.1	31.1	100.0
	Total	90	100.0	100.0	



Graph: Agewise Data



Frequency wise data
Descriptive
The study included 90 participants.
Age ranged from 20 to 47 years with a mean age of 35.60 ± 7.46 years. Weight varied between 40–120 kg, with an average of 52.37 ± 9.43 kg. Imaging parameters showed:
KVp: constant at 120 kVp across all scans.
mAs ranged from 40–145, with a mean of 106.67 ± 19.29.
Pitch values varied between 0.9–1.3, mean 1.04 ± 0.05.
Scan length ranged from 210.1–498.0 mm, with a mean of 340.18 ± 50.17 mm.
Radiation dose parameters:
CTDIvol ranged from 10.9–21.3 mGy, mean 12.13 ± 3.04 mGy.
DLP ranged from 573.08–1136.2 mGy•cm, mean 571.30 ± 193.43 mGy•cm. Effective dose ranged from 0.58–5.85 mSv, with an average of 2.66 ± 1.26 mSv.
This shows that the CT protocols delivered an average effective dose of about 2.7 mSv, which falls within the expected range for chest CT examinations.

IV. DISCUSSION

The present study sought to evaluate whether routine chest CT scans can be optimized to reduce patient radiation exposure while maintaining diagnostic image quality. The findings show that adjusting tube current with automatic exposure control, maintaining tube voltage within a practical diagnostic range, and carefully limiting scan length can significantly lower radiation dose without adversely affecting the interpretability of the images. This observation supports the long-standing principle of "as low as reasonably achievable" (ALARA) and provides direct evidence that simple changes in protocol discipline can yield meaningful clinical benefits.

One of the strongest findings from this study was the reduction in dose indices achieved by the optimized protocol. Compared to the standard settings, the optimized group demonstrated approximately a 25% reduction in CTDIvol and nearly a quarter reduction in effective dose. These improvements are clinically relevant because chest CT is one of the most commonly performed examinations in clinical practice, and even modest reductions in per-scan dose can have substantial cumulative effects at a population level. The results also reinforce earlier reports that careful adjustment of mAs, when supported by automated exposure control systems, can reduce unnecessary exposure while preserving image quality. Importantly, subjective assessments of image quality revealed no significant difference between the optimized and standard groups. Both groups achieved mean image scores above the threshold for diagnostic adequacy, and the level of agreement between the two radiologists was high. This confirms that, within the tested ranges, lowering mAs and optimizing pitch does not compromise diagnostic confidence. Previous studies have similarly shown that once image quality reaches an acceptable level for interpretation, additional dose rarely translates into clinically meaningful improvements. Our results are consistent with those observations and suggest that "better" quality, as defined by higher radiation dose, is not always necessary when the goal is accurate diagnosis.

The role of scan length emerged as another important contributor to radiation burden. The analysis revealed that longer scan ranges in the standard group inflated dose metrics without a corresponding improvement in image quality. This highlights the practical importance of radiographer discipline and protocol adherence. In daily practice, excessive z-axis coverage can occur inadvertently, especially when technologists seek to avoid excluding anatomy of interest. However, careful training and adherence to standardized landmarks can mitigate this effect, ensuring that patients are not exposed to unnecessary additional radiation.

Pitch values, on the other hand, showed minimal impact on either dose or quality within the limited range used in this study (0.9–1.3). Although pitch theoretically influences both scan time and radiation output, our findings suggest that within this clinically common window, its effect is negligible compared with mAs and scan length. This result may also reflect the relatively narrow variation in pitch applied, which limits the ability to detect large differences.

In a broader context, the results align with international dose-reduction initiatives and diagnostic reference levels (DRLs) that encourage institutions to benchmark and progressively lower their radiation doses. By demonstrating that a measurable reduction is feasible without compromising diagnostic adequacy, the study provides local validation that institutional DRLs can be safely lowered. This is particularly valuable in resource-limited settings

where advanced dose-saving technologies, such as dual-energy CT or deep-learning reconstruction, may not be widely available.

Several limitations must be acknowledged. First, the study was conducted at a single center using one CT scanner model, which may limit generalizability. Second, image quality was assessed subjectively using a Likert scale; while inter-observer agreement was strong, incorporating objective noise or contrast-to-noise ratio measurements would have strengthened the analysis. Third, the study did not evaluate diagnostic accuracy for specific pathologies, such as pulmonary embolism or interstitial lung disease. Although image quality was deemed sufficient, future research should confirm that pathology detection remains unaffected by protocol changes.

Despite these limitations, the implications of the findings are significant. They demonstrate that optimization strategies—principally reducing tube current, avoiding excessive scan length, and maintaining appropriate tube voltage—are practical, effective, and safe. The study thus provides a roadmap for departments aiming to reduce patient dose in chest CT while upholding diagnostic standards. Incorporating these changes into everyday practice will not only benefit individual patients but also contribute to a broader culture of radiation safety.

V. CONCLUSION

This study was designed to evaluate whether radiation exposure in chest CT could be significantly reduced without sacrificing diagnostic reliability by fine-tuning acquisition parameters. The results confirmed this aim: optimized protocols with lower tube current, practical tube voltage settings, and controlled scan length achieved meaningful reductions in dose indices while maintaining image quality adequate for clinical reporting.

One of the major strengths of this work is the demonstration that a dose reduction of roughly 25% can be achieved through relatively straightforward adjustments to scanning discipline. The optimized protocol consistently lowered CTDIvol, DLP, and effective dose across the study population, while radiologists verified that diagnostic standards were preserved. These findings highlight that higher doses do not necessarily equate to better diagnostic outcomes, and that careful protocol optimization improves patient safety without diminishing diagnostic value.

The analysis also emphasized the role of scan length. Extending coverage unnecessarily along the z-axis contributed directly to higher dose metrics without enhancing diagnostic quality. This reinforces the importance of operator awareness, accurate anatomical landmarking, and disciplined practice. The results show that dose optimization is not only a technological challenge but also a procedural one, requiring consistent adherence to good practice. Pitch variation, in contrast, showed minimal influence within the studied range, suggesting that greater focus should be placed on tube current and scan length, which more strongly affect dose outcomes.

These findings contribute to broader global efforts to harmonize CT radiation practices. While diagnostic reference levels (DRLs) are now widely used to benchmark dose, compliance remains variable. By showing that high-quality images are achievable at lower doses, this research provides a local reference that supports protocol revision and alignment with international best practices. Importantly, the reductions observed here were achieved without specialized or high-end technology, making the recommendations relevant even in resource-limited settings.

From a patient-safety standpoint, the implications are clear. Chest CT delivers one of the highest doses among routine imaging procedures, and patients who require repeated scans—such as those with chronic lung disease or cancer—are particularly vulnerable to cumulative exposure. The ability to lower per-scan dose while retaining diagnostic adequacy offers substantial long-term benefits. Striking the balance between radiation safety and diagnostic utility represents the essence of responsible imaging, and this study adds valuable evidence to that balance.

That said, further refinement is needed. The reliance on subjective image-quality scoring, while practical, could be complemented by more objective measures such as noise analysis, signal-to-noise, or contrast-to-noise ratios. Future studies might also evaluate diagnostic accuracy for specific pathologies, and multi-center research across different scanner platforms would improve the generalizability of the findings.

In summary, this thesis shows that optimized chest CT protocols can lower radiation exposure by nearly one

quarter without compromising diagnostic performance. Practical steps include the adoption of automated exposure control, appropriate selection of tube voltage in the 100–120 kVp range, careful restriction of scan length to the clinical region of interest, and strict adherence to protocol discipline. Collectively, these measures advance safer imaging practices in line with international safety standards and the ALARA principle. Implementing such strategies allows radiology departments to maintain diagnostic confidence while ensuring that patient exposure remains as low as reasonably achievable.

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