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RESEARCH ARTICLE

MDCT -TRIPLE RULE OUT- ANGIOGRAPHY IN THE EVALUATION OF ACUTE CHEST PAIN

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ABSTRACT

Triple rule out (TRO)-Multidetector computed tomography (MDCT) angiography denominates an ECG-gated protocol that allows for the depiction of the pulmonary arteries, thoracic aorta, and coronary arteries within a single examination in patients with heart rate of upto 80 beats per minute. TRO MDCT Angiography is most appropriate for the patient who is judged to be at low to intermediate risk for acute coronary syndrome (ACS) and whose symptoms may also be attributed to acute aortic syndrome (AAS) or acute pulmonary embolism (PE). In this study we evaluated Noninvasive 256 slice MDCT Triple rule out angiography in fifty patients, in the diagnosis of different causes of acute chest pain.

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INTRODUCTION

Acute Chest pain (ACP) is one of the most common symptoms in emergency departments, comprising 5–20% of emergency department visits (Erhardt *et al*., 2002 and Erhardt *et al*., 1991). The acute coronary syndrome (ACS), pulmonary embolism (PE) and acute aortic syndrome (AAS) are the most common and three major life-threatening causes in ACP (Johnson *et al*., 2008). ACP may induce severe mortality and morbidity, and the malpractice litigation over omitted diagnosis of myocardial infarction. Despite this relatively common symptom, however, early triage of these patients remains difficult. The patient's history, initial biomarkers, and the results from Electrocardiography (ECG) often do not allow a safe distinction between patients who require hospital admission with further testing and those who can be safely discharged home (Lee *et al*., 1987; Swap *et al*., 2005 and Zimmerman *et al*., 1999). This complexity results in a high number of unnecessary hospital admissions that in turn have enormous economic consequences for the health-care system (Kaul *et al*., 2004). Nowadays, chest CT using a non-ECG-gated protocol represents the reference imaging modality for the diagnosis or exclusion of pulmonary embolism (PE) and aortic dissection (Hayter *et al*., 2006 and Hayter *et al*., 2005).

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On the other hand, potentially life threatening underlying diseases such as acute coronary syndrome (ACS) accounting for 15–25% of the patients with acute chest pain (Erhardt, 2002) cannot be assessed by using a non-ECG-gated protocol. Recently, several studies have demonstrated that an ECG-gated CT of the entire chest is feasible and allows for an accurate evaluation of the pulmonary artery, the thoracic aorta, and the coronary arteries as well as of non-vascular structures within a single examination (Johnson *et al*., 2008 and Schertler, 2007). Such a protocol, in jargon also called triple rule-out CT, requires the adjustment of the contrast media application protocol for the simultaneous attenuation of three vascular territories i.e., aorta, pulmonary, and coronary artery (Johnson, 2007). Injection of iodinated contrast material (<100 mL) is tailored to provide simultaneous high levels of arterial enhancement in the coronary arteries and aorta (>300 HU) and in the pulmonary arteries (>200 HU). To limit radiation exposure, the TRO MDCT examination does not include the entire chest but is constrained to incorporate the aortic arch down through the heart. Scanning parameters, including prospective ECG tube current modulation and prospective ECG gating with the "step-and-shoot" technique, are tailored to reduce radiation exposure (optimally 6-9msv). TRO CT, which has potential to identify both coronary and other life-threatening etiologies of chest pain such as coronary stenos is, pulmonary embolism (PE), and aortic dissection, is emerging as a diagnostic modality in some clinical settings for patients at low to moderate risk for acute coronary syndromes (ACS) in whom PE or aortic dissection are also being considered in the differential diagnosis (David Ayaram *et al*., 2013). This article is intended to evaluate256 slice MDCT -Triple rule out angiography parameters and contrast media administration protocols that allow performing a triple rule-out CT examination in the acute chest pain patient and discusses radiation dose issues pertinent to the protocol. A few life-threatening and non-life-threatening diseases causing acute chest pain are illustrated.

MATERIAL AND METHODS

Objective: The aim of our study was to evaluate the efficacy & validity of noninvasive 256 slice MDCT Triple rule out angiography, in diagnosis of different vascular causes of chest pain in fifty consecutive patients.

Ethics: This prospective study was approved by the local ethics committee. Because we used the standard Triple rule out protocol, the patients / Relatives written consents were acquired before they underwent TRO angiography.

Patients: Triple rule-out CTA examinations were performed on 50 consecutive low to moderate risk, emergency department patients with clinically suspected ACS, PE and AAS, over a 2-year period(between 2011 to 2013) from Dr. Ramesh Cardiac and Multispecialty Hospital, in coastal Andhra Pradesh, were included in the study. They presented with chest pain and shortness of breath, while their ECG findings were non-conclusive of heart disease and their initial myoglobin and troponin I levels were unremarkable. Out of the total patients, 60% were male in the age group 25-80 years and remaining were female in the age group 32-83 years with mean age of 56.8 years.

Exclusion criteria: Contraindication to CT angiography such as allergy to iodine contrast, impaired renal function and pregnancy patients were excluded. Marked heart failure, heart rate more than 100 bpm not responding to medication, severe breathless patients, who were unable to hold breath, during examination and calcium score more than 1000,were excluded. Patients who underwent CT pulmonary angiography, aortography or coronary CT angiography, before admission were also excluded.

System and Technique used

Triple rule out procedure

Intravenous access for TRO CTA was obtained by placement of an 18- 20 gauge intravenous catheter into a large vein in ante-cubital fossa. To optimize the flow of contrast material during the study, the arm with the IV line was positioned on the CT gantry anterior to the patient to minimize compression of the subclavian vein by the clavicle. In each patient, ECG leads were positioned on both shoulders and along the left side of the abdomen for cardiac gating of coronary CTA. The ideal heart rate for ECG-gated studies is a slow regular rhythm, usually a sinus bradycardia at 50–60 beats per minute (bpm). Oral B-blockers may be given in the Emergency department at least 1 hour before the scan for control of heart rate. For patients with a heart rate of more than 60 bpm, IV metoprolol was administered in 2.5 to 5 mg doses, every 3–5minutes to achieve a heart rate of 50–60 bpm. The maximum dose of metoprolol was 30 mg. Tab Evabradin 5-20 mg was also given in addition, in some patients to reduce heart rate. In patients with contraindication to metoprolal, diltiazem (Dilzem) 30-90 mg was given. Sublingual nitroglycerin was administered as a spray (800mcg) approximately 2 minutes before the TRO CTA procedure. The heart rate achieved in our patients was 43-100 bpm (average 67 bpm) for RGH mode, and 49-68 bpm (average 59.8 bpm) in PGT mode.

Contrast material injection protocol

Depending upon the patient weight, about 70-120 ml (average 73.9ml) of nonionic iohexol (Omnipaque 350mgI/ml, GE imaging) contrast was injected at 5-5.5ml/sec, for RGH mode and 70-95 ml (average 81ml) contrast was injected at 5.5 ml/sec for PGT mode and was followed by a 40 ml of saline flush at 4-5ml/sec. Coronary CTA was initiated with a bolus-tracking technique 5 seconds after the contrast bolus reached the left atrium. To obtain optimal contrast enhancement for both the coronary and pulmonary arteries, proper breath-hold was practiced with each patient before the study. The patient was instructed not to take a large breath, which can result in increased return of un-opacified blood from the inferior vena cava and suboptimal opacification of the pulmonary arteries.

Triple rule out protocol

The imaging protocol used in the study was the standard Triple rule out angiogram protocol used in our hospital. All patients underwent TRO CT on a 256 slice MDCT scanner (Brilliance iCT 256 slice, Philips Health care). The images were processed by iDose4 reconstruction using Philips EBW 4.5 workstation. A scout view of the chest was obtained to determine the proper location and extent for the triple rule-out scan. The scan was programmed from the lower margin of the clavicles through the estimated lower border of the heart based on the scout view. In this study, scan length of all TRO CTA examinations was 16-28 cms with an average length of 22.7 cm.

The scanner is equipped with several radiation reduction capabilities, including a dynamic helical collimator and an adaptive axial collimator to reduce z-over scanning. This novel scanner with a detector z-coverage of 80 mm allows a fast z-coverage. The acquisition parameters include 128 x 0.625 mm slice collimation by means of a dynamic z-focal spot (ZFS) for double sampling, and 270 ms gantry rotation time, which translates to an approximate temporal resolution of 135 ms (Hameed *et al*., 2009; Walker *et al*., 2009). Two scanning protocols, retrospective ECG gated (RGH) and prospective ECG triggering (PGT), were applied on the patient. The RGH scan mode with full exposure within the whole cardiac interval (0-100%) was performed as the standard protocol, while PGT with data acquired only in 75 +_ 5%cardiac phases at a step-and-shoot mode, were also conducted for reducing radiation doses. Prospective ECG gating should be reserved only for patients with a very stable heart rate, since any change in cardiac rhythm will either prolong the scan time or result in degraded image quality from cardiac motion.

As the cone beam geometry of the large coverage, system requires overlap between adjacent axial slices, cranio-caudal coverage of 22.7 cm can be covered with four axial acquisitions each with X-ray exposure during a rest phase of four heart beats and three beat between used for translating the patient couch. Overall, the acquisition time for RGH mode was 6.3 s, and that for PGT mode was about 8.2 s, respectively (Chia-Jung Tsai *et al*., 2011). needed when the 75% phase was suboptimal. Systolic phase images at 40% of the cardiac cycle were reconstructed for all patients who were scanned without ECG-based tube current modulation.

Diagnostic criteria

Each major coronary artery (i.e., left main, left anterior descending, left circumflex right coronary and Posterior

Table 1. Imaging parameters for RGH and PGT modes

Scan technique	RGH	PGT
Tube voltage (kV)	120	120
Current-time product (mAs)	600 for wt less than 80 1180 for wt more than 80	285 for wt less than 80 300 for wt more than 80
Pulsing window	0-100%	70-80%
Pitch	0.16 for HR less than 70 0.18 for HR more than 70	
Scan length (cm)	22.7	22.7
Collimation	128x0.625	128x0.625
Heart rate	Less than 100	Less than 70
EDCTDI (mSv)	12-14 for wt less than 80 kgs. 16-18 for wt more than 80 kgs	5-7 for wt less than 80 kgs 6-8 for wt more than 80 kgs

Note: RGH-retrospective ECG-gated; PGT-prospective ECG-triggering; EDCTDI- effective dose calculated from CTDI method. Wt-weight.

Table 2. Distribution of Vascular & Nonvascular findings in all patients with acute chest pain after TRO Angiography

LESION	MALE	FEMALE	TOTAL	% OF THE TOTAL
Coronary lesion	8	2	10	20
Aortic lesion	4	1	5	10
Pulmonary lesion	3	2	5	10
Non significant vascular abnormality	11	7	18	36
Nonvascular abnormality	2	4	6	12
Negative study	2	4	6	12
Total	30	20	50	100

Table 3. Distribution of Significant coronary lesions in patients with chest pain after TRO Angiography

CORONARY LESION	MALE	FEMALE	TOTAL	% OF THE TOTAL
Single vessel disease	5	0	5	10
Double vessel disease	2	1	3	6
Triple vessel disease	2	0	2	4
Total	9	1	10	20

Table 4. Distribution of significant aortic diseases in patients with chest pain after TRO Angiography

AORTIC LESION	MALE	FEMALE	TOTAL	% OF THE TOTAL
Stanford type A Dissection	1	0	1	2
Aneurysm	1	0	1	2
Aneurysm + Stanford type A Dissection	1	1	2	4
Stenosis	1	0	1	2
Total	4	1	5	10

Interpretation of CT scans

Axial images were examined. Each patient was evaluated with slab maximum-intensity projection (MIP) images to visualize each vessel in multiple planes. Vessels with complex plaque were also evaluated using curved multiplanar reformations vessel-tracking software (Extended Brilliance workstation, Philips Healthcare). Additional Imaging rendering tools such as cine viewing, coronal & sagittal multiplanar images, virtual angioscopy & 3D volume rendered image analysis were used in examination of patients. An initial interpretation was performed with reconstructed images from the 75% cardiac phase. Additional diastolic phases were reconstructed as descending coronary arteries), as well as all visible obtuse marginal and diagonal branches, was graded for stenos is. Detection of central pulmonary embolism included analysis of the main pulmonary artery, right & left pulmonary artery, lobar, segmental, and sub segmental pulmonary arteries for mural thrombus and filling defects. The ascending, arch & descending thoracic aorta were evaluated, regarding their size, presence of filling defects, dissections, wall irregularities, calcification and mural thrombus. Other nonvascular structures such as cardiac size, pleural, pericardial and parenchymal abnormalities were assessed.

Effective dose determination

Effective dose (ED) was computed by using TLD measurement and CT dose index (CTDI) method, respectively. Effective dose for TLD method was calculated as the summation of the measured absorbed organ doses, multiplied by individual tissue weighting factors published by the ICRP-103. Effective dose estimates for CTDI method was determined using the volume CT dose index (CTDIvol) in Gy, as provided on the scanner console. The dose-length productis defined as the volume CT dose index multiplied by scan length, and is an indicator of the integrated radiation dose of an entire CT examination. An approximation of the effective dose was obtained by multiplying the dose-length product by a conversion factor, k (equal to 0.017 mSv mGy^{1} cm^{1}) (Schoepf, 2004).

RESULTS

The study included a total number of 30 males and 20 females, their age ranging from 25 to 83 years with mean age of 56.8 years. TRO Angiography study was suboptimal in 9 (18%) due to improper breath hold and increased heart rate during the scan. All patients with significant coronary stenos is >50% on coronary CTA underwent invasive coronary catheterization. Important other pathological findings were recorded.

All patients had a 90-day follow-up period for major adverse cardiac events (MACE). CT coronary angiography revealed total 77 stenotic segments; 18 of them showed significant stenosis (Fig. 1), while the other 59 segments showed non-significant stenosis and another 3 segments showed occlusion (Fig. 2) and focal myocardial bridging without significant stenos is in 9 (18%).

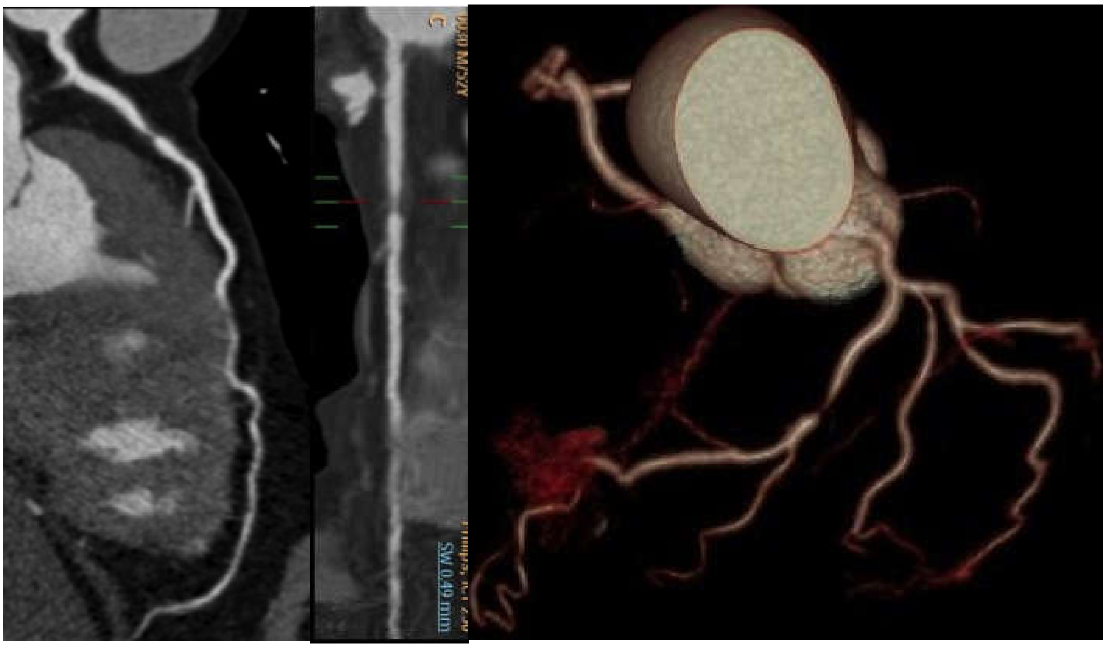
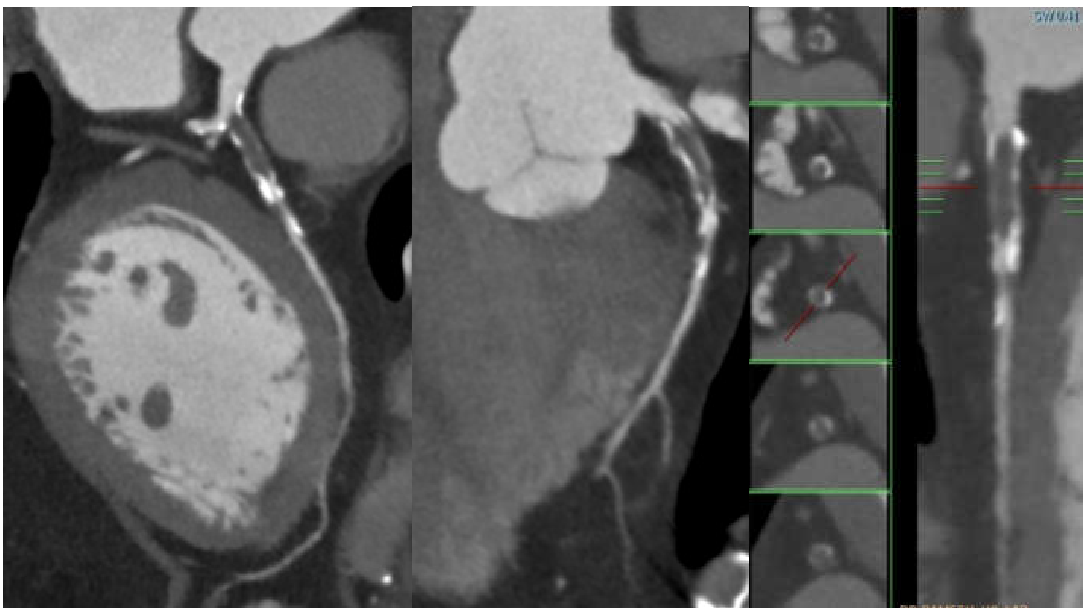


Fig.1. TRO CT angiogram in 52-year-old man with no relevant cardiac history who presented with sudden onset of chest pain while at work.TRO CT Angiography ,MPR curved (a), straight vessel (b) and coronary tree (c) images demonstrated a soft plaque with smooth 75-80% focal stenosis of the Proximal left anterior descending artery (Single vessel disease)



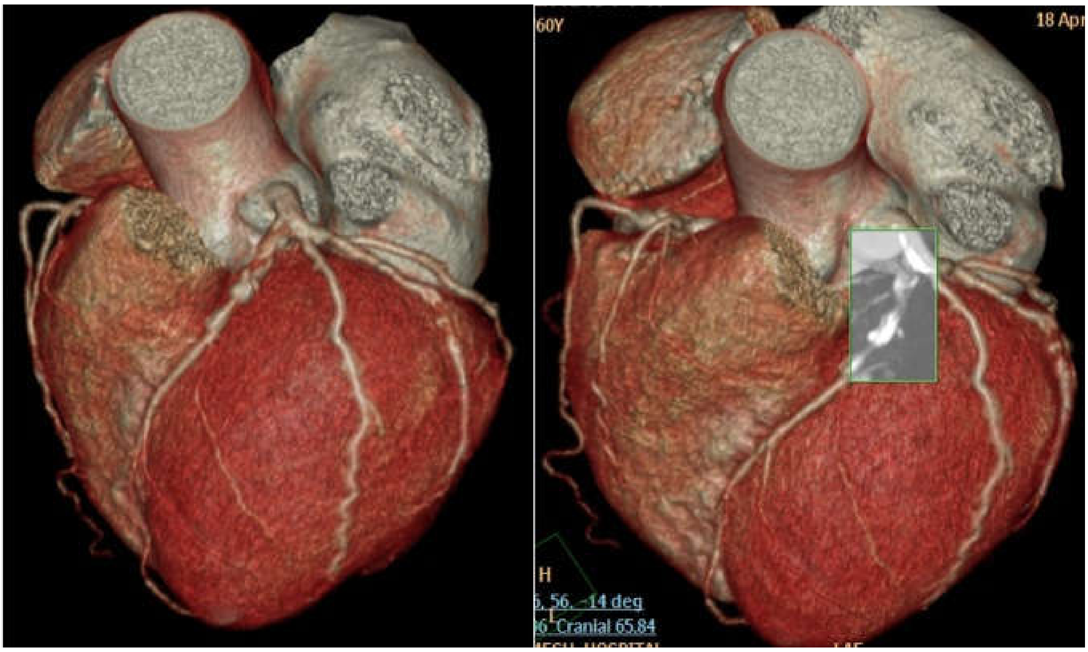


Fig.2.MPR curved (a,b)) , straight vessel analysis (c) & 3D volume rendered images(d,e) of LAD in a 60 years old male with chest pain shows proximal Left anterior descending artery thrombotic occlusion

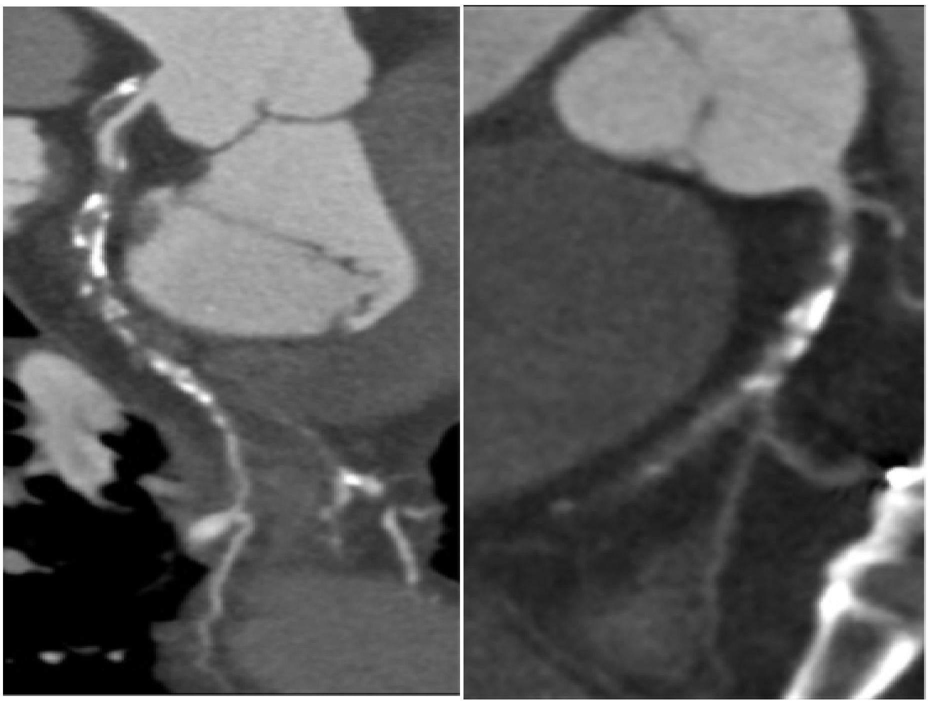


Fig. 3. TRO CT angiogram in 58year-old with no relevant cardiac history, who presented with atypical chest pain while resting at home. TRO CT MPR curved images (a,b) demonstrate irregular narrowing of left anterior descending artery and right coronary artery with significant stenosis (Double vessel disease)

Three coronary stents in three patients were evaluated for patency, in-stent re-stenos is and occlusion. The stents were distributed as follows: 1 in the proximal RCA, 1in the proximal LAD and 1 in the mid LCX. According to the angiographic findings; LCX stent was patent (Fig. 4), LAD stent had in-stent rest enosis (Fig.5), and RCA stent was occluded. From the 5 patients with pulmonary lesions; there were 2 patients with bilateral medium sized pulmonary emboli (Fig.6), 2 cases with massive pulmonary embolism (Fig.7) and 3 cases with small peripheral emboli at both lower and upper lobes (Fig.8). One of these cases showed right minimal pleural effusion. The nonvascular findings in these TRO angiography patients include-Acute pulmonary edema in 2(4%), Consolidation collapse in 2(4%), Right heart enlargement with pulmonary hypertension in 1(2%) and Pleural effusion in 1(2%).

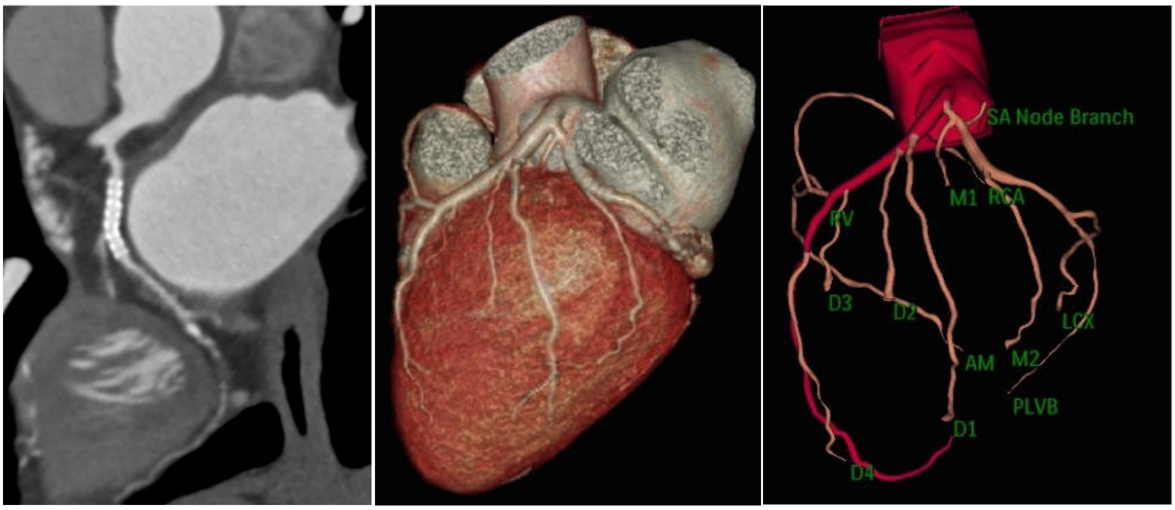


Fig. 4. 55 years old male with PCI to LCX presenting with chest pain. TRO CT, MPR curved (a), 3D (b) & coronary tree (c) views shows patent LCX stent

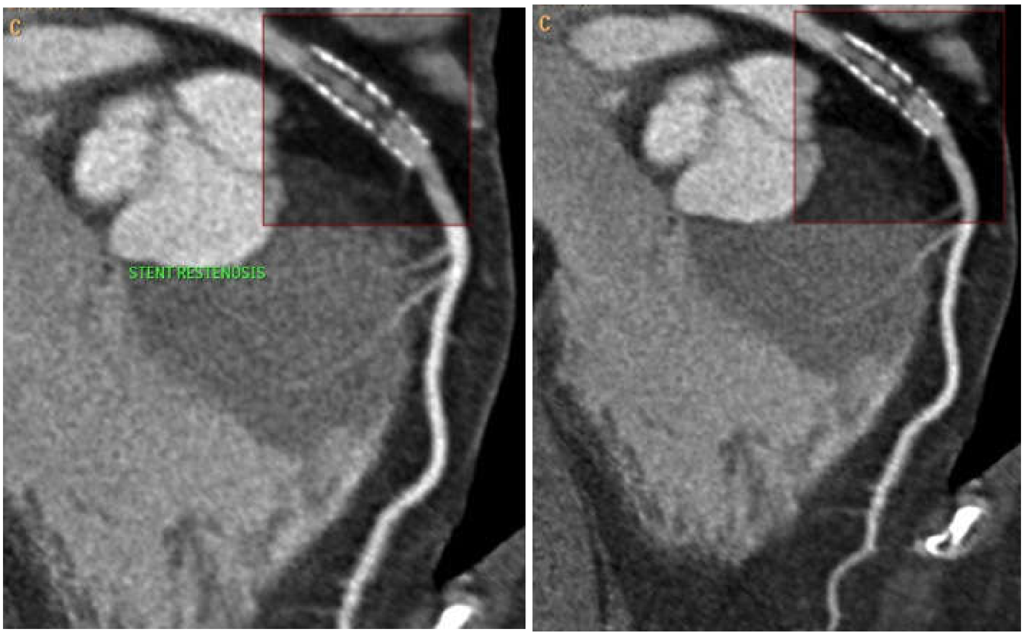
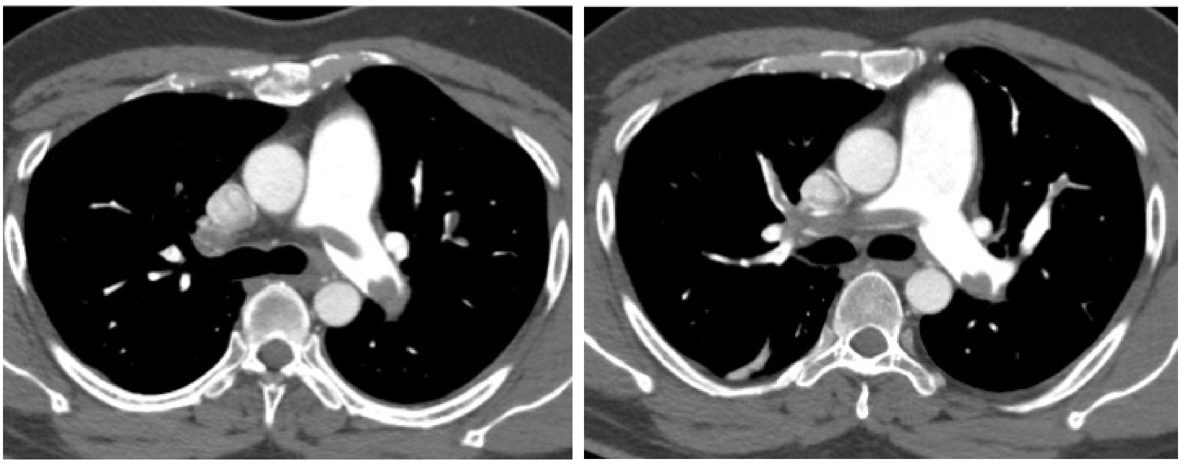
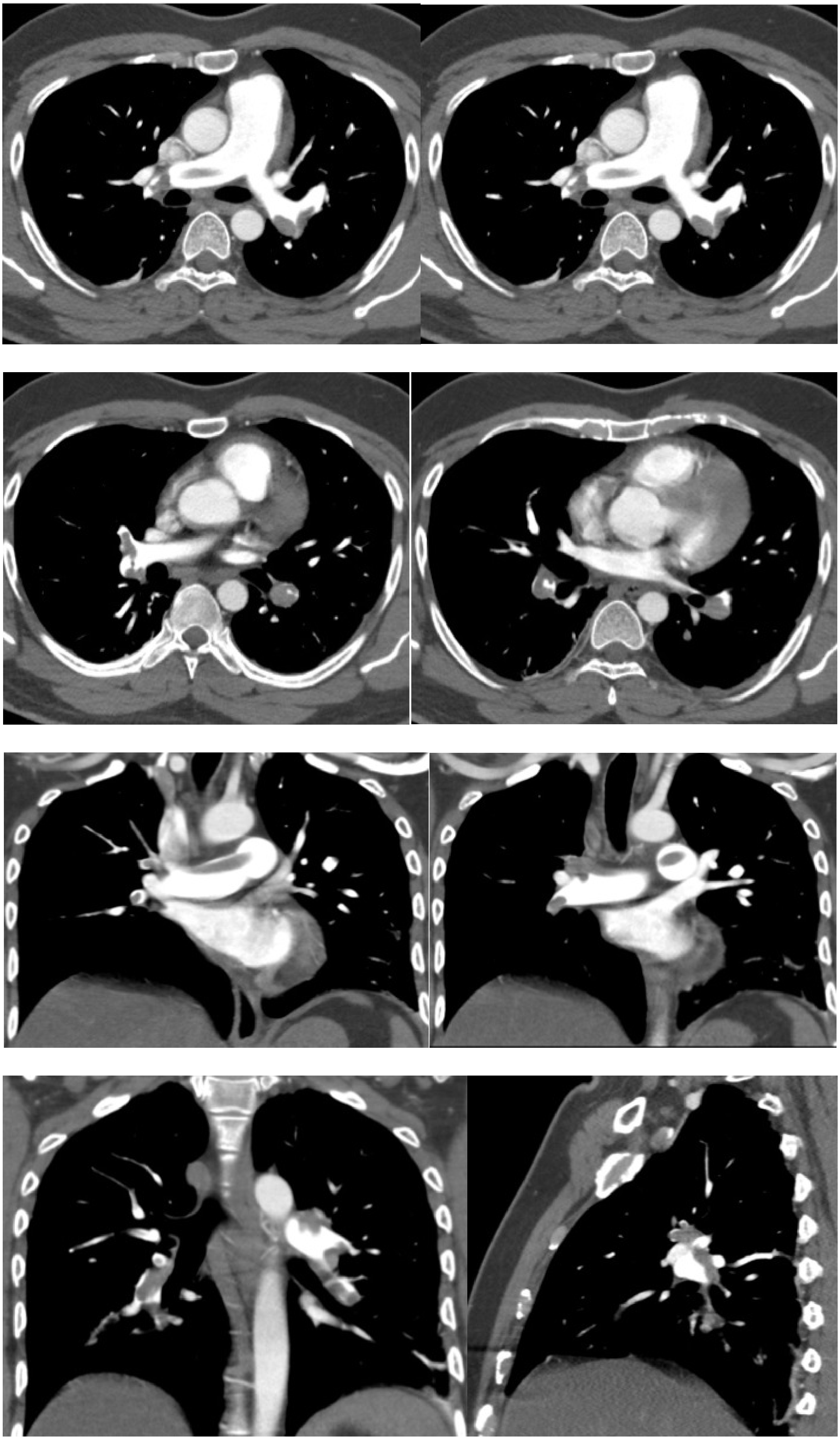


Fig. 5. 74 years old male with PCI to LAD, curved MPR views (a,b) show in-stent re-stenos is





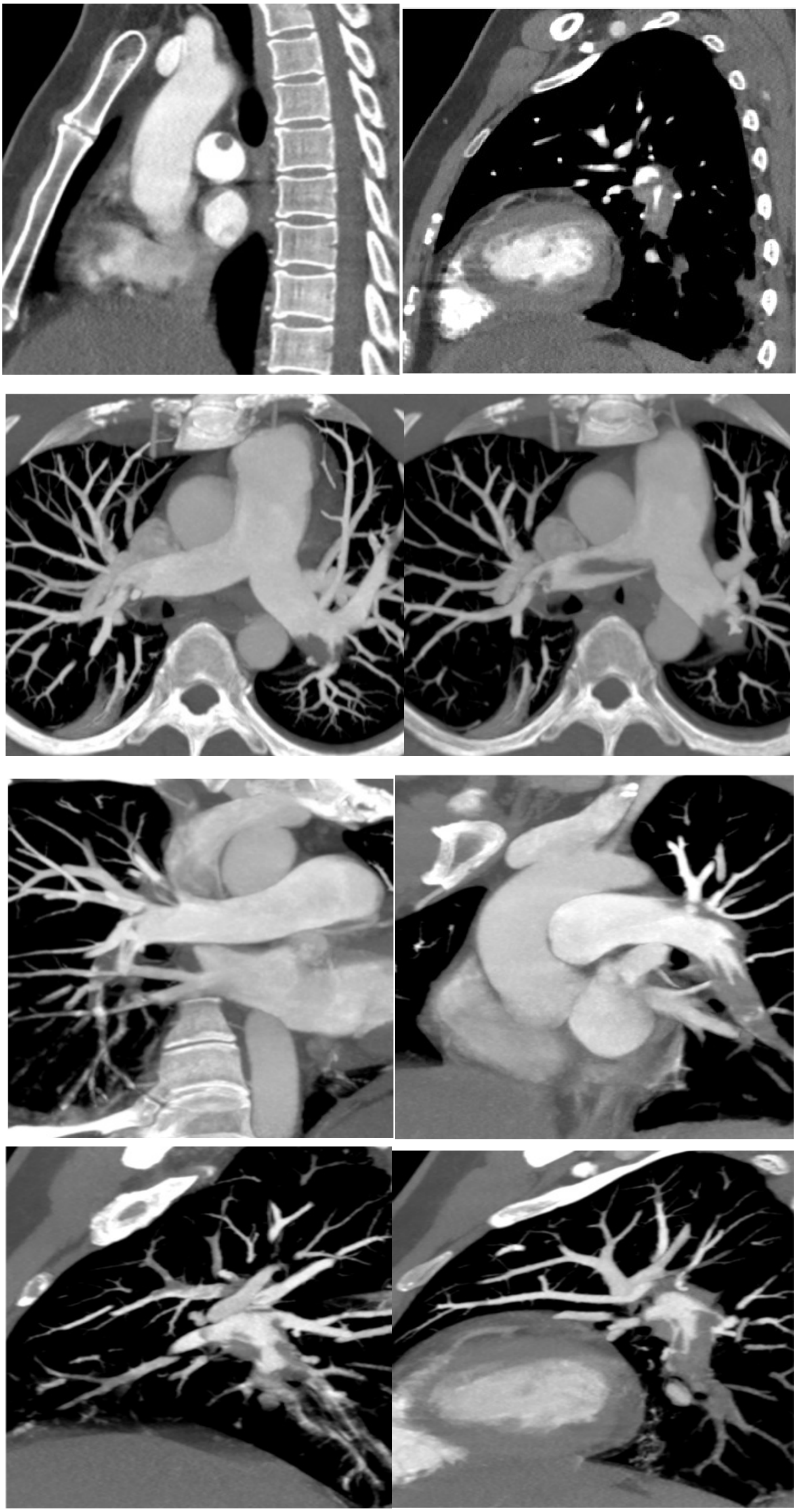


Fig.6. 45 years old male with sudden onset of chest pain & breathlessness TRO CT Axial images (a,b,c,d,e,f),coronal images (g,h,i), sagittal images (j,k,l,)&MIP axial, coronal & sagittal pulmonary tree images (o,p,q,r,s,t) reveal Bilateral massive pulmonary embolism with saddle thrombus at bifurcation

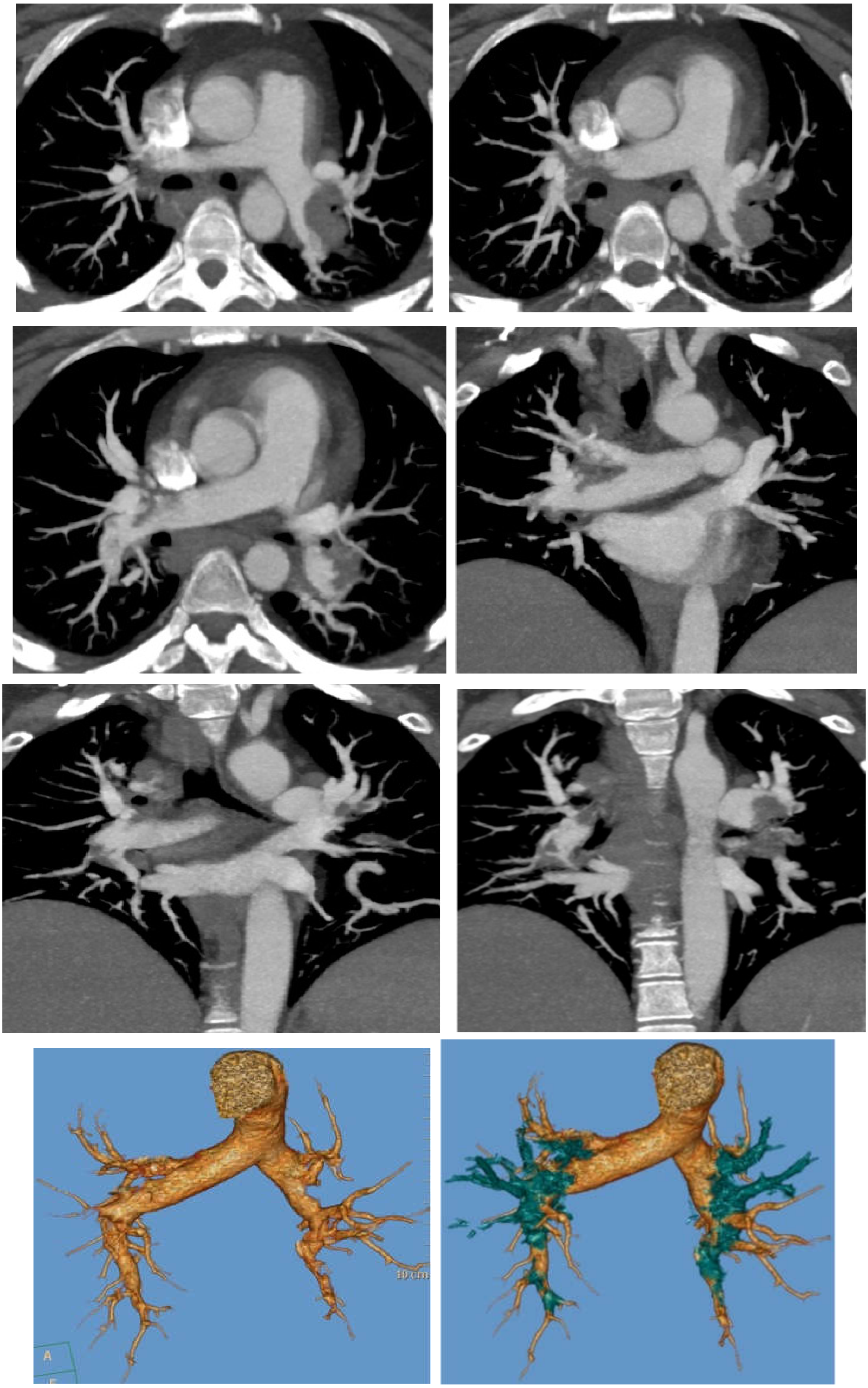
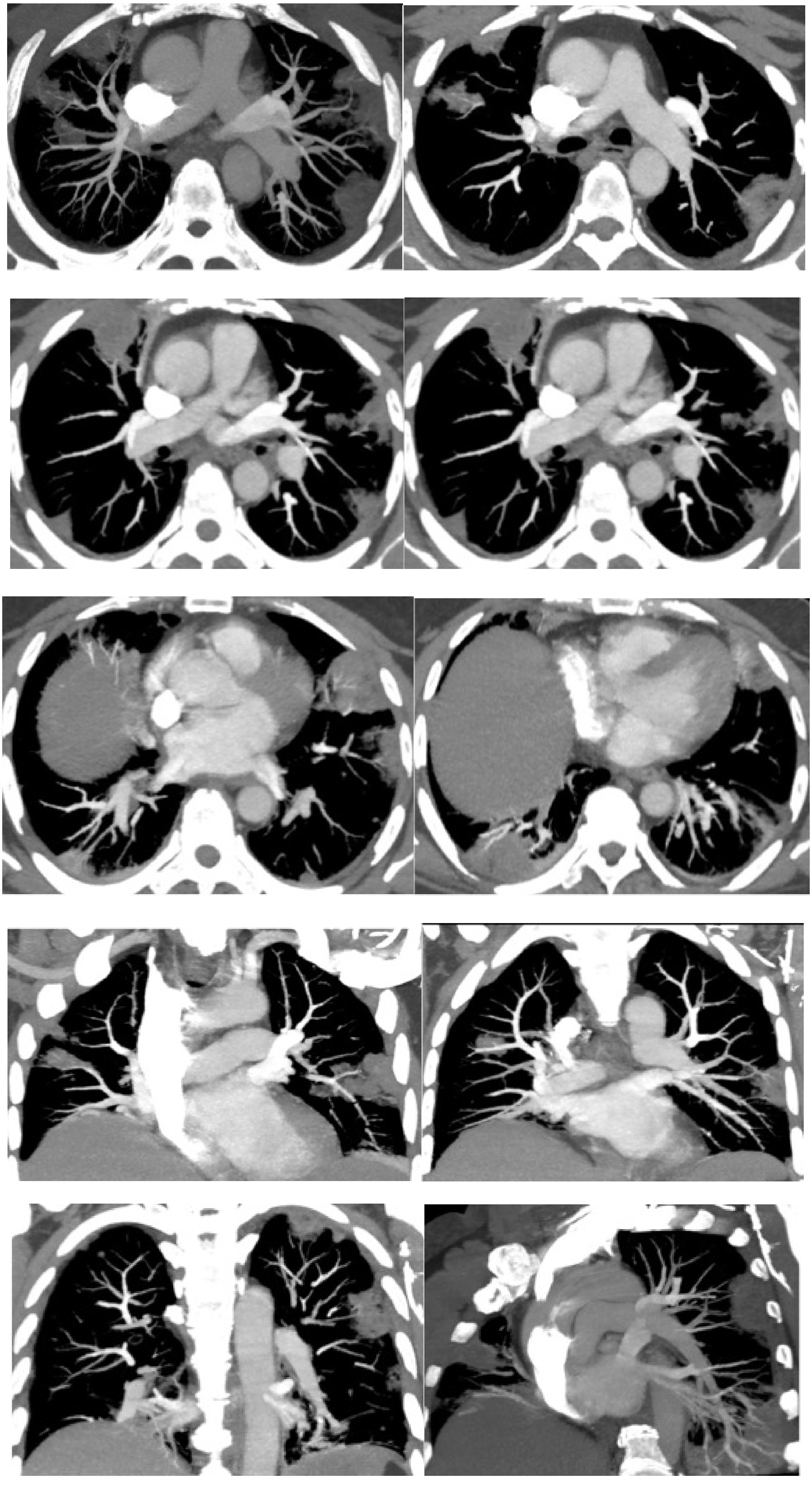


Fig.7. TRO CT angiogram in 30-year-old woman with chest pain that was atypical for angina but without severe shortness of breath

TRO CT demonstrates bilateral pulmonary embolism with normal aorta and coronary arteries. Axial (a,b,c), coronal (d,e,f) &3D volume rendered images (g,h) show-partial thrombotic occlusion of distal bilateral pulmonary arteries, complete and partial thrombotic occlusion of lobar & segmental arteries.



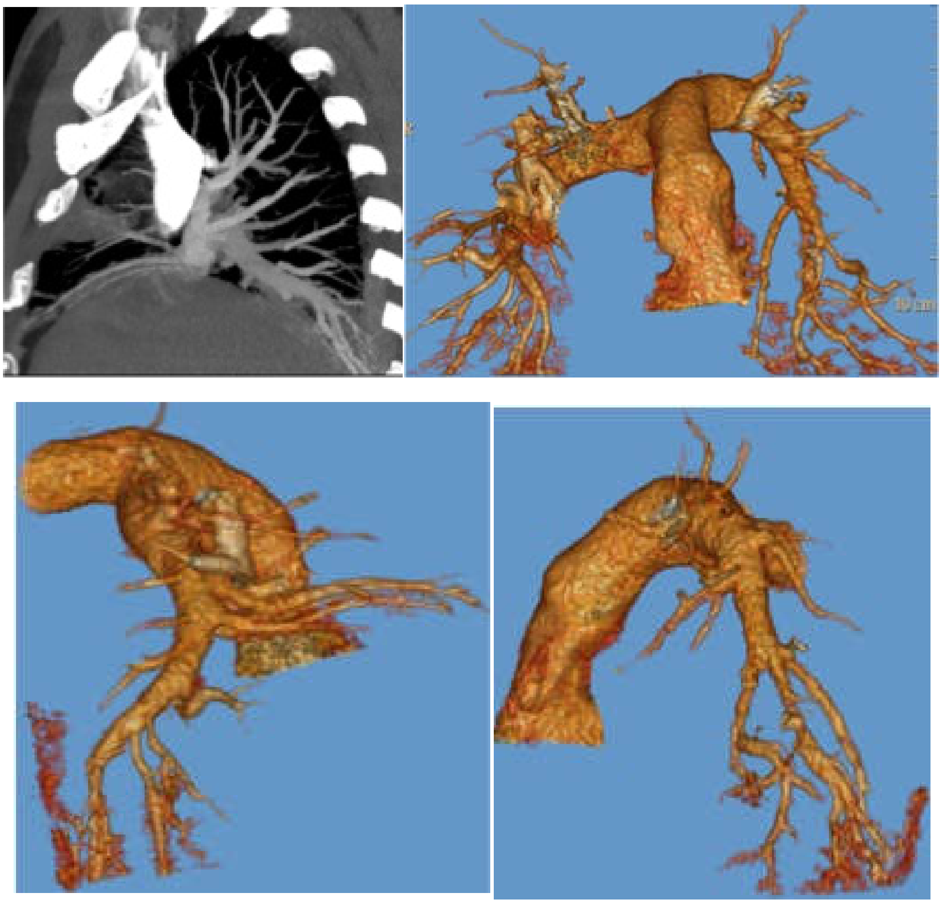
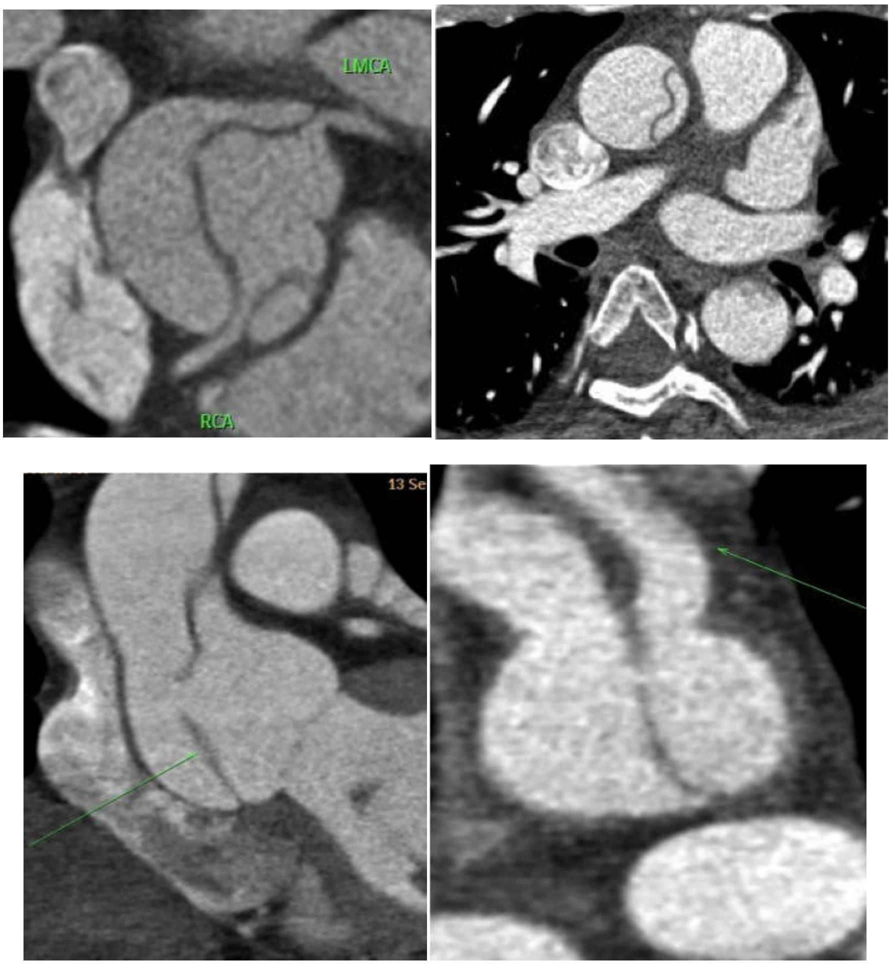


Fig.8. 47 years old female with respiratory distress. TRO angiogram shows normal coronary arteries and aorta. Axial mediastinal window (a,b,c,d,e,f), coronal (g,h,i) sagittal (j,k) and 3D volume rendered images (l,m,n), show peripheral subpleural wedge shaped areas of pulmonary consolidation with feeding pulmonary arteries at apex (Hampton's hump)



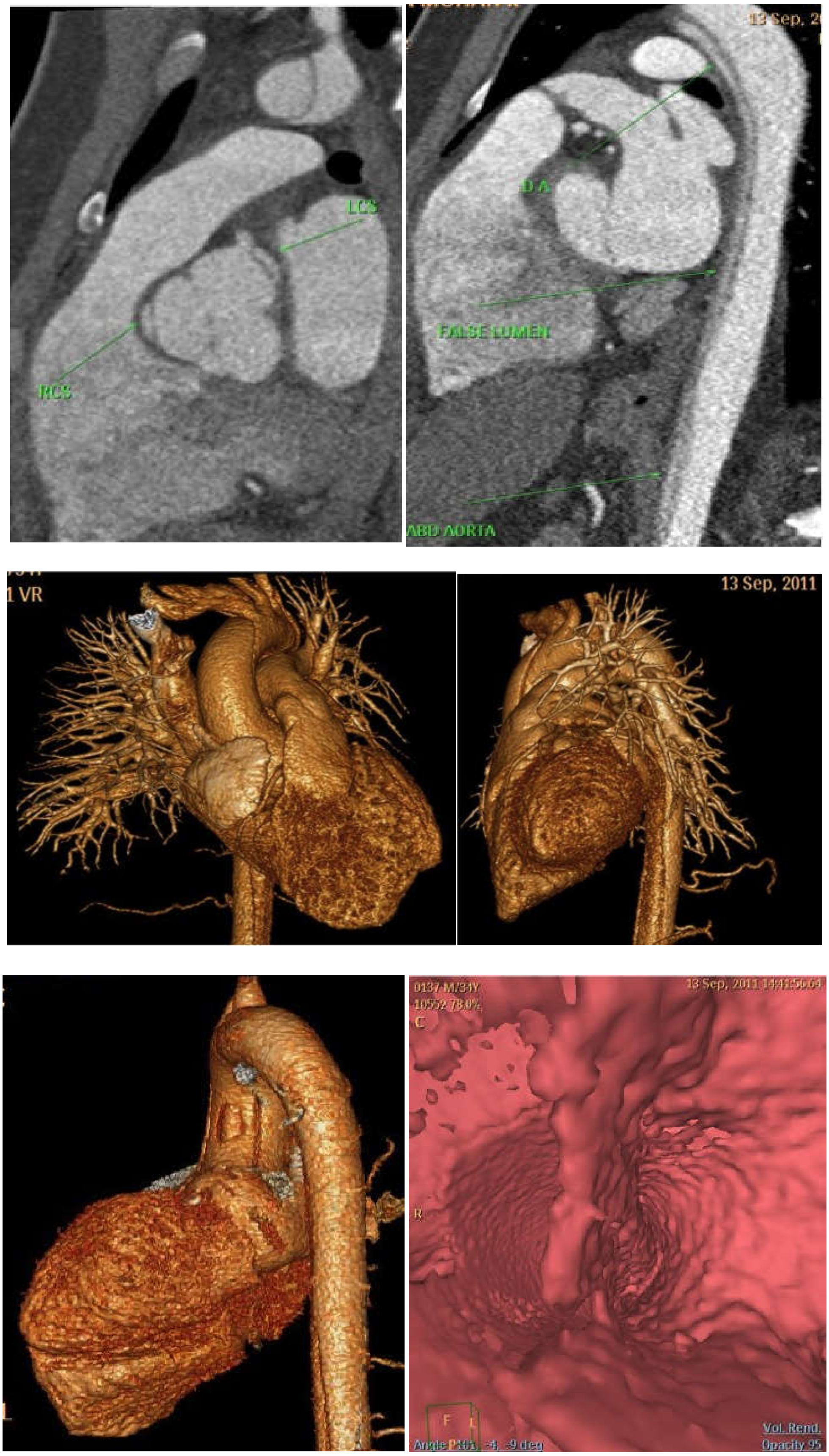


Fig.9. TRO CT angiogram in 34-year man with recent onset of vague chest discomfort. TRO CT MPR Axial image (a,b), Coronal (c,d), Sagittal (e,f), 3D images (g,h,i) and virtual aortic angioscopy (j) demonstrates Stanford type A aortic dissection involving ascending aorta, arch& descending aorta. Extending into the abdomen

Fig.10. 36 yrs old male TRO CT axial (a,b,c,d), coronal(e), sagittal (f) & 3D images (g,h) reveal, Ascending aorta aneurysm and Stanford type A dissection of root, ascending, arch and descending thoracic aorta

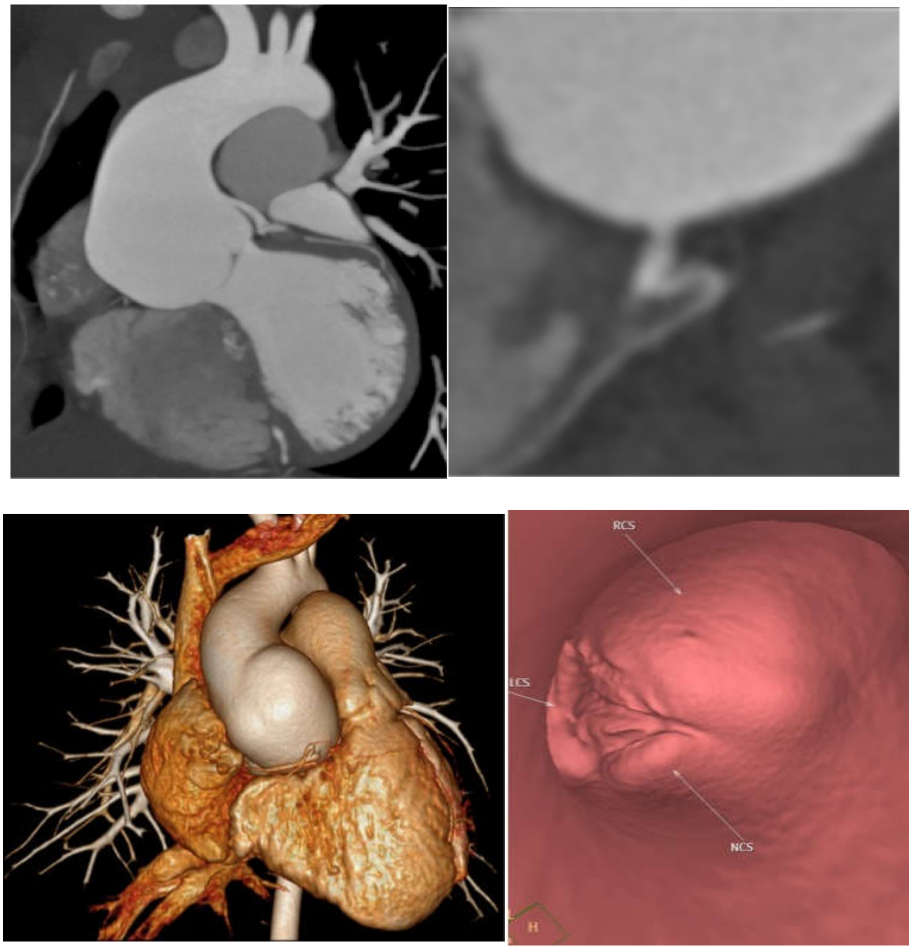
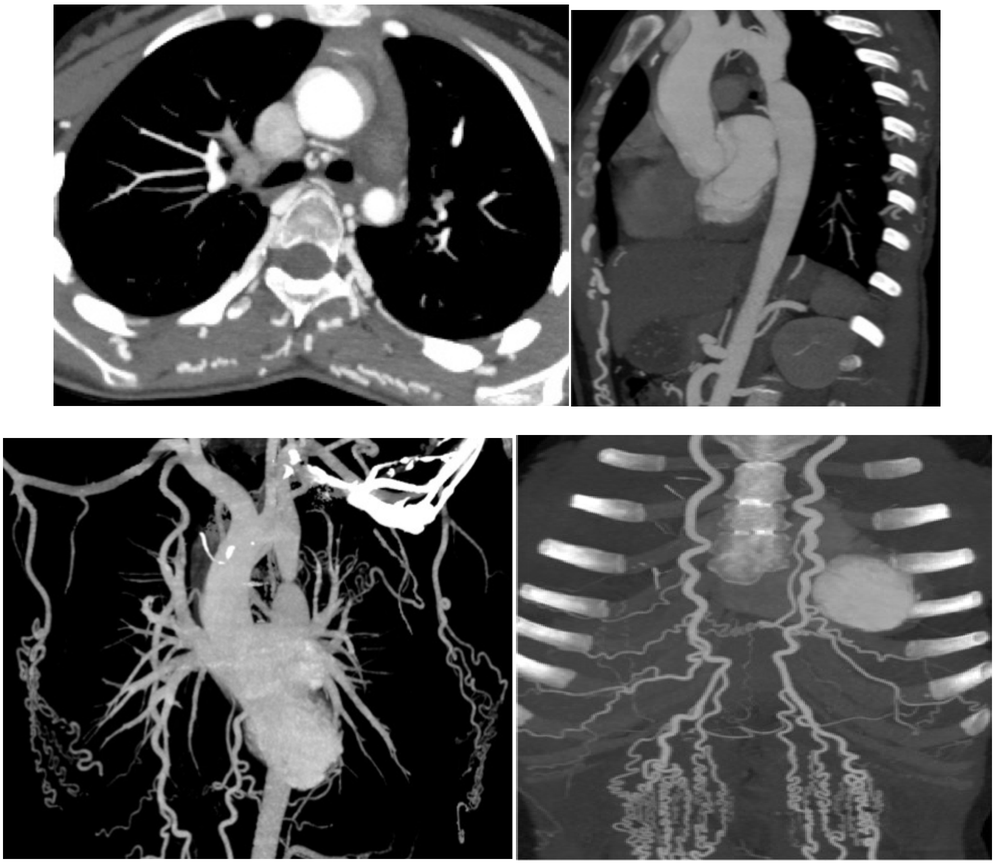


Fig.11. 53 yrs old male TRO CT MPR oblique coronal images (a,b), 3D (c) & virtual angioscopy images (d) shows aortic root aneurysm involving right coronary sinus



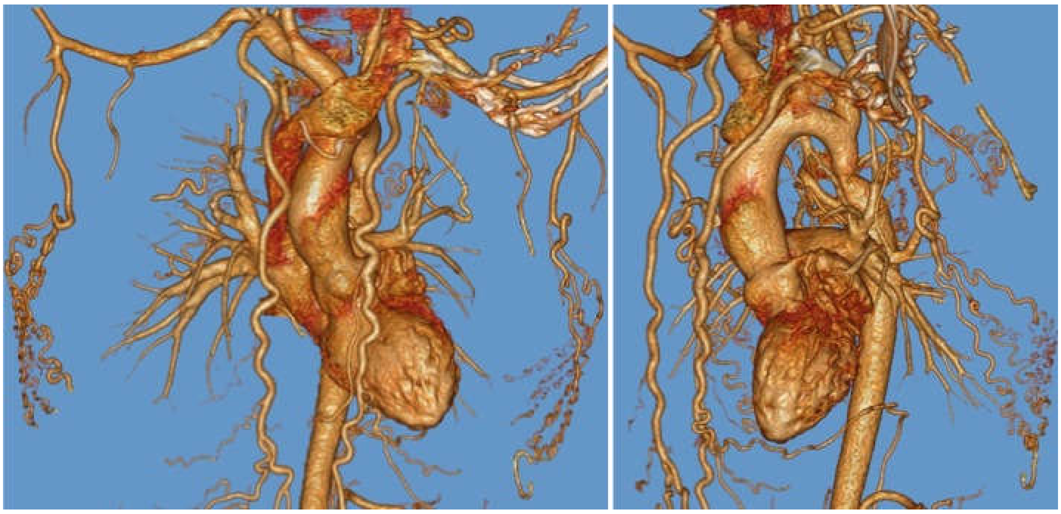


Fig.12. 25 yrs old male TRO CT Axial(a), sagittal MPR(b), MIP images (c,d) & 3D images (e,f) reveal proximal descending thoracic aortic stenosis. Multiple collateral arteries from distal aortic arch, subclavian arteries, intercoastal arteries and paravertebral arteries communicating with distal descending thoracic aorta

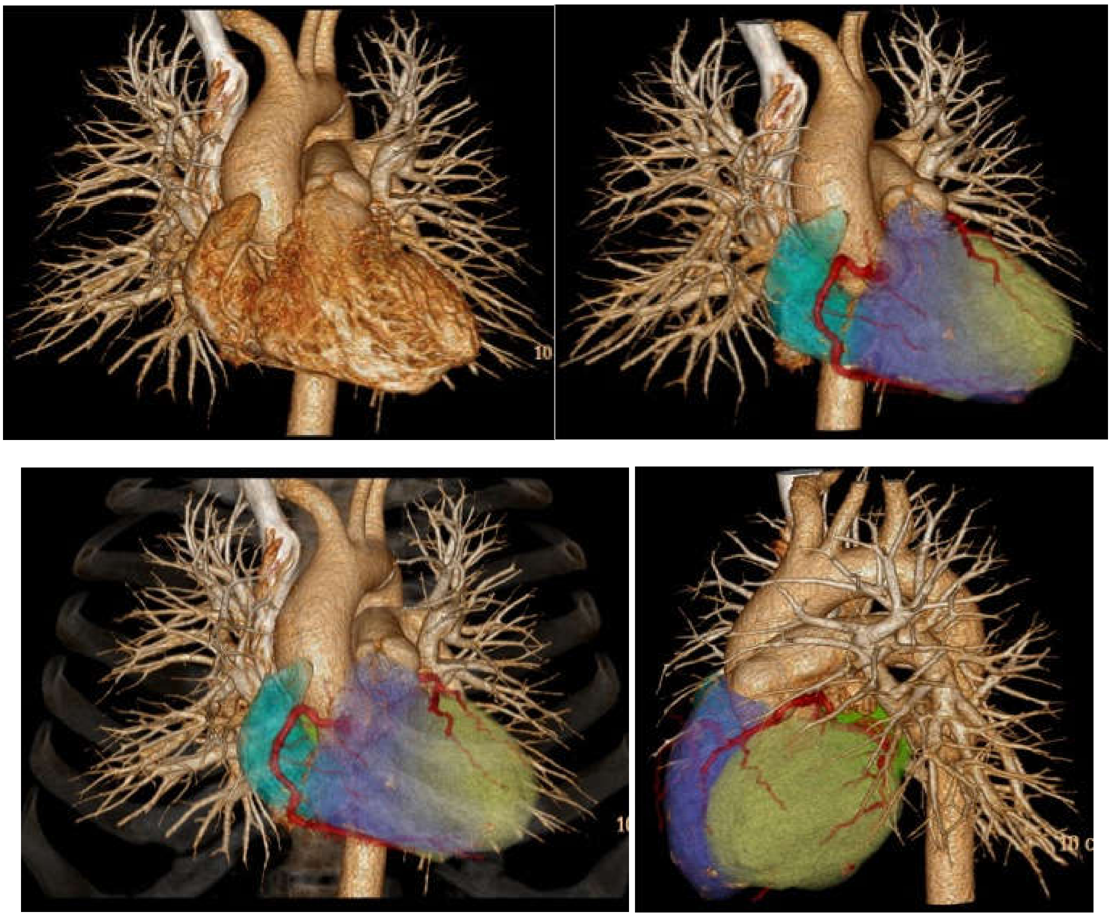


Fig.13. 3D volume rendered images (a,b,c,d) show normal coronary arteries, pulmonary arteries & aorta

DISCUSSION

Evaluating the causes of chest pain or a complex of symptoms that might be related to time-sensitive acute coronary syndrome (ACS), remains one of the most difficult challenges for ED physicians. Missed heart attacks account for an estimated 20%–39% of all malpractice judgments and represent an important medico-legal burden for ED physicians. A rapid, accurate, and cost effective approach for the diagnosis or exclusion of ACS is needed (Storrow, 2000). TRO CT had the following pooled diagnostic accuracy estimates for coronary artery disease: sensitivity of 94.3%, specificity of 97.4%, positive likelihood ratio of 17.71 and negative likelihood ratio of 0.08(12). TRO coronary CT angiography can provide similar image quality in coronary artery evaluation as compared with coronary CT angiography (Rahmani, 2009). In addition, it has the advantages of evaluating pulmonary arteries and aorta, for possible diagnosis of acute chest pain, because of a larger field of view (FOV) including the entire thorax. However, one disadvantage of this technique is that patients have to practice breath-hold for as long as possible to eliminate motion artifact.

The recently introduced 256-slice CT provides superior spatial and temporal resolutions with around 270-ms gantry rotation, and has a larger z-coverage of 80 mm, allowing scan time for the whole thorax to be as low as 10s for a 220 mm, z-axial coverage using RGH technique. This scanner thus is very suitable for TRO CTA examinations (Mok, 2010). The detection of non-coronary lesions that explain the presenting complaint, is a major advantage of the TRO CT examination over nuclear stress testing. Another important limitation of TRO CT angiography is the increase in radiation dose in comparison to the conventional coronary CT angiography, due to the larger longitudinal coverage of entire thorax. The actual doses for any individual will vary, depending on the scanning modes, tube current, heart rate, heart rate variability, z-coverage and patient body habitus. Our results showed that effective dose is 12-14 msv for weight less than 80 kilograms (kgs) and 16-18msv for weight more than 80 kgs, in TRO protocol with RGH mode, which is approximately 10% higher than that in conventional coronary CTA with RGH mode, which is similar in comparison to the study by Rahmani *et al.* (2009).

In order to reduce radiation dose, PGT protocol were attempted to exam for TRO CTA. Our results showed that effective dose is 5-7msv, for weight less than 80 kgs and 6-8 msv for weight more than 80 kgs, in TRO protocol with PGT mode. In this study, we obtained dose reduction on effective dose for PGT by a factor of 50%, as comparing to that for RGH protocol. We concluded that radiation dose could be efficiently reduced by applying the PGT protocols in TRO CTA examinations. The effective dose for RGH & PGT in this study, was lower than that in the 64-slice TRO CT studies (Rahmani *et al*., 2009 and Mok, 2010). Study done by Kevin *et al.* (2008), on 197 low-to-intermediate risk emergency department patients to assess the role of TRO provided a non-coronary diagnosis that explained the presenting complaint in 22 patients (about 11%). Clinically important non-coronary diagnoses that did not explain patient symptoms were identified in 27 additional patients (about 14%), suggested the presence of significant moderate-to-severe coronary disease in 22 patients (about 11%) and facilitated a safe, rapid discharge of the remaining low-to-moderate risk ED patients suspected of having ACS without further diagnostic testing. On the contrary, our study revealed a non-coronary diagnosis explaining patients symptoms were detected in 20% of cases. Clinically important non-coronary diagnoses that did not explain patient symptoms were identified in 6 additional patients (about 12%), suggested the presence of significant moderate-to-severe coronary disease in 20% patients and facilitated a safe, rapid discharge of the remaining low-to-moderate risk ED patients, suspected of having ACS without further diagnostic testing.

Though the percentage of coronary and non-coronary lesions responsible for chest pain was slightly higher in our study, but are of equal percentage, similar to the study by Kevin and Ethan, (2008) and the Clinically important non-coronary diagnoses that did not explain patient symptoms were identified, in nearly similar percentage of patients (about 12%). In our experience we consider that TRO is a good study to be done in selected cases, where there is strong clinical suspicion of pulmonary embolism, AAS and ACS and that TRO should be cautiously used in patients with chest pain from emergency room (ER), especially in young patients under 40 years of age, due to relatively high radiation dosage. A recent survey of radiology practices found that 33% used CT in the ED for the work-up of chest pain and that 18% were using a TRO protocol (Halpern Ethan *et al*., 2009).

Conclusion

MDCT Triple rule out (TRO) angiography can provide a cost-effective, safe, rapid and accurate evaluation of the coronary arteries, aorta, pulmonary arteries and adjacent intra-thoracic structures for the patient with acute chest pain. Careful consideration regarding, patient selection, patient preparation, injection and scanning techniques will result in high-quality TRO CT studies. TRO-CTA allow a rapid and safe discharge in the majority of patients presenting with acute chest pain and an intermediate risk for ACS, while at the same time identifies those with significant coronary artery stenosis and non-coronary conditions causing chest pain, like pulmonary embolism and Acute aortic syndrome. When compared with conventional management of acute chest pain in the ED, appropriate application of TRO CT can reduce (a) time for patient triage, (b) number of required diagnostic tests, (c) ED costs, and (d) radiation exposure to the patient (Soliman *et al*., 2015).

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