ASSESSMENT OF THE IMPACT OF COMPUTED TOMOGRAPHY (CT) SLICE THICKNESS ON IMAGE NOISE AND NOISE POWER SPECTRUM (NPS)

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UNIVERSITI SAINS MALAYSIA

2025

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By

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Dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor in Medical Radiation (Honours)

July 2025

CERTIFICATE

This is to certify that the distribution entitled "**ASSESSMENT OF THE IMPACT OF COMPUTED TOMOGRAPHY (CT) SLICE THICKNESS ON IMAGE NOISE AND NOISE POWER SPECTRUM (NPS)**" is the bona fide record of research work done by AKMA FATINY BINTI MOHAMMAD NADZIM during the period from October 2024 to August 2025 under my supervision. I have read this dissertation and in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment of the degree of Bachelor of Health Science (Honours) (Medical Radiation).

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DECLARATION

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AKMA FATINY BINTI MOHAMMAD NADZIM

Date: July 2025

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest gratitude to my beloved parents, Mama and Abah, for their unwavering love, support, and encouragement throughout my academic journey. Their sacrifices, guidance, and belief in me have been the foundation upon which I have built my dreams. To my family members, your constant presence and love have kept me grounded, providing me with the strength to overcome every challenge. Thank you for always being there for me, offering both emotional and moral support.

I would also like to extend my sincere appreciation to my supervisor, whose guidance, support, and expertise have been essential to the success of my FYP. From the very beginning to the end, your mentorship has helped me grow academically and personally, and I am truly grateful for all the time and effort you invested in guiding me.

I am also truly grateful to my loved one, who has been a source of immense encouragement and positivity. Your unwavering faith in me has inspired me to push through every hurdle. A heartfelt thanks to all my friends, whose motivation, advice, and companionship have helped me stay focused and determined. Your support, whether directly or indirectly, has been invaluable throughout my degree journey.

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LIST OF ABBREVIATIONS

AMDI	Advanced Medical and Dental Instituition
CT	Computed Tomography
DLR	Deep Learning Reconstruction
FWHM	Full Width At Half Maximum
FOV	Field of View
IR	Iterative Reconstruction
MBIR	Model-based Iterative Reconstruction
NPS	Noise Power Spectrum
QA	Quality Assurance
ROI	Region of Interest
SNR	Signal-to-Noise Ratio
ST	Slice Thickness
2D	2-Dimensional

PENILAIAN TERHADAP KESAN KETEBALAN IMEJ HIRISAN DALAM TOMOGRAFI BERKOMPUTER (CT) TERHADAP KEBISINGAN IMEJ DAN SPEKTRUM KUASA KEBISINGAN (NPS)

ABSTRAK

Ketebalan hirisan dalam tomografi berkomputer (CT) memainkan peranan penting dalam kualiti imej dan ketepatan diagnosis. Kajian ini bertujuan untuk menilai kesan ketebalan hirisan CT terhadap kebisingan imej dan Spektrum Kuasa Kebisingan (NPS) dengan menggunakan perisian IndoQCT. Imej CT diperoleh menggunakan fantom air pada pelbagai ketebalan hirisan, dan data yang dijana dianalisis menggunakan modul analisis imej dalam IndoQCT. Penilaian hingar imej dilakukan dengan mengira sisihan piawai dalam kawasan seragam imej, manakala NPS dikira untuk menilai taburan frekuensi kebisingan. Hasil kajian menunjukkan bahawa ketebalan hirisan yang berbeza memberi kesan yang ketara terhadap tahap kebisingan dan ciri-ciri frekuensi dalam imej CT. Ketebalan hirisan yang lebih kecil cenderung menghasilkan imej dengan kebisingan yang lebih tinggi tetapi memberikan resolusi yang lebih baik, manakala ketebalan hirisan yang lebih besar mengurangkan kebisingan tetapi boleh menjejaskan perincian imej. Dalam projek ini, imbasan dilakukan ke atas fantom air dengan ketebalan hirisan yang berbeza, bermula dari 0.6 mm hingga 10 mm. Imej yang diperoleh dianalisis menggunakan perisian IndoQCT bagi mengukur tahap hingar imej serta menilai NPS bagi setiap ketebalan hirisan. Hingar imej diukur berdasarkan sisihan piawai dalam kawasan

minat (ROI) yang seragam, manakala NPS digunakan untuk mencirikan taburan frekuensi spatial hingar.Penemuan ini penting dalam menentukan ketebalan hirisan optimum bagi tujuan kawalan kualiti dan pengimbasan klinikal.

ASSESSMENT OF THE IMPACT OF COMPUTED TOMOGRAPHY (CT) SLICE THICKNESS ON IMAGE NOISE AND NOISE POWER SPECTRUM (NPS)

ABSTRACT

Slice thickness in computed tomography (CT) plays a critical role in image quality and diagnostic accuracy. This study aims to assess the impact of CT slice thickness on image noise and the Noise Power Spectrum (NPS) using the IndoQCT software. CT images were acquired using a water phantom at various slice thicknesses, and the resulting data were analyzed using the image analysis module in IndoQCT. Image noise was evaluated by calculating the standard deviation within a uniform region of interest, while the NPS was computed to examine the frequency distribution of the noise. The findings indicate that varying slice thickness significantly affects the level of image noise and its frequency characteristics. Thinner slices tend to produce images with higher noise but better spatial resolution, whereas thicker slices reduce noise at the expense of image detail. In this project, a water phantom was scanned using varying slice thicknesses ranging from 0.6 mm to 10 mm. The resulting images were analysed using IndoQCT software to quantify image noise and evaluate the NPS across the different slice thicknesses. Image noise was measured in terms of standard deviation within a uniform region of interest, while the NPS was used to characterise the spatial frequency distribution of the noise. These results are essential for determining the optimal slice

thickness for quality control and clinical scanning purpose.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Computed tomography (CT) is a widely use diagnostic imaging modality that provides detailed cross-sectional images of the body. It is preferable because it is a fast, and non-invasive method that produces good contrast and spatial resolutions images. The image quality of CT imaging relies on several factors, including acquisition parameters, image pre-processing and image image post-processing parameters. The image acquisition parameters or exposure factors includes the field of view (FOV), effective mAs, tube voltage, image reconstruction method, beam collimation, and slice thickness determine the final image quality (Lasiyah et al., 2021).

Among the many parameters that influencing image quality and radiation dose, slice thickness plays a critical role. In directly affects image noise characteristics, spatial resolution, and the overall diagnostic utility of CT images. In this project, the influence of slice thickness on image quality in CT scans was evaluated, as it plays a crucial role in determining the diagnostic value of the images. It is controlled by collimator settings, typically ranging from 0.625 mm to 10 mm, depending on the clinical examination requirements set by the operator. This range is commonly used to balance spatial resolution and spatial resolution and scan effciency, thinner slices offer improved spatial resolution, while thicker reduce scan time and radiation dose (Abdulkareem et al., 2023).

Image noise, a key factor in image quality, can obscure fine anatomical details, while the Noise Power Spectrum (NPS) provides a more comprehensive assessment of noise texture and distribution. Understanding how slice thickness impacts image noise and NPS is essential for optimising CT protocols to ensure high image quality with the lowest reasonable radiation exposure. This study aims to assess the effect of varying slice thickness on image noise and NPS, providing insights that can guide protocol adjustments for improved diagnostic performance and patient safety.

1.2 PROBLEM STATEMENT

Image noise is a critical factor that affects the diagnostic quality of CT scans by reducing the visibility of fine anatomical details. While traditional metrics like standard deviation (SD) provide a basic measure of noise magnitude, the Noise Power Spectrum (NPS) offers a more comprehensive evaluation by describing the spatial distribution and texture of noise. Despite its importance, the relationship between image noise characteristics and CT acquisition parameters, particularly slice thickness, remains underexplored in clinical settings. In CT systems, image noise and resolution are inversely related, where spatial resolution refers to the system's ability to distinguish closely positioned objects as separate entities.

Slice thickness, determined during both acquisition and reconstruction, directly influences the amount of image noise an the shape of the NPS. Slice thickness in CT imaging is a critical parameter for achieving optimal image quality while minimising radiation dose and scan time to the patient. Thinner slices improve anatomical detail and spatial resolution (increased visibility and improved detection), but are associated with increased image noise and longer scan times. Conversely, thicker slices reduce noise and shorten scan time but may compromise image detail. It is also possible to reduce image noise without increasing the X-ray dose by adjusting the voltage within an optimal range. Thinner slices help reduce partial volume artifacts, but they also increase patient dose, image noise, and scan time (Abdulkareem et al., 2023).

Besides, thicker slices improve the signal-to-noise ratio (SNR) by allowing more photons to reach the detector, thereby reducing image noise. However, it may compromise spatial resolution along the Z-axis. Conversely, thinner slices enhance spatial resolution and anatomical detail, but increase image noise and scan time. Since image noise varies linearly with slice thickness, optimising this parameters is essential to achieve a balance between diagnostic value, and image quality.

Noise in CT images is typically assessed through signal-to-noise ratio (SNR), which compare the level of desired signal (photons) to the background noise (random pixel value deviations), (Abdulkareem et al, 2023). SNR is calculated as the ratio of average pixel value (ave_p) to the standard deviation of pixel values, σ_p. A higher SNR indicates lower noise and better image quality. However, while thicker may reduce noise and increase SNR, they can compromise the ability to detect fine structures due to reduced spatial resolution. Therefore, determining the optimal slice thickness of CT is crucial for balancing image noise, spatial resolution and diagnostic accuracy.

1.3 RESEARCH OBJECTIVE

1.3.1 GENERAL OBJECTIVE

This study aims to evaluate the impact of computed tomography (CT) slice thickness on image noise an Noise Power Spectrum (NPS) using the IndoQCT software for quantitative image quality analysis.

1.3.2 SPECIFIC OBJECTIVES

- To quantitatively measure image noise as a function of slice thickness in CT images
- To quantitatively measure signal to noise ratio (SNR) as a function of slice thickness in CT images.

- To analyse the Noise Power Spectrum (NPS) using IndoQCT for different slice thicknesses, focusing on spatial frequency components.

1.4 SIGNIFICANCE OF STUDY

This study investigates the impact of varying CT slice thicknesses image noise and the Noise Power Spectrum (NPS), using the IndoQCT software for quantitative image quality assessment. The primary goal is to evaluate how changes in slice thicknesses influence noise characteristics and to identify the optimal settings of slice thickness that produce high quality images with minimal noise. CT image quality is very important for accurate and early disease detection. Thinner slices offer greater anatomical detail, but tend to create more noise. In contrast, thicker slices reduce noise but may compromise the visibility of small details.

By identifying the ideal balance between image detail and noise, this study provides guidance for optimising CT protocols across, various clinical applications, including brain, lung, or abdominal imaging. Additionally, improving slice thickness settings can contribute to reduce radiation dose to patients, particularly important for patients requiring frequent imaging, such as those undergoing follow up or screening. Ultimately, this research aims to enhance the diagnostic value, safety, and efficiency of

CT scans, benefiting both patients and healthcare providers through improved image quality, reduced scan repetition, and more informed clinical decision making.

1.5 SCOPE AND LIMITATIONS

This project focuses on evaluating the effect of CT slice thickness on image noise and the Noise Power Spectrum (NPS) using IndoQCT software. The scope of the study includes the acquisition of CT images from a uniform water phantom using a range of slice thicknesses, specifically from 0.6 mm to 10 mm. The collected images are then analysed using IndoQCT software to measure the level of noise and to evaluate the NPS. The study aims to understand how changes in slice thickness influence both the magnitude and spatial frequency characteristics of noise in CT images. By using a standard water phantom in a controlled environment, the study ensures that the analysis is consistent and unaffected by anatomical variations or patient-related factors.

However, this project also has several limitations. The study is confined to the use of a water phantom and does not include clinical CT images, which means that it does not take into account anatomical complexity or variability. In addition, only one CT scanner and a single scanning protocol are used throughout the study. As a result, the findings may not be generalisable to other scanner models or imaging conditions. Furthermore, other technical parameters such as tube current (mAs), tube voltage (kVp), and reconstruction algorithms are kept constant and are not examined for their potential interactions with slice thickness. Finally, the study focuses solely on objective measurements of image noise and does not assess diagnostic performance or subjective image quality.

1.6 THESIS ORGANISATION

This thesis is structured into five main chapters, each designed to address a specific component of the study. Chapter 1 introduces the overall research, including the background of the study, the problem statement, research objectives, research questions, significance of the study, scope and limitations, and a brief overview of how the thesis is organised.

Chapter 2 presents a review of the relevant literature, focusing on the fundamentals of computed tomography (CT), key parameters related to image quality, the concept of image noise, and the Noise Power Spectrum (NPS). It also discusses past studies concerning the effects of slice thickness on CT image characteristics and the use of software-based analysis tools.

Chapter 3 describes the methodology employed in this research. It outlines the CT scanning procedure, the imaging protocol, and the use of a water phantom. Additionally, it details the slice thickness variations used during image acquisition and explains how the IndoQCT software was applied to analyse image noise and NPS.

Chapter 4 is dedicated to presenting and interpreting the results obtained from the analysis. This chapter includes a comparison of image noise and NPS across various slice thicknesses, and evaluates how changes in thickness influence image quality characteristics. The findings are discussed in relation to the research objectives.

Chapter 5 concludes the study by summarising the key outcomes and findings. It also discusses the implications of the results for medical imaging practices, proposes recommendations for future research, and highlights the contributions of the project to the field of medical physics.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO COMPUTED TOMOGRAPHY (CT) IMAGING

Computed Tomography (CT) is a medical imaging technique that combines multiple X-ray measurements taken from different angles to produce cross-sectional images (slices) of the body. These images provide detailed information about internal organs, bones, soft tissues, and blood vessels. CT imaging plays a crucial role in medical diagnosis, treatment planning, and disease monitoring, especially in fields like oncology, neurology, and cardiology (Brenner & Hall, 2007). Computed Tomography (CT) is an advanced medical imaging modality that employs a rotating X-ray source and an array of detectors to capture projection data from multiple angles around a patient. A computer then applies tomographic reconstruction algorithms (e.g., filtered back-projection or iterative reconstruction) to generate cross-sectional "slice" images of internal anatomy (Lasiyah et al., 2021).

CT is a sophisticated medical imaging modality that uses X-ray measurements taken from multiple angles around the patient to produce detailed cross-sectional images of the body. Unlike conventional radiography, which provides two-dimensional projections, CT reconstructs these projections into thin slices, allowing visualization of internal structures in three dimensions. This capability is essential for accurate diagnose of a wide range of clinical conditions by revealing anatomical details of bones, soft tissues, and blood vessels with high spatial resolution and contrast differentiation (Seeram, 2010).

Recent reconstruction algorithms such as iterative and deep-learning-based reconstructions aid in reducing artifacts and enhancing image quality, while maintaining or lowering radiation exposure. Modern studies reinforce these trade-offs: using 1–2 mm slices yields better noise and contrast compared to thicker slices while allowing a potential dose reduction of 20–40% in abdominal CT protocols. However, thinner slices require careful consideration to avoid excessive noise unless compensated by advanced reconstruction methods (Kataria et al., 2019).

Image quality in computed tomography (CT) is determined by multiple interdependent metrics such as noise, spatial resolution, and contrast resolution, all of which influence diagnostic performance.

Noise refers to random fluctuations in voxel values, typically quantified as the standard deviation of Hounsfield Unit (HU) values within a uniform phantom region. Recent studies have shown that thinner slice thickness increases noise magnitude and shifts noise texture towards higher spatial frequencies, as measured by the Noise Power Spectrum (NPS). For instance, experiments varying slice thickness from 0.625 mm to 10 mm confirm an inverse relationship between slice thickness and NPS peak values—thicker slices produce lower noise and coarser noise texture (Mohammadinejad et al., 2021).

Spatial resolution describes the ability of the system to distinguish closely spaced structures. Phantom studies (e.g. Mercury phantom) using task-transfer functions (TTF) have quantified how reconstruction algorithms and dose settings affect resolution at both high-contrast and low-contrast levels (Solomon et al., 2020).

Contrast resolution, or low-contrast detectability, assesses the ability to differentiate tissues with small attenuation differences. The contrast-to-noise ratio (CNR) is commonly used for this purpose, defined as the HU difference between objects divided by image noise standard deviation. Optimal imaging protocols require careful balance while reducing noise helps CNR, overly aggressive noise suppression may impair contrast detection, especially for subtle lesions.

2.2 IMAGE QUALITY METRICS

Fundamentally, CT image quality is defined by key parameters such as contrast, spatial resolution, image noise, and artefacts. Spatial resolution refers to the ability of a CT scanner to distinguish and display two closely spaced objects as separate structures. Spatial resolution is a fundamental aspect of CT image quality, reflecting the system's ability to distinguish small, closely spaced structures. A recent study introduced and validated a method for directly measuring spatial resolution in clinical chest CT images using modulation transfer function (MTF) analysis.

Next, contrast resolution is the ability of the CT scanner to display the object with considerably different in density from its surrounding objects, where it depends on the bit-depth of the system. The 8-bit system shows less gray values which total in 256 gray values, and the 12-bit system that shows total 4096 gray values. If the system can clearly show two nearby gray value intensities, the system will have high contrast resolution.

Third factor of the image quality is image noise where it defined as the grainy appearance of cross-sectional imaging. Noise will decrease in picture quality and reduces the contrast resolution. The cause of noise is because of a low photon count in an image and be measured by the signal to noise ratio (SNR). The higher the ratio, the lesser the noise present in the image. SNR is calculated as the ratio of average pixel value, ave_p to the standard deviation of the pixel values, $\sigma_{p.}$

Noise, defined as the standard deviation of CT numbers in a uniform image, refers to unwanted information that interferes with the intended signal in electronics systems. This noise arises from various sources, including electronic interference, and manifests as an irregular grainy pattern in images, negatively impacting image quality and the information they convey. Noise levels can be reduced by lowering the standard deviation of pixel values. Thus, noise is another critical factor impacting CT image quality. It is defined as the random variation in pixel values and is influenced by both technical parameters and patient factors.

Besides that, image artefact that is one of the factors in image quality. Artefacts may be defined as any structure that is seen on an image but does not represent the actual anatomy. Most artefacts can be classified into 3 main categories which are shading artefacts, ring artefacts, or streak artefacts. The most common type of artefact is the shading artefact, which is primarily cause by beam-hardening effects. Beam-hardening artefacts are present to some extent in all CT images and are due to imperfect correction of beam-hardening. They appear as nonuniformities in CT numbers of a uniform material, such as CT numbers that are lower at the center of a uniform phantom than at the periphery. Such uniformities are generally quite small about less than 5 HU and not apparent unless one is viewing a scan of a uniform phantom with a very narrow window. Example of shading artefact is shown in Figure 2.1 below.

Figure 2.1: Example of shading artefact on CT image

Scatter can also cause shading artefacts, although these are uncommon in most modern scanners. Ring or partial ring (arc) artefacts are associated with third-generation scan geometry and were discussed previously. Ring artefacts arise from errors, imbalances, calibration drifts, or other measurement inaccuracies in an element of a detector array relative. Ring or arc artefacts are usually readily recognizable by software ring-correction algorithms and thus can be removed from the image (Goldman, 2007). Example of ring artefact on CT image is shown in Figure 2.2 below.

Figure 2.2: Example of ring artefact on CT image

Small-radius rings or arcs of small angular extent may not be recognized as artifacts and thus wind up in the image. Streak artifacts may occur in all scanners. Although arising for many reasons, most are due to inconsistent or bad detector measurements.

Figure 2.3: Example of streak artefact on CT image

2.3 ASSOCIATED FACTORS WITH CT IMAGE QUALITY

These parameters are influenced by several technical factors, including slice thickness, which plays a critical role in balancing image detail, noise level, and patient dose. Radiation dose parameters are closely associated with image quality and patient safety., requiring careful optimisation to achieve diagnostic effectiveness while minimising risk. A recent study introduced the size-specific dose-length product (DLPs) to more accurately estimate patient-specific radiation exposure during CT scans. The findings highlighted significant variability in radiation dose based on patient size and scan parameters, such as tube current, tube voltage, and scan length. The study emphasised that optimising these parameters is essential to both minimise radiation risk and maintain adequate image quality, especially since CT contributes significantly to the collective radiation dose (Dominika Sabiniewicz-Ziajka et al., 2024). another study that involved large-scale analysis reported that scanner model, slice thickness, tube current, tube voltage, and patient size are among the most influential factors affecting both image quality and radiation dose, with significant variability observed across different facilities and patient populations (Smith et al., 2021).

Slice thickness is a significant determinant of both image noise and spatial resolution. A previous study shows that thinner slices (e.g., 0.625 mm) reduce partial volume artefacts and enhance the visibility of small structures, but they also increase image noise and patient dose. Conversely, thicker slices improve the signal-to-noise ratio (SNR) and reduce scan time, but may obscure fine anatomical details. Therefore, selecting the optimal slice thickness involves carefully balancing the need for diagnostic detail with the goal of minimising image noise and radiation exposure (Abdulkareem et al., 2023).

In digital imaging, spatial resolution is influenced by pixel size. Smaller pixels allow for better differentiation between adjacent structures, while larger pixels may blur the distinction. Spatial resolution is typically measured in line-pairs per milimeters (lp/mm), with higher values indicating greater resolving capability. Factors that affect the spatial resolution include the focal spot, where the smaller the focal spots, it gives a higher resolution, thus, the spatial resolution improves. Next, detector width also contributes as a factor such when the width of the detector is small, it gives a higher resolution and the spatial resolution improves. Furthermore, slice thickness has the biggest contribution in spatial resolution as thinner slices will produce sharper images, so it gives a higher resolution (Goldman, 2007).

This method demonstrated that spatial resolution is sensitive to changes in reconstruction kernels, with higher kernel values yielding improved resolution. The study confirmed that accurate spatial resolution measurement provides a more precise assessment of CT image quality, especially when comparing different reconstruction approaches. Additionally, other research highlights that spatial resolution is not uniform across a CT image and can be affected by noise and artifacts, emphasizing the need for comprehensive assessment methods (Liu et al., 2025).

Factors that affecting contrast resolution are mAs, pixel size, slice thickness and FOV. If the mAs in increasing the better contrast resolution in result. Other than that, decreases in pixel size will decreases the contrast resolution. Next, the slice thickness increases will improve the contrast resolution as well. Lastly, the bigger FOV will give better result in contrast resolution (Goldman, 2007).

Factors that affecting CT noise is because the decresases in pixel size that cause the increases in noise. Higher the mAs will lower the noise. Larger patients will absorb more radiation hence fewer photons will reach the detector, which will reduce the signal-to-noise ratio (Goldman, 2007). The quality of medical images, particularly in computed tomography (CT), is often degraded by noise resulting from factors such as data acquisition limitations, raw data processing errors, and technological constraints. Accurate identification of the predominant noise type in CT images is crucial for selecting appropriate denoising techniques and ensuring reliable image interpretation in clinical applications. In a study, Nasr et al. (2025) proposed a comprehensive framework for classifying noise types, utilizing three independent methodological approaches.

Detector performance, particularly quantum noise, is influenced by the number of photons received, with image noise decreasing as photon count increases. In CT systems, noise and resolution are inversely related where spatial resolution refers to the system's ability to distinguish closely positioned objects as separate entities. It is also possible to reduce image noise without increasing the X-ray dose by adjusting the voltage within an optimal range.

Recent study reported that image noise is inversely related to the number of photons received by the detector, which is determined by the tube current (mAs) and the slice thickness. Thinner slices improve spatial resolution but increase noise, whereas thicker slices reduce noise by allowing more photons to reach the detector but may compromise resolution along the Z-axis. The study also noted that adjusting the tube voltage (kVp) within an appropriate range can help manage noise without necessarily increasing the radiation dose (Abdulkareem et al., 2023).

Factors causing inconsistencies include motion (anatomy in different locations during different parts of the scan), partial-volume effects, metal (a measured intensity that is under the calibrated range of the detector, and possibly beam-hardening and partial-volume effects), insufficient x-ray intensity (leading to high random errors), and malfunctions (tube arcing or system misalignment). Regardless of the source, the effect of an inconsistency is the creation of a streak artefact because of the nature of back projection reconstruction (Goldman, 2007). Example of streak artefact on CT image is shown in Figure 2.3.

Tube current (mA) directly governs photon flux, affecting image noise and patient dose. In low-dose CT protocols, in a study mentioned such as those developed during the COVID-19 pandemic where a 50% reduction in mA linearly halved radiation exposure and increased noise, which could be mitigated by iterative reconstruction techniques. CT scanning parameters which can affect the radiation dose (such as scan length, tube current, tube potential, pitch factor, etc.), and low-dose CT protocols (Azadbakht et al., 2021).

Reconstruction algorithms and technical settings further influence CT image quality. Advances in reconstruction techniques, such as iterative reconstruction and the use of different convolution kernels, have enabled significant improvements in spatial resolution and noise reduction. These methods can be tailored to the clinical task, allowing for lower radiation doses without compromising diagnostic accuracy. Recent literature confirms that the choice of reconstruction algorithm and kernel directly affects both the objective and subjective quality of CT images, highlighting the need for careful selection based on clinical requirements (Smith et al., 2021).

2.4 IMAGE NOISE EFFECT OF CT SLICE THICKNESS ON IMAGE NOISE

Noise, or fluctuation that is not part of a desired signal, occurs in all electronic systems and can be caused by a variety of factors, including electronic interference. In all photos, it destroys image information and manifests as an uneven granular pattern. The severity may make it invisible or make photos non-diagnostic. Although noise is an artifact in and of itself, it should not be confused with other artifacts, which are less random and supposed to be repeatable in theory. The region of interest (ROI) tool can be used to quantify noise in an image when it is put in an area with consistent physical properties, such as water or air. The standard deviation of the pixel values (σ) in a region of interest with uniform physical parameters is a popular way to quantify noise. The noise level increases with the standard deviation. The quantity of distinct x-ray photons that reach the detector determines the amount of noise (quantum noise) in CT. Refer to the noise (CT) article separately. The reconstruction kernel and detector system noise combine to produce the electronic noise in CT (noisier images are produced by sharper kernels). Increasing the mAs, increasing the tube current, or altering the filters during reconstruction can all reduce noise in a CT scan image. Various computational ways to reduce noise in digital images after they are formed are usually referred to as noise reduction, also known as noise suppression or denoising (Bell & V, 2011).

However, other sources use the term more broadly to refer to anything that reduces noise. At different points following acquisition, digital image processing applies a variety of techniques, the majority of which are filtering approaches. These techniques may use frequency filters (discrete Fourier transform), morphological filters, statistical filters, or spatial filters (convolutions) (Bell & V, 2011). Image noise is proportional to the fluctuation in CT number values over a homogeneous area. As a result, the standard deviation of the CT number or the pixel intensity values within a physically uniform region are used to statically define image noise. The lower the variance (standard deviation) for pixel value, the lower the noise. Furthermore, the quantity of photons that the detectors receive determines the definition of CT noise (quantum noise). As the number of photons received by the detectors increases, image noise reduces (Alshipli & Kabir, 2017).

In recent years, the effect of CT slice thickness on image noise has been extensively studied, revealing a clear relationship between these two parameters. A recent study investigated a single-source of multi-slice CT head protocols which found that image noise increases as slice thickness increases, demonstrating a linear relationship between slice thickness and noise levels. Specifically, thinner slices (e.g., 0.625 mm and 1.25 mm) were associated with reduced image noise, improved visibility, and enhanced lesion detection compared to thicker slices. The study identified 1.25 mm as the optimal slice thickness that balances noise reduction with sufficient diagnostic content, emphasising that while thicker slices can enhance structural detail, they also introduce more noise which may degrade image quality (Abdulkareem et al., 2023).

This inverse relationship between slice thickness and image noise is explained by photon statistics where thinner slices receive fewer photons per slice, which tends to increase noise. However, the studies showed that advanced image processing and reconstruction techniques can mitigate this effect, allowing thinner slices to maintain or improve image quality. Conversely, thicker slices accumulate photons over a larger volume, which improves the signal-to-noise ratio (SNR) but at the cost of spatial resolution and potential partial volume effects that can obscure small structures (Abdulkareem et al., 2023).

Furthermore, the diagnostic value of CT images is influenced by this trade-off. Thinner slices reduce partial volume artifacts and improve contrast resolution, thereby enhancing the detection of small lesions and fine anatomical details. However, the increase in noise with very thin slices necessitates careful protocol optimization to avoid compromising diagnostic accuracy. Studies recommend that clinical protocols consider this balance, tailoring slice thickness to the diagnostic task while controlling noise through appropriate tube current and reconstruction algorithms (Abdulkareem et al., 2023).

2.5 NOISE POWER SPECTRUM (NPS) MEASUREMENT IN CT IMAGING

Noise Power Spectrum (NPS) is a key metric used in imaging physics to quantify the spatial distribution and texture of noise in medical images, particularly in CT imaging. Noise Power Spectrum (NPS), is derived from a homogeneous field of radiation, is one of the key metrics for comprehending the noise in terms of amplitude and texture in