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(Case Report)

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# Glagov's phenomenon and limitations of coronary CT angiography in asymptomatic 65 year male with severely elevated Agatston score: Case report and literature review

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## Abstract

Noninvasive identification of patients with coronary artery disease (CAD) remains a clinical challenge despite the widespread use, and possible overuse, of imaging and provocative testing; more than 50% of patients currently referred to coronary angiography show normal or non-obstructive CAD.

Evaluation of coronary artery disease (CAD) using coronary computed tomography angiography (CTA) has seen a paradigm shift in the last decade. Evidence increasingly supports the clinical utility of CTA across various stages of CAD, from the detection of early subclinical disease to the assessment of acute chest pain. Additionally, CTA can be used to noninvasively quantify plaque burden and identify high-risk plaque, aiding in diagnosis, prognosis, and treatment.

Coronary artery calcium (CAC) is a highly specific feature of coronary atherosclerosis. CAC scoring has emerged as a widely available, consistent, and reproducible means of assessing risk for major cardiovascular outcomes. Glagov's phenomenon of arterial wall remodeling and numerous limitations in the technique of CTA may pose hinderances in the correct estimation of obstructive CAD in severely and very highly elevated Agatston score.

Recently, the 2-dimensional Speckle Tracking Echocardiography (STE) has gained substantial clinical interest. Left ventricular longitudinal strain, derived using two-dimensional speckle-tracking echocardiography, has emerged as a noninvasive marker of both global and regional LV dysfunction in patients at risk for developing CAD. Current evidence supports the use of global longitudinal strain (GLS) in the detection of moderate to severe obstructive CAD in symptomatic patients. GLS may complement existing diagnostic algorithms and act as an early adjunctive marker of cardiac ischemia.

Here, we are presenting a 65 year old asymptomatic male with a normal 2Dimensional echocardiography and negative treadmill stress test (TST) during a routine health check up. The patient requested for CTA which demonstrated severely elevated calcium score of 468 Agatston units accompanied by extensive triple vessel disease. These non-invasive tests were conducted at a local corporate hospital and their cardiology consultants suggested either a multivessel percutaneous coronary intervention (PCI) with stenting or triple vessel coronary artery bypass grafting (CABG). Hence, the patient visited our centre to obtain a definitive opinion regarding revascularization.

**Keywords:** Cardiac computed tomography; Coronary artery calcium; Coronary artery disease; Global longitudinal strain

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## 1. Introduction

Cardiovascular disease remains a global health concern with profound implications for patient well-being and healthcare systems [1]. Coronary artery disease (CAD) is a major contributor characterized by the development of atherosclerosis, narrowing the coronary arteries and restricting the blood flow to the heart muscle [2]. Even before overt symptoms, subtle changes in myocardial function may occur due to the presence of atherosclerosis [3].

CT coronary angiography (CTA) is an emerging tool for the non-invasive assessment of coronary artery disease. Several expert consensus documents endorse the use of CTA for excluding coronary artery disease (CAD) in symptomatic patients with reference to numerous studies which have reported high negative predictive values [4, 5]. However, predictive values heavily depend on disease prevalence within the study population, thus they cannot be applied outside the context of a defined patient group [6-8]. Accordingly, an assessment of pretest probability of coronary artery disease may help predicting the value of CT angiography for excluding or confirming the presence of CAD. In this regard, coronary arterial calcification detected by non-contrast CT correlates well with CAD prevalence and therefore may help to identify patients in whom ruling out or confirming CAD by CT angiography is of low yield. Furthermore, coronary arterial calcification may also alter the diagnostic performance of CT angiography [9-12].

The Agatston Calcium Score is a quantitative measure used in cardiac computed tomography (CCT) to assess the coronary artery calcium burden and can be employed to estimate a patient's risk of cardiovascular events and guide treatment [13, 14] (Figure 1, 2).

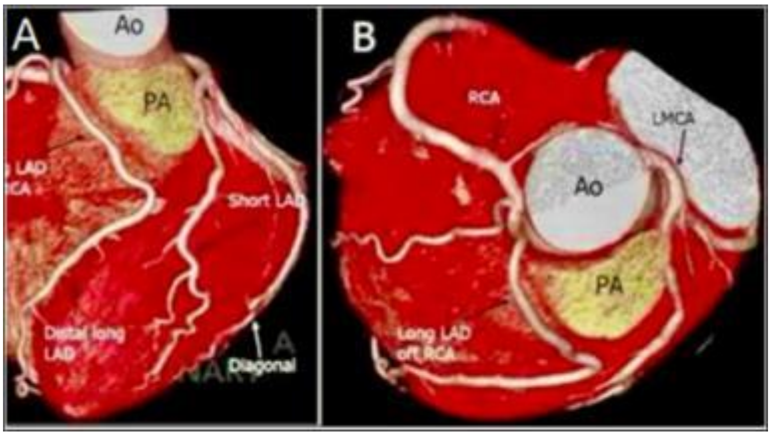
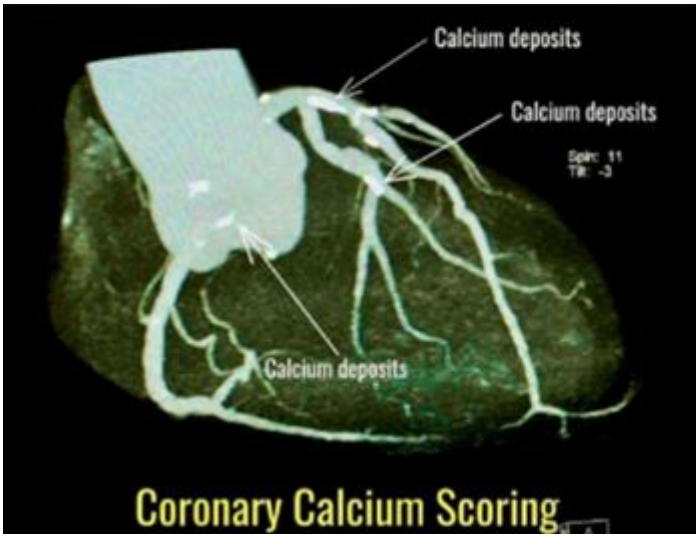
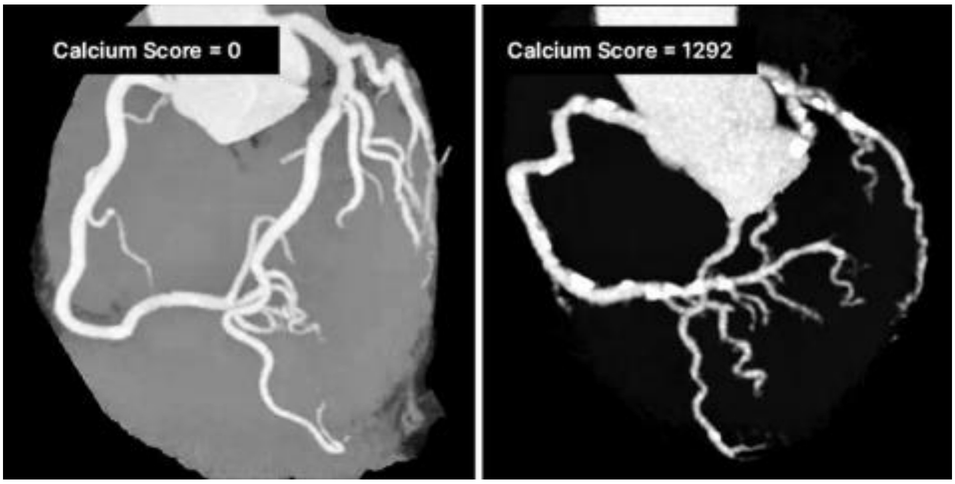



**Figure 1** Coronary CT angiography images in a normal patient




(A)




(B)

**Figure 2** (A) Coronary calcium scoring on coronary CT angiography; (B) Coronary CT angiography in patients with 0 and 1292 Agatston score

Coronary calcium substantially attenuates X-ray penetration leading to "blooming" artifacts with current CT image reconstruction that may obscure the coronary lumen. Because of the perceived limitation of CTA in patients with severe coronary calcification, many investigators have favored obtaining a coronary calcium score to inform the decision of proceeding or not with CTA [15] (Table 1).

**Table 1** Agatston score - absolute values

| **Absolute value (Agatston units)** | **Ranking** |
|---|---|
| 0 | Absent |
| > 0 < 10 | Minimal |
| ≥10 < 100 | Mild |
| ≥ 100 < 400 | Moderate |
| ≥ 400 < 1000 | Severe |
| ≥ 1000 | Extensive |
| Classification of coronary calcium absolute content evaluated by cardiac CT and quantified by Agatston units [16]. | |

However, the utilization of a coronary calcium score threshold for deciding to perform or not coronary CTA remains controversial [17, 18].

Recent technological advancements in echocardiography have enabled superior assessments of myocardial function through global longitudinal strain (GLS) analyses, offering a particulate understanding of subclinical myocardial dysfunction [19]. 4Dimensional XStrain speckle tracking echocardiography (4DXStrainSTE) is a feasible newer technology to evaluate global longitudinal strain [20]. Previous research has demonstrated compromised left ventricular function patients with significant CAD, as assessed through invasive coronary angiography [21]. However, whether the extent of incremental impairment GLS corresponds to increasing CAC score remains unknown.

The interplay between the two parameters, that is, CAC and GLS holds the potential to unravel subtleties in the interaction between atherosclerosis and myocardial performance (Figures 3, 4).

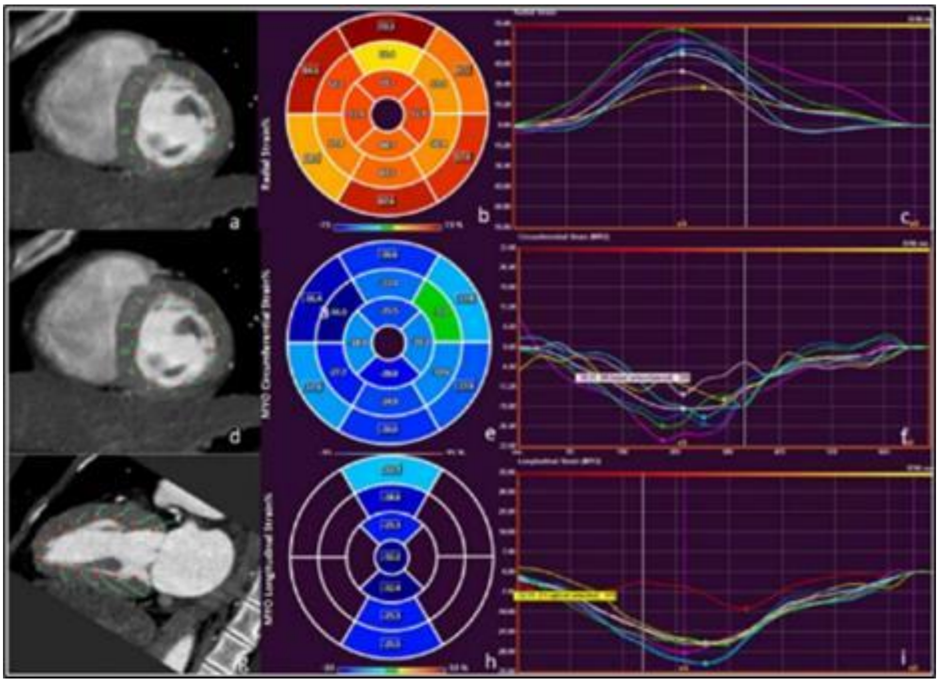


**Figure 3** Schematic diagram of myocardial strain on post-processing software. (a, d, g) Images of different planes of the cardiac; (b, e, h) images of radial strain, circumferential strain and longitudinal strain; (c, f, i) curves of myocardial strain and time in the cardiac cycle

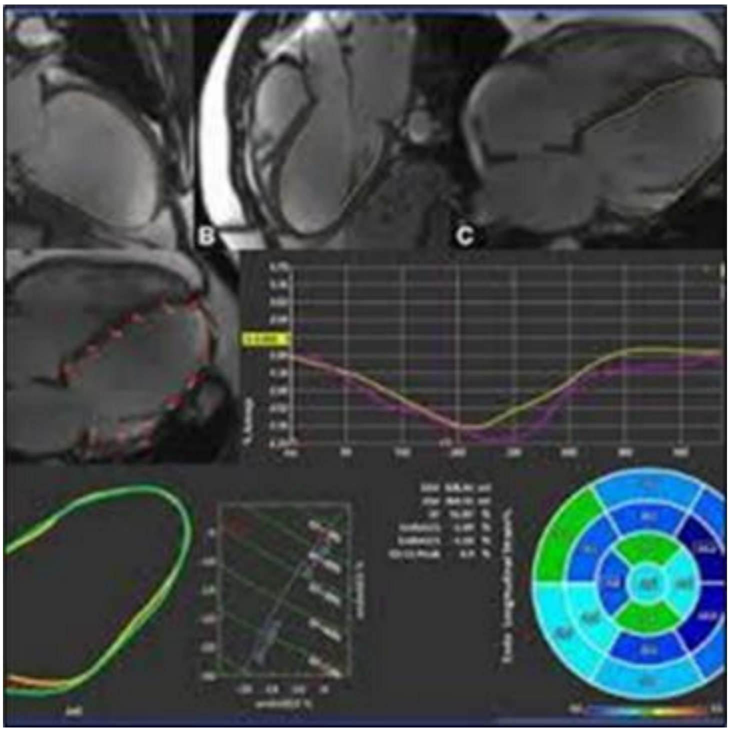


**Figure 4** Left ventricular global longitudinal strain assessment using feature tracking software. Endocardial borders were delineated on long-axis two- (A), three- (B), and four-chamber (C) SSFP cine images in end-systole and end-diastole. The final automatic calculation was performed by the software: the average GLS of all 17 cardiac segments in this case was -5.09 (D)

## 2. Case Report

A 65 year adult male presented to our cardiology OPD for a routine check up and discuss about coronary CT angiogram report which was conducted on himself on 18-5-22, after he had specifically requested the hospital to undertake this investigation. Due to the current surge in acute coronary syndrome in India, he wanted to know the status of his coronary arteries. Moreover, the patient informed that he was diagnosed hypertension few years back, which was now controlled on antihypertensives. He denied any history of other cardiovascular risk factors - smoking, tobacco, chewing, diabetes, dyslipidemia etc. He was currently asymptomatic and walking daily 30-45 minutes, 5 days/week.

On clinical examination, the patient was healthy looking and normally built (Figure 5). The patient's weight was 61 kg, height was 156 cm, pulse rate was 90/min, blood pressure was 124/60 mmHg, respiratory rate was 16/min and SPO2 was 99 % at room air. All the peripheral pulses were normally palpable without any radio-femoral delay. Cardiovascular and systemic examination were normal.

**Figure 5** Facial appearance of our index patient

Xray chest (PA) view (Figure 6) was typically normal and the cardiac size was within normal limits.

**Figure 6** X-ray chest (PA view). X ray chest (PA) showed normal cardiac size with normal pulmonary blood flow

The resting ECG (Figure 7) was also normal.

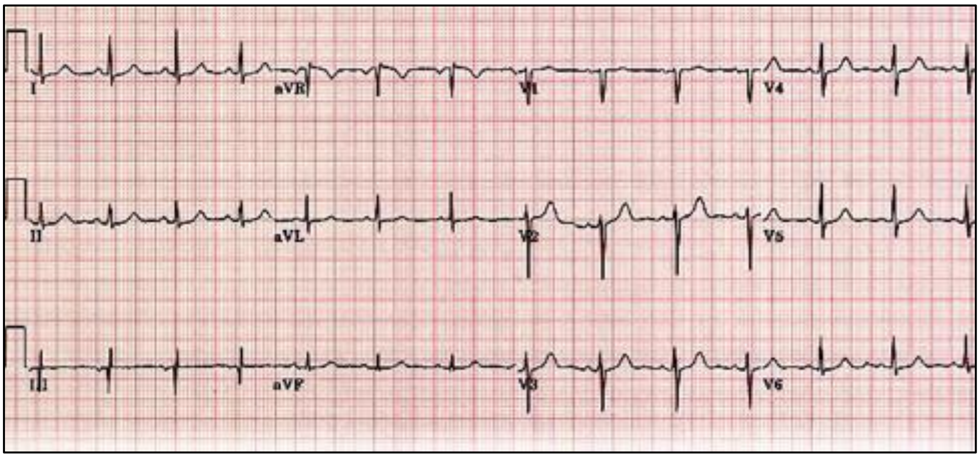



**Figure 7** Resting ECG. The resting ECG was normal. There is normal sinus rhythm with a ventricular rate of 80/min and normal QRS axis

Agatston score: 468 units

His CTA portrayed (Figure 8):

CTA exhibited triple vessel disease (TVD) with a calcium score of 468 Agatston units

Left main coronary artery

Circumferential soft plaque causing 20-30 % stenosis.

Left anterior descending coronary artery

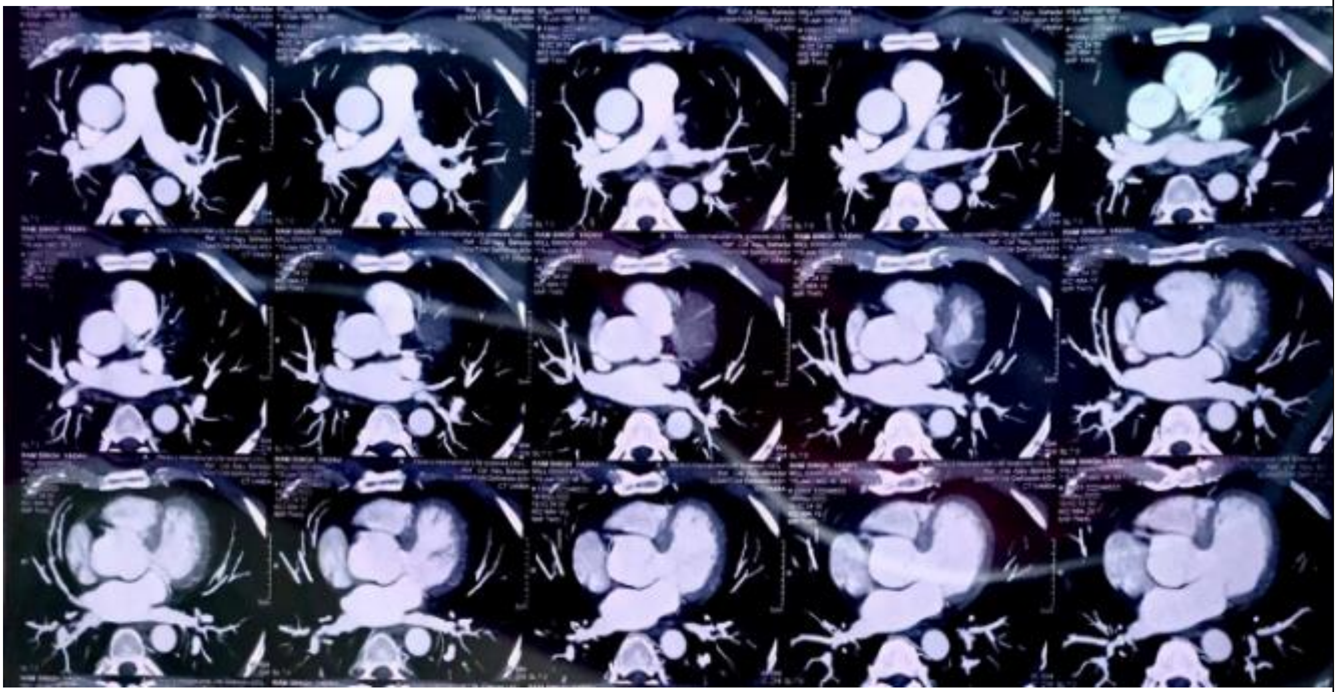
- Ostio-proximal LAD showed 80-90 % stenosis extending from LAD ostium to the origin of D2.
- Mid LAD revealed 70-80 % stenosis.
- D2 ostium and the proximal part identified 80-90% stenosis.

Left circumflex coronary artery

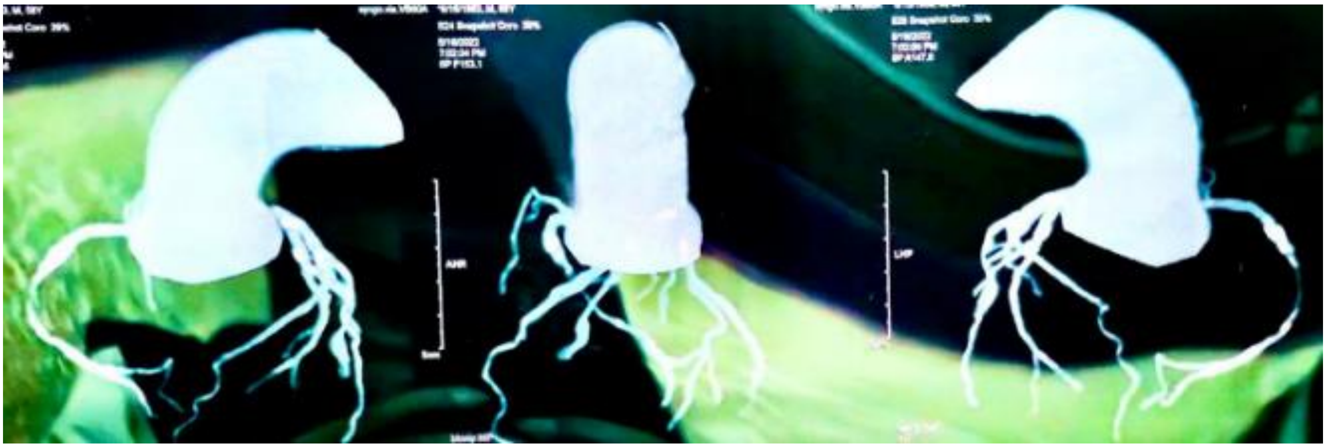
- Proximal LCX and OM2 ostium demonstrated 70-80 % and 80-90 % stenosis, respectively.

Right coronary artery

- 70-80% stenosis was present in the proximal RCA and > 90 % stenosis was detected in the mid RCA.



(A)



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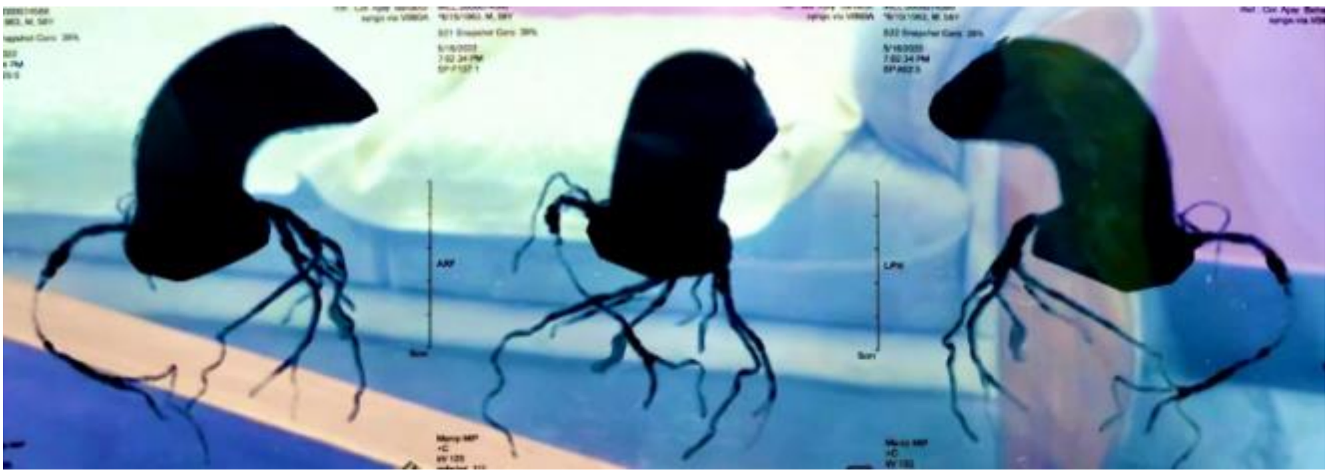


(C)

**Figure 8** 126 Slice CT coronary angiography of our patient. (A) CT of the heart; (B) and (C) Coronary CT angiogram-Agatston score was 468 units

### 2.1. Transthoracic Echocardiography

All echocardiography evaluations were performed by the author, using My Lab X7 4D XStrain echocardiography machine, Esaote, Italy. The images were acquired using an adult probe equipped with harmonic variable frequency electronic single crystal array transducer while the subject was lying in supine and left lateral decubitus positions.

Conventional M-mode, two-dimensional, pulse wave doppler (PWD) and continuous wave doppler (CWD) echocardiography was performed in the classical subcostal, parasternal long axis (LX), parasternal short axis (SX), 4-Chamber (4CH), 5-Chamber (5CH) and suprasternal views (Figures 9-13).

### 2.2. M-mode Echocardiography

M-mode echocardiography of left ventricle was performed and the estimated measurements are outlined (Table 2, Figure 9).

**Table 2** Calculations of M-mode echocardiography

| **Measurements** | **LV** |
|---|---|
| IVS d | 13.1 mm |
| LVID d | 45.8 mm |
| LVPW d | 5.5 mm |
| IVS s | 17.6 mm |
| LVID s | 28.6 mm |
| LVPW s | 13.4 mm |
| EF | 68 % |
| % LVFS | 38 % |
| LVEDV | 96.3 ml |
| LVESV | 31.1 ml |
| SV | 65.2 ml |
| LV Mass | 143 g |

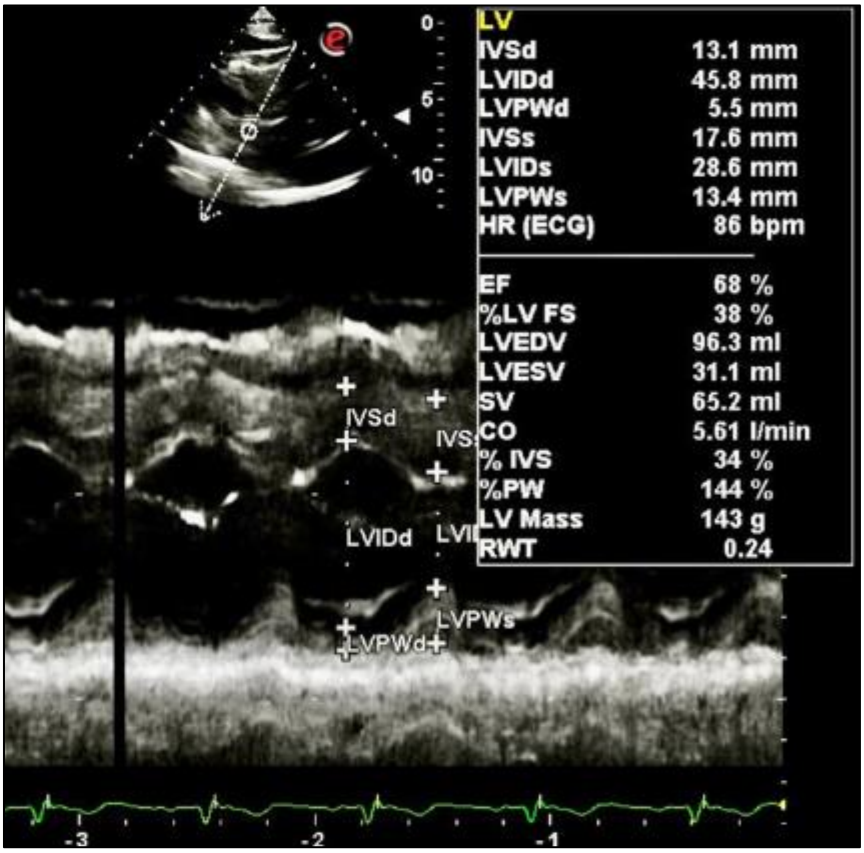



**Figure 9 M-**mode measurements of left ventricle

### 2.3. Summary of M-mode echocardiography

The LV was of normal size and the LVEF was 68 %. Ventricular septum found to be thickened (D = 13.1 mm). There was no apparent regional wall motion abnormality.

### 2.4. 2 Dimensional transthoracic echocardiography

2-Dimensional transthoracic echocardiography (2D TTE) was conducted in explicit detail, particularly to look for any regional wall motion abnormalities or any valvular regurgitation.

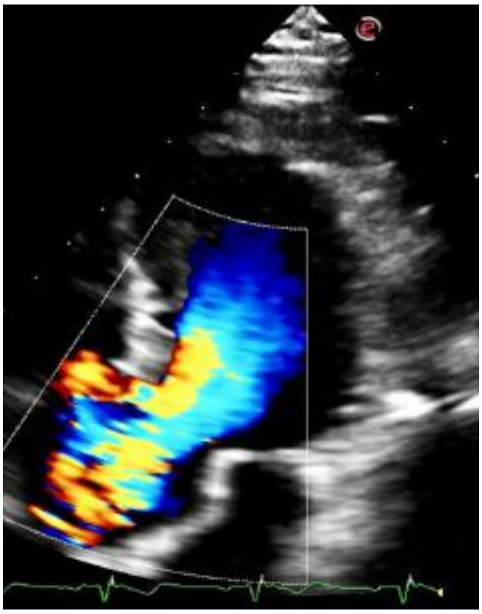
However, the 2D TTE was absolutely normal (Figures 10-13). There was normal LV dimensions and systolic functions (Table 3):

- Simpson's biplane method: LVEF was 69 % (Figure 11A)
- 4Dimensional volumetric analysis by 4D XStrain STE: LVEF was 62.84 % (Figure 11B)

We implemented with precision the GLS estimation by 4DXStrain STE (Table 4) and to our dismay we found normal values of GLS (-17.22%) (Figure 12D) and time to peak endocardial strain (Figure 13B) consistent with strain values of healthy adults.

(A)

(B)



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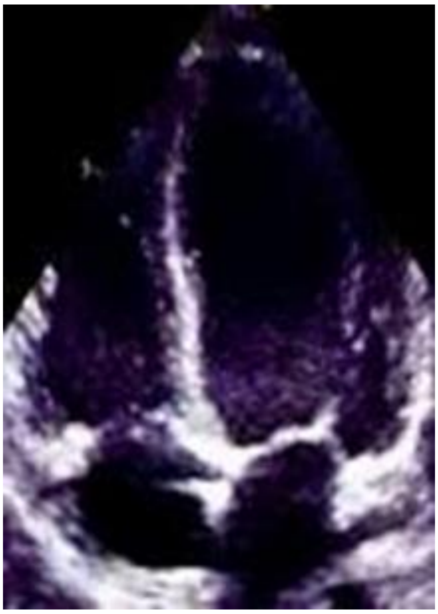
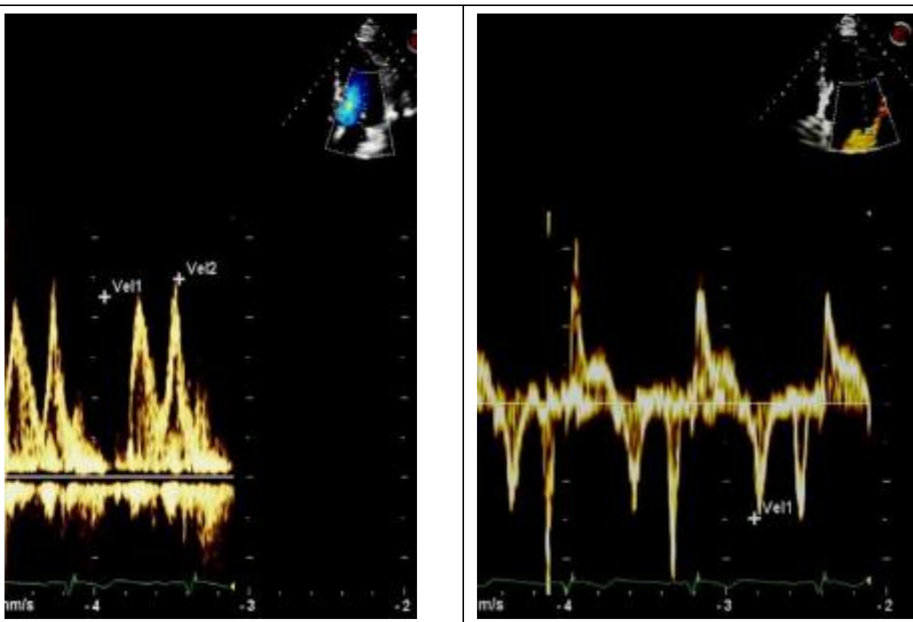
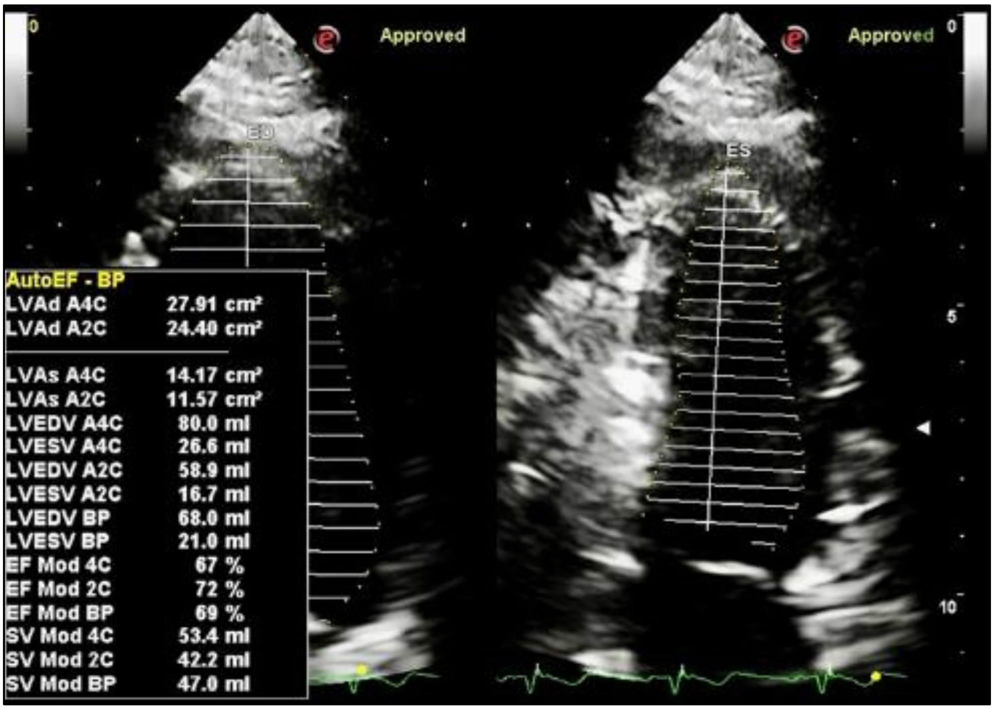


(D)

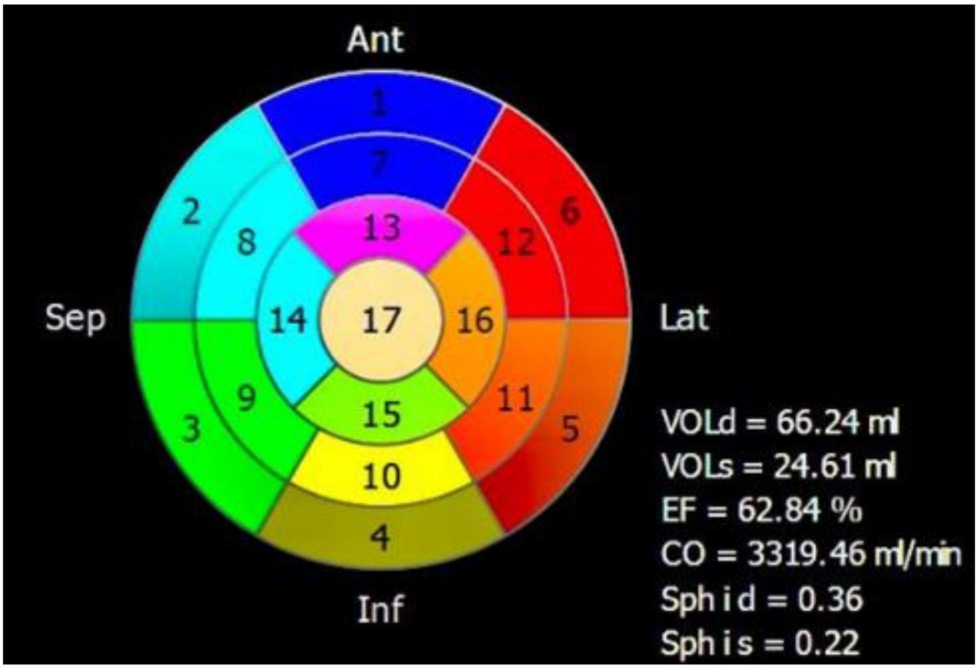



| (E) | (F) |
|---|---|

**Figure 10** 2Dimensional transthoracic echocardiography. (A) LX view; (B) SX view; (C) Apical 3CH view; (D) Apical 4CH view; (E) Pulse wave Doppler velocity signal across mitral valve; (F) Tissue Doppler Imaging at the lateral basal LV wall




(A)




(B)

**Figure 11** (A) Simpson's biplane method of calculation of LVEF; (B) 4Dimensional volumes and sphericity index in our patient. Sph i, Sphericity index; d, diastole; s, systole; EF, ejection fraction

**Table 3** Calculations of Auto EF - Simpson's biplane method

| **Auto EF - Biplane** | | | | | |
|---|---|---|---|---|---|
| LVAd A4C | 27.91 | $cm^2$ | LVAd index A4C | 17.4 | $cm^2/m^2$ |
| LVAs A4C | 14.17 | $cm^2$ | LVAd A2C | 24.40 | $cm^2$ |
| LVAd index A2C | 7.2 | $cm^2/m^2$ | LVAs A2C | 11.57 | $cm^2$ |
| LVEDV (MOD A4C) | 80.0 | ml | LVESV (MOD A4C) | 26.6 | ml |
| LVEDV (MOD A2C) | 58.9 | ml | LVESV (MOD A2C) | 16.7 | ml |
| LVEDV (MOD BP) | 68.0 | ml | LVESV (MOD BP) | 21.0 | ml |
| LVEDV index (MOD A4C) | 50.0 | $ml/m^2$ | LVEDV index (MOD BP) | 42.5 | $ml/m^2$ |
| EF (MOD A4C) | 67 | % | EF (MOD A2C) | 72 | % |
| EF (MOD BP) | 69 | % | SV (MOD A4C) | 53.4 | ml |
| SV (MOD A2C) | 42.2 | ml | SV (MOD BP) | 47.0 | ml |
| SV index (MOD A4C) | 33.4 | $ml/m^2$ | SV index (MOD A2C) | 26.4 | $ml/m^2$ |
| SI (MOD BP) | 29.4 | $ml/m^2$ | | | |

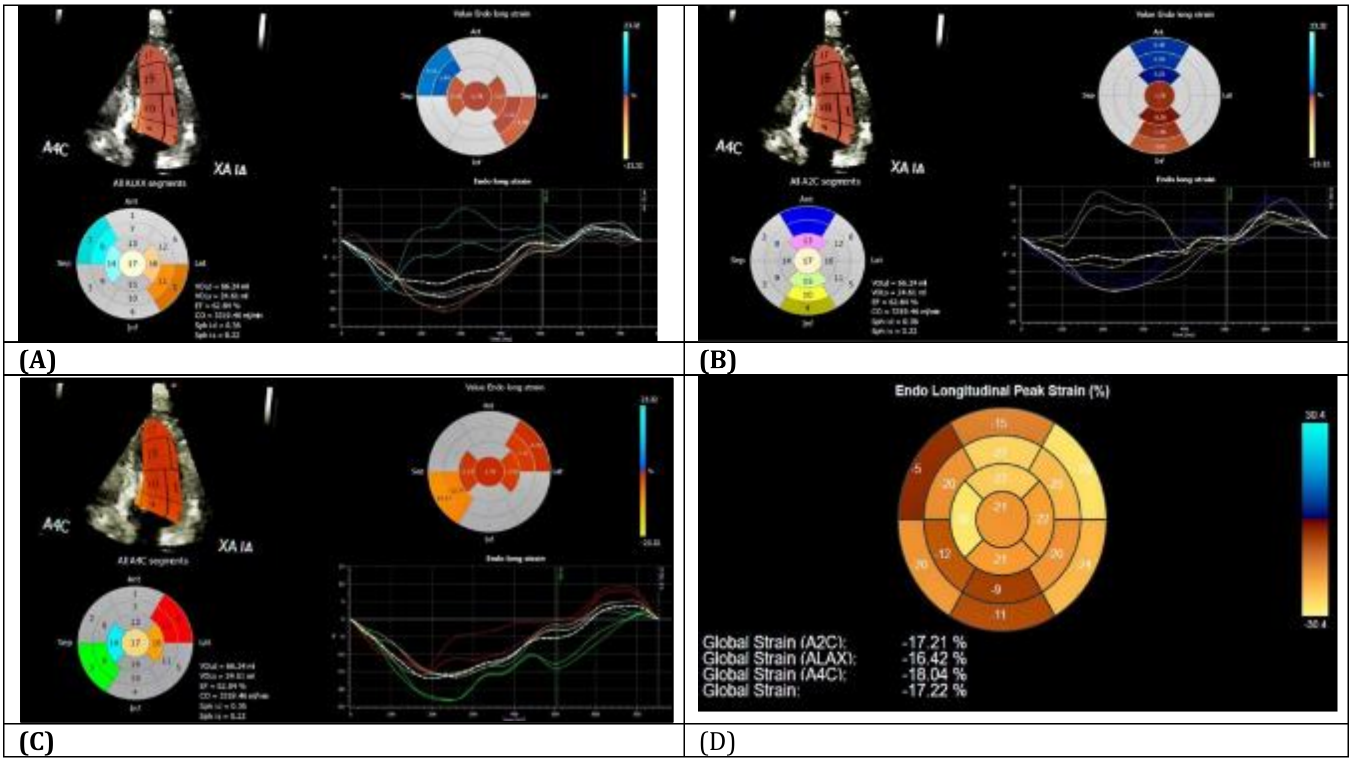



**Figure 12** Global longitudinal strain derived from 4DXStrain STE. (A) Apical LAX view; (B) Apical 2C view; (C) Apical 4C view; (D) Global Longitudinal strain

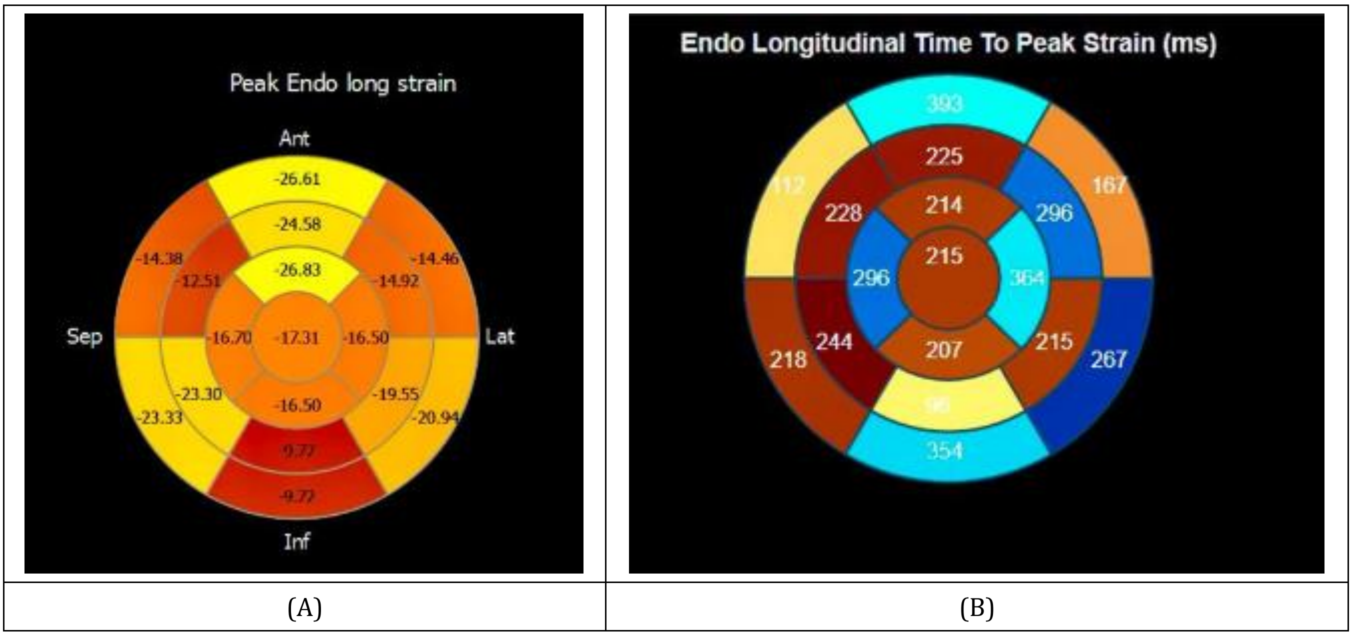



**Figure 13** (A) Peak endocardial strain; (B) Time to peak endocardial strain

**Table 4** Segmental strain values derived from 4D XStrain STE

| 17 segment model | Peak longitudinal strain | | Time to peak longitudinal strain | |
|---|---|---|---|---|
| Bas Ant | -15.35 | % | 522 | ms |
| BasAntSep | -5.07 | % | 86 | ms |
| Bas Sep | -19.84 | % | 112 | ms |
| Bas Inf | -10.51 | % | 354 | ms |
| Bas Post | -24.49 | % | 241 | ms |
| Bas lat | -29.34 | % | 254 | ms |
| Mid Ant | -27.27 | % | 212 | ms |
| MidAntSep | -19.50 | % | 293 | ms |
| Mid Sep | -12.32 | % | 86 | ms |
| Mid Inf | -9.11 | % | 225 | ms |
| Mid Post | -20.11 | % | 267 | ms |
| Mid Lat | -24.64 | % | 241 | ms |
| Apic Ant | -26.87 | % | 207 | ms |
| Apic Sep | -30.40 | % | 304 | ms |
| Apic Inf | -21.08 | % | 204 | ms |
| Apic lat | -22.08 | % | 430 | ms |
| Apex | -20.73 | % | 225 | ms |
| Global Strain (A2C) | -17.21 | % | | |
| Global Strain (A4C) | -18.04 | % | | |
| Global Strain (ALAX) | -16.42 | % | | |
| Global Strain | -17.22 | % | | |

## 3. Discussion

### 3.1. Global longitudinal strain in predicting coronary artery disease severity

Echocardiography is an important cardiac imaging tool in patients with suspected cardiac disease [22]. Speckle tracking echocardiography (STE) is a semi-automated software that allows fast, quantitative, and angle-independent assessment of myocardial deformation, with great feasibility and reproducibility particularly of the longitudinal one. Several clinical studies confirmed the feasibility of STE-derived longitudinal strain analysis as an adjunctive method for CAD detection [23].

Biering-Sørensen et al [24], Gaibazzi et al [25], and Billehaug et al [26] showed that GLS is significantly lower in patients with obstructive CAD (at least one stenosis > 50% or ≥ 70% luminal area reduction) when compared with patients with non-obstructive CAD. They reported that GLS values at rest have moderate diagnostic accuracy in predicting significant CAD while in the study of Abdelrazek et al [27] revealed high diagnostic accuracy; GLS value of < 16.5 predicted significant CAD with sensitivity 93 % and specificity 91 %. Biering-Sørensen et al [24] showed that GLS ⩽ − 18.4% can predict significant coronary stenosis (> 70%), with sensitivity 74% and specificity 58%. Similarly, Gaibazzi et al [25] showed that GLS ⩽ − 20.7 may predict significant coronary stenosis (> 50%), with sensitivity 81.6% and specificity 84.9%.

In the study of Billehaug et al [26], GLS measurements have moderate diagnostic accuracy in predicting significant CAD in patients presenting with chest pain. They showed that GLS cutoff value for prediction of CAD varied between − 17.4

and – 19.7% with sensitivity from 51 to 81% . In yet another study of Radwan and Hussein et al [28], the optimal cutoff value of GLS for prediction of significant CAD was -15.6%. The sensitivity, specificity and accuracy of GLS for detecting significant CAD were 93.1 %, 81.8 %, and 90 %, respectively. There was incremental significant decrease in GLS with increasing number of coronary vessels involved. The authors [28] strongly recommended that global longitudinal strain (GLS) assessed by 2D-STE at rest is a predictor of significant CAD. GLS has high sensitivity 93% for early detection of significant CAD. 2D-STE has the potential to improve the value of echocardiography in the detection of the CAD, identifying high-risk patients and to provide more information for clinical physician**.**

### 3.2. Agatston calcium score

Agatston score is a semi-automated tool to calculate the extent of coronary artery calcification detected by an unenhanced low-dose CT scan, which is routinely performed in patients undergoing cardiac CT. The score allows for early risk stratification as patients with a high Agatston score (>160) have an increased risk for a major adverse cardiac event (MACE) [29]. Although it does not allow for the assessment of soft non-calcified plaques, it has shown a good correlation with contrast-enhanced CT coronary angiography [30].

### 3.3. Grading of coronary artery disease (based on total calcium score) [30]

- No evidence of CAD: 0 calcium score
- Minimal: 1-10
- Mild: 11-100
- Moderate: 101- 400
- Severe: > 400

### 3.4. Stratification of coronary risk in relation to coronary calcium score

The coronary calcium score (CAC) score plays a relevant role in the stratification of cardiovascular risk. Several studies have shown that the CAC score is significantly associated with the occurrence of major cardiovascular events (all-cause mortality, cardiac mortality, and nonfatal myocardial infarction) in the medium- and long-term follow-up.

In an American College of Cardiology Foundation/American Heart Association (ACCF/AHA) consensus [31], data from six large studies that collectively included 27,622 asymptomatic patients were aggregated and the relative risk of major cardiovascular events was calculated for patients with a positive CAC score and for those with a CAC score of zero. The following results were obtained (Table 5):

**Table 5** Calcium Score, Interpretation and Future Risk of Major Adverse Cardiac Events (MACE) [31]

| Calcium score | Interpretation/Prognosis |
|---|---|
| 0 | No calcium, low risk of future MACE |
| 1–112 | Average risk; RR 1.9% (95% CI 1.3–2.8%) of future MACE |
| 100–400 | Moderate risk; RR 4.3% (95% CI 3.1%–6.1%) of future MACE |
| 400–999 | High risk; RR 7.2% (95% CI 4.2%–9.9%) of future MACE |
| >1000 | Very High risk; RR 10.8% (95% CI 4.2–27.7%) of future MACE |
| RR = relative risk; CI = confidence interval | |

In patients of stable angina pectoris [32], GLS decreased incrementally with increasing calcium score. Of the 592 patients, 147 (24%) were classified as having a high calcium score. Mean GLS was -19.4% ± 0.15 in patients with low calcium score and -17.4% ± 0.5 in patients with high calcium score, p<0.001. GLS remained a significant independent predictor of high calcium score after adjustment for clinical risk factors being age, gender, hypertension, hypercholesterolemia, smoking, diabetes, BMI, family history of cardiovascular disease and heart rate.

The CAC score adds value to the Framingham risk score and to other methods, providing a substantial increase in the accuracy of the risk stratification [33-35]. It is of note that the incidence of cardiovascular events reported for patients classified as being at intermediate risk by the Framingham risk score and with an elevated CAC score is equal to or greater than that reported for patients classified as being at high risk by the Framingham risk score and with a low CAC score [36].

### 3.5. Glagov's Phenomenon

An exceptionally high coronary calcium score, greater than 10,000 UA, superior to any other found in the literature reviewed, was reported in an asymptomatic, adult man with hypertension, obesity and dyslipidemia, without myocardial ischemia and no significative coronary stenosis, associated to **Glagov's phenomenon** in the left coronary artery [37]. The authors Castro-Villacorta et al [37] concluded (Figures 14-16):

In asymptomatic patients, a high CAC:

- Is not an equivalent to myocardial ischaemia
- Is not an indication of invasive coronary angiography
- A function, rest-stress evaluation by perfusion myocardial SPECT imaging or any other kind of non invasive test looking for ischemia would be an excellent approach to select the intensity of medical therapy and the type definitive management with high Agatston score.

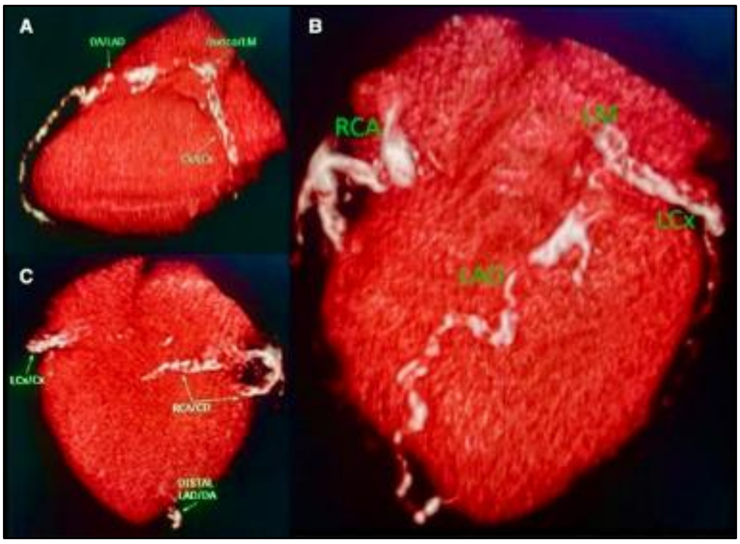



**Figure 14** Left lateral (A), anterior (B) and posterior (C) 3-D views in a standard non- contrasted cardiac tomography, normally used to obtain the Agatston score. Note the enormous amounts of calcified atheroma along the coronary tree makes possible this volume rendering reconstruction showing all the epicardial segment of the vessels.

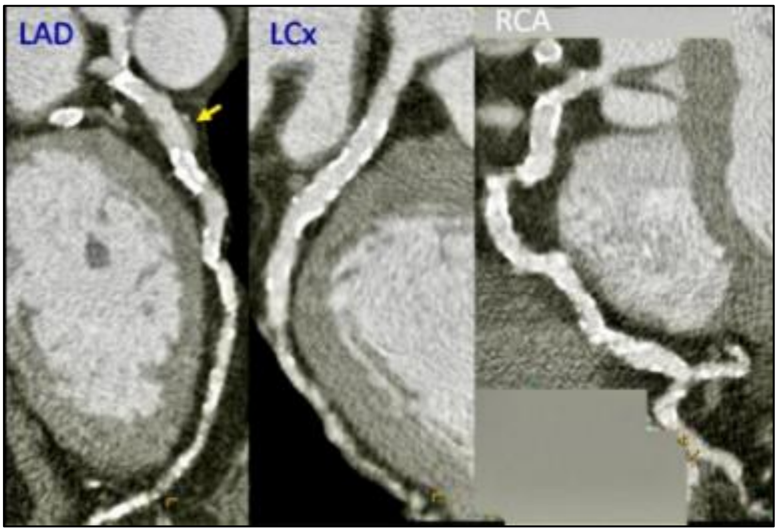



**Figure 15** Curved 2-D views of LAD, RC and LCx in cardiac CT with contrast, where severe and extensive calcified disease can be appreciated. The Glagov's phenomenon in proximal LAD is identified by yellow arrow

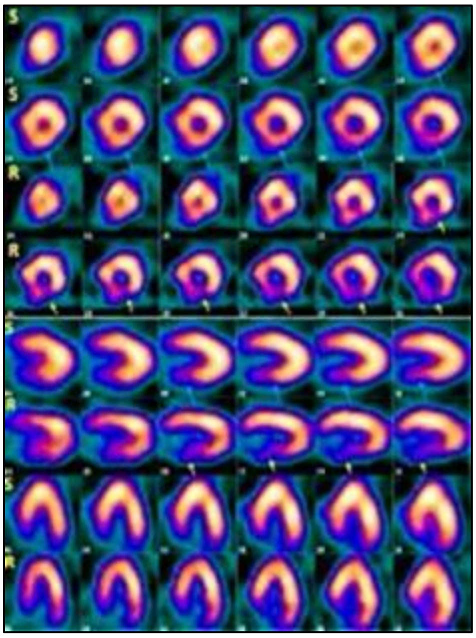


**Figure 16** Normal rest/exercise gated myocardial SPECT imaging with short, vertical,and horizontal long axis (SA, VLA, HLA) .The perfusion defect at rest in inferobasal region (orange arrows) showed in SA and VLA clearly improves during stress ( blue arrows)

In our index patient, we did perform GLS estimation by 4Dimensional XStrain STE and the average GLS was -17.22 % (apical 2 chamber view -17.21 %, apical 4 chamber view -18.04 % and in apical long axis view -16.42 %, respectively).

### 3.6. Glagov's phenomenon for vascular remodeling

An important concept for vascular remodeling, termed Glagov's phenomenon, is that arteries remodel to maintain constant flow despite increases in atherosclerotic lesion mass [38]. In 1987 Glagov reported the surprising finding that atherosclerotic arterial lumen narrowing is not simply the result of enlargement of atherosclerotic lesions. He and several colleagues found instead that arteries remodel over a large range of changes in wall mass, increasing the external diameter in a manner that allows preservation of the arterial flow. This ability of arteries to adapt is central to most arterial diseases (atherosclerotic coronary artery disease, peripheral vascular disease and systemic hypertension) [38] (Figures 17-19).

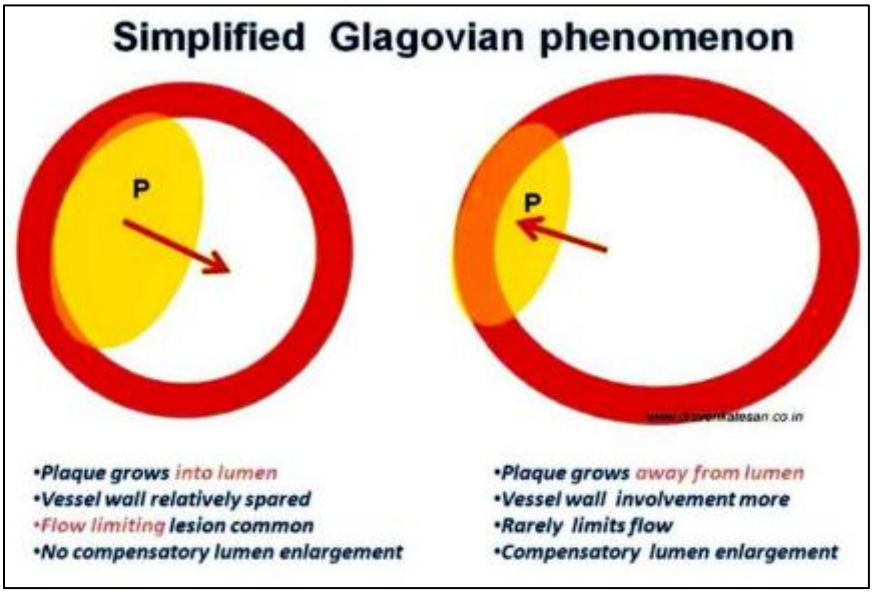



**Figure 17** Glagov phenomenon: Hypothesis of coronary artery remodeling

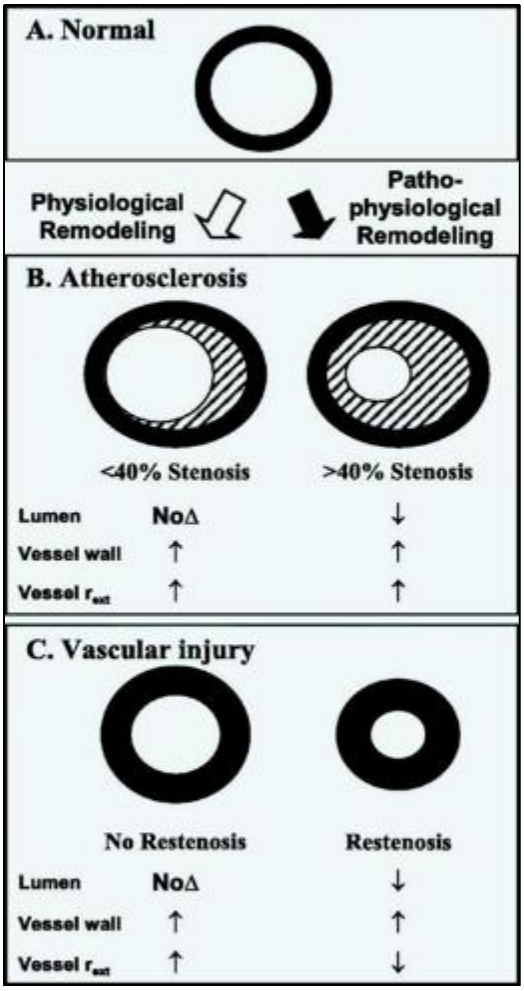



**Figure 18** Scheme for vascular remodeling. A, Normal artery. White arrow points to physiological remodeling, black arrow to pathophysiological remodeling. B, Progression of atherosclerosis causes lumen narrowing when stenosis exceeds 40%. C, Vascular injury after percutaneous transluminal angioplasty (PTCA) causes constrictive remodeling with decreased vessel size (restenosis), whereas probucol treatment promoted outward vessel remodeling and prevented lumen narrowing (No restenosis: -0.2 mm in probucol versus -1.2 mm in placebo, a 6-fold inhibition of restenosis)

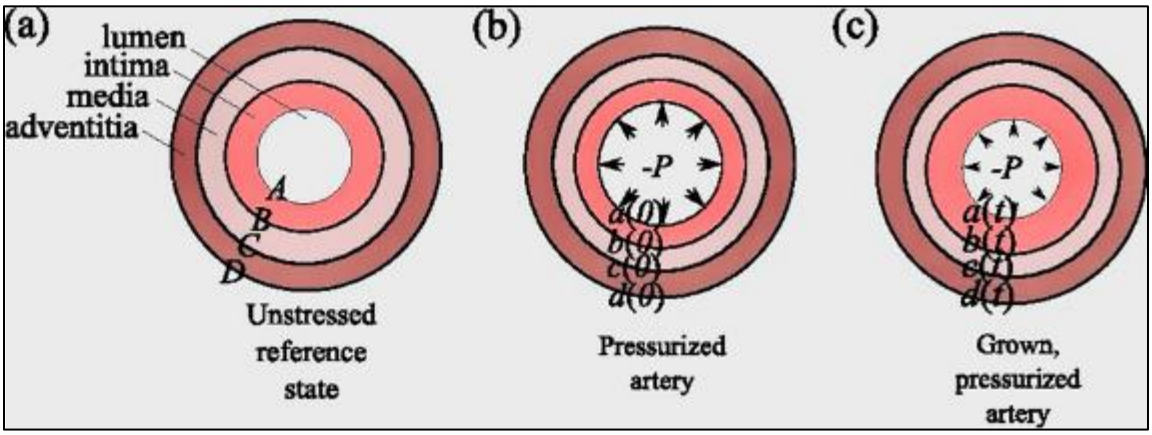



**Figure 19** Multi-layer axisymmetric model for arterial remodeling. Geometry in the (a) reference, unstressed configuration when t<0, (b) pressurized configuration at t = 0 and (c) grown, pressurized configuration for t > 0; t, time

### 3.7. Relation of calcium score with global longitudinal strain

In a study of Venkataraman et al [39] that evaluated the relation of CAC with GLS in 159 asymptomatic patients illustrated that there was no significant difference between in mean GLS (19.2 vs 19.5, P = .14), in those without or with coronary artery calcium. Similarly, ELSA - Brasil study [40] demonstrated no correlation between absolute CAC values and GLS. In the study, patients were classified according to the presence of coronary calcification (CAC >0 Agatston units) and in 3 CAC ordinal categories (0, 1 to 100, and >100 Agatston units). GLS did not differ among those with CAC >0 when adjusted for age and gender. These findings suggest that subclinical dysfunction evaluated by GLS is not a marked effect of underlying subclinical atherosclerosis.

High coronary calcium score-challenges in interpretation of coronary CT angiography

Technical pitfalls and limitations of coronary CT angiography

Coronary CT angiography- challenges and limitation

The high negative-predictive value of coronary CT angiography (CTA) makes it a suitable tool for excluding significant coronary artery disease [41]. Coronary CTA is technically complex and places a greater emphasis on scanning technologies than any other type of CT examination. Indeed, coronary arteries both have small calibre and varying degrees of motion during the cardiac cycle [41]. Image quality can be degraded by many patient- and technique-related factors. Image artefacts are causes for misinterpretation, making the diagnostic accuracy of coronary CTA to a great extent dependent on their recognition and operator-awareness [41]. Potential problems related to these artefacts include insufficient tissue contrast, limited spatial and temporal resolution and inadequate volume coverage.

The principal causes of artefacts on coronary CT angiography are outlined on Table 6.

**Table 6** Main coronary CT angiography artefacts

| Artefacts | Problem | Cause |
|---|---|---|
| Blurring | Motion | –HR > acquisition speed<br>–Respiration during acquisition<br>–Inappropriate cardiac cycle phase reconstruction |
| Stairstep or banding | –Motion<br>–Cardiac cycle phase misregistration | –HR variation (tachycardia/arrhythmia)<br>–ECG signal failure<br>–Respiration during acquisition |
| Streak | Dark bands through objects adjacent to high-attenuation structures (beam-hardening effect) | –Metallic implants, surgical clips and coronary stents<br>–Vessel filled with high iodine concentration |
| Blooming | High-attenuation objects appear larger than they are | –Coronary calcifications<br>–Metallic implants, clips and coronary stents |
| Windmill | Highly attenuating structures are surrounded by low-attenuating rims, and low attenuating structures appear larger and have a “fan-like” appearance | –Moving structures during acquisition<br>–HR > temporal resolution > spiral acquisition pitch |
| Low attenuating | Air bubbles | –Air within the contrast material bolus<br>–Surgery |
| ECG, electrocardiogram; HR, heart rate. | | |

The main challenge in CTA is that there is a strong demand for high temporal resolution, which translates into the time required to acquire cardiac images in a very short period. The temporal resolution is significantly inferior to that of invasive coronary angiography. Heart rate control is necessary to produce the best images. Use of beta blockers are necessary in studies performed with these coronary CTA [41].

Coronary CT angiography is unable to determine which plaques are "vulnerable" or unstable from those that are stable. Therefore, differentiation of lipid-rich content from fibrous content with multislice CT remains challenging owing to considerable overlap in the attenuation values of lipid and fibrous tissue. Atherosclerotic plaque and natural progression of the disease and may have an important clinical predictive value. It is widely accepted that plaque composition rather than the degree of luminal narrowing may be predictive of the patient's risk for cardiac events [41].

With increasing application of CTA in the diagnosis of CAD, radiation dose associated with coronary CT angiography has raised serious concerns in the literature, as the risk of developing malignancy is not negligible. The reduction of radiation dose in CTA remains a continuing challenge, and it is expected that more research will be conducted in cardiac imaging with the use of multislice CT [42].

A high Agatston score is known to affect the diagnostic information from CTA due to partial volume effects and beam hardening [43].

CTA disadvantages include reduced image quality in patients with morbid obesity, dense calcifications, multiple or small-diameter stents, elevated heart rates, or arrhythmia; the need for intravenous contrast, which may be nephrotoxic; and the risk of excess downstream testing. CTA remains limited in spatial and temporal resolution. Other tests are preferable for patients with multiple stents, extensive calcifications, or lesions of uncertain hemodynamic significance [44].

### 3.8. 2-Dimensional speckle tracking echocardiography-utility in CAD

GLS measured by 2-D STE at rest has been recognized as the most sensitive and reproducible indicator of ischemia used in the detection of the significant CAD where regional wall motion abnormality is often not detected by resting echocardiography [45, 46]. 2DSTE can be used as a non-invasive screening test in predicting presence, extent and severity of significant CAD patients with suspected stable angina pectoris [47]. On one hand multiple authors have reported [24-27] that GLS values at rest have significant diagnostic accuracy in predicting extensive CAD. On the other hand several reports have suggested otherwise.

Conversely, in the study reported by Caunite et al [48], left ventricular systolic function assessed by global longitudinal strain had a statistically significant weak correlation with complexity of coronary artery disease.

Several studies have reported that global longitudinal strain measured by 2-D STE at rest were significantly lower in patients with advanced CAD, as compared with patients without CAD [45-46].

Similarly, ELSA - Brasil study [49] demonstrated no correlation between absolute CAC values and GLS. In the study, patients were classified according to the presence of coronary calcification (CAC >0 Agatston units) and in 3 CAC ordinal categories (0, 1 to 100, and >100 Agatston units). GLS did not differ among those with CAC >0 when adjusted for age and gender. These findings suggest that subclinical dysfunction evaluated by GLS is not a marked effect of underlying subclinical atherosclerosis.

## 4. Conclusion

Our index patient, a healthy asymptomatic 65 year old male, with a normal 2D echocardiography and TST, on a routine coronary CT angiography was found to have an extensive three vessel coronary artery disease accompanied by an Agatston calcium score of 468. He was suggested elsewhere, to undergo either a mutlivessel PCI with stenting or CABG. However, due to manifold limitations and pitfalls of CTA alongwith knowledge of Glagov's remodeling phenomenon, we conducted a global longitudinal strain echocardiography by 4D XStrain speckle tracking imaging and were amazed to find a GLS value of -17.2 % which is within normal range. The presence of normal GLS value rules out the existence of significant obstructive CAD.

Hence, accordingly we advised a statin and low dose aspirin for prevention of CAD and moreover, suggested to him to undergo yearly TST and GLS estimation for supervising the progress of CAD, if any, in future.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

### *Statement of ethical approval*

The ethical approval was obtained from the Institutional Ethics Committee of Prakash Heart Station, Niralanagar, Lucknow.

### *Statement of informed consent*

Informed consent was obtained from the parents of our index patient.

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