Original Article

Multi Slice Spiral CT Pulmonary Angiography in Dynamic Pitch Mode using Volume Helical Shuttle Technology for the Diagnosis of Pulmonary Embolism

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Introduction : Multi slice Computed Tomography Pulmonary Angiography (CTPA) in dynamic pitch (Volume Helical Shuttle-VHS) mode is an evolving method to visualize pulmonary arteries including the peripheral pulmonary vasculature. The purpose of this study is to evaluate CT Pulmonary Angiography in dynamic pitch mode (Volume Helical Shuttle) for pulmonary embolism in comparison with standard pitch mode.

Methods : We have done a multicentric analytical comparison study with study group involving patients undergone CTPA in dynamic pitch mode-Volume Helical Shuttle (VHS) and comparison group involving patients undergone CTPA in standard pitch mode.

Results : Optimal contrast enhancement phase of the pulmonary artery in the study group in Phase I to III were 22.6%, 43.4% and 34%. The best phases were the last two phases in our study. Study Group main pulmonary artery mean signal intensity is 423.83±75.94 HU and comparison groups mean signal intensity is 361.74±98.28HU (P value = 0.039). The percentages of analyzable segmental arteries were 91.6% in study group and 87.3% in comparison group (P value-0.008). The percentages of analyzable sub segmental arteries were 89.5% in study group and 84% in comparison group (P value-0.004). The study group shows less percentage of motion artefacts and higher image quality than the comparison group, however it was not statistically significant (P value >0.05).

Conclusions : Multislice CTPA in dynamic pitch mode using Volume Helical Shuttle (VHS) technology increase the ability to obtain the Optimal contrast enhancement in pulmonary arteries, improves the overall image quality, obviate the need for breath holding.

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***Key words* : Multi slice Computed Tomography Pulmonary Angiography, Pulmonary embolism, Dynamic pitch mode, Volume Helical Shuttle-VHS, Standard Pitch Mode.**

Pulmonary embolism is the third most common Acute Cardiovascular Disease after Myocardial Infarction and Stroke and results in thousands of deaths each year because it often goes undetected. Computed Tomographic Pulmonary Angiography (CTPA) has been evaluated with meta-analysis and has demonstrated sensitivities of 53%-100% and specificities of 83%–100%, wide ranges that are explained in part by technologic improvements over time[1].

Today multi slice helical CT technology has made it possible to image the thorax in a short period of time. This technique can cover the entire chest in 1-mm slice thickness or less, in one short breath-hold and allows a better analysis of peripheral pulmonary arteries with a better depiction of sub-segmental and peripheral clots[2].

Editor's Comment :

- Multi slice CTPA in dynamic pitch mode [Volume Helical Shuttle-(VHS)] is a safe, non-invasive and patient-friendly method for CT pulmonary angiography.
- Fast scanning using dynamic pitch (VHS) technology obviates the need of breath holding and is useful in patients with acute pulmonary thromboembolism.
- Dynamic mode CTPA allows to take three or more angiographic phases using fast scanning technology which is useful for attaining optimal contrast enhancement in the pulmonary arteries and improves overall image quality.

The main limitations of Multi-slice spiral CT are :

(A) Lack of optimal Pulmonary Artery contrast enhancement :

Pulmonary CT Angiography is often performed with fixed scan delays. In patients with normal right ventricular outflow, a 12-15 second scanning delay usually provides sufficient latitude so that the pulmonary arteries almost always well opacified. For patients with right ventricular failure and patients with pulmonary hypertension, a longer scanning delay is required, varying from 15-18 seconds[3,4-6].

With MDCT, a bolus-tracking method has been

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increasingly used to determine timing and reported to be particularly beneficial for patients with Right Heart Failure or Pulmonary Hypertension. However, no analytic study has been conducted on the appropriate implementation of a bolus-tracking method[4,7].

(B) Motion artefacts in patients with poor breath holding:

In some instances, results in suboptimal diagnostic quality of pulmonary CT angiographic images are motion artifact due to patient respiration or transmitted cardiac pulsation. The shorter breath-hold times that are possible with multi–detector row CT should facilitate investigation in dyspnoeic patients and reduce the occurrence of respiratory motion artifacts[8,9].

Pulmonary Angiography with Multi-slice spiral CT in Dynamic Pitch mode using Volume Helical Shuttle (VHS) Technology.

CTPA is widely used in clinical diagnosis of pulmonary embolism as a non-invasive method. Imaging in the optimal pulmonary artery enhancement phase is one of the key factors in the success of CTPA. According to conventional CTPA, after contrast injection 13~16s scan, most of which can obtain satisfactory image; but because there are individual differences in optimal pulmonary artery enhancement phase, in some cases catch less than optimal pulmonary enhancing phase. VHS technology has a wide range of fast roundtrip shuttle scan imaging advantages may facilitate capture optimal pulmonary artery enhancement phase[2].

With helical (also called spiral) scanning, the table moves at a constant speed while the gantry rotates around the patient. This geometry results in the X-ray source forming a helix around the patient. The pitch of the helical scan is defined as, Pitch = F table /nT, where F_{table} is the table feed distance per 360-degree rotation of the gantry and nT is the nominal collimated beam width. With the latest generation of multi detector CT scanners, it is possible to cover large volumes of anatomy in a very short time. However, when width of coverage increases, it might increase phenomena's such as cone beam artifact (wide cone angle for wide-area detector), heel effect (non-uniform illumination of X-ray of the tube anode for wide-area detector) and scatter of X-ray photons. These inconveniences are reduced by VHS method.

Shuttle mode allows a CT scanner to repeatedly image a volume of tissue that is wider than the detector array (nT). The table rocks back and forth a prescribed distance, during the temporal acquisition procedure. Due to the change in direction of the table, shuttle mode results in image data being acquired during table acceleration and deceleration, which implies that the reconstruction algorithm needs to accommodate for the changing pitch. The result is more than 300mm of high-resolution volume coverage for 4D CTA studies can perform a 4D CTA study to characterize the inflow and outflow of contrast in the arterial and venous system over a length of 312.5mm, equivalent to a 500-slice image[2] (Fig 1).

Using VHS technology, continuous scanning bed regularly move back and forth, to achieve a wide range of the z-axis direction of the reciprocal scanning in a short time, improving the time resolution in CT acquisition. An entire lung scan path about 3s, continuous scanning is possible to capture the best phase[2].

When imaged using VHS CTPA performed, in order to reduce radiation, which adopt a higher noise figure. Automatic dose adjustment technology CT scan, as noise increases exponentially lower radiation dose scan. CTPA using VHS technology for imaging can evaluate the average rate of pulmonary artery segment level to 88.39 percent, with the literature reported similar to bolus tracking technology. Compared with bolus tracking technology CTPA imaging, the process of operation is relatively simple, high success rate, more suitable for patients with severe Acute Pulmonary Embolism[2].

Volume Helical shuttle allows you to characterize arterial and venous inflow and outflow, measure volume coverage for a length of 312.5mm, perform perfusion studies for the body and organs, improve temporal sampling and use acquired scan data during acceleration and deceleration[2].

The advantages of Multi slice CT Pulmonary

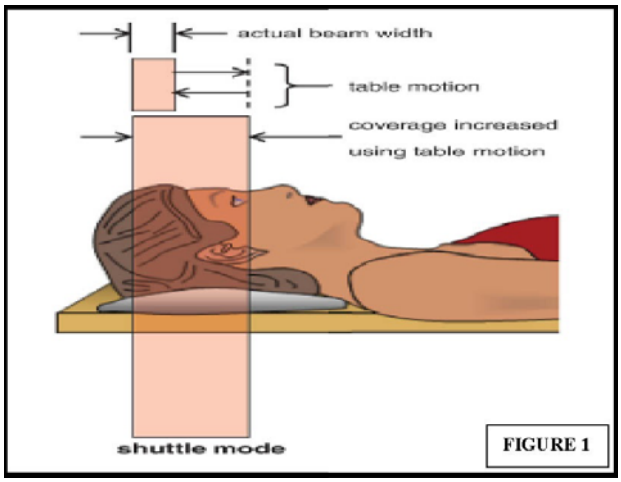

Fig 1 — Shuttle mode: Table rocks back and forth a prescribed distance, during the temporal acquisition procedure and increase the volume of coverage.

angiography in dynamic pitch mode using Volume Helical Shuttle technology are:

(1) Fixed delay of 10 seconds makes it operator independent.

(2) Good contrast delivery providing superior luminal contrast and obtain optimal contrast opacification.

(3) Shuttle mode with fast scanning obviates the need for breath holding.

(4) Lack of partial voluming[2].

Materials and Methods

The analytical comparison study was conducted in the Department of Radiodiagnosis and imaging, Medical Trust Hospital, Ernakulam and Department of Radiodiagnosis, Malankara Orthodox Syrian Church Medical College, Ernakulam for the time duration of January 2015 to December 2018 after taking consent from patients and approval by the ethics committee.

Reference population :

The patients selected for study were referred from Respiratory Medicine/General Medicine/Cardiology Department at our Hospital, who were clinically suspected to have pulmonary embolism.

Study group : Patients with suspected pulmonary embolism, referred to the Radiology Department, Medical Trust Hospital, Ernakulam from January 2015 to December 2018 for CT Pulmonary Angiography. (Undergone CTPA in Dynamic Pitch mode-Volume Helical Shuttle, VHS using 128 slice CT GE Optima 660)

Comparison group : Data collected from records from the Department of Radiodiagnosis, Malankara Orthodox Syrian Church Medical College, Ernakulam for the time duration of January 2015 to December 2018. (Undergone CTPA in standard pitch mode using PHILIPS BRILLIANCE 64 slice CT).

Total 106 patients (53 patients each in study group and comparison group) were included in the study.

Exclusion criteria included age <18 years, history of severe allergy to contrast media and severe renal dysfunction (eGFR <30 mL/min) not on dialysis.

Scanning technique :

Dynamic pitch (Volume Helical Shuttle-VHS) CTPA Protocol (Study group)

- Dynamic pitch CTPA done using Volume Helical Shuttle (VHS) technology by GE with 128 slice CT GE Optima 660.
- Automatic control technology mA, tube voltage 120kV, noise figure 18, FOV 50cm, pitch 1.375:1,0.4 sec / rev, reconstruction using adaptive statistical iterative algorithm (Adaptive statistical iterative reconstruction, ASIR) reconstruction, ASIR take 50%.
- Scans with fixed 10 sec delay
- Contrast media – Omnipaque 350 mg/ml
- Contrast administration – bolus of 90ml at the rate of 4.5ml/sec.
- Injector used is MEDRAD salient single head S-80465
- 18 gauge cannula through antecubital vein
- Scans were taken without breath holding
- Three passes(arterial phase) taken in dynamic pitch (VHS) mode at 12sec,15sec and 18sec, covering from lung apices to diaphragm
- Venous phase scan taken to include IVC (Helps to plan IVC filter) Standard CTPA protocol (Comparison group)
- Standard CTPA studies done with PHILIPS BRILLIANCE 64 slice CT.
- Automatic control technology mA, tube voltage 120kV, noise figure 9.8, FOV 50cm, pitch 0.984:1,0.8 sec / rev
- Scan done with bolus tracking method, ROI in SVC, 3 sec delay
- Contrast media – Omnipaque 350 mg/ml
- Contrast administration – bolus of 90ml at the rate of 4.5ml/sec.
- Injector used is MEDRAD salient single head S-80465
- 18 /20 gauge cannula through antecubital vein
- Scans were taken with single breath holding

AIMS

- To evaluate CT Pulmonary Angiography in dynamic pitch mode (Volume Helical Shuttle) to obtain optimal contrast enhancement phase.
- To compare dynamic pitch (Volume Helical Shuttle) CTPA with standard pitch CTPA with respect to:

a) Motion artefacts in aortic root, ascending aorta and main pulmonary artery.

b) Optimizing contrast enhancement in Main pulmonary artery

c) Visualisation of peripheral pulmonary vasculature(Segmental and sub segmental arteries)

d) Overall image quality

Image Interpretation :

Image analysis using the GE Advantage Windows 4.4 workstation after processing.

All cases were analyzed by two experienced radiologists.

Observed all scans including study group and comparison group in random order for —

(1) Motion artefacts :-

In the Aortic root, ascending aorta and main pulmonary artery

(2) Optimal main pulmonary artery contrast enhancement :-

Measuring the Main Pulmonary Artery (MPA) mean signal intensity (HU value) using circular or elliptical ROI placed in the corresponding blood vessels, ROI > 1cm2, to avoid artefacts.

Recorded the main pulmonary artery standard deviation. The MPA and branch pulmonary artery optimal enhancement phase is considered as the best phase. If more than one phase came good, then considered an earlier phase as best phase. Mean signal intensity value >250HU is considered as satisfaction level.

(3) Analysis of peripheral pulmonary arteries:

By using a scoring sheet similar to that used by Remy Jardin *et al*[5], 20 segmental, and 40 sub segmental arteries were evaluated in each patient. Each artery was individually coded and was considered analyzable when depicted from the proximal to the distal portions on a single or successive transverse CT scans without partial volume effects. The reason for inadequate arterial depiction including respiratory and/or cardiac motion artifacts, partial volume effects due to the small size of the vessel, and absence of an artery because of anatomic variants.

Each artery was individually coded as analyzable or not, leading the readers to determine the number of arteries analyzable per patient in each lung. These results were presented as rates of recognition of pulmonary arteries, expressed as percentages and calculated by means of the following formula: The rate of recognition equalled the number of arteries coded as analyzable in a given patient multiplied by 100 and divided by the maximum number of arteries anatomically present per patient.

(4) Overall Image Quality :

Two Radiologists asses the overall image quality using five point scoring system.

1-Poor, 2-Suboptimal, 3-Satisfactory, 4-Good, 5-Very Good.

Mean of both scores calculated and classified as, Excellent (> 3 points), Can be diagnosed (3 points), Poor (<3 points).

Statistical Methods :

Tabulation: Data from the proforma were entered into a Microsoft Excel spread sheet and exported into a statistical analysis suite. Analytical statistical analysis has been carried out in the present study. Results on continuous measurements are presented as Mean ± SD (Min-Max) and results on categorical measurements are presented in Number(%). Significance is assessed at 5% level of significance.

Statistical software: All data were expressed as Mean ± SD, and statistical analysis was performed with SPSS version 20.Chi square test and student t test used to compare between study group and comparison group, P value < 0.05 was considered statistically significant.

Statistical comparison and diagrams were carried out using Microsoft Excel and SPSS version 20 software.

Results

In this analytical comparison study, we included 53 patients with suspected pulmonary embolism in the study group who had undergone multislice CTPA in dynamic pitch mode (Volume Helical Shuttle), which we compared with 53 patients who had undergone multislice CTPA in standard pitch mode (comparison group).

The age distribution of study group from 37 to 86years, mean (61.51±12.28) years. The age distribution of comparison group from 33 to 81years, mean (62.92±11.55) years. The maximum numbers of patients were seen in the age group 61-70 years in both study group (35.86%) and comparison group (32.07%).In the present study, there is female predominance in both study group and comparison group.

Optimal Contrast Enhancement Phase in Study Group (Dynamic mode-VHS) :

Optimal contrast enhancement phase in the pulmonary artery can be evaluated in the study group. In our study, three arterial phases are included in the study group (Dynamic pitch mode CTPA-VHS mode).The phases are: Phase I (at 12 second scan delay), Phase II (at 15second scan delay) and Phase III(at 15 second scan delay).

The percentage of cases in Phase I to III was 22.6% (12/53), 43.4% (23/53) and 34% (18/53). The best phases were the last two phases (Phase II & III).

Mean signal intensity (HU value) in Main Pulmonary Artery :

In present study, study Group(multislice dynamic pitch CTPA-VHS) Main Pulmonary Artery mean signal intensity is 423.83± 75.94 HU and the comparison groups(multislice standard CTPA) mean signal intensity is 61.74± 98.28HU.

Study Group MPA mean signal intensity lowest value is 274HU and comparison group MPA mean signal intensity lowest value is 190HU. The comparison group had eight cases of MPA mean signal intensity value

lower than 250HU. Study Group main pulmonary artery mean signal intensity value satisfaction rate (> 250HU) is higher than the comparison group.

Student t test was used to compare mean signal intensity (HU value) in MPA between study group and comparison group. There is statistically significant difference (P value = 0.039) of mean signal intensity value between the study group and comparison group.

Motion artefacts in pulmonary angiography :

The percentage of motion artefacts in the study group was 16.9% at the level of aortic root, 5.7% at the level of ascending aorta and 7.5% at the level of MPA. The percentage of motion artefacts in the comparison group was 58.5% at the level of aortic root, 17% at the level of ascending aorta and 30.2% at the level of MPA.

In the present study, the study group shows less percentage of motion artefacts than the comparison group.

Chi square test was used to compare motion artefacts between study group and comparison group. Table 1 shows that there is no statistically significant difference (P value >0.05) between the study group and comparison group.

Analysis of peripheral pulmonary arteries :

The two readers analyzed 1060 segmental arteries (third order arteries) in study group and comparison group (20 segmental arteries per patient).They analyzed 2120 sub segmental arteries (fourth order arteries) in both study group and comparison group (40 sub segmental arteries per patient). The percentages of analyzable segmental arteries were 91.6% (971 of 1060 segmental arteries) in study group and 87.3% (925 of 1060 segmental arteries) in comparison group. The percentages of analyzable subsegmental arteries were 89.5% (1898 of 2120 sub segmental arteries) in study group and 84%(1781 of 2120 subsegmental arteries) in comparison group.

Student t test was used to compare the total number of analyzable segmental and sub segmental arteries between the study group and the comparison group.

Table 1 — *Percentage of motion artefacts in the aortic root, ascending aorta and MPA*

Motion artefacts		Study group	Comparison Group	P value
Aortic root	Yes	9(16.9%)	31(58.5%)	0.72
	No	44(83%)	22(41.5%)	
Ascending aorta	Yes	3(5.7%)	9(17.0%)	1.000
	No	50(94.3%)	44(83.0%)	
MPA	Yes	4(7.5%)	16(30.2%)	0.077
	No	49(92.5%)	37(69.8%)	

Statistically signiûcant difference (P-value <0.05) was found in the total number of analyzable segmental and sub segmental arteries in between study group and comparison group.

Overall Image Quality :

In the study group showing 86.79% 'excellent'(> 3 points), 11.32% 'can be diagnosed'(3 points) and 1.89% 'poor'(<3 points) scores. In the comparison group showing 60.38% 'excellent', 18.87% 'can be diagnosed' and 20.75% 'poor' scores. In the study group, very less number of patients are included in poor image quality score.

Chi square test was used to compare overall image quality between study group and comparison group. There is no statistically significant difference (P value >0.05) between the study group and comparison group.

Representative Cases :

(1) Comparison of Motion Artefacts (Fig 2) :

(2) Optimal Phase in CTPA Dynamic Pitch Mode (VHS) (Fig 3) :

(3) Optimal Contrast Enhancement in MPA (Fig 4) :

(4) Visualization of Peripheral Arteries (Fig 5):

(5) Overall Image Quality (Fig 6) :

Discussion

CTPA is widely used in clinical diagnosis of pulmonary embolism as a noninvasive method. Optimizing the best imaging phase in the pulmonary artery is one of the key factors in the success of CTPA. According to conventional multislice CTPA experience after contrast injection 13 ~ 16s scan, most of which can obtain satisfactory image; but because of the individual differences in pulmonary artery optimal enhancement, in some cases catch less than optimal

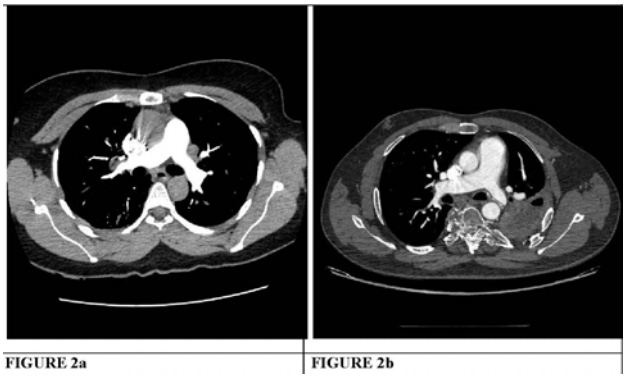

Fig 2 — Transverse MDCT views (WL-40,WW-400) of (a) dynamic pitch mode CTPA scan and (b)standard CTPA scan at the level of MPA shows reduced motion artefacts in dynamic pitch mode CTPA in comparison with standard CTPA scan

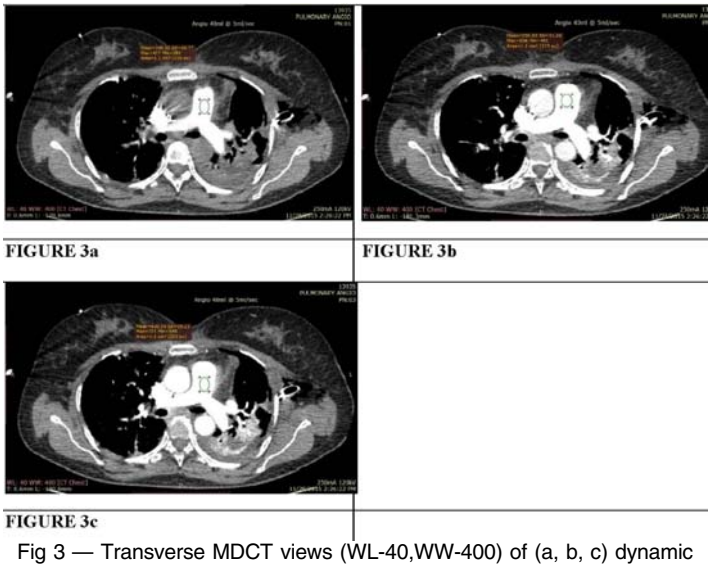

Fig 3 — Transverse MDCT views (WL-40,WW-400) of (a, b, c) dynamic pitch mode CTPA scan (in 56 years old female) showing three arterial phase in dynamic mode. a) Phase- I, Mean HU-348.02±28.77, Only pulmonary vasculature is filled with contrast. b) Phase- II, Mean HU-550.95±31.26. c) Phase- III, Mean HU-626.55±29.23, Mean signal intensity is higher in this phase.

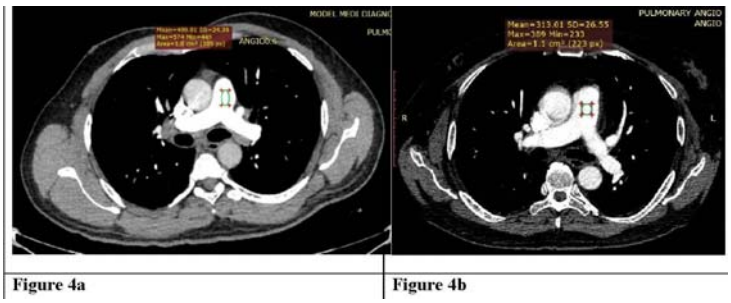

Fig 4 — Transverse MDCT views (WL-40,WW-400) of (a) dynamic pitch mode CTPA scan and (b)standard CTPA scan at the level of MPA shows mean signal intensity (identical region of interest with ROI>1cm^2) is higher in dynamic CTPA scan(Mean HU-499.91±24.38) than standard CTPA scan(Mean HU-313.01.39±16.76)

pulmonary artery enhancement phase. Using VHS technology, continuous scanning bed regularly move back and forth, to achieve a wide range of the z-axis direction of the reciprocal scanning in a short time, improving the time resolution in CT acquisition. An entire lung scan path about 3s, continuous scanning is possible to capture the best phase. When imaged using VHS CTPA performed, in order to reduce radiation, which adopt a higher noise Figure[2].

Multi slice Computed Tomography (CT) Pulmonary Angiography in dynamic pitch (VHS-Volume Helical Shuttle) mode is an evolving method to visualize pulmonary arteries including the peripheral pulmonary vasculature. Dynamic pitch mode (Volume Helical Shuttle) is a new adaptive technology enabling the CT table to travel back and forth using continuous periodic table movement during the acquisition. This allows to take multiple scans during the passage of contrast without inter scan delay within a short period of time. Multislice CTPA in dynamic pitch mode enabled a fast imaging technique and reduce the percentage of motion artefacts in patients due respiratory and cardiac movement in comparison with multislice CTPA in standard mode.

With the introduction of multi slice CT scanners in dynamic pitch mode, allows to perform up to 500-slice (312.5-mm) dynamic studies. Dynamic pitch cone beam reconstruction offers reconstruction for non-constant or dynamic helical pitch and creates images acquired during table acceleration and deceleration and thereby making it possible to scan entire Pulmonary Arterial System with good contrast opacification and less artefacts. Advances in reconstruction algorithms using Adaptive Statistical Iterative Reconstruction (ASIR) technology make it possible to reduce the radiation dose for each examination to acceptable levels[2].

Shuttle mode allows a CT scanner to repeatedly image a volume of tissue that is wider than the detector array. The table rocks back and forth a prescribed distance, during the temporal acquisition procedure. Due to the change in direction of the table, shuttle mode results in image data being acquired during table acceleration and deceleration, which implies that the reconstruction algorithm needs to accommodate for the changing pitch. The result is more than 300mm of high-resolution volume coverage for 4D CTA studies. We can perform a 4D CTA study to characterize the inflow and outflow of contrast in the arterial and venous system over a length of 312.5mm, equivalent to a 500-slice image[2].

Conclusion

From the present study it was noted that multislice CTPA in dynamic pitch mode using VHS Technology is a promising technology for pulmonary Angiography for acute Pulmonary Embolism. The ability to obtain the optimal contrast enhancement in pulmonary arteries using shuttle mode and detection of segmental, sub segmental & more distal pulmonary arteries make it superior to other methods of spiral CTPA. VHS method provides fast imaging with wide range of Z-axis coverage and has reduced the need for breath holding and is more favorable in patients with acute pulmonary embolism. Adaptive Statistical

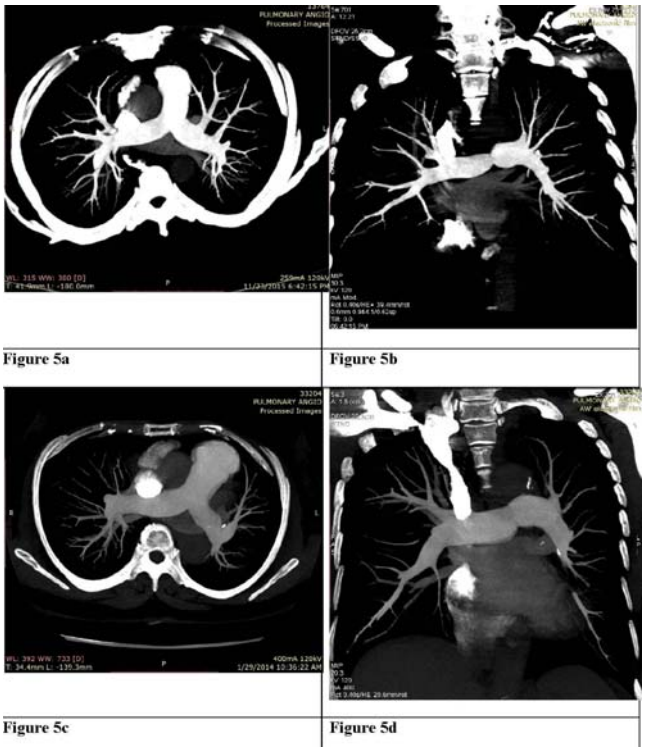

Fig 5 — MDCT Maximum Intensity Projection (MIP), axial and coronal views of dynamic pitch mode CTPA scan (a, b) and standard CTPA scan(c, d) showing better visualization segmental (third order) and sub segmental (fourth order) arteries in dynamic pitch mode CTPA scan.

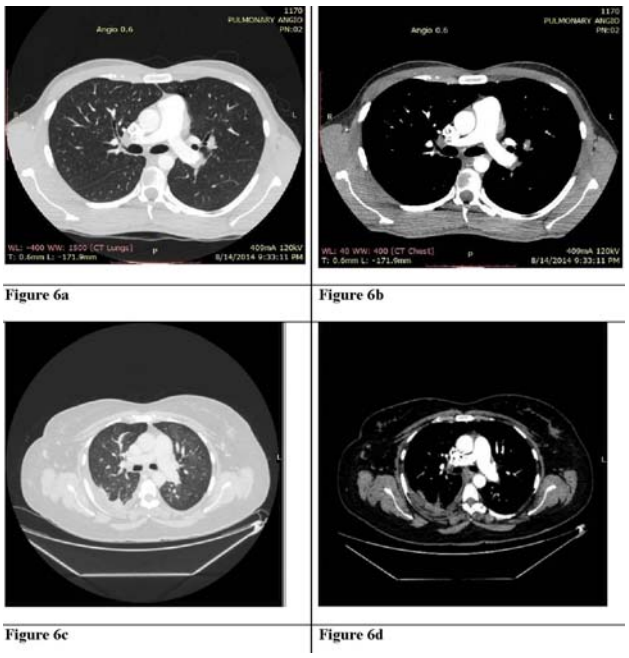

Fig 6 — MDCT Transverse views (Lung window & mediastinal window) of dynamic pitch mode CTPA scan (a, b) and standard CTPA scan(c, d) showing better overall image quality in dynamic mode CTPA scan.

Iterative Reconstruction (ASIR) technology used to maintain the high noise figure, which reduces the radiation dose and improves the overall image quality. Using VHS technology multislice CTPA advantageous to capture the best imaging pulmonary artery enhancement phase. Using a larger noise figure and appropriate ASIR value, the image quality to meet the diagnostic needs.

Acknowledgements

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