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Original Article

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Cardiac Magnetic Resonance Imaging Feature Tracking for Quantifying Left Ventricle Deformation in Type 2 Diabetic Patients

Qurain Turki Alshammari[1*], Wed Almutairi[1,2], Eman Alshammari[1,2], Ohood Alrashidi[1], Meshari T Alshammari[1,3], Amjad R Alyahyawi[1,4], Yasser Alzamil[1], SD Shahanawaz[5], Shashi Kumar CG[5]

[1]Department of Diagnostic Radiology, College of Applied Medical Sciences, University of Hail, Hail, Saudi Arabia.
[2]Department of Diagnostic Radiology, Hail Health Cluster, Ministry of Health, Saudi Arabia.
[3]Translational Medical Sciences and National Institute for Health Research (NIHR) Nottingham Biomedical Research Centre, Nottingham University Hospitals NHS Trust and the University of Nottingham, Nottingham NG7 2UH, UK.
[4]Centre for Nuclear and Radiation Physics, Department of Physics, University of Surrey, Guildford, Surrey, UK.
[5]Department of Physical Therapy, College of Applied Medical Sciences, University of Hail, Saudi Arabia.

***Email:** *g.algrain@uoh.edu.sa*

ABSTRACT

An evaluation of myocardial function is necessary to assess the condition of a patient's heart. Although ejection fraction is used as a measure of myocardial function, many common cardiac illnesses affect the myocardium locally rather than globally. It may therefore be possible to determine the motion of the regional wall of the heart by evaluating myocardial strain. Studying the efficacy of CMR feature tracking in diabetics Type 2 To determine whether the use of MRI feature tracking is effective in detecting myocardial strain deformations in diabetics and healthy individuals.
This study involved 80 patients, 40 of whom had Type 2 diabetes and 40 of whom did not, who were subjected to cardiac MRI and echocardiography. Post-processing was done offline using CMR feature tracking and echocardiography speckle tracking, followed by SPSS analysis of the data. T2DM patients and controls did not demonstrate any significant differences in the study. There was a significant decrease in the LV GLS and LV GRS values among T2DM patients (p 0.0001) as compared to normal controls. Where the LV GLS was in controls (-20±5) and diabetes (-15±2). The CMR-FT method is well suited for accommodating STE, providing additional information in clinical trials, which can be used interchangeably. This study recommends that feature tracking (FT-CMR) and speckle tracking echocardiography (STE-Echo) be incorporated into the clinical practices of hail hospitals due to their positive results in diagnosing myocardial deformation.

Key words: *Cardiac magnetic resonance imaging, Feature tracking, Speckle tracking echocardiography, Type 2 diabetes mellitus*

INTRODUCTION

Diabetes mellitus (DM) is one of the non-communicable chronic diseases and a major public health concern accompanied by high healthcare costs, morbidity, and early mortality.
This metabolic disorder has rapidly increased due to a lack of physical activity, poor food habits, obesity, and obesity [1]. According to the International Diabetes Federation (IDF), 537 million adults aged 20 to 79 are

estimated to be affected by diabetes by 2021 - one out of every ten adults. This number is expected to increase to 643 million by 2030, and 783 million by 2045. There are 73 million diabetics in the Middle East and North Africa, and the number is expected to rise to 135.7 million by 2045 [2].

Diabetes mellitus is characterized by elevated blood sugar levels. This leads to several macrovascular and microvascular complications such as neuropathy, retinopathy, renal failure, and cardiovascular disorder [1].

Diabetes-related mortality and morbidity are primarily caused by cardiovascular complications. When diabetes is untreated or inadequately treated, it can result in overt diabetic cardiomyopathy. Myocardial dysfunction is the most common complication of diabetes, causing clinically silent myocardial dysfunction [3].

Diabetic cardiomyopathy can be categorized as either having coronary artery disease or hypertension [4]. In addition to advanced glycation end products, atherosclerosis, microinfarctions in the subclinical stage, mitochondrial dysfunction, and lipotoxicity, several metabolic impairments contribute to diabetic cardiomyopathy [5] These impairments may affect both left ventilatory function (LV) and right ventilatory function (RV), due to their systematic nature [6].

It is believed that cardiovascular diseases represent a significant international public health burden due to the difficulty of evaluating heart contractile function in modern cardiology, which continues to be an issue [6]. In fact, the conventional parameter that describes left ventricular (LV) function, ejection fraction (EF), has considerable limitations due to its volumetric nature, suboptimal reproducibility, and a loss of ability to reflect local LV function. As a result, LV mechanics can be more comprehensively characterized by measuring myocardial deformity (strain) non-invasively [7].

A myocardial strain is a deformation caused by the application of force to the myocardium. The rate at which the myocardial length changes from relaxed to contracted is called myocardial strain [8]. As opposed to strain, ejection fraction (EF) offers the possibility of examining components of contractions in longitudinal (LS), circumferential (CS), and radial directions (RS). Non-invasive methods to analyze myocardial deformation, such as cardiac magnetic resonance feature tracking (CMR-FT) and speckle tracking echocardiography (STE), are available in addition to cardiac magnetic resonance feature tracking [9].

Patients with type 2 diabetes have been subjected to echocardiographic studies to determine how much strain they are under. With cardiac magnetic resonance feature tracking (CMR-FT), a novel method has been developed for quantifying left and right ventricular myocardial deformation using high-resolution images [10-12]. Further, studies have shown that speckle-tracking echocardiography (STE) is a reliable, reproducible, and accurate method of measuring LV deformations in a wide range of clinical applications. A prospective clinical trial evaluating this technique has not yet been conducted in large populations. The lack of information about CMR-FT and STE for LV deformation assessment is largely due to this fact. Thus, this study aimed to determine if longitudinal, radial and circumferential strains in diabetic patients were correlated with features tracked through Cine SSFP Imaging and speckle tracking echo.

MATERIALS AND METHODS

The Institutional Ethics Review Board of the University of Hail and King Salman Hospital approved this study (No. H-2022-205) and in compliance with proper guidelines for medical research, we adhere to the Declaration of Helsinki (2000 edition). There were a total of 40 persons diagnosed with diabetes mellitus and 40 individuals who were healthy controls, who visited the radiology department at King Salman Specialist Hospital (KSSH) and underwent routine CMR-FT and STE examinations between December 2021 and March 2022 in the Hail region of Saudi Arabia.

A diagnosis of Type 2 Diabetes (T2DM) at age 18 was required, without any symptoms, signs, or history of heart disease (known coronary artery disease, cardiomyopathy, or valvular heart disease); sinus rhythm; normal ejection fraction over 50%; and absence of contraindications to MR imaging.

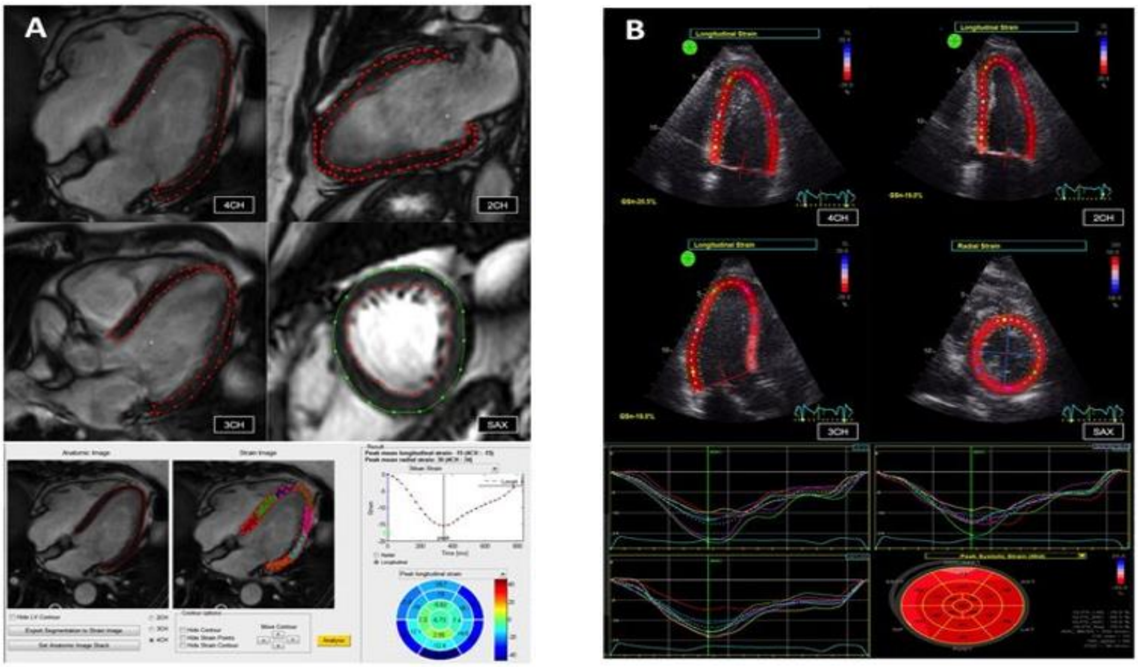
Participants with severe renal impairment (estimated glomerular filtration rate = 30 mL/min/1.73 mm2), uncontrolled blood pressure at rest (systolic blood pressure > 180mmHg and/or diastolic blood pressure > 100mmHg), or contraindicated for MRI were excluded.

Procedure

The research design is to analyze retrospectively MRI FT offline data, using the software of circle CVI-42 that measures the strain in a 17-segment software-generated mode, in a different direction.

Global longitudinal strain (GLS) is measured on the long axis (2,3 4 chambers views) while circumferential (GCS) and radial strains (GRA) are measured on the short axis without the need to use additional sequences and the same for echocardiography using the STE.

At end-diastole, the epi- and endocardial borders were defined on all pictures. Following the initiation of an automated calculation, the used software program automatically demarcated the boundary all through the cardiac cycle. The efficiency of the tracking and contouring is visually assessed and manually corrected as appropriate. To compute the left ventricular ejection fraction, further cine-CMR studies were performed (LVEF).



a) b)

Figure 1. Myocardial strain is measured with FT-CMR and STE. Feature-tracking cardiac magnetic resonance imaging, a) and 2-D speckle-tracking echocardiography, b) are used for the analysis of myocardial segmentations and global longitudinal strains. A four-chamber view is called a 4CH; a two-chamber view is called a 2CH and a three-chamber view is called a 3CH.

Speckle tracking echocardiography (STE)

In this study, an experienced cardiologist utilized the Vivid E9 equipped with the M5S M5 3.5–5MHz transducer (GE Vingmed Ultrasound, Horten, Norway) for conventional two-dimensional Doppler ultrasonography on the patients. Each patient with attached ECG leads had an electrocardiogram performed. There were three consecutive image cycles of the apical 4-chamber, 2-chamber, and long-axis in apical structures for the data to be collected, and all three cycles were collected at a high frame rate (>45 s 1).

EchoPAC software (version 203, GE Vingmed Ultrasound, Norway) has been used as a measurement tool to measure global longitudinal strain and mean vertical wave (MW). Based on the timing of the events in the aortic valve spectrum, the time of aortic valve closure was determined. Therefore, the apical long-axis perspective, four-chamber perspective, and two-chamber perspective were analyzed using Ten, APLAX, A4C, and A2C per the study design. Upon dividing the LV myocardium into 18 segments, the program uses this information to automatically calculate the global longitudinal strain (GLS) **(Figure 1)**.

Feature tracking CMR

An MR scanner with 1.5 Teslas was used to perform CMR imaging. We recorded 2- and 4-chamber CVs with ECG-gated b-SSFP cine sequences as well as a short-axis stack. As a result, we used the following parameters for scanning the cardiac cycle: 40 frames per cardiac cycle, 0.8mm x 0.8mm pixel spacing, 8mm slice thickness, 1.5mTR, and 3ms TE. In order to evaluate the LVEF, the SA stack was used.

For the measurement of strain in CMR-FT, commercial software available from "CVI" was used (CVI42, Version 5.6.5, Circle Cardiovascular Imaging Inc., Calgary, Canada) **(Figure 2)**. An FT was performed at the diastole's end. An endocardial and epicardium boundary scan was conducted on the left ventricle. The RV boundaries could also be tracked using CV in the same way. Using tracking algorithms, tissue characteristics have been tracked during the cardiac cycle. The tracking accuracy was verified visually, and any modifications were made only to the initial outlines if necessary. Afterward, the process was repeated three times and the average was taken. A global longitudinal strain measurement (GLS) was performed on the LV and RV, along with a global circumferential strain measurement (GLS/GRS) on the LV. The GLS was determined using two, three, and four long-axis CVs and averaging peak strains. In contrast, the RV strain was exclusively derived from the 2-CV and 4-CV strains. Global short axis (SA) strains (GCS and GRS) were calculated from an average of three slices: basal slices (last slices showing the entire circular myocardium with no outflow tract), midventricular slices, and apical slices (blood pool maintained throughout the cardiac cycle).

Data analysis

Using SPSS, the data will be analyzed (v23). If relevant, data are reported as percentages or standard deviations with a confidence level of 95%. (CI). p-values less than 0.05 were deemed statistically significant.

Using linear regression analysis and Bland-Altman plots, the concordance with FT-CMR and STE myocardial strain measurements was determined. To determine if FT-CMR and STE12 exhibited considerable variation, a paired Student's t-test has been used. Inter-observer (two readers) and intra-observer (two readings) repeatability was determined by calculating the standard deviation of an estimate, coefficient of variation (CV), and intraclass correlation coefficient (ICC).

RESULTS AND DISCUSSION

The inclusion criteria were met by a total of 54 patients. Fourteen participants were removed from the trial as a result of low-quality pictures (n=5), tachycardia (n=6), or an irregular pulse (n=3). In the study overall number of 80 patients was first separated into two groups: healthy individuals (n=40, mean age 52±13 years, 20 men) and T2DM patients (n=40, mean age 54±11 years, 21 men).

There was a significant difference between the levels of arterial blood pressure, fasting blood glucose, and HbA1c in patients with T2DM compared to healthy controls (p0.05), however, the level of low-density lipoprotein was not significantly different (P>0.05). Patients with T2DM had significantly higher e', a′, and E/e′ values than healthy controls (p0.05). Compared to healthy controls and T2DM patients, there is a significant difference in the E and A variables (p>0.05). Patients with T2DM showed levels that were considerably lower than those in healthy individuals when compared to the values of LV GLS and LV GRS (p-0.001). In terms of LV GCS, there were no significant differences between normal LV GCS and diabetic LV GCS. This is summarised in **Table 1**. A significant difference was observed between FT-CMR and STE in GCS as well as in GLS (<0.001). Co-relation coefficient analysis revealed that there was a positive co-relation between FT-CMR and STE in GCS, GRS AND GLS respectively (<0.001) This is summarised in **Table 2**.

Table 1. Characteristics of STE and CMR-FT in type 2 diabetes mellitus subjects and control subjects.

	Normal subjects (40)	T2DM (40)	p-value
Age (yrs)	52±13	54±11	0.36
Male%	20 (50)	21(55)	0.84
BMI (kg/m^2)	22±1.4	23±1.7	0.21
Heart rate (bpm)	72±9	75±11	0.34
LVEF%	66±4	60±3	<0.001
DBP (mmHg)	74±10	77±9	0.19
SBP (mmHg)	121±12	125±11	0.38
Fasting Plasma glycose (mmol/L)	4.97±0.6	14±3.9	<0.001
HbA1c (%)	5.18±0.5	10.20±2.09	<0.001
TCH (mmol/L)	3.8±0.7	3.9±0.6	0.62
TG (mmol/L)	1.1±0.2	1.1±0.5	0.34
HDL (mmol/L)	1.24±0.2	1.20±0.4	0.42
LDL (mmol/L)	2.1±0.5	2.2±0.6	0.17
ECHOCARDIOGRAPHY			

E (m/s)	0.83±0.15	0.76±0.12	<0.001
A (m/s)	0.65±0.11	0.69±0.20	<0.001
E/A	1.31±0.29	1.23±0.31	0.08
e' (m/s)	0.13±0.04	0.08±0.02	<0.001
a' (m/s)	0.09±0.03	0.10±0.02	<0.001
E/e'	7.1±1.5	10.56±2.3	<0.001
Feature tracking CMR			
LV GCS% (SAX)	-24±6	-22±5	0.32
LV GRS% (SAX)	22±11	16±7	<0.001
LV GLS% (LAX)	-20±5	-15±2	<0.001

Table ٢. Myocardial strain evaluating FT-CMR vs STE

			Difference		
	FT-CMR	**STE**	**Absolute**	**95%CI**	**p**
LV GCS% (SAX)	-28±6	-27±5	-1.0 ± 0.8	1.2 to 0.6	<0.0001
LV GRS% (SAX)	25±11	21±7	4.0 ± 3.2	4.2 ± 12.3	0.04
LV GLS% (LAX)	-27±5	-21±2	6.0 ± 3.9	4.1 ± 4.2	<0.0001
			Correlation		
	FT-CMR	**STE**	**Intercept**	**95%CI**	**p**
LV GCS% (SAX)	1.2	2.8	2.5	0.64	<0.0001
LV GRS% (SAX)	0.6	9.5	12.4	0.48	<0.0001
LV GLS% (LAX)	0.7	3.5	3.9	0.72	<0.0001

FT-CMR, Feature tracking cardiac magnetic resonance; STE, speckle tracking echocardiography; CI, confidence interval; SEE, Standard error of estimate; GLS, Global longitudinal strain; GRS, Global radial strain; GCS, Global circumferential strain.

BMI Body Mass Index, SBP Systolic Blood Pressure, DBP Diastolic Blood Pressure, TCH Total Cholesterol, TG Triglyceride, HDL High-Density Lipoprotein, LDL Low-Density Lipoprotein, LAD Left Atrial Diameter, LVEF Left Ventricular Ejection Fraction, E Peak velocity during early diastole of the anterior mitral valve, A peak velocity during late diastole of the anterior mitral valve, e′ peak early diastolic annular velocities using TDI, a′ peak late diastolic annular velocities using TDI, GCS (SAX) Global Circumferential Starin (Short axis), GRS (SAX) Global Radial Strain (Short axis), GLS (LAX) Global Longitudinal Stain (Long axis).

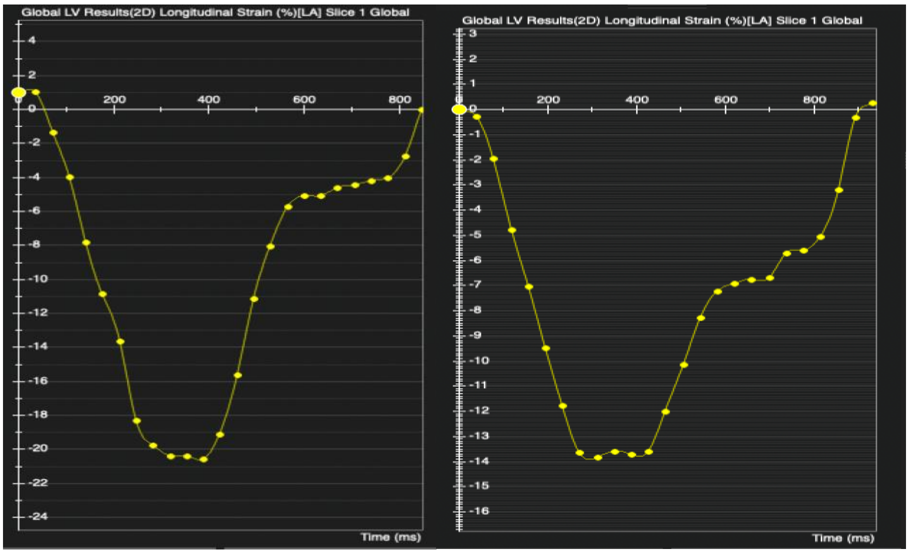


Figure 2. GLS in Control (left) and diabetic subject (right). The GLS in control = -21% and in diabetic patients = -14%.

Currently, cardiovascular magnetic resonance imaging (CMR) is the most accurate and reproducible imaging technique available for quantifying the volumes of the left ventricle and the ejection fraction. As for the quantification of LV mechanics, such as myocardial strain, experts generally agree that there is no non-invasive "gold standard" technique that can be used in humans at present [13]. While numerous studies have demonstrated the accuracy and reliability of MRI tagging for measuring myocardial strain, limited availability and expertise have significantly limited its use in a comparative research with echocardiography [13-17]. It appears that the limited data on comparisons of STE and CMR-FT results reflected inter-technique differences. MRI and echocardiography may not be comparable adequately due to these techniques' differences. Therefore in the current study, Longitudinal, Radial, and Circumferential Strains were compared using feature tracking from Cine SSFP Imaging with CMR-FT and Speckle Tracking Echo (STE) in medium coherent diabetic patients and healthy subjects.

Currently, there is a very good spatial resolution of the SSFP sequences that are being used in magnetic resonance imaging, which allows distinguishing between myocardium and trabeculae, but it also complicates the detection of the endocardial borders, which can be quite challenging. Since automated border detection algorithms are currently not sufficient to detect the small indentations between the trabeculae of the LV and manual tracing is simply too time-consuming and labor-intensive, there is a general consensus that the papillary muscles and the trabeculae be included in the LV cavity. Thus, it can be assumed that, in addition to EDV being overestimated, stroke volume may be understated as well, since compacted trabeculae behave in much the same way as regularly compacted myocardium at the end of the contractile cycle [18]. Additionally, SSFP sequences are known to overestimate LV volumes when compared to turbo gradient-echo sequences [19]. Further, including a basal slice based on the criterion of having at least 50% of its circumference covered by left ventricle myocardial tissue remains subjective; partial volume artifacts can measure LV volume extremely difficult to apply with confidence. These artifacts have a significant impact on the accuracy and reproducibility of LV volume measurements [20]. As an alternative, STE is characterized by low frame rates, which in turn could result in an underestimation of the EF due to the lack of the actual end-systolic frame, resulting in subjective underestimation. Considering the difference in the LVEF measurements obtained from STE and CMR-FT, both measurements appear to be highly comparable.

The results of this study indicate that the values of LV GLS and LV GRS in type2 diabetes patients were considerably less than those in control subjects and that no significant changes were observed in LV GCS between healthy and T2DM patients, the outcome of the feature tracking CMR and Speckle tracking echocardiography (STE-Echo) showed similar values, and the two software were easy to use and required less time. With feature tracking CMR, it has been demonstrated that patients with type 2 diabetes could use this technique to assess RV myocardial deformation before clinically evident RVEF reductions. These measurements provide objective evaluations of subclinical RV dysfunction before clinically obvious RVEF reductions.

The CMR-FT method has recently been identified as a novel method of assessing the quantitative function of the biventricular myocardium [12, 21]. This technology is based on tissue voxel motion-tracking technology derived from CMR cine imaging. A primary advantage of this method is that it requires relatively little post-processing. In addition, this method has been estimated to require a 10-minute post-processing time for each subject, thus providing the possibility of routine use [22, 23].

In individuals with diabetes with subclinical left ventricular (LV) systolic dysfunction, Arezoo Zoroufian used speckle tracking echocardiography (STE) to detect changes in LV longitudinal strain (ST). According to the study, all 37 patients with type 2 diabetes enrolled in the study had normal coronary arteries, an LVEF greater than 50%, and no localized abnormalities of wall motion. It was also found that control patients had normal coronary arteries. These patients were subjected to routine transthoracic echocardiography, tissue Doppler imaging (TDI), and magnetic resonance imaging (MRI) (STE). The end-systolic ST and time-to-peak systolic strain were measured in 18 segments of the left ventricle. However, the sample size of the study was limited, suggesting that STE investigations may be able to detect early changes in systolic function during the natural progression of type 2 diabetes [24].

In research and clinical trials conducted by Zia Ur Rahman, FT-CMR was evaluated in the literature despite their validity, normal and abnormal values, advantages, and limitations. Despite the limitations of CMR-FT, the author noted their potential utility despite the limitations of their validation, normal values, advantages, and limitations. It is more feasible, accessible, and time-effective to use feature tracking to analyze myocardial function globally and segmentally than other CMR-based strain approaches; further research is needed to determine whether feature tracking can be used to evaluate right ventricular/right atrial dysfunction [25].

CONCLUSION

A comparison of strain analysis methods revealed that CMR-FT may be used interchangeably with STE in clinical trials to determine the global longitudinal strain (GLS) for the left ventricle and right ventricle as well as global circumferential and radial strain (GLS/GRS) for the left ventricle.

Recommendation

This study advised involving the software of Feature tracking (FT-CMR) and Speckle tracking echocardiography (STE-Echo) in the clinical practices of hail hospitals due to its positive outcome in the diagnosis of myocardial deformation.

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CONFLICT OF INTEREST : None

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