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# Effect of slice thickness on image noise and diagnostic content of single-source-dual energy computed tomography

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# Effect of slice thickness on image noise and diagnostic content of single-source-dual energy computed tomography

**Marwan Alshipli.[1] and Norlaili A. Kabir[1]**

[1]School of Physics, Universiti Sains Malaysia, 11800, Pulau Pinang, Malaysia

E-mail: marwanayasrh@yahoo.com

**Abstract**. Computed tomography (CT) employs X-ray radiation to create cross-sectional images. Dual-energy CT acquisition includes the images acquired from an alternating voltage of X-ray tube: a low- and a high-peak kilovoltage. The main objective of this study is to determine the best slice thickness that reduces image noise with adequate diagnostic information using dual energy CT head protocol. The study used the ImageJ software and statistical analyses to aid the medical image analysis of dual-energy CT. In this study, ImageJ software and F-test were utilised as the combination methods to analyse DICOM CT images. They were used to investigate the effect of slice thickness on noise and visibility in dual-energy CT head protocol images. Catphan- 600 phantom was scanned at different slice thickness values; **.**6, 1, 2,3,4,5 and 6 mm, then quantitative analyses were carried out. The DECT operated in helical mode with another fixed scan parameter values. Based on F-test statistical analyses, image noise at 0.6, 1, and 2 mm were significantly different compared to the other images acquired at slice thickness of 3, 4, 5, and 6 mm. However, no significant differences of image noise were observed at 3, 4, 5, and 6 mm. As a result, better diagnostic image value, image visibility, and lower image noise in dual-energy CT head protocol was observed at a slice thickness of 3 mm.

## 1. Introduction

Computed tomography scan (CT) is a cross-sectional medical imaging technology introduced in 1972 by British engineer Godfrey Hounsfield. Computed tomography is the first radiologic modality that requires the use of computers to scan the internal organ of the body. This technology creates data depending on the different attenuation levels of the scanned area [1]. CT is classified according to the type of energy technology; the classifications are single- (SECT) and dual-energy CT (DECT). DECT provides two different attenuation levels (low and high) that construct two data sets for the same scanned area. Therefore, DECT presents more advantages to improve image quality in comparison with SECT, including the correction of the beam-hardening artifact, reduction in the radiation dose level and increase of the diagnostic content [2]. In addition, DECT developed additional techniques, such as the reduction in the number of slices and virtual non-enhanced images techniques, for reducing the radiation dose level while increasing the image quality [3].

Image noise impacts the image quality in CT images. This appears as an irregular granular pattern that degrades image quality. Image noise is based on the standard deviation of pixel intensity values or CT number for uniform anatomical region. Although DECT improves image quality, it still has approximately the same or slightly lower image noise level compared with single-energy CT [4, 5]. Despite the thinner slices increased the image noise, the image visibility of a small lesion has been improved by provide more diagnostic information. As a result, a balance between the change in slice thickness with diagnostic information and image noise must be taken into account. Therefore, a number of studies were conducted to reduce image noise in DECT protocols. The present study primarily aims to use statistical analysis combined with ImageJ program to determine the effect of slice thickness on image noise with the maximisation of diagnostic content in DECT head protocol.

### *1.1. Effect of image noise and slice thickness on DECT images*
Image noise is proportionally related to the variation in CT number values for a homogeneous area [6]. Therefore, image noise is statically defined based on standard deviation of CT number or pixel intensity values in a physical uniform region. Noise decreases as the variance (standard deviation) for pixel value decreases. In addition, CT noise is defined depending on the number of photons received by the detectors (quantum noise). Image noise decreases, when the quantity of the photons received by the detectors increase [6, 7].

Slice thickness values are determined by the operator in accordance with clinical examination requirements; its values usually fall from 1 to 10 mm. Image noise is inversely relational with the variation square root in the beam thickness (slice thickness). Thinner slice thickness increases image noise [8]. Despite thinner slices increasing image noise, the visibility of a small lesion was improved by providing more diagnostic content [9]. Therefore, a balance between the change in slice thickness with the diagnostic content and image noise should be considered. As a result, several researchers including Yao [10] and others [11] [12] compared CT image quality and diagnostic content. In addition, different CT modalities were used to assess the noise and visibility of CT images. For example, in a study conducted in 2016, cone beam computed tomography (CBCT) was used to scan two phantoms consisting of materials that mimic the mandible and its surrounding tissue. The study concluded that the lowest slice thickness increased the CT image details and structures despite the higher noise [13].

### *1.2. Use of statistical analysis to evaluate image quality in literature survey*
According to a review in 2014 [14], a statistical analysis using SPSS software was used to determine the mean and standard deviation to express the image noise (SD). The authors used independent t test samples to compare the significance of the quality of CT images between the data presented as mean ± SD. The data was collected to assess the image quality and radiation dose in multidetector CT with two groups: the first group at 120 kVp and the second group used automated attenuation-based tube potential optimisation mode (CARE kV). The t-test results determined that CARE kV reduced the radiation dose level without a significant difference in image quality between the two groups [14].

Another study by Matsumoto et al. compared the image noise in virtual monochromatic images (VMSI) with conventional 120 kVp CT image through statistical analysis. They used paired Student’s statistical t test to determine the significance among the different CT images. We investigated varying impact noise levels by comparing the mean standard deviation in the regions of interest. The statistical results indicate that the noise level on the 67 to 72 keV images is significantly lower than on the 120 kVp image [15].

In 2016, Ford et al. published a paper describing the direct impact of slice thickness value on the 3D reconstruction of anatomical structures using a GE Light-Speed VCT 64 slice scanner head protocol at an initial of 0.625 mm slice thickness .The initial slice thickness values were resliced for each head of the patients and arranged from 1 to 5 mm. The statistical analysis using one-way ANOVA confirmed the significant differences in volume, surface area, and part-to-part comparison analyses from the 0.625 mm skulls. The study recommended that a maximum slice thickness of 1.25 mm can be utilised when the 3D reconstruction of anatomical features and thicknesses were greater than 1.25 mm resulted in a loss of fidelity on the representative anatomy [16].

## 2. Materials and methods
This study was conducted at the Imaging Unit, Advanced Medical and Dental Institute, Universiti Sains Malaysia, Bertam, Pulau Pinang, Malaysia. The study was performed using a Catphan 600

phantom (150 x 190 mm). As shown in Figure 1, the phantom was made from five different modules; CTP 404, 591, 528, 515 and 486. However, the fifth module (image uniformity module CTP 486) performed in this study to measure image noise. The phantom was scanned using a single-source dual-energy CT scanner (SOMATOM Definition AS, Siemens 2014, serial number 95187, Germany). After processing and reconstructing, three series of images will be produced; The first one will be with a low energy with the value (80 kVp), the second series will be a high energy with the value (140 kVp) and the third series creates by the combination of two datasets of two energies [2] [4].

CT Images were acquired at different slice thickness to determine the best slice thickness that reduces image noise with better image quality. The ImageJ Java-based image processing program software developed at the National Institutes of Health was used to analyse the DICOM CT images. F-test statistical analysis method was carried out to compare the variance significance of the obtained data. This test applied to determine the significance of variances between two groups of samples created depending on the change of the slice thickness value. The F-test distribution is formed by the ratio of two independent chi-square variables divided by their respective degrees of freedom. Therefore, this function is used to determine if two samples have different variances or not. The F value can be used to decide whether results are significant enough to reject the null hypothesis. The null hypothesis is rejected if the F value calculated from the data is greater than the critical value of the F -distribution for some desired false rejection probability.

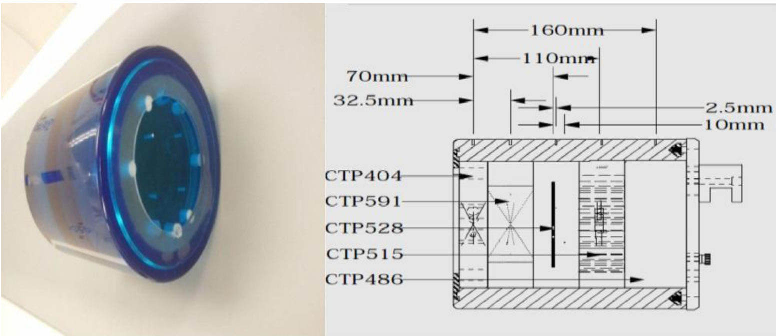


**Figure 1.** Modules and diameters of the Catphan 600 phantom.

### *2.1. Scan process*

The DECT head protocol was employed on the Catphan 600 phantom with different slice thickness values of 0.6, 1, 2, 3, 4, 5, and 6 mm. The DECT was operated in axial projection and helical scanning mode with another constant scan parameter values and fixed kVp (80 and 140). The phantom was centered, and the topogram image was produced. Afterwards, the DECT head adult protocol was applied to create different images with various slice thickness values. Table 1 shows the main parameters used in this study for DECT head protocol.

**Table 1.** DECT routine head protocol parameters.

| **Parameters** | **Head protocol dual-energy CT** |
|---|---|
| Scan mode | Spiral |
| mAs | 330 for 80 kVp<br>78 for 140 kVp |
| Pitch | 1.2 |
| Slice thickness (mm) | Range of (0.6 to 6 mm) |
| Rotation time (s) | 0.5 |
| Field of view (mm) | 217 mm |
| CARE dose type | CARE Dose4D |

### *2.2. Analysis process*

Image analysis was carried out using the ImageJ software. The pixel intensity values of the Catphan 600 phantom images at varied slice thickness were measured. The region of interest (ROI) for all DICOM images was drawn as a rectangular shape with an area approximately 1,500 mm² as shown in Figure 2. Statistical analysis was implemented using the F-test function. The F-test function was utilised to compare the statistical noise between DECT DICOM images at different slice thickness. The F-test was applied to determine the significance of variances between the two sample groups created depending on the change of the slice thickness value because variance and standard deviation are measures of how spread out a distribution is.

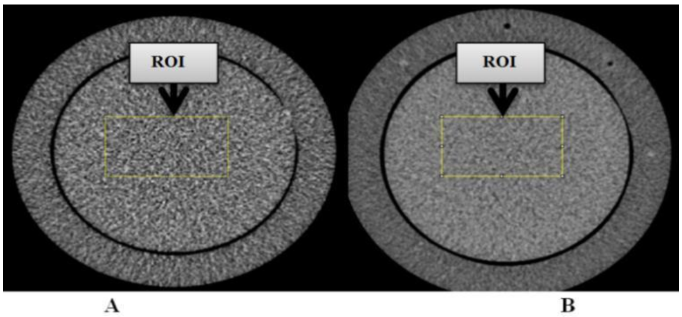


**Figure 2.** Regions of interest at 0.6 (A) and 6 mm slice thicknesses (B).

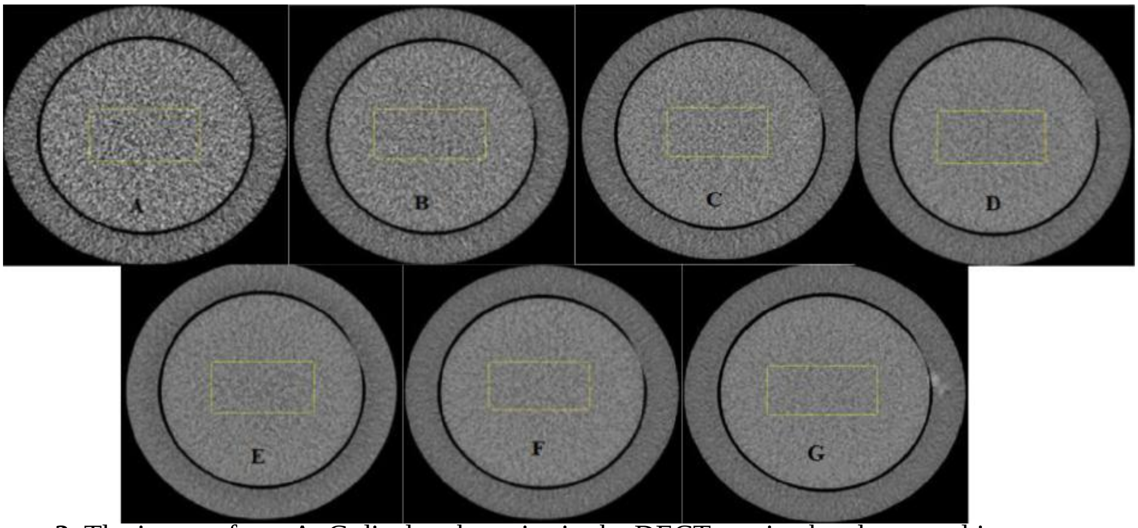


**Figure 3.** The images from A–G display the noise in the DECT routine head protocol images at different slice thickness values of 0.6, 1, 2, 3, 4, 5, and 6 mm, respectively.

## 3. Results and discussion

Statistical noise refers to the variance among the pixel intensity values (standard deviation) in the physical uniform region. Figure 3(A–G) shows the image noise in CT images using the DECT routine head protocol at different slice thickness values of 0.6, 1, 2, 3, 4, 5, and 6 mm, respectively. The results show that noise is decreased with the increase of slice thickness. The noise was measured by calculating the standard deviation (SD) in the ROI. Table 2 displays the mean and standard deviation for the ROIs using various slice thickness values at a depth of about 19 cm. Figure 4 illustrates that the increase of the slice thickness reflected on image noise decrement. Following the standard deviation analysis, the F-test statistical analysis was carried out.

Hypothetically, increment of slice thickness simultaneously decreases the image noise and the diagnostic content of the CT images. When the slice thickness is decreased, the distinction of small lesions remarkably improved owing to the decreased partial volume effects. Thus, decreasing the slice thickness value provides higher diagnostic content for the CT image. As a result, in this article, the lowest slice thickness value with a lower image noise is considered as the best value. Based on the F-test results, the significant difference exists between slice thickness values of 0.6, 1, 2, and 3 mm and non-significant values of 3, 4, 5, and 6 mm. Table 3 shows that the *F* values are less than the *F* critical value (2.168) at a range of 3 to 6 mm. The critical value is appointed on the test distribution to determine whether to reject the null hypothesis. However, the results show that image noises between the slice thickness values from 3 to 6 mm are no significantly different. Given that lower slice thickness value has more diagnostic content, the 3 mm value is considered as the best value to reduce image noise and to provide more possible diagnostic content using the DECT head protocol.

**Table 2.** Main statistical measurements for different slice thickness values using the DECT head protocol.

| Slice thickness (mm) | Mean | Standard deviation | Variance | Area mm² | Slice number |
|---|---|---|---|---|---|
| **0.6** | 79.759 | 5.379 | 28.932 | 1,500 | 91/229 |
| **1** | 78.428 | 3.690 | 13.618 | 1,500 | 318/381 |
| **2** | 77.906 | 2.715 | 7.370 | 1,500 | 96/115 |
| **3** | 78.484 | 2.333 | 5.445 | 1,500 | 64/77 |
| **4** | 77.863 | 1.860 | 3.460 | 1,500 | 49/58 |
| **5** | 79.293 | 1.821 | 3.317 | 1,500 | 39/64 |
| **6** | 78.613 | 1.694 | 2.870 | 1,500 | 33/39 |

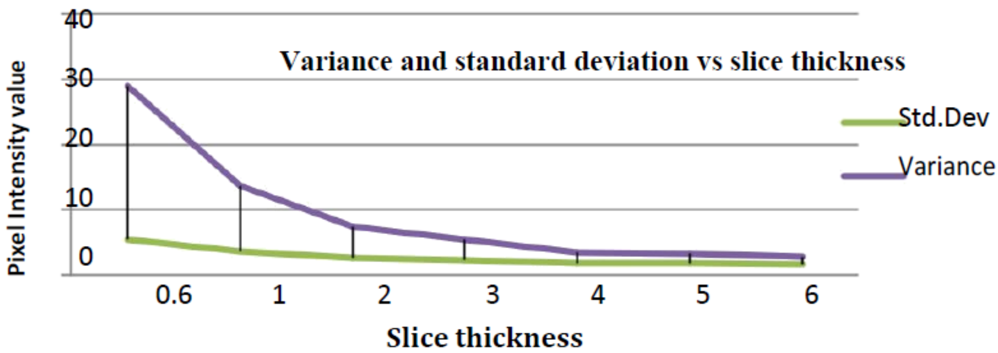


**Figure 4.** Standard deviation and variance versus slice thickness values. Standard deviation and variance are decreased with the increase of the slice thickness values especially at values less than 3 mm.

**Table 3.** F test results for slice thickness values; 3, 4, 5, and 6 mm.

| Slice thickness (mm) | Another slice thickness (mm) | *F* value | *F* critical value | Significant |
|---|---|---|---|---|
| **3** | 4 | 1.574 | 2.168 | **Non-significant** |
| | 5 | 1.642 | 2.168 | **Non-significant** |
| | 6 | 1.897 | 2.168 | **Non-significant** |
| **4** | 5 | 1.043 | 2.168 | **Non-significant** |
| | 6 | 1.206 | 2.168 | **Non-significant** |
| **5** | 6 | 1.156 | 2.168 | **Non-significant** |

Finally, as noted in Table 2 and Figure 3, the change in variance and standard deviation from 3 to 6 mm is lower than that of 0.6 to 3 mm. The effect of the increased slice thickness value from 3 to 6 mm is minimal compared with the images acquired at other slice thickness values. These results match the F-test measurements which concluded that no significant image noise exist at a range of 3 to 6 mm.

## 4. Conclusions

The imageJ analyses show that image noise decrease with the increase of slice thickness. However, the F-test results show no significant difference of the image noise of DICOM images acquired at 3, 4, 5, and 6 mm. As the diagnostic value decrease with the increased of slice thickness, the 3 mm slice thickness is considered as the best slice thickness value that reduces image noise with adequate diagnostic content in the dual-energy CT head protocol. The major limitation of this study is the single source dual energy CT was limited to fixed tube energy technique. Knowing that, the ability to change values between two different energies might help in giving better image quality

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