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Comparative study of radiation dose levels in automatic and manual slice thickness selection in contrast enhanced computed tomography of the abdomen

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ABSTRACT

Purpose: To compare the radiation dose in automatic and manual slice thickness selection in Contrast Enhanced Computed Tomography (CECT) Abdomen.

Material and Methods: In the department of Radiodiagnosis and Medical Imaging, this prospective study involved 52 participants who were referred for CECT Abdomen scan with a 128-slice CT scanner (GE Revolution EVO). The study involved 26 participants in the automatic slice selection group and another 26 participants in the manual slice thickness based on the participants' cooperation while scanning. Intravascular (IV) contrast material was administered to the patient during a CECT Abdomen scan. After the scan, the dose report was measured based on the slice thickness with the help of DLP to compare the radiation dose between the automatic and manual slice thickness selection methods.

Results: IThere was a significant difference in DLP between the automatic slice thickness (AST) and manual slice thickness (MST) groups (p value <0.001). The mean DLP in the automatic slice thickness group was 1152.54

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mGy-cm, while in the manual slice thickness group it was notably lower at 802.69 mGy-cm. In the automatic slice thickness and manual slice thickness groups, we observed a statistically significant difference in mean DLP between arterial and venous phases (p value <0.001). Pearson's correlation was used to compare the correlation among the variables, and we found that, in AST, the arterial and venous phases are closely related, with a correlation of 0.852 (p value <0.0001). In MST, similarly, the arterial and venous phases are strongly related with a correlation of 0.920 (p value <0.0001).

Conclusion: This study's findings demonstrated that manual slice thickness was the most effective approach for reducing radiation dose in dual-phase CECT Abdomen scans compared to automatic slice thickness selection.

KEY WORDS

Computed Tomography, Contrast Enhanced Computed Tomography, Automatic slice thickness, Manual slice thickness, Dose Length product, Radiation dose, Plain scan, Arterial phase, Venous phase.

Introduction

Abdominal and pelvic imaging is among the medical diagnostics that have been transformed by Computed Tomography (CT). It has proven to be a vital tool for the diagnosis and treatment of numerous illnesses due to its capacity to provide intricate cross-sectional views of internal organs.

From the creation of multi-detector CT scanners to the incorporation of advanced software that improves image quality and minimizes motion artefacts, the development of CT technology has been characterized by notable breakthroughs. Notwithstanding these developments, there are still serious worries about the radiation dosages to patients from CT scans [1,2].

The possible CT radiation risk, which could increase a person's lifetime risk of acquiring cancer, is a growing source of concern [3]. Due to rising CT usage and widespread worries about the risk of radiation exposure from medical imaging, the precise radiation dose to each patient from a CT scan is notoriously difficult to measure. Due to this, dosage monitoring devices are now more frequently used in clinical settings [4,5].

By using CT as an imaging modality sparingly, dosage reduction can be accomplished. There are several parameters that affect the radiation dose, including tube current (mA), product of the tube current-time (mAs), tube voltage (kVp), time per rotation, collimation, scan length, pitch, and slice thickness [6]. The CT parameters are important in calculating the radiation dose. Slice thickness is a crucial parameter that needs to be optimized based on clinical demands.

The slice thickness values range from 1mm to 10mm [7]. A CT scan's slice thickness influences the radiation dose that a patient is exposed to. In CT imaging, the link between slice thickness and collimation width is crucial since both factors affect the radiation dose, quality, and resolution of a CT scan. With a single rotation of the CT gantry, many slices can be acquired concurrently with multi-slice CT scanners because multiple detectors are stacked in parallel.

The collimation width and the quantity of slices obtained per rotation both affect the slice thickness. In multi-slice CT scanners, slice thickness can be changed apart from collimation.

However, the detector system's architecture and the collimation's width typically limit the shortest slice thickness that can be achieved. It is possible to choose the slice thickness as a percentage of the collimated width.

Depending on the clinical requirements, the slice thickness and collimation width of contemporary CT scanners can be independently changed. This adaptability enables personalised imaging techniques that strike a compromise between radiation dose, scan time, and resolution [8]

Thicker slices yield higher SNR images with shorter scan times than thinner slices. In certain instances, it could be advantageous to use thinner, more closely spaced slices to detect the existence of tiny regions of bone sequestration.

Using thicker slices is advantageous if the imaging features are more gross, like seeing thick curvilinear interior septae. Therefore, patient safety and accurate diagnosis, a balance between radiation and image quality, is essential [9]. Recently, CT technology and software have been merged to provide both automatic and manual slice thickness selection.

Slice thickness is set at 7.5 mm for manual slice selection and 5 mm for automatic slice thickness. Compared to 7.5 mm slices, 5 mm slices offer superior spatial resolution and image quality, making it possible to scan finer features, lesions, and smaller structures more clearly.

This is very helpful for spotting mild diseases or smaller structures. Another benefit is that, in contrast to 7.5 mm slices, the partial volume effect is less noticeable.

Because each slice catches finer information and distinguishes tissues more clearly, the image can more properly depict the boundaries of various tissues.

Additionally, the improved spatial resolution makes it possible to perform more comprehensive reconstructions in several planes, which is crucial for accurate anatomical localisation in Multi-Planar Reconstruction (MPR).

Because more data must be collected to cover the same space, one of the primary drawbacks is a longer scan time compared to 7.5 mm slices. In some populations, the patient may have to remain motionless for an extended amount of time, which can be difficult. For situations where speed is more crucial than fine detail, a 7.5 mm slice thickness is appropriate.

Helpful for patients who struggle to stay motionless or in emergencies, it is useful for imaging the abdomen, chest, and pelvis, particularly when high-resolution detail is not the main need. [10,11]

The CT scanner uses a routine to automatically determine a slice thickness; it does not take the patients' age or Body Mass Index (BMI) into account. The selected thickness is the same for every patient.

While most radiographers use automatic slice selection, manual slice thickness selection necessitates the radiographer selecting a slice thickness. Regardless of the patient's age, the main disadvantage of automatic slice selection is that it will expose kids to more radiation.

Automatic slice thickness selection enhances the efficiency of imaging by automatically selecting the slice thickness. Benefits of automatic slice selection include reduced workload for the radiographer, increased consistency and accuracy in slice selection.

Automatic slice selection achieves higher resolution images, but more slices are needed, and thus, more X-ray exposure is required, leading to an increased radiation dose to the patient.

The skill and judgement of the technologist play a crucial role in manual slice thickness selection. Under these conditions, using the manual slice thickness selection will provide patients a reduced radiation dose while still producing an image with a good level of diagnostic quality.

The CT dose report shows the current radiation dose output from the CT scanner after patient imaging in terms of the Dose Length Product (DLP) and volume CT dose index (CTDI vol). DLP offers a highly practical means of comparing the dosages administered by various scan protocols [12].

With this background, the current study aims to compare the radiation dose in automatic and manual selection of slice thickness in CECT abdomen.

Material and Methods

Study population

This descriptive cross-sectional study was conducted in the department of Radiodiagnosis and Medical Imaging, Yenepoya Medical College Hospital, Mangalore, between July 2023 and January 2024.

The study approval was obtained from the Yenepoya Ethical Committee after approval from the Scientific Review Board. The study enrolled 52 participants aged ranging from 20 to 80 years who satisfied the inclusion and exclusion criteria, including those undergoing dual-phase CECT Abdomen with normal BMI (18.5-24.9 kg/m2).

Participants with a history of contrast allergy, severe heart disease, creatinine levels exceeding 1.3mg/dl, and pregnant women were excluded from the study.

After explaining the procedure to the patient, a written informed consent was obtained. The CT scan was conducted using a 128-slice General Electronics (GE) Revolution Evo scanner.

The 52 participants were categorized into two groups, the automatic slice thickness selection group and the manual slice thickness selection group, using a simple random selection method, with each group consisting of 26 participants.

Imaging Protocol and analysis

A non-ionic contrast media, Iohexol, with an iodine content of 350 mg I/ml, was used in this study.

Using a sterile technique, 70 ml of contrast was given at the rate of 2-3ml/s by a pressure injector controlled by the technologist, which was the same for both automatic slice selection and manual slice selection.

Adult patients underwent contrast-enhanced abdominal dual-phase scans with normal BMI and were classified into two groups based on their cooperation during scanning.

Participants who readily cooperated during scanning were categorized in automatic slice thickness selection (group 1), while participants who were less cooperative were categorized in manual slice thickness selection (group 2).

7.5 mm was chosen for manual slice thickness and 5 mm for automatic.

The CT system automatically presets the 5 mm slice thickness, which is why it is utilised for automatic slice selection.

A 7.5 mm slice thickness works well in scenarios where speed is more important than fine detail. beneficial for patients who have trouble remaining still; for this reason, it was used for the manual selection.

A plain abdominal scan was conducted, which was identical for both groups. Following the initial scan (plain), participants who adhered to breathing instructions and remained motionless during the scan were included in group 1.

Participants who moved and did not follow breathing instructions were included in group 2.

In group 1, a plain abdominal scan was taken with a 10mm slice thickness. After the plain scan, participants were scanned for the arterial and venous phases with a 5mm slice thickness using automatic slice selection. After the completion of the scan, the radiation dose was measured based on the slice thickness using the DLP from the dose report.

In group 2, a plain abdominal scan was taken with a 10 mm slice thickness. After the plain scan, participants were scanned for the arterial and venous phases with a 7.5mm slice thickness using manual slice selection.

After the completion of the scan, the radiation dose was measured based on the slice thickness using DLP from the dose report. Group 1 and Group 2 were compared based on the total DLP value.

Table 1. CECT Abdomen protocol.

Patient position	Supine feet first
Scan type	Helical
Scano/Scout	AP/Lateral
Area coverage	Domes of the diaphragm to the pubic symphysis
Scan direction	Cranio caudal
Start location	Domes of the diaphragm
End location	Pubic symphysis
Slice thickness	5mm (AST)
	7.5mm (MST)
kVp/mAs	120/250
Gantry angle	0°
Resolution	Standard
Pitch	1.375:1
Rotation time	0.75 second
FOV	350mm
Matrix	512^{x}512
Collimation	64^{x}0.625
Contrast	Volume: 70ml Flow rate: 2-3ml/s Locator/tracker: Abdominal aorta Threshold: 80 HU
Reconstruction	MPR 3mm

Statistical analysis

For statistical analysis, the data were analysed in SPSS version 21.0 in descriptive statistics. Mean and standard deviation for continuous variable, frequency and percentage for categorical variable. A paired t-test was used to compare the automatic and manual slice thickness selection, and an independent sample t-test was used to compare the arterial and venous phases.

Results

The selection of slice thickness has a major influence on radiation exposure in CECT examinations. DLP between arterial and venous phases within both groups, as well as between automatic and manual slice thickness selections, showed a significant difference.

As shown in Table 2 and illustrated in Figure 1, the Paired sample t-test revealed a statistically significant difference ($p < 0.0001$) between the mean DLP values of the automatic slice thickness (AST) and manual slice thickness (MST) groups in CECT abdomen scans. The mean DLP in the AST group was 1152.54 mGy-cm, while in the MST group, it was notably lower at 802.69 mGy-cm. In the AST group, in plain scan, the mean DLP was 186.6496 mGy-cm (SD=3.5209). The mean DLP of the arterial scan was 509.1481 mGy-cm (SD=57.7907), in the venous scan, the mean DLP was 456.7404 mGy-cm (SD=50.0578) (Figure 2).

Table2. Paired t-test to compare the DLP between AST and MST.

	Mean	Std Deviation	t	p Value	95% Confidence Interval of the Difference	
					Lower	Upper
Total DLP in AST	1152.54	105.54	15.433	<0.0001*	303.16	396.53
Total DLP in MST	802.69	44.53				

(* significant)

Figure 1. Comparison of total DLP between AST and MST.

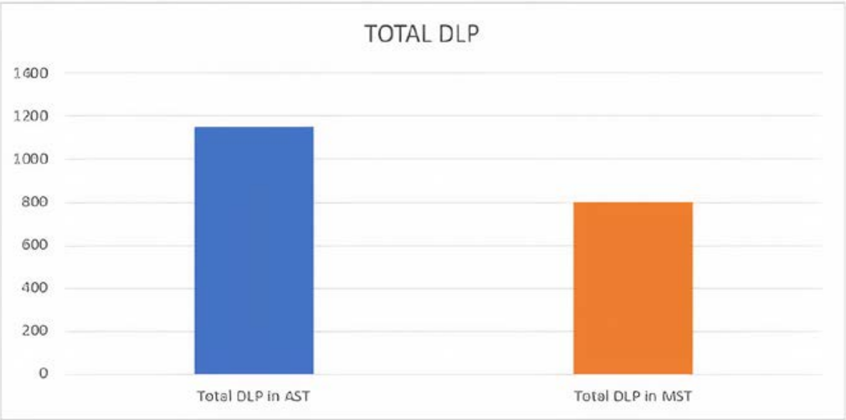
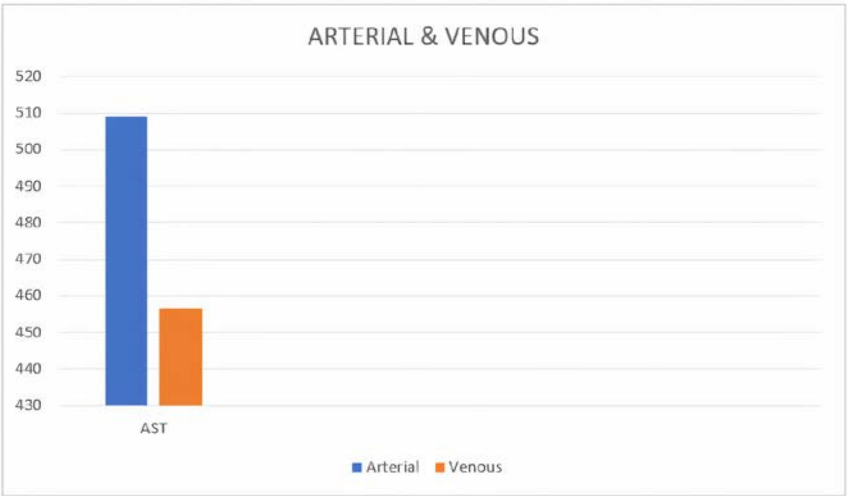


Figure 2. Comparison of DLP between arterial and venous phase in AST.



In the MST group, the mean DLP of plain scan was 185.6062 mGy-cm (SD=3.5084). In arterial and venous scans, the mean DLP was 320.8504 mGy-cm (SD=22.4191) and 295.8742 mGy-cm (SD=23.2704), respectively (Figure 3).

The DLP of arterial and venous phases between the two groups was compared using an independent sample t-test. Table 3 indicates a statistically significant difference between automatic and manual slice thickness in the arterial phase and venous phase, with a p-value of <0.001 (Figures 4, 5). No significant difference in DLP was noted between automatic and manual slice thickness in plain scan, with the mean difference of 1.0435 mGy-cm (p-value >0.05).

Figure 3. Comparison of DLP between arterial and venous phase in MST.

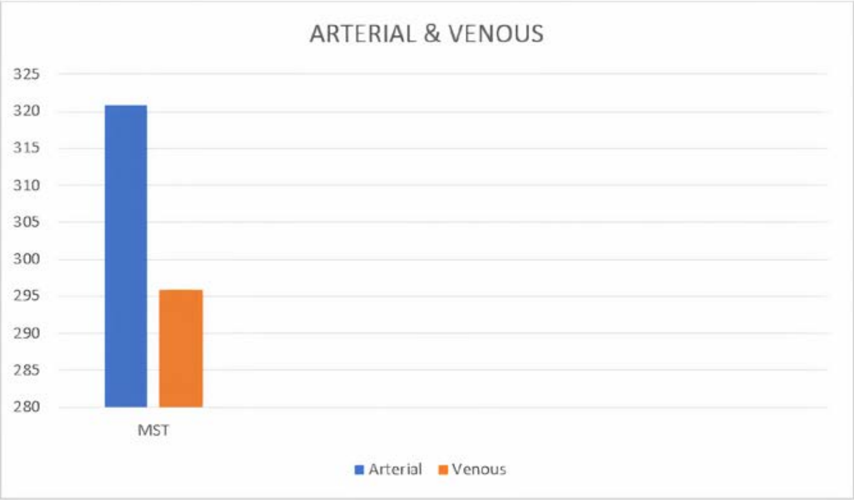


Table 3. Comparison of the radiation dose between Arterial and Venous phase.

Variables	Group	Mean	Std. Deviation	Test Statistics	p value	Mean difference	95% CI for difference	
							lower limit	upper limit
Plain	AST	186.6496	3.5209	1.0704	0.2896	1.0435	-0.9145	3.0014
	MST	185.6062	3.5084				3.5084	
Arterial	AST	509.1481	57.7907	15.4893	<0.001*	188.2977	163.8804	212.7150
	MST	320.8504	22.4191					
Venous	AST	456.7404	50.0578	14.8591	<0.001*	160.8662	139.1214	182.6110
	MST	295.8742	23.2704					

(* significant)

Figure 4. Comparison of DLP between AST and MST in arterial phase.

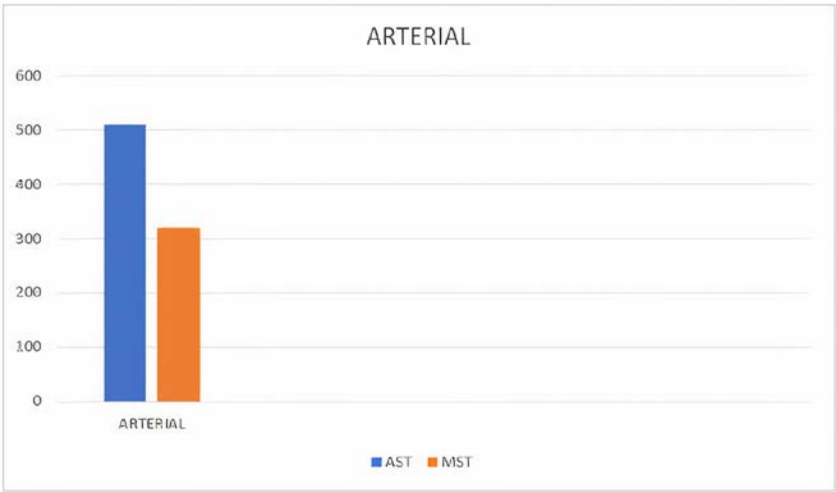
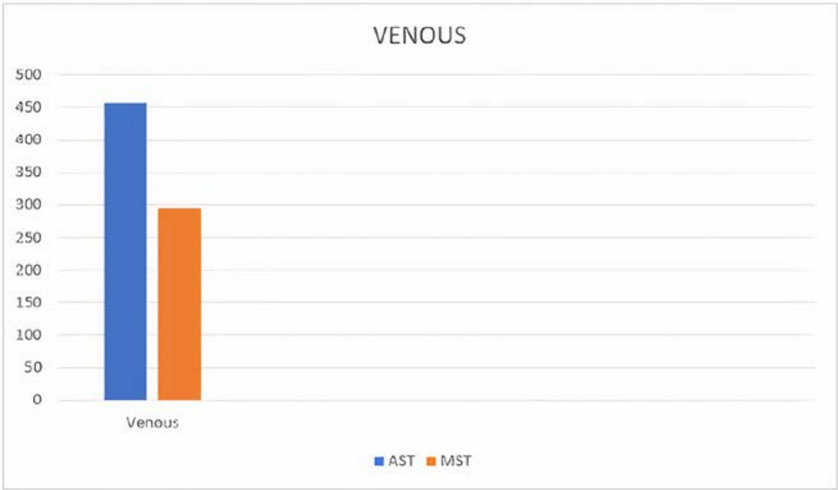


Figure 5. Comparison of DLP between AST and MST in venous phase.



The correlation between the variables was examined using the Pearson correlation test. Table 4 shows how different phases of the CECT scan relate to each other. A correlation value of 0.517 between the plain and arterial phases (p-value 0.007) means they are slightly related. The plain and venous phases have a correlation of 0.452 (p-value 0.021), showing a moderate connection. The arterial and venous phases are closely related, with a correlation of 0.852 (p-value <0.0001). These numbers tell us that the arterial and venous phases are strongly related, while the plain phase is less related to the other two in the AST group.

Table 4. Pearson correlation among the variables for AST.

Variables		correlation	p value
Plain	Arterial	0.517	0.007*
	Venous	0.452	0.021*
Arterial	Venous	0.852	<0.0001*

(* significant)

In the present study, we found that there was a correlation between plain and arterial (p value is 0.007), plain and venous (p value is 0.021), and arterial and venous (p value <0.0001), which is statistically significant.

Table 5 shows how different phases of the CECT scan are related for MST. The plain phase doesn't have a strong relationship with the arterial phase (correlation -0.122, p-value 0.552) or the venous phase (correlation -0.132, p-value 0.521). This means changes in the plain phase don't match changes in the arterial or venous phases. However, the arterial and venous phases are closely related (correlation 0.920, p-value less than 0.0001). This means that when the arterial phase changes, the venous phase changes in a similar way. So, the plain phase is not related to the other phases, but the arterial and venous phases are strongly related.

Pearson's correlation test was used to compare the correlation among the variables. In the present study, we found that there was a correlation between arterial and venous (p value <0.0001), which is statistically significant. No significant difference between the plain and arterial (p value 0.552), as well as plain and venous (p value 0.521), was found. Hence, they were not correlated with each other.

Table5. Pearson correlation among the variables for MST.

Variables		correlation	p value
Plain	Arterial	-0.122	0.552
	Venous	-0.132	0.521
Arterial	Venous	0.920	<0.0001*

(* significant)

Discussion

The exact radiation dose that each patient received from a CT scan was notoriously difficult to estimate due to the growing use of CT scans and general concerns about the risk of radiation exposure from medical imaging [4].

Dosage monitoring systems are therefore being employed in clinical settings more frequently [5]. Reduction in the dose can be achieved by using different dose reduction techniques and also by altering the protocol.

The tube current (mA) regulates how much radiation the X-ray tube emits. Although they increase the radiation exposure, higher mA settings typically result in better image quality.

Tube voltage (kV) affects both the penetration depth and the X-rays' energy level. Larger patients may require higher kV settings to guarantee sufficient penetration, although doing so may result in an increase in dosage. The ratio of slice thickness to table movement per rotation is known as pitch. By reducing the overlap of the slices, a greater pitch can lower the radiation dose, but image quality may suffer.

Collimation refers to the process of shaping and limiting the X-ray beam so that it only exposes the area of interest. Collimation lowers radiation exposure to non-imaged regions and minimizes scatter radiation, which happens when the X-ray beam strikes tissues outside the target region. In addition to contributing to needless radiation exposure, scatter radiation can deteriorate image quality. In order to maximise the balance between radiation exposure and image quality, Automatic Exposure Control (AEC) systems that automatically modify collimation and tube current are frequently included in modern CT scanners. The scan length impacts the total radiation dose; the dose increases as more body areas are scanned. Exposure can be decreased by reducing the scan area or length. Rotation time is the amount of time it takes the CT scanner to go around the patient one full rotation. Shorter rotation durations may need more radiation to produce high-quality images, but they can lessen motion artefacts [8,13,14].

The thickness of a CT scan's slices determines the radiation dose to which a patient is exposed. It is a critical metric that must be optimized for clinical use [9]. With the recent merger of CT technology and software, slice thickness selection can now be performed automatically and manually.

The thickness that is automatically set for each patient is the same regardless of their age or BMI, which results in a high radiation dosage. However, an adequate diagnostic quality image can be produced with a lower radiation dose when the slice thickness is manually adjusted by the radiographer, specifically by increasing the slice thickness slightly. In terms of image quality, automated slice thickness adjustment is superior [12].

In our study, we compared the radiation dose in the automatic and manual slice thickness selection groups in CECT Abdomen. For manual and automatic slice thickness, 7.5 mm and 5 mm, respectively, were selected. Because of the predefined thickness value for the CECT abdominal scan protocol, a 5mm slice thickness is chosen as the automatic slice selection. 7.5mm is adjacent to the 5mm slice thickness in our CT system, it was chosen as the manual slice thickness.

The reason we are not regarded as having the thinner slice thickness for manual slice selection is because the participants who underwent manual slice selection in CECT abdomen scan did not follow the breathing instructions and movement during the scan; in those cases, choosing the thinnest slice thickness will take more scan time and affect image quality and produce artefacts. In order to overcome that, we chose a slice thickness of 7.5 mm, which falls between 10 and 5 mm, offers a balanced image quality, and enables faster data collecting, which reduces the amount of time required to finish the scan. This can help patients who might have trouble staying still or in emergencies.

Paired t-test (p value <0.001) was used to compare the automatic and manual slice thickness selection. We found that there was a significant difference in radiation dose between automatic and manual slice thickness selection, with a mean DLP of 1152.54 mGy-cm, 802.69 mGy-cm, respectively. An increased radiation dose was seen in automatic slice thickness selection with a slice thickness of 5mm compared to manual slice thickness selection with a slice thickness of 7.5 mm.

It revealed that an increased slice thickness led to reduced radiation dose. In a study conducted by N. Hirasawa et al. (2010), where they compared 1mm and 3mm slice thickness, they found that a CT scan acquired using 3mm slice thickness was optimal with a reduced radiation dose compared to a 1mm slice thickness, which was similar to our study. CT scans acquired using thinner slices are considered to increase radiation exposure [15].

In the present study, we compared the radiation dose in automatic and manual slice selection in Arterial and Venous phase by using the independent sample t-test (p value <0.001). We found that there was a significant difference in mean DLP between Arterial and Venous phases in both automatic and manual slice thickness selection. The Pearson's correlation shows that there was a significant correlation between DLP of arterial and venous phases in both groups (p value <0.001) using Pearson's correlation test.

Compared to the venous phase, the arterial phase has more contrast deposition, which leads to more radiation in the arterial phase.

Because faster image acquisition is required to capture the rapid passage of contrast via the arteries, the arterial phase frequently necessitates a greater radiation dose. To distinguish between surrounding tissues and high-contrast arterial arteries, a greater radiation level is required for sufficient resolution.

Compared to the arterial phase, the venous phase often requires less radiation. This is because contrast moves through the veins more slowly in the venous phase. Hence, in our study, we found that the radiation dose was higher in the arterial phase of the CECT Abdomen scan compared to the venous phase in both automatic and manual slice thickness selection.

In automatic slice thickness selection, the mean DLP of the arterial phase was 509.1481 mGy-cm, and the mean DLP of the venous phase was 456.7404 mGy-cm. In manual slice thickness selection, the mean DLP of arterial and venous phase was 320.8504 mGy-cm and 295.8742 mGy-cm, respectively. In a similar study conducted by Kostas Perisinakis et al. (2018) found that administration of iodinated contrast media considerably increases radiation dose to tissue from CT exposure. These observations support our study [16].

There are no further studies similar to the present study. Our study concluded that manual slice thickness selection provides efficient dose reduction in CECT abdomen examination compared to automatic slice thickness selection.

There was a significant difference in radiation dose between the arterial and venous phases in both groups, the arterial phase always had more radiation dose compared to the venous phase due to its greater contrast deposition. Also, there was a positive correlation between the arterial and venous phases. In AST, the arterial and venous phases are closely related with a correlation of 0.852 (p value <0.0001).

In MST, the arterial and venous phases are closely related with a correlation of 0.920 (p value <0.0001). Pearson's correlation admits that, arterial and venous phases are strongly related in both groups. In plain scan, there was no significant difference between AST and MST, due to the same slice thickness of 10mm in the plain scan in both groups. Compared to arterial and venous scans, plain scans provided a reduced radiation dose due to the thicker slice thickness and absence of contrast media.

The null hypothesis stated that manual selection of slice thickness will not provide a reduction of radiation dose in CECT Abdomen, which is not true, whereas the alternate hypothesis stated that manual selection of slice thickness will provide a better reduction of radiation dose. Through our study, we found a reduced radiation dose in the manual slice thickness group.

Our research findings indicate that using MST with a 7.5mm slice thickness in CECT Abdomen examinations resulted in a decreased radiation dose compared to AST with a 5mm slice thickness. This highlights that thinner slice thicknesses typically entail higher radiation doses than thicker slices. Expanding the future scope of this study involves increasing the sample size and conducting it across multiple centers in a multicenter study setting.

Limitation

One limitation of this study is that the automatic slice thickness was only compared with a single manually selected slice thickness of 7.5mm.

Conclusion

In CECT examinations, the choice of slice thickness significantly impacts radiation dose. A significant difference was observed in DLP between automatic and manual slice thickness selections, as well as DLP between arterial and venous phases within both groups. Our findings revealed that automatic slice thickness selection resulted in a higher radiation dose with a thinner slice thickness compared to a thicker slice of manual slice thickness. Therefore, we conclude that manually selecting slice thickness is an effective approach for reducing radiation exposure in CECT Abdomen scans while maintaining good diagnostic image quality. **R**

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Ethical approval

"The Institutional Review Board of Yenepoya Deemed to be University approved informed consent form due to the prospective nature of the study".

Conflict of interest

There is no conflict of Interest in this study.

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