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Assessment of myocardial viability using Nuclear Medicine imaging in rare cardiac malposition of dextrocardia – understanding right approach.

running title: Myocardial viability in dextrocardia

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Abstract:

Imaging of dextrocardia in human needs understanding orientation of heart chambers and walls. There are many types of cardiac malpositions as dextrocardia (with or without situs inversus), mesocardia and levocardia. The myocardial perfusion Scintigraphy (MPS) of dextrocardia has been explained in case reports and imaging atlas; however the myocardial viability assessment using Nuclear Medicine imaging techniques is less documented in literature.

Methods: Two cases of dextrocardia with situs inversus and one case of mesocardia were included in the study to assess the myocardial viability using ^{99m}Tc Sestamibi rest perfusion scintigraphy and ^{18}Fluorine Fluorodeoxy glucose positron emission tomography (^{18}F FDG PET). Cardiac Single Photon Emission Computed Tomography (SPECT) images of dextrocardia with situs inversus were acquired using 'feet in supine' position with 180^0 arc from Left anterior oblique (LAO) to right posterior oblique (RPO); whereas right lateral to left lateral arc was used for mesocardia. The processing and reconstruction was done by entering the same patient position and repeated after entering 'feet first prone' position. The two reconstructed images were compared for orientation of walls and cardiac chambers.

Results: The first processing using 'feet first supine' position revealed interchanged septum and lateral wall in reconstructed images in dextrocardia with situs inversus. The same was corrected after changing patient position to 'prone' for rest perfusion and PET raw data during processing. The display of cardiac slices in various axes matched conventional nomenclature of septum and lateral wall leading to easy interpretation. However this change was not required in mesocardia; where location of chambers of heart was not interchanged.

Conclusion: The acquisition protocol of SPECT being semicircular orbit needs careful selection of arc by keeping the patient position as ‘feet first supine’ for various types of dextrocardia. The processing and reconstruction of data by changing patient position to prone was found to be most useful method to match the septal and lateral wall orientation for interpretation of images.

Key words: human dextrocardia, myocardial viability, rest perfusion

Introduction:

Dextrocardia is a rare cardiac malposition in which the heart is positioned in right hemi thorax and occurs in approximately 1 in 12,000 people. The term cardiac malposition implies location of the heart anywhere other than in its usual position in the left hemithorax, or it may describe location of the heart in the left hemithorax when other organs are in abnormal positions, as in situs inversus viscerum. Dextrocardia, levocardia, and mesocardia are general terms that indicate the cardiac position only and do not describe intracardiac anatomy. Dextrocardia denotes a right-sided heart, levocardia a left-sided heart, and mesocardia a midline heart (1).

Arcilla et al classified dextrocardia into 5 types. In Type I dextrocardia (mirror-image dextrocardia) the anatomic right atrium and right ventricle are situated to the left of and anterior to the corresponding systemic chambers. A mirror-image arrangement of the cardiac chambers is present since the frontal relationship of the chambers is reversed, yet, the anteroposterior arrangement is normal. In Type II dextrocardia (dextroversion complex) the relations of the cardiac chambers are normal; the right atrium and right ventricle are situated to the right of and posterior to the corresponding systemic chambers. In complete dextroversion the cardiac apex is situated anteriorly and to the right; in incomplete dextroversion or mesoversion, it is located in the substernal region and the longitudinal axis of the heart is parallel to the midsagittal axis of the chest. Type III dextrocardia (mixed dextrocardia) is characterized by inversion of the atria alone or of the ventricles alone. The arrangement of the cardiac chambers is therefore in part similar to that of Type I and of Type II dextrocardia. In Type IV dextrocardia (congenital dextroposition) the heart is in the midchest, but the arrangement of the chambers is normal and the cardiac apex is still directed to the left and anteriorly. Types I, II, III, and IV represent the intrinsic group of dextro-

cardia, since the cardiac heterotaxy is caused by a developmental anomaly of the primitive heart tube. In Type V dextrocardia (congenital extrinsic) the abnormal position of the heart is due to its displacement by congenital anomalies of the lungs, diaphragm, or chest cage. The rightward displacement may be in the frontal plane only (simple dextroposition) or may occur in both the frontal and horizontal planes (dextroposition with pivotal rotation) (2).

Patients with dextrocardia may also suffer from coronary artery disease similar to the general population and would also need similar investigation. Myocardial perfusion scintigraphy (MPS) and myocardial viability assessment using ^{18}F Fluorodeoxyglucose positron emission tomography (^{18}F FDG PET) are two non-invasive procedures to diagnose ischemia, evaluate significance of coronary artery lesions and myocardial viability respectively.

Since dextrocardia is a rare clinical condition, general experience regarding acquisition, processing and interpretation of cardiac Single emission computer tomography (SPECT) is limited with only few reports in literature regarding myocardial perfusion scintigraphy, whereas myocardial viability assessment is less documented. Due to the different orientation of the heart in the hemithorax in patients with dextrocardia, they would require modification of the usual acquisition protocols. However even if acquisition is performed based on anatomical differences in dextrocardia, it may cause some difficulties during the processing and analysis of data, with the currently available software of gamma cameras available. This makes the cardiac SPECT study in patients with dextrocardia even more challenging.

There are many case reports published that guide about positioning and processing of myocardial perfusion imaging in dextrocardia patients (3-9); however assessment of myocardial viability using ^{18}F FDG PET is less reported in literature.

^{18}F FDG PET myocardial viability study includes rest myocardial perfusion and ^{18}F FDG PET imaging; both required use of different acquisition methods. The purpose of this case series study was to assess various methods of reconstruction and processing to understand orientation of heart chambers and walls for interpretation in various types of dextrocardia.

Methods, Materials and case wise results:

This is a retrospective study of cases of dextrocardia referred to the Nuclear Medicine Department of Seth G S Medical College and KEM Hospital, Mumbai, India during period of Jan 2015 to Dec 2018. The study included various types of cases of dextrocardia referred to the department for assessment of myocardial viability. The cases that have undergone surgery or coronary intervention treatment were excluded from the data. This retrospective study was approved by the institutional ethics committee and patient consent was waived. There were three such cases included in the study series (Supplemental Table 1) and details of each case are as follows:

Case 1:

66 year hypertensive gentleman presented with retrosternal discomfort on exertion and excessive perspiration. He was diagnosed with non ST Segment Elevation Myocardial infarction (NSTEMI) (Figure1A) and Creatinine Kinase (CK-MB) was raised. Chest X ray and 2D Echocardiography revealed dextrocardia, concentric left ventricular hypertrophy and left ventricular ejection fraction (LVEF) of 60%.

Coronary angiography demonstrated 90% lesion in mid-section of Left Anterior Descending (LAD) and ostial total occlusion in Obtuse Marginal (OM_1). Left main, Rest of Left Circumflex

(LCx), and Right Coronary Artery (RCA) were normal. The patient was referred to Nuclear Medicine for evaluation of myocardial viability in LAD and OM1 territory.

Myocardial Viability study consisted of two parts as resting MPS followed by ^{18}F FDG cardiac PET imaging. Resting myocardial perfusion was performed 45 minutes after intravenous injection of 20mCi (740MBq) of ^{99m} Tc Sestamibi at rest. Image acquisition was done on dual head gamma camera (Infinia Hawkeye, Wipro GE, Milwaukee, USA); with low energy high resolution (LEHR) collimator, in L-mode, 'feet first supine' position from 45^0 left anterior oblique (LAO) to 135^0 right posterior oblique (RPO) in clockwise direction (10). On same day cardiac PET study was performed after intravenous injection of 185MBq (5mCi) ^{18}F-FDG at rest after ensuring a fasting blood sugar level of <140mg%. Image acquisition was performed 60 minutes after injection in supine position on PET/CT machine (Discovery 710, Wipro GE Milwaukee, USA). The scan was acquired in 3D static mode in one bed position for 10 minutes. The images were reconstructed using iterative reconstruction algorithm (11). The rest perfusion and ^{18}F FDG PET images were processed and reconstructed using Emori Cardiac Toolbox^{TM} software version 3.0.

The maximum intensity projection (MIP) image demonstrated dextrocardia with situs inversus (Figure 1B). Since this patient had mirror image dextrocardia; the position of the septum and lateral walls were interchanged. Also the right ventricle was on the left of the left ventricle. Thus reconstructeddisplay image of SPECT and PET done with the position of heart in the given acquisition parameters displayed interchanged septum and lateral walls on the slices more clearly noted in horizontal long axis (HLA) and short axis. (Figure 1C&D) A second reconstruction was done by selecting 'prone' position for rest perfusion and ^{18}F FDG PET data; correction of septal and lateral wall was noted (Figure 1E&F). The reconstructed images were displayed in short axis

(SA), HLA and vertical long axis (VLA) and studied for perfusion defects and ^{18}F FDG uptake in corresponding areas.

Result 1.1:

The reconstructed slices of the first processing revealed interchanged septal and lateral walls and the interpretation was difficult. So the second processing with selection of 'prone' positioning allowed correct reorientation of heart with correct positioning of septal and lateral wall in the slices. After comparing the rest perfusion and ^{18}F FDG PET matched slices; the study demonstrated evidence of absence of perfusion in mid and basal antero-septal and mid and basal infero-septal segments with presence of FDG uptake in the same segments; thus suggesting viable myocardium (mismatched perfusion and metabolism) corresponding to LAD territory. He underwent angioplasty with stenting of LAD territory and is now symptom free.

Case 2:

61 year type II Diabetic and hypertensive lady complained of breathlessness on exertion over 6months that worsened and complaining breathlessness even at rest (NYHA Grade IV) since 15 days. She did not complain of chest pain or past history of myocardial infarction. The Troponin T test was negative. The 2D Echo revealed dextrocardia with situs inversus and reduced LVEF of 30% with hypokinesia in anterior wall segments, apex, antero-septal and anterolateral segments. The coronary angiography done to assess coronary arteries showed LAD type III vessel with minor plaque followed by 90% occlusive lesion; LCx was patent and RCA was found to be dominant artery with minor plaque proximal and distal portion. This patient was referred for assessment of myocardial viability in LAD territory.

The acquisition was done with similar parameters mentioned in first case. The reconstruction was also done twice in the similar way as the first case to understand the differences in the re-constructed slices and positioning of walls of the myocardium. (Figure 2).

Result 1.2:

As mentioned in the results of first case; the second processing done by selecting prone position during data selection allowed correct positioning of myocardial septal and lateral wall in slices. The scan results showed absence of perfusion in apex, apical septum, mid and basal anterior wall, mid and basal anteroseptal segments. All the mentioned segments showed presence of ^{18}F FDG uptake suggesting viable myocardium (perfusion and metabolism mismatch) corresponding to LAD territory. She was subjected to coronary bypass graft surgery with grafting of LAD and RCA.

Case 3:

42 year old male presented with dyspnoea on exertion (NYHA grade II). He had risk factors of hyperlipidemia and type II diabetes mellites. He was on medical management for ischemic heart disease and later developed sudden onset chest pain and worsening of breathlessness. Electrocar-diogram showed q waves with Right Bundle Branch Block. The 2D Echocardiography showed mesocardia with dilated left atrium and left ventricular ejection fraction of 25% and hypokinesia in apex, septum and anterior wall segments. The viability study was advised to assess the myo-cardial involvement.

The resting perfusion images were also obtained in 'feet first supine' position from right lateral to left lateral 180^0 arc in anticlockwise direction and ^{18}F FDG PET images were acquired using standard acquisition parameters used in case earlier two case scenarios.

The reconstruction of raw data was done without changing position of patient in the dataset entered. The septum and lateral wall were positioned normally. (Figure 3)

Result 1.3:

This patient did not have mirror image dextrocardia; the orientation of cardiac chambers had not changed and septum and lateral walls were not interchanged in position, during processing of the raw data in the same position demonstrated normal positioning of septum and lateral wall. (Figure 3 C&D)

The rest perfusion slices showed absence of perfusion in apex, apical anterior, apical septal, apical inferior, apical lateral, basal anteroseptal and mid inferior segments. There is reduced perfusion in entire anterior wall and septum. The ^{18}F FDG PET images did not show uptake in corresponding myocardial segments where perfusion was reduced or absent. Thus there was absence of viable myocardium in infarcted segments (matched perfusion and metabolism).

Discussion:

According to the classification provided by Arcilla and Gasul (2); the first two cases mentioned in our series were of Type I (dextrocardia with situs inversus) and the third case was of type IV (mesocardia).

There have been many approaches followed in published literature for acquisition and processing of MPS. As the complete dextroversion of heart has anterior and inferior walls in normal orientation; but the septum and lateral walls are interchanged and right ventricle is positioned to left of left ventricle. Thus after processing and reconstruction of raw data display shows interchanged septal and lateral wall.

There are many case reports and imaging atlas that mention acquisition of MPS for dextrocardia in LAO to RPO arc and reporting in interchanged position of walls. However they have reported using conventional nomenclature keeping interchanged walls in mind (7,8,12,13).

Slart J A et added attenuation correction using computer tomography (CT). The CT based attenuation correction helped in two ways by correcting perfusion defects due to diaphragmatic attenuation and understanding orientation of heart chambers and walls (9).

Özdemir et al described two methods of performing the acquisition. The first MPS was performed according to clinical routine protocols. SPECT procedure was carried out by using a 180^0 counterclockwise circular orbit, beginning at 45^0 RAO projection and ending at 45^0 LPO projection in head out (Feet First Supine) position. The first raw images were reconstructed by using normal analysis parameters. The second processing was done using Feet First Prone position while doing the analysis so that the heart and spatial position of the patient with dextrocardia was positioned like a normal patient.

The second MPS acquisition was performed according to dextrocardia protocols by using a 180^0 counterclockwise circular orbit, beginning at 45^0 LAO projection and ending at 45^0 RPO projection in head in (Head First Supine) position. The second raw images were reconstructed by using dextrocardia analysis parameters of camera software (4).

Ayeni O A et al also acquired MPI of situs inversus totalis using feet in supine position and processed in two different ways. The second analysis of data was done using feet first prone position fed while entering the data. The lateral wall and septum were reconstructed in normal axis with this change (3).

Qutbi et al also suggested the change from ‘feet in’ during acquisition to ‘head in’ or ‘prone’ during processing to correct the orientation of lateral wall and septum (5,6).

Multiple methods can be used to acquire the study by placing the patient either supine or prone with either head first or feet first and by either selecting the appropriate protocol or choosing not to (3-9). However we feel that this adds to the complexity of acquisition, processing and interpreting the images and may lead to artefacts as found by other authors also (12,13).

As the American Society of Nuclear Cardiology (ASNC) imaging guidelines mention to keep the heart in the center of arc of rotation (10); acquisition from LAO to RPO with ‘feet first supine’ position in clockwise direction appears to be the simplest method of acquiring MPI images in a patient of dextrocardia with situs inversus. However right to left lateral arc was used in the third case of our case series with mesocardia; where the heart was in retrosternal position. Thus it should clarified to the technical staff attending patient. It is easier for attending technical staff to positionthe patient as usual (feet first supine for dual head gamma camera) and only the direction of acquisition needs to be changed. The acquisition protocol for ^{18}F FDG PET cardiac imaging acquires counts in 360^0; so no additional modifications are required.

The authors find changing the position of patient from ‘supine’ during acquisition to ‘prone’ during processing as the best way of reorienting heart walls to match the conventional nomenclature of display. The above change provides correction of orientation of walls in both SPECT (acquired in 180^0 arc) and PET data (acquired in 360^0 arc) making processing and interpretation easy. However in case of dextrocardia when merely the entire heart is in the middle of the chest (mesocardia), but the chambers do not change their orientation (the right ventricle is on the right of the left ventricle), the scan images are to be processed as usual.

The authors would like to mention that whichever method of patient positioning and acquisition is used, it is essential to know the exact details about the orientation of heart and its chambers, so that correct interpretation of images is possible.

Conclusion:

While imaging myocardial viability in the rare cardiac malposition of dextrocardia, the simpler approach is to acquire images using the same position that is used for patients with normal orientation of heart, (which is commonly feet first supine for dual head gamma camera) changing just the direction of arc during acquisition. However the processing of rest perfusion and ^{18}F FDG PET images met the conventional nomenclature of walls by selecting prone position. This allowed easy interpretation of perfusion defects and myocardial viability.

Disclosure: none

Conflict of interest: No potential conflicts of interest relevant to this article exists.

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however could not contribute to writing up, data analysis or reviewing of this manuscript.

References:

1. Maldjian PD, Saric M. Approach to dextrocardia in adults: review. *AJR Am J Roentgenol*. 2007;188(6 Suppl):S39-S38.

2. Arcillaa RA, Gasul BM. Congenital dextrocardia. Clinical, angiocardiographic, and autopsy studies on 50 patients. *J Pediatr*. 1961;58:251-262.

3. Ayeni OA, Malan N, Hammond EN, Vangu MD. Myocardial Perfusion SPECT Imaging in Dextrocardia with Situs Inversus: A Case Report. *Asia Ocean J Nucl Med Biol*. 2016;4(2):109-112.

4. Ozdemir S, Gazi E. Myocardial perfusion spect imaging in dextrocardia: a case report. *Mol Imaging Radionucl Ther*. 2013;22(2):70-72.

5. Qutbi M. SPECT myocardial perfusion imaging in patients with Dextrocardia. *J Nucl Cardiol*. 2019;26(4):1197-1204.

6. Qutbi M, Soltanshahi M, Ansari M, Hashemi H, Neshandar Asli I, Shafiei B. Quantitation in Dextrocardia on myocardial perfusion imaging: how to perform quantitative analysis using Cedars-Sinai software. *Nucl Med Rev Cent East Eur*. 2018;21(1):50-52.

7. Kashyap R, Abrar ML, Bhattacharya A, Rohit MK, Mittal BR. Myocardial perfusion scintigraphy in a case of dextrocardia: Doing it "right". *Indian J Nucl Med*. 2012;27(4):252-253.

8. Turgut B, Kitapci MT, Temiz NH, Unlü M, Erselcan T. Thallium-201 myocardial SPECT in a patient with mirror-image dextrocardia and left bundle branch block. *Ann Nucl Med*. 2003;17(6):503-506.

9. Slart RH, de Boer J, Jager PL, Piers DA. Added value of attenuation-corrected myocardial perfusion scintigraphy in a patient with dextrocardia. *Clin Nucl Med*. 2002;27(12):901-902.

10. Dorbala S, Ananthasubramaniam K, Armstrong IS, et al. Single Photon Emission Computed Tomography (SPECT) Myocardial Perfusion Imaging Guidelines: Instrumentation, Acquisition, Processing, and Interpretation. *J Nucl Cardiol*. 2018;25(5):1784-1846.

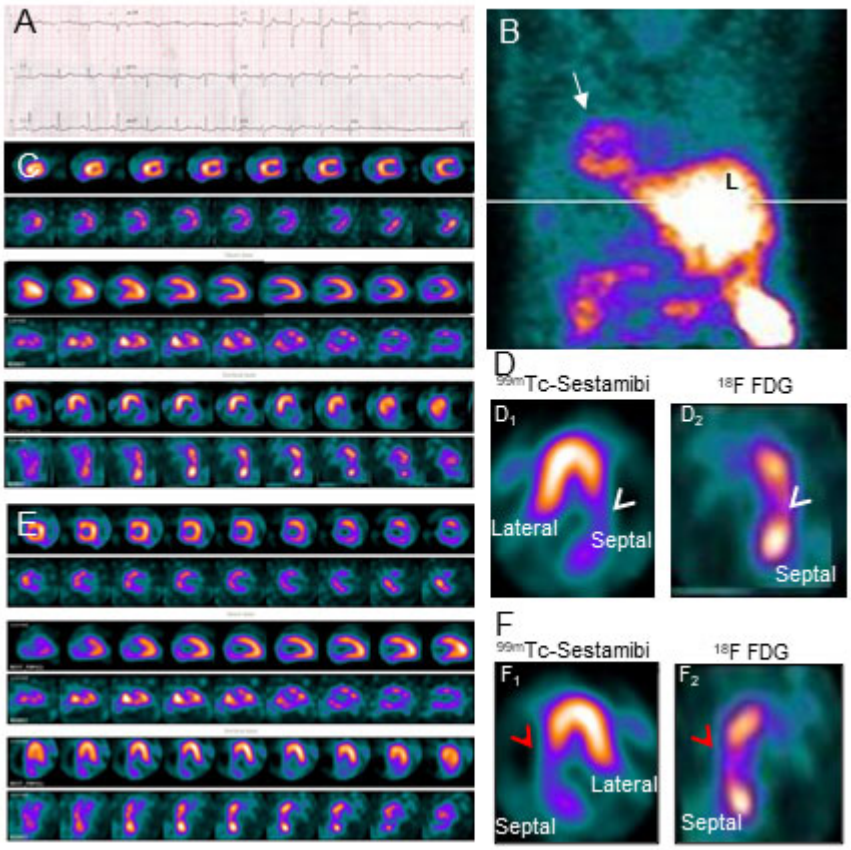
11. Dilsizian V, Bacharach SL, Beanlands RS, et al. ASNC imaging guidelines/SNMMI procedure standard for positron emission tomography (PET) nuclear cardiology procedures. *J Nucl Cardiol*. 2016;23(5):1187-1226.

12. Fathala A. Myocardial perfusion single photon computed tomography: An Atlas. *J Saudi Heart Assoc*. 2011;23(2):107-122.

13. Muzaffar R, Raslan O, Ahmed F, Goldfarb L, Sterkel B, Osman MM. Incidental Findings on Myocardial Perfusion SPECT Images. *J Nucl Med Technol*. 2017;45(3):175-180.

Figure legends:

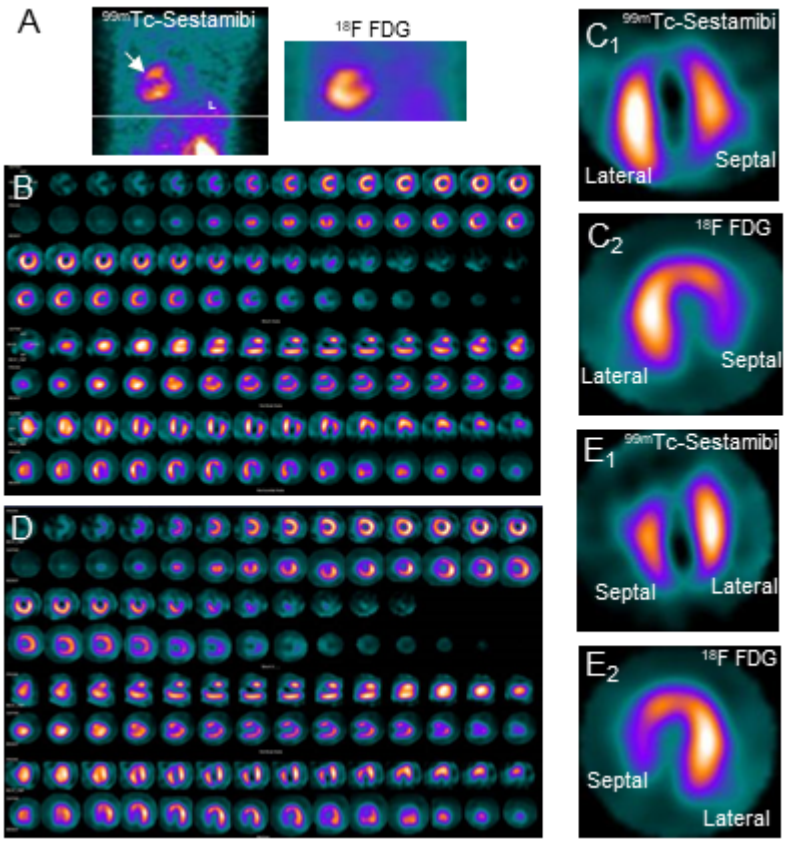
Figure 1:



A 66 yrs gentleman had dextrocardia with situs inversus; presented with NSTEMI and poor R wave progression in V3 to V6 chest leads on Electrocardiogram (A) that was obtained with chest leads arranged on right chest wall. Maximum intensity projection image (B) of rest perfusion SPECT showed heart in right chest (white arrow) and liver on the left side. (C) The processing of raw data in 'feet first supine' position showed interchanged lateral and septal walls in HLA axis (D- white arrowheads) in reconstructed display image in three axes. There was correction of orientation of septum and lateral wall in repeat processing (E) done after entering 'feet first prone' position instead of 'feet first supine' matched the conventional nomenclature of display image

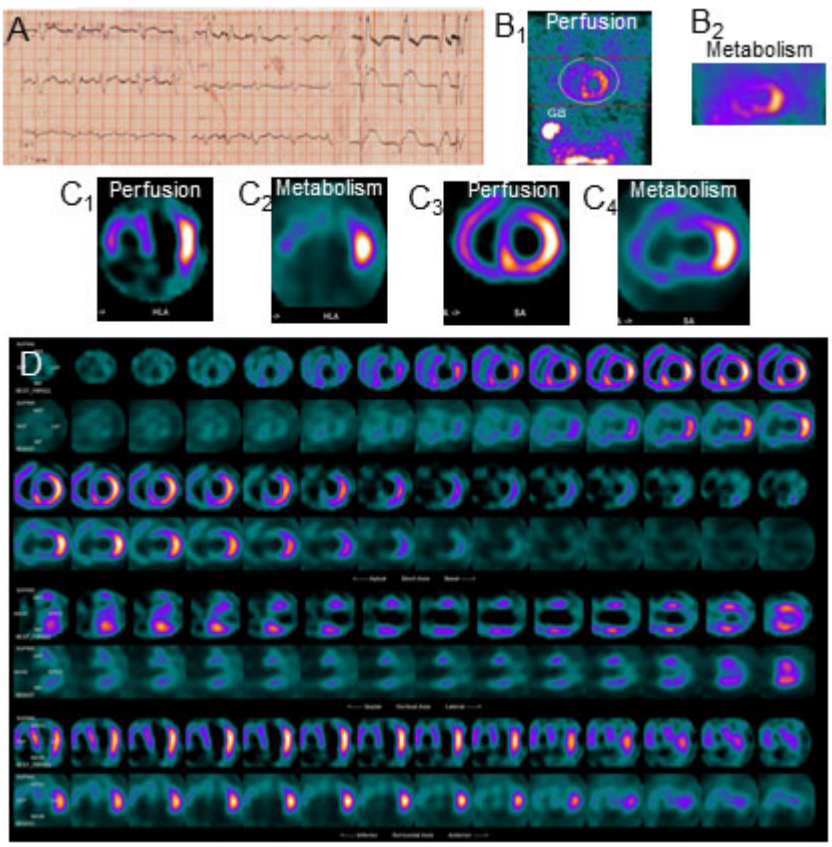
(F- red arrowheads). There was absence of perfusion in mid anteroseptal, basal antero-septal, mid inferoseptal and basal inferoseptal segments with presence of FDG uptake in the same segments; thus suggesting viable myocardium (mismatched perfusion and metabolism)

Figure 2:



A 61 yrs lady had dextrocardia with situs inversus. The heart in right chest and liver on the left side was noted in maximum intensity projection (A- white arrow). The processing of raw data in 'feet first supine' position showed interchanged lateral and septal walls in 3 axes display image (B) display image and in HLA axis ($C_{1\&2}$) during reconstruction. There was correction of orientation of septum and lateral wall in repeat processing (D) done after entering 'feet first prone' position instead of 'feet first supine' matching the conventional nomenclature of display image ($E_{1\&2}$). There was absence of perfusion in apex, apical septum, mid and basal anterior wall, mid and basal anteroseptal segments. All the mentioned segments showed presence of ^{18}F FDG uptake suggesting viable myocardium (perfusion and metabolism mismatch).

Figure 3:



A 42 yrs gentleman had mesocardia; presented with breathlessness. Electrocardiogram (A) showed ST segment elevation in V4&5, q waves in V1, V4-6 and RBBB. The heart in midline of chest and gall bladder and liver on the right side was noted in maximum intensity projection ($B_{1\&2}$). The processing of raw data in 'feet first supine' position showed normal position of lateral and septal walls in HLA axis ($C_{1\&2}$) and SA ($C_{3\&4}$) during reconstruction and in the display image (D). The rest perfusion slices showed absence of perfusion in apex, apical anterior, apical septal, apical inferior, apical lateral, basal anteroseptal and mid inferior segments. There is reduced perfusion in entire anterior wall and septum. The ^{18}F FDG PET images did not show uptake in corresponding myocardial segments suggesting absence of viable myocardium in infarcted segments (matched perfusion and metabolism).

Table 1: Patient details regarding dextrocardia, acquisition and processing

Variable	Case 1	Case 2	Case 3
Age/Sex	66/M	61/F	42/M
Presentation	NSTEMI*	Breathlessness	chest pain
Type of dextrocardia	Complete	Complete	Incomplete (mesocardia)
Situs inversus	yes	yes	no
Patient positioning during acquisition			
SPECT	Feet first supine	Feet first supine	Feet first supine
^{18}F FDG PET	Head first supine	Head first supine	Head first supine
Arc of imaging during acquisition			
SPECT	45^0 LAO to 135^0 RPO clockwise	45^0 LAO to 135^0 RPO clockwise	right lateral to left lateral 180^0
^{18}F FDG PET	360^0	360^0	360^0
Processing using Emori Cardiac Toolbox^{TM} software version 3.0			
Routine Processing			
SPECT	Feet first supine	Feet first supine	Feet first supine
^{18}F FDG PET	Head first supine	Head first supine	Head first supine
Orientation of cardiac walls	Interchanged septum and lateral	Interchanged septum and lateral	Not affected
Processing change	Required	Required	Not required

SPECT	Feet first prone	Feet first prone	-
^{18}F FDG PET	Head first prone	Head first prone	-
Orientation of cardiac walls	Corrected	Corrected	-

*NSTEMI- non ST elevation myocardial infarction