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# Comparison study between different contrast administration protocols for routine CT thorax examination in two tertiary centres

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**Abstract.** The purpose of this study was to evaluate the degree of contrast enhancement and image quality of computed tomography (CT) thorax examination using different contrast administration protocols. Data was retrospectively collected from 140 patients from two centres; 70 patients (Group A) from Advanced Medical and Dental Institute (IPPT), Universiti Sains Malaysia [19 males, 51 females; mean age ± standard deviation (SD) 53.6 ± 11.2 years; mean weight ± SD 54.04 ± 13.77 kg] using automatic bolus tracking (ABT) with weight-based contrast volume (WBV) administration, and 70 patients (Group B) from Hospital Pulau Pinang (HPP), Ministry of Health Malaysia [24 males, 46 females; mean age ± SD 54.5 ± 13.2 years] using fixed time-delay (FTD) with fixed contrast volume (FV) technique. The degree of enhancement was quantified by measuring Hounsfield unit (HU) values in different arteries and veins, and rated on a 5-point scale (1 = very poor, 5 = excellent) for qualitative assessment. The mean enhancement values in Group B were found to be higher than those in Group A ($P < 0.001$). There was no statistically significant difference between mean qualitative scores on a 5-point scale in both groups ($P = 0.185$). A weak correlation was seen between HU values with administered contrast volume ($r = 0.1152$). Overall, FTD with FV protocol was found to have higher degree of contrast enhancement for routine CT thorax examination. The qualitative assessment showed no significant difference between both protocols although higher mean grading in CT image quality was given by assessors for ABT with WBV technique.

## 1. Introduction

Multi-detector computed tomography (CT) has evolved in its ability to image faster, to accurately capture rapidly moving structures and to improve resolution. Contrast enhancement is a key component in CT imaging which helps to distinguish abnormal body structure from other structures. With rapid and short scanning times, it is essential to optimise the contrast medium (CM) administration and image acquisition in achieving maximal contrast. Contrast enhancement is needed in determination of image quality and it is dependent on numerous interacting factors. Significant factors that may influence contrast transit time are interindividual variation such as patient's body weight and height, heart rate, and circulation time. However, many important variables that help to determine image quality are controllable by the operator.

Most common selections for CT protocols are fixed time delay (FTD), timing bolus and automatic bolus tracking (ABT). FTD technique uses administration of CM as a trigger to start CT scanning. This delay will be determined based on historical data and operator's understanding, which individual variations were usually ignored [1, 2]. Although this technique promised a good result, particularly in patients with no underlying cardiovascular disorder, scan delay should be tailored to each individual. As for timing bolus technique, CM is injected in small volume (of 15 to 20 ml) and followed by repetitive low dose CT scanning. Enhancement-time relationship's graph is plotted to determine time to peak enhancement, and subsequently, scan delay. Pitfall that remains for timing bolus technique is that although the amount of contrast use is high, there is no obvious improvement in contrast enhancement degree seen. ABT technique uses multiple low dose scan, which will be initiated after an entire bolus of CM administered, and arterial enhancement at the anatomic region of interest (ROI) reaches a certain threshold. This technique helps to conserve CM, and is effective, but scan can fail to initiate if the ROI is placed incorrectly, if the patient moves, or if there is venous inflow problem.

Tailoring the CM volume to patient's body weight can help to reduce interpatient variability during portal phase scan [3]. This weight-based volume (WBV) technique seems to be superior to fixed volume (FV) technique. Contrast administration using FV of 70 to 80 ml for CT thorax examination, is a common practice.

This study aims to quantitatively evaluate the degree of contrast enhancement and assess image quality acquired on 16-slice CT scanner in two tertiary centres using different scanning protocols and CM administration method for routine CT thorax examination.

## 2. Methodology

### *2.1. Study population*

Data was collected retrospectively from two tertiary centres consisting of 140 patients who underwent CT thorax examination using different protocols; 70 patients (Group A) from Advanced Medical and Dental Institute (IPPT), Universiti Sains Malaysia, using ABT with WBV technique, and 70 patients (Group B) from Hospital Pulau Pinang (HPP), Ministry of Health Malaysia, using FTD with FV technique. Group A consisted of 19 males and 51 females with mean age ± standard deviation (SD) of 53.6 years ± 11.2 years (age range, 29-77 years) and mean weight ± SD of 54.04 ± 13.77 kg (weight range, 32-100 kg). Group B consisted of 24 males and 46 females with mean age ± SD of 54.5 ± 13.2 years (age range, 20-80 years). Data from patients of 18 years old and above who underwent CT thorax examination using 16-slice scanner in each centre was included in this study. Data from those with underlying shock, renal impairment and heart disease was excluded. For specific exclusion criteria in IPPT and HPP, data from patients that were administered with non-WBV CM and scanned using non-ABT technique, and data obtained from patients that were scanned using non-FTD technique and administered with non-FV CM were excluded respectively.

### *2.2. Contrast medium administration*

CT scan technique used in IPPT was ABT technique and patients were administered with CM of 350 mgI/ml. Total iodine per kilogram of body weight was kept constant at 400 mgI/kg. Total volume of CM injected was according to patient's body weight and administered using a dual injector at a rate of approximately 4.0 ml/s, followed by a saline flush at similar rate. For patients from HPP, scanning technique used was FTD, with administered CM of 300 mgI/ml. A FV (of 80 to 85 ml) CM was injected using a dual injector at a rate of approximately 1.5 to 2.0 ml/s followed by saline flush at similar rate (Table 1).

**Table 1.** Details of scanning protocols used in both centres.

| Scanning parameters | Group A (IPPT) | Group B (HPP) |
|---|---|---|
| Tube voltage (kVp) | 120 | 120 |
| Tube current (mAs) | 98-395 | 300 |
| Rotation time (sec) | 0.6 | 0.5 |
| Contrast scanning protocols | Automatic Bolus Tracking (ABT) | Fixed Time Delay (FTD) |
| Contrast medium administration | Weight-based volume (WBV) | Fixed volume (FV) |
| Volume of contrast medium | 48-149 ml | 80 ml |

### *2.3. Image Analysis*

Qualitative and quantitative assessment was performed on selected CT images. A blinded scoring were performed by two radiologists with more than three years' experience from each centre (IPPT and HPP). The radiologists were blinded to the scanning techniques and contrast administration protocol. The quantitative analysis was performed using OsiriX DICOM viewer (Bernex, Switzerland) by placing the ROIs manually in selected anatomy which were the ascending aorta (AA), main pulmonary trunk (PT) (before its bifurcation into the right and left pulmonary artery), superior vena cava (SVC) and pulmonary vein (PV), and the attenuation readings in Hounsfield Unit (HU) values were recorded (Figure 1). Vascular calcifications were avoided during the ROI analysis. All CT images from both centres were also reviewed qualitatively in separate and independent reading sessions. The score ranged between 1 to 5 scales to express overall image quality, based on five characteristics as follow: 1 = very poor; 2 = poor; 3 = fair; 4 = good; and 5 = excellent. An image was scored very poor if the vessel was indistinguishable from surrounding and there was absence or minimal vascular enhancement. If there was slight vascular enhancement and some contrast between vessels and surrounding structures, it was scored as poor; fair if vascular enhancement and contrast between lesions and surrounding structures were present but some images were inadequate for evaluation. The scoring of good will be given if vascular enhancement and contrast between vessels and surrounding structures were present in all the images in a level that allows proper but not easy evaluation of images. An excellent score will be for those images with marked vascular enhancement and strong contrast between vessels and surrounding structures, leading to clear and easy evaluation.

### *2.4. Statistical analysis*

The mean attenuation values of measured structures using the two different protocols were assessed and compared. Pearson's correlation coefficient (r) test was performed to find the relationship between HU values and administered contrast volume. Mean of qualitative scores from both protocols were assessed and compared. A P-value of less than 0.05 was considered statistically significant. Statistical analysis was performed using commercially available software, IBM SPSS Statistics 24.

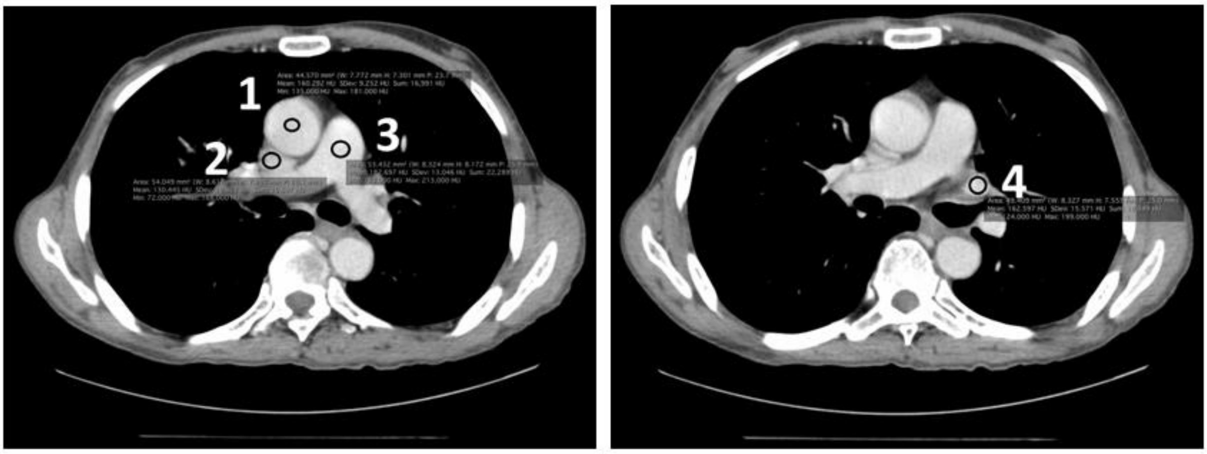


**Figure 1**. Axial contrast enhanced CT of thorax showing the mean HU values in ascending aorta (1), superior vena cava (2), pulmonary trunk (3) and pulmonary vein (4) that were measured.

## 3. Results

Comparison between Group A and Group B showed that mean contrast enhancement values in Group B were greater than those in Group A ($p < 0.001$). The mean HU ± SD of the great vessels in Group A and B were as follows: AA 174.8 ± 33.9, 229.2 ± 54.1; SVC 161.9 ± 47.3, 327.9 ± 123.4; PT 170.3 ± 37.8, 227.1 ± 58.5; and PV 165.1 ± 35.5, 222.3 ± 53.6, respectively (Table 2). There was no statistically significant difference ($P = 0.185$) between mean qualitative scores on a 5-point scale in Group A (4.4 ± 0.6) and Group B (4.3 ± 0.7) (Table 3). A positive but weak correlation was seen between HU values with administered contrast volume; $r = 0.1152$.

**Table 2.** Mean of HU values of ascending aorta, superior vena cava, pulmonary trunk and pulmonary vein.

| Region of Interest | Group A | | Group B | | P value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| AA | 174.8 | 33.9 | 229.2 | 54.1 | <0.001 |
| SVC | 161.9 | 47.3 | 327.9 | 123.4 | <0.001 |
| PT | 170.3 | 37.8 | 227.1 | 58.5 | <0.001 |
| PV | 165.1 | 35.5 | 222.3 | 53.6 | <0.001 |

**Table 3.** Mean of quality grading for Group A and Group B.

| | Group A | | Group B | | P value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Quality | 4.4 | 0.6 | 4.3 | 0.7 | 0.185 |

## 4. Discussion

There are several related factors that may determine the degree of contrast enhancement and image quality, such as scan time, injection rate, CM volume and concentration, which are controllable by the operator [4]. However, certain factors such as body weight and cardiac output are beyond operator's control [5]. We investigated two CM administration techniques in two different centres (ABT with WBV, and FTD with FV) to determine the protocol that exhibits better contrast enhancement and image quality. In this study, we found that higher mean contrast enhancement was seen using FTD technique (Group B). Of all four great vessels that were measured, the mean value and SD of SVC in

Group B was found to be relatively higher as compared to the rest of the vessels in the same group. Nonetheless, the mean qualitative scores on a 5-point scale did not demonstrate significant difference between both groups.

Tube current-time product, milliampere seconds (mAs) is one of the factors that contribute to high contrast enhancement and quality image. Takeshi et al. found that a high tube current with tube potential of 80 peak kilovoltage (kVp) improved image quality significantly when compared to 120 kVp [6]. Raman et al. concluded that improvement in image quality with decreased image noise was associated with the tube current or the product of tube current and scan time (mAs) [7]. In our study, with constant usage of 120 kVp for every CT thorax examination in both centres, tube current-time of 300 mAs which was used in Group B may have contributed to higher degree of contrast enhancement when compared to Group A.

Previous study by Como et al. concluded that both FTD and ABT showed no significant difference at liver venous and delayed phases [8]. The study also stated that these two techniques were actually comparable, and FTD were preferred as it simplified the work flow and reduced patient exposure. Mehnert et al. demonstrated that during portal venous phase, there was no significant difference in parenchymal enhancement between ABT and FTD technique [9]. In a study by Sheiman et al., the usage of FTD technique for scanning in patients with normal cardiac function appeared to have equivalent magnitude and uniformity in aortic enhancement as compared to ABT technique [10]. In achieving optimum aortic contrast opacification during CT scanning, Rubin et al. chose a FTD of 20 seconds for 13 out of 15 subjects, and 11 of them showed complete abdominal aortic opacification [11]. Bonaldi et al. found that 67% of their study subjects scored 2.5 out of 3 for qualitative assessment when a standardised 15 seconds FTD technique was used during scanning [12]. In another study by Adibi and his colleague, higher contrast enhancement of the aorta and spleen at the portal phase was achieved using ABT, but has no effect in liver enhancement [13].

We demonstrated a positive but weak correlation between HU values with administered contrast volume in our study. Benbow et al. found that there was a good correlation (r = -0.825) between patients' weight and contrast enhancement which was observed when a FV of CM was used [14]. Frush et al. showed that the use of FV CM produced significantly better contrast enhancement even when this technique scored lower grades in terms of image quality [15]. However, in achieving comparable vascular enhancement and image quality, Laurent et al. suggested that CM administration protocols to be individualised and tailored to each patient, regardless of the technique used [16].

## 5. Conclusions

Overall, a higher degree of contrast enhancement for routine CT thorax examination was seen using FTD technique with FV CM protocol. Nevertheless, ABT with WBV protocol demonstrated higher grading by assessors in CT image quality although statistically not significant. Indeed, to achieve the full benefits of multi-detector CT with more shorter scanning times in the future, we must be aware that scan timing and CM administration protocols need to be individualised and optimised by considering multiple inter related factors affecting contrast enhancement and quality. Further study is needed to investigate each CM technique and their validity in clinical practice.

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