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RESEARCH

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Multislice CT coronary angiography and coronary artery calcium scoring, correlation with Heart Score

Ahmed Kamel Elkhoraiby[1,2*], Nireen Khalifa Okasha[1], Yaser Gomaa Elkashlan[1] and Ahmed Fathy Tamara[1]

Abstract

Background Coronary atherosclerosis is the number one leading cause of death. According to estimates, if all primary cardiovascular diseases (CVDs) had been eradicated, life expectancy could increase by nearly seven years. Long asymptomatic latent phases of coronary heart disease allow for early preventive measures. Egypt has a high prevalence of premature Coronary Artery Disease (CAD).

Aim of study We aimed to evaluate the correlation between the cardiovascular risk assessed by the Systematic COronary Risk Evaluation (HeartScore) and Coronary Artery Calcium Score (CACS) versus the actual extent of atherosclerotic CAD affection among a sample of Egyptian patients assessed by Multislice Computed Tomography (MSCT) due to chest pain complaints.

Methods An observational cross section study included one hundred studied cases: aged 40 to 69 years old, of which 63% were males, 63% were hypertensive, 39% were diabetic, and 28% were smokers. Those patients presented with symptoms suggestive of coronary artery disease (chest pain). All studied cases had been subjected to history and examination, electrocardiograph (ECG), kidney functions, lipid profile, SCORE calculation, and coronary MSCT scan.

Results Our observational study found a moderately significant positive relationship between the HeartScore and CACS and CAD; having a higher score carries a higher probability of having CAD. Having a very low score is a good negative test for exclusion. Also, there is a weak relationship between HeartScore, CACS, and the number of diseased coronaries, i.e. these cannot differentiate single vessel disease (SVD) from Multivessel Disease (MVD). In addition, both scores could not determine Obstructive Coronary Artery Disease (OCAD) and Nonobstructive Coronary Artery Disease (Non-OCAD).

Conclusions From the clinical point of view, our research suggests that HeartScore and CACS have moderate value in predicting CAD.

Keywords Coronary heart disease, Coronary artery calcium score, HeartScore, Multislice CT coronary angiography

*Correspondence:
Ahmed Kamel Elkhoraiby
ahmed.elkhoraiby@must.edu.eg
[1] Department of Cardiology, Faculty of Medicine-Ain Shams University, Cairo, Egypt
[2] Department of Cardiology, Faculty of Medicine, Misr University for Science and Technology, Giza, Egypt

Background

In the twentieth century, the prevalence of cardiovascular disease (CVD) was increasing, which could be explained by the rise in smoking and dietary differences leading to rising in serum cholesterol levels. Moreover, the ability to identify coronary heart disease before death by using an electrocardiogram to detect acute myocardial infarction grew. As a result, the only century in history where heart disease had been the leading reason for mortality was the twentieth century. That high prevalence persisted into the twenty-first century. In 2022, the World Health Organization (WHO) statistics about CVD showed.

According to estimates, 17.9 million deaths worldwide in 2019 were attributable to CVDs, or thirty-two percent of all fatalities. Heart attacks and strokes were to blame for eighty-five percent of these deaths [1].

In low-and middle-income nations, CVD deaths account for over seventy-five percent of all fatalities. By addressing behavioral risk factors like tobacco use, unhealthy eating and obesity, inactivity, and problematic alcohol consumption, many cardiovascular illnesses could be avoided [2].

Hence with this high prevalence of Coronary Artery Disease (CAD), a significant decrease in morbidity and death must follow the accurate detection of those who will benefit most from cardiovascular risk reduction. Still, the question is how competent is the Systematic COronary Risk Evaluation (HeartScore) in predicting and subsequent primary prevention of CAD?

Aim of work

To evaluate the correlation between cardiovascular risk assessed by the European HeartScore and the extent of atherosclerotic CAD affection among a random sample of Egyptian patients assessed by Multislice Computed Tomography (MSCT) due to chest pain complaints.

Methods

This observational cross-sectional study was conducted at Ain Shams University Hospital from Feb 2019 to Jan 2020. This study enrolled 100 Egyptian patients who presented for MSCT coronary angiography scan. Written informed consent was taken from all studied cases involved in the research. They were divided based on HeartScore risk SCORE into very high risk, high risk, intermediate risk, and low risk.

Inclusion criteria All patients aged > 40 years presented to MSCT coronary angiography for assessment of atypical chest pain or undergoing MSCT as part of a pre-operative non-cardiac surgery workup. (N.B. HeartScore was studied on age 40 years or older).

Exclusion criteria Dye allergy. Renal impairment (creatinine > 1.5). Difficulties in performing CT, such as inadequate breath holding, Patients with typical chest pain or electrocardiograph ECG changes suggest ischemia. (ST depression, Pathological Qs, Bundle branch block). Previous history of invasive coronary maneuvers, Percutaneous Coronary Intervention (PCI), Coronary Artery Bypass Graft (CABG) or recent myocardial infarction. Patients with irregular heart rhythm ex: Atrial fibrillation and frequent premature ventricular contractions (PVCs).

The 100 patients fulfling the inclusion criteria were sampled from a 483 patients (where 383 were excluded). All studied cases were subjected to Full history taking and clinical examination, fulfilling the following data: birth date, gender, hypertension (described as Blood Pressure > 130/80 mmHg or being on therapy for diagnosed hypertension) (2018 European Society of Cardiology Guidelines for management of arterial hypertension). Diabetes Mellitus (definite as Glycated hemoglobin HBA1C ≥ 6.5 percent) (2018 American Diabetes Association guidelines for Classification and Diagnosis of Diabetes), smoking, family history of IHD, Blood Pressure Measurement: 2 office BP reading during setting and relaxed in 2 limbs, divided by three minutes (not receiving tea or coffee at past two hours), cardiac examination(as regard signs of cardiomegaly, previous surgery, abnormal auscultatory findings as a murmur, pulmonary rales, pericardial rub).

All patients were subject to a 12-lead Surface electrocardiogram (ECG) and Routine laboratory investigations with particular concern on Serum creatinine (reference range: 0.5–1.5 mg/dL). Complete lipid profile. HbA1c (normal up to 6.5%). Then Calculating HeartScore for each patient: To estimate CAD risk at ten years: the low-risk group scored less than 1%, the moderate-risk group scored 1:5%, the high-risk group scored 5:10%, and the very high-risk group scored more than 10% (Fig. 1).

Coronary multi-detector computed tomography: All studied cases underwent a gated CT angiography using a dual source scanner that produces enhanced coronary tree visibility. All coronary arteries have been assessed at various stages of the cardiac cycle by acquiring thin slice Sects. (0.6 mm) until reaching the ideal stage for reconstruction. All scans began with a non-contrast improved scan for coronary calcium score to rule out studied cases with dense coronary calcification. Coronary artery calcium SCORE [pixel or pixels with a density greater than 130 Hounsfield units (0.18 mm^2/pixel) were considered 1]. Representative histological sections were stained after each artery had been split into appropriate three-mm segments. Each studied case's Coronary Artery Calcium Score (CACS) was recorded as a whole. Studied patients were then classified as follows based on total CACS value: Having no calcium (total SCORE = 0), Low (total SCORE = 1–100), Moderate (total SCORE = 101–400), or Severe (total SCORE > 400).

MSCT coronary angiograms were used to detect obstructive CAD (luminal narrowing of more than fifty percent). Vessels were subsequently categorized as follows: perfectly normal having atherosclerotic lesions less than fifty percent of luminal diameter, and nonobstructive CAD. If atherosclerotic lesions cover more than fifty percent of the luminal diameter, you have obstructive

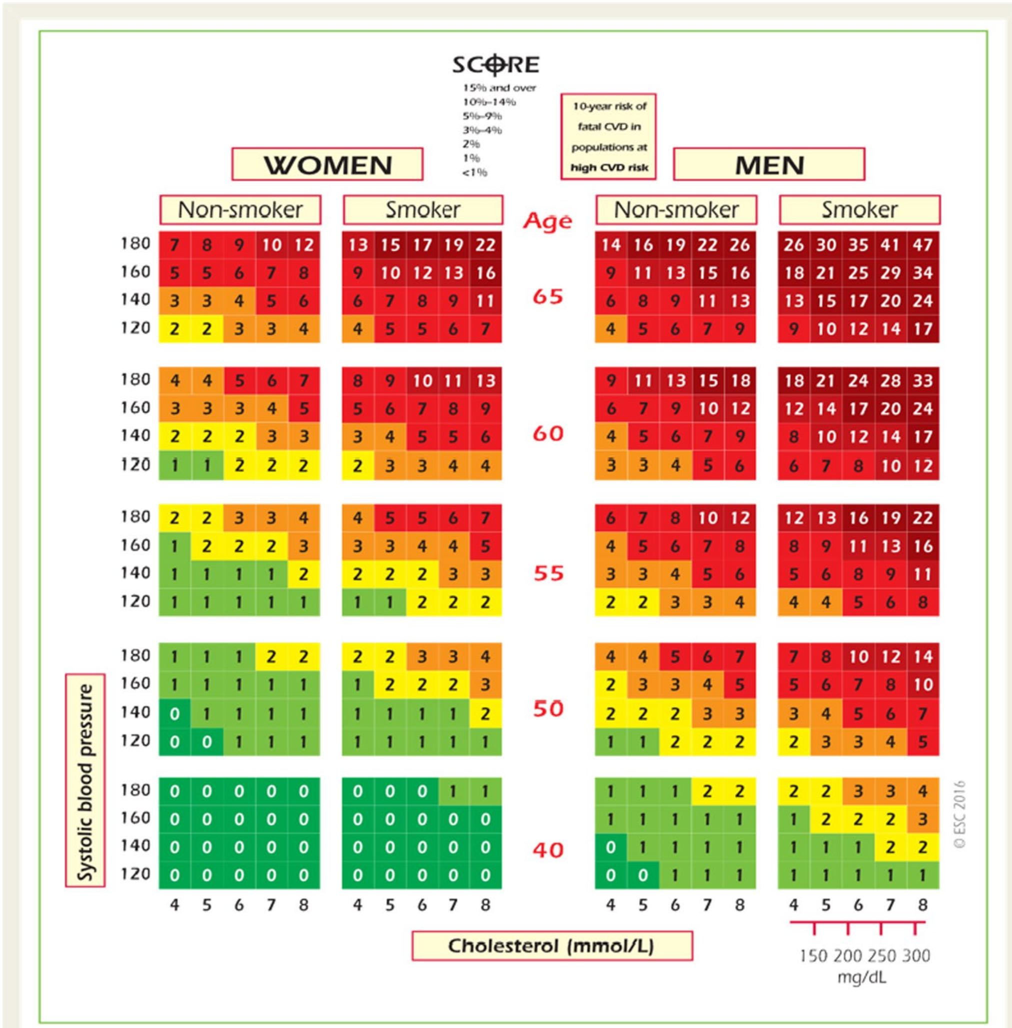

Fig. 1 HeartScore chart: In populations in nations with high cardiovascular risk, the ten-year risk of fatal cardiovascular disease [3]

CAD. There was a discussion of the prevalence of CAD (both obstructive and nonobstructive CAD) and whether obstructive CAD affected only one vessel (single-vessel disease) or two or three vessels (multivessel disease).

Statistical analysis (before commencing selectin) statement

A sample size of at least 97 subjects results in a two-sided 95% confidence interval with a width of 0.199 if the value of κ is 0.700 and the standard deviation SD(κ), is 0.50 (Power Analysis and Sample Size Software, 2009).The categorical variables will be expressed as numbers and percentages, and continuous variables as the mean ± SD. The variables will be compared using the Chi-square test for categorical variables and independent samples t-test for continuous variables with equal variance.

Statistical method

Using IBM SPSS Statistics (Statistical Package for Social Sciences) software version 28.0, IBM Corp., Chicago, USA, 2021, gathered data were coded, tabulated, and statistically evaluated. Shapiro–Wilk tests are used to determine if quantitative data are normally distributed. If they are, they are compared using independent t-tests (between 2 separate groups) and ANOVA tests (3 independent groups). Chi-square and Fisher's Exact tests can compare qualitative data expressed as numbers and percentages for variables with low expected values. The post hoc Bonferroni test was utilized. Receiver Operating (ROC) curve was used to evaluate how well various tests performed at differentiating among various groups. p values below 0.050 had been

Table 1 Demographic features and medical history of cases

Features	Mean ± SD	Range
Years old	56.6 ± 8.7	40–69
	N	**%**
Sex		
Male	63	63.0
Female	37	37.0
Hypertension	62	62.0
Diabetes mellitus	39	39.0
Smoking	28	28.0
Family history of IHD	5	5.0

Table 2 Clinical and laboratory results among patients

Items	Mean ± SD	Range
SBP (mmHg)	136.9 ± 16.2	110.0–190.0
DBP (mmHg)	82.1 ± 8.9	70.0–100.0
Creatinine (mg/dL)	0.9 ± 0.2	0.4–1.3
Total cholesterol (mg/dL)	248.3 ± 37.2	26.0–312.0
Triglycerides (mg/dL)	154.7 ± 20.3	80.0–226.0
HDL (mg/dL)	40.4 ± 4.5	30.0–52.0
LDL (mg/dL)	176.7 ± 27.5	103.0–235.0

SBP Systolic Blood Pressure, *DBP* Diastolic Blood Pressure, *HDL* High Density Lipoprotein, and *LDL* Low Density Lipoprotein

considered significant, while values over this threshold were considered non-significant.

Results

The study included 100 patients. Their baseline demographics and medical history are found in the following Table 2.

Table 1 showed that of the studied population: two third were males, with an average aged of 56 years, and less than two-thirds of patients had hypertension. More than one-third of patients had diabetes mellitus. More than one-quarter of the studied cases were smokers. A minority of subjects had a Family history of premature CAD.

Table 3 HEARTSCORE among the studied cases

Items	Mean ± SD
HEARTSCORE	6.9 ± 4.2
	N
Low < 1%	6
Moderate 1: < 5	32
High ≥ 5: < 10	39
Very high ≥ 10	23

Table 2 shows the clinical and lab results among the studied sample.

Table 3 shows that: HEARTSCORE among the studied cases where 32% had moderate risk, 39% had high risk while 6% were low, and 23% were very high.

Table 4 showed that: Coronary artery calcium SCORE among the studied cases where 36% were in the zero group, 37% were in the mild group while 19% were in the moderate group, and 8% were in the severe group.

Table 5 shows that: Only 37% of the studied cases had normal MSCT, 39% had Nonobstructive Coronary Artery Disease (Non-OCAD), and 24% had Obstructive CAD (OCAD).

The left anterior descending artery was the most frequently impacted coronary artery; found in 50 patients (50% of the whole studied cases) and 14 patients in the OCAD group (58% of the OCAD group).

From Table 6, it was found that

The normal group was younger in age (mean 52 years versus 59 years in the disease group), and they had average blood pressure measurement values (versus the diseased group where the majority had hypertension and it was the most significant and frequent risk factor).

Most of the normal group were non-smokers (about 84%) versus the diseased group, in which 46% were smokers.

The normal group had a higher HDL levels (mean HDL 42 mg/dl) versus the diseased group (mean HDL 39 mg/dl).

HEARTSCORE had been lowest in the normal group, followed by the Nonobstructive Coronary Artery Disease (Non-OCAD) group, and greatest in the Obstructive CAD (OCAD) group; variations were significant among all groups. (p value ^ < 0.001).

Coronary artery calcium SCORE was significantly lower in the normal group (p value ^ < 0.001) with no variations among non-OCAD and OCAD groups.

From Table 7, it was found that

HEARTSCORE had been lowest in the normal group, followed by the non-OCAD group, and highest in the OCAD group; variations had been significant among all groups. Coronary artery calcium score had been lower in the normal group, with no differences among non-OCAD and OCAD groups.

From Table 8 HeartScore and Coronary artery calcium SCOREs had moderate diagnostic performance in differentiating normal form abnormal (with the best cutoff below 2 for HeartScore and below 6 for Calcium score). However, HEART and Coronary artery calcium SCOREs

Table 4 Coronary artery calcium SCORE among cases

Items	Mean ± SD
Coronary artery calcium SCORE	104.6 ± 184.6
	N
No: Zero	36
Mild 1: 100	37
Mod 101: 400	19
Severe > 400	8

Table 5 Final diagnosis of the studied cases

Characteristics		N	%
Multislice CT coronary angiography	Normal	37	37.0
	Non-OCAD	39	39.0
	OCAD	24	24.0
Affected coronary arteries	Left anterior descending	50	50.0
	Right	41	41.0
	Left circumflex	36	36.0
	Left main	1	1.0
Affected coronary arteries in cases with OCAD (total = 24)	Left anterior descending	14	58.3
	Right	13	54.2
	Left circumflex	9	37.5
	Left main	1	4.2

had poor diagnostic performance in differentiating OCAD from non-OCAD grades.

From Table 9, it was found that

A HEARTSCORE ≥ 2.0 had the best sensitivity, Negative Predictive Value, and Negative likelihood ratio. A HEARTSCORE ≥ 8.0 had the best specificity, Positive Predictive Value, and Positive likelihood ratio.

Coronary artery calcium SCORE ≥ 6.0 had the best-balanced characteristics; Youden's index, Diagnostic accuracy, and Diagnostic odds ratio.

Table 10 indicates that: Smoking was more frequent in patients with single-vessel disease than the multivessel disease.

Table 11 shows that HeartScore could not differentiate between single-vessel disease and multivessel disease groups. (p value ^ 0.999).On the other hand, Coronary artery calcium score had a statistically weak ability to differentiate between single vessel disease and multivessel disease groups. (p value ^ 0.047).

Table 12 and Fig. 2 show that HEART and Coronary artery calcium SCOREs had no statically significant Cutoff point in diagnosing multivessel affection (Figs. 3, 4).

Discussion

Cardiovascular risk prediction aids in personalizing lifestyle, risk factor modification, and care by identifying high-risk individuals who require immediate and more

Table 6 Comparison according to Multislice CT coronary angiography regarding demographic, clinical, and laboratory findings

Variables	Normal (N = 37)	Non-OCAD (N = 39)	OCAD (N = 24)	*p* value
Age (years)	52.1 ± 9.0a	59.2 ± 7.1b	59.6 ± 7.8b	**^ < 0.001***
Sex				
Male	19 (51.4%)	26 (66.7%)	18 (75.0%)	#0.145
Female	18 (48.6%)	13 (33.3%)	6 (25.0%)	
Hypertension	17 (45.9%)a	28 (71.8%)b	17 (70.8%)b	**#0.040***
Diabetes mellitus	13 (35.1%)	12 (30.8%)	14 (58.3%)	#0.078
Smoking	6 (16.2%)a	11 (28.2%)ab	11 (45.8%)b	**#0.042***
Family history of IHD	2 (5.4%)	2 (5.1%)	1 (4.2%)	§0.999
SBP (mmHg)	129.7 ± 11.4a	140.3 ± 16.0b	142.3 ± 19.2b	**^0.002***
DBP (mmHg)	78.6 ± 8.1a	84.1 ± 8.9b	84.0 ± 9.0b	**^0.013***
Creatinine (mg/dL)	0.9 ± 0.2	0.9 ± 0.2	0.9 ± 0.1	^0.997
Total cholesterol (mg/dL)	238.2 ± 47.2	254.8 ± 29.4	253.0 ± 28.0	^0.117
Triglycerides (mg/dL)	154.5 ± 17.5	153.3 ± 21.0	157.1 ± 23.6	^0.773
HDL (mg/dL)	42.0 ± 4.4a	39.5 ± 4.2b	39.4 ± 4.6b	**^0.019***
LDL (mg/dL)	168.3 ± 29.8	182.6 ± 25.1	180.2 ± 25.2	^0.059
HeartScore	2.8 ± 2.3a	7.5 ± 5.1b	12.3 ± 8.8c	**^ < 0.001***
Coronary artery calcium score	12.2 ± 48.0a	148.9 ± 208.7b	175.3 ± 221.1b	**^ < 0.001***

Bold: A p-value less than 0.05 (typically ≤ 0.05) is statistically significant

^ANOVA test. #Chi square test. §Fisher's Exact test. *Significant Homogenous groups had the same symbol "a,b,c" based on the post hoc Bonferroni test

Table 7 Comparison according to Multislice CT coronary angiography regarding HEART and Coronary artery calcium SCOREs

Variables	Normal (N = 37)	Non-OCAD (N = 39)	OCAD (N = 24)	*p* value
HEARTSCORE				
HEARTSCORE	2.8 ± 2.3a	7.5 ± 5.1b	12.3 ± 8.8c	**^ < 0.001***
HEART grades				
Low < 1%	6 (16.2%)	0 (0.0%)	0 (0.0%)	§ **< 0.001***
Moderate 1: < 5	20 (54.1%)	11 (28.2%)	1 (4.2%)	
High ≥ 5: < 10	11 (29.7%)	17 (43.6%)	11 (45.8%)	
Very high ≥ 10	0 (0.0%)a	11 (28.2%)b	12 (50.0%)c	
Coronary artery calcium SCORE				
CAC SCORE	12.2 ± 48.0a	148.9 ± 208.7b	175.3 ± 221.1b	**^ < 0.001***
CAC grades				
No: Zero	30 (81.1%)a	4 (10.3%)b	2 (8.3%)b	§ **< 0.001***
Mild 1: 100	5 (13.5%)	22 (56.4%)	10 (41.7%)	
Mod 101: 400	2 (5.4%)	8 (20.5%)	9 (37.5%)	
Severe > 400	0 (0.0%)	5 (12.8%)	3 (12.5%)	

Bold: A p-value less than 0.05 (typically ≤ 0.05) is statistically significant

^ANOVA test. §Fisher's Exact test. *Significant Homogenous groups had the same symbol "a,b,c" based on the post hoc Bonferroni test

aggressive intervention and modifying the intensity of preventative actions.

As coronary atherosclerosis is a prevalent health issue, everyone should receive lifestyle counseling and help reduce risk factors; however, the level of effort may vary. For example, it has been proven that high-risk patients reap the greatest absolute risk reduction from cholesterol-lowering therapy. Because of this, the strength of all prevention recommendations is based on the risk level.

While Systematic Coronary Risk Evaluation had been created to estimate the risk of cardiovascular death, currently employed risk estimation assesses established risk factors at a single time point to forecast the ten-year risk of events [4].

Coronary artery disease is regarded as a sequence that starts in adolescence with few alterations and culminates with clinical occurrences, some of which can be fatal [5]. It was fair to seek for correlation between HeartScore and silent atherosclerosis given the "hard" character of endpoints used to develop risk scoring system, which was intended to avoid earlier stages of the disease. In addition, multislice computed tomography provided a noninvasive window to examine calcium scores and the existence of CAD.

Our study questioned the differentiating ability of HeartScore and CACS between:

1. Normal and diseased.
2. OCAD and Non-OCAD.
3. Single vessel disease (SVD) and Multivessel Disease (MVD).

To our knowledge, that is the first research to test the HeartScore model in CAD detection.

Our study included 100 patients who underwent MSCT-CA and had no sure symptoms or signs of CAD. A detailed history, examination, review of lab results, ECG, HeartScore calculation, CACS, and a coronary angiogram were done for all patients.

Table 8 Diagnostic performance of HEART and Coronary artery calcium SCOREs in differentiating: Normal form abnormal and OCAD from non-OCAD

SCOREs	AUC	SE	*p* value	95% CI	Cut point
Normal from abnormal grades					
HEART	0.854	0.037	**< 0.001***	0.782–0.925	≥ 2.0 ≥ 8.0
Coronary artery calcium	0.898	0.036	**< 0.001***	0.829–0.968	≥ 6.0
OCAD from Non-OCAD grades					
HEART	0.671	0.071	0.054	0.532–0.810	Not applicable
Coronary artery calcium	0.557	0.075	0.449	0.410–0.705	

Bold: A p-value less than 0.05 (typically ≤ 0.05) is statistically significant

AUC: Area under the curve. SE: Standard error. CI: Confidence interval, *significant

Table 9 Diagnostic features of HEART and Coronary artery calcium SCOREs cut points in diagnosing abnormal Multislice CT coronary angiography grades

Characteristics	HEARTSCORE ≥ 2.0		HEARTSCORE ≥ 8.0		CACS ≥ 6.0	
	Value	95% CI	Value	95% CI	Value	95% CI
Sensitivity	**95.2%**	**86.7%–99.0%**	47.6%	34.9%–60.6%	85.7%	74.6%–93.3%
Specificity	45.9%	29.5%–63.1%	**97.3%**	**85.8%–99.9%**	89.2%	74.6%–97.0%
DA	77.0%	67.5%–84.8%	66.0%	55.8%–75.2%	**87.0%**	**78.8%–92.9%**
YI	41.2%	24.3%–58.1%	44.9%	31.5%–58.3%	**74.9%**	**61.7%–88.1%**
PPV	75.0%	64.1%–84.0%	**96.8%**	**83.3%–99.9%**	93.1%	83.3%–98.1%
NPV	**85.0%**	**62.1%–96.8%**	52.2%	39.8%–64.4%	78.6%	63.2%–89.7%
LR +	1.76	1.30–2.38	**17.62**	**2.51–123.91**	7.93	3.13–20.11
LR-	**0.10**	**0.03–0.33**	0.54	0.42–0.69	0.16	0.09–0.30
DOR	17.00	4.51–64.12	32.73	4.22–253.61	**49.50**	**14.11–173.62**

Bold-underline: A p-value less than 0.05 (typically ≤ 0.05) is statistically significant

CI: Confidence interval. DA: Diagnostic accuracy. YI: Youden's index PPV: Positive Predictive value. NPV: Negative Predictive value. LR + : Positive likelihood ratio. LR-: Negative likelihood ratio. DOR: Diagnostic odds ratio

Table 10 Demographic, clinical, and laboratory findings Comparison according to affected vessels number Single Vessel disease (SVD) or Multivessel Disease (MVD)

Variables	Single (N = 24)	Multiple (N = 39)	*p* value
Age (years)	57.8 ± 8.4	60.3 ± 6.5	^0.202
Gender			
Male	17 (70.8%)	27 (69.2%)	#0.893
Female	7 (29.2%)	12 (30.8%)	
Hypertension	15 (62.5%)	30 (76.9%)	#0.218
Diabetes mellitus	10 (41.7%)	16 (41.0%)	#0.960
Smoking	12 (50.0%)	10 (25.6%)	#**0.049***
SBP (mmHg)	141.5 ± 20.0	140.8 ± 15.4	^0.878
DBP (mmHg)	84.8 ± 8.7	83.6 ± 9.0	^0.604
Creatinine (mg/dL)	1.0 ± 0.1	0.9 ± 0.2	^0.398
Total cholesterol (mg/dL)	249.3 ± 28.1	257.1 ± 29.0	^0.293
Triglycerides (mg/dL)	149.9 ± 23.7	157.8 ± 20.4	^0.169
HDL (mg/dL)	40.6 ± 3.6	38.7 ± 4.6	^0.086
LDL (mg/dL)	181.5 ± 23.9	181.8 ± 25.9	^0.964

Bold: A p-value less than 0.05 (typically ≤ 0.05) is statistically significant

^Independent t-test. #Chi square test. §Fisher's Exact test. *Significant

Table 11 HEART and Coronary artery calcium SCOREs Comparison according to affected vessels number (SVD vs MVD)

Variables	Single (N = 24)	Multiple (N = 39)	*p* value
HEARTSCORE			
HEARTSCORE	9.3 ± 6.6	9.3 ± 7.5	^0.999
HEART grades			
Low < 1%	0 (0.0%)	0 (0.0%)	#0.931
Moderate 1: < 5	4 (16.7%)	8 (20.5%)	
High ≥ 5: < 10	11 (45.8%)	17 (43.6%)	
Very high ≥ 10	9 (37.5%)	14 (35.9%)	
Coronary artery calcium SCORE			
CAC SCORE	117.5 ± 158.8	226.3 ± 268.3	^**0.047***
CAC grades			
No: Zero	2 (8.3%)	4 (10.3%)	§0.168
Mild 1: 100	11 (45.8%)	21 (53.8%)	
Mod 101: 400	5 (20.8%)	12 (30.8%)	
Severe > 400	6 (25.0%)	2 (5.1%)	

Bold: A p-value less than 0.05 (typically ≤ 0.05) is statistically significant

^Independent t-test. #Chi square test. §Fisher's Exact test. *Significant

Table 12 Diagnostic performance of HEART and Coronary artery calcium SCOREs in diagnosing multivessel affection

SCOREs	AUC	SE	*p* value	95% CI	Cut point
HEART	0.503	0.078	0.966	0.350–0.656	Not applicable
Coronary artery calcium	0.607	0.076	0.157	0.458–0.755	Not applicable

AUC: Area under the curve. SE: Standard error. CI: Confidence interval

Of this patient sample, 63 were males, 62 were hypertensive patients, 39 were diabetics, and 28 were smokers. The mean age was 56.6, the mean HeartScore was 6.9, and the mean CACS was 104.6

Regarding angiography results, 37 patients were normal, and 67 were diseased. Of the diseased group, 24 patients had OCAD and 39 had MVD (of whom ten patients had OCAD and 29 had non-OCAD).

Our research showed that even in people at moderate risk of experiencing a cardiovascular incident, CAD was a frequent condition. Even in the absence of typical symptoms of CAD, MSCT revealed coronary lesions in sixty-three percent of individuals in our

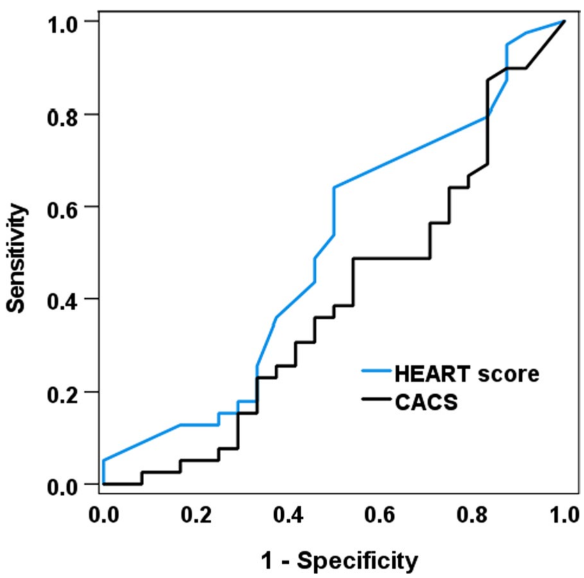

Fig. 2 ROC curve for HEART and Coronary artery calcium SCOREs in diagnosing multivessel affection

sample, with more than one-third having obstructive plaques (fifty percent lumen narrowing). Furthermore, although the percentage of studied cases with coronary lesions who were considered to be at low risk by HeartScore was 0, the percentage of studied cases with coronary lesions who were supposed to be at moderate risk by HeartScore was not low (thirty-seven percent). High-risk patients had rarely been free of coronary calcification.

That was concordant with the Egyptian registry of acute coronary syndromes run by Reda et al. 2021 who conducted a study of 3224 patients presented with ACS to evaluate risk factors. He reported that atherosclerotic CAD is a common problem in Egypt and the prevalence of premature ACS (existence of ACS before the age of fifty-five in males and sixty-five in females) was 51% (of the 3224 patients) [6].

That was in concordance with (Eyuboglu et al. 2020), who studied 400 and 52 hypertensive studied cases with an invasive coronary angiogram, Synergy between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (Syntax) score, and HeartScore and stated that the frequency of stenotic CAD and mean SYNTAX score, had been higher in moderate HeartScore group compared to studied cases with low HeartScore group [7].

In addition, (García-Lledó et al. 2016), who studied 582 Patients for the relation between risk-scoring models and coronary atherosclerosis detected on MSCT-CA, reported that coronary atherosclerosis is a common condition in individuals considered at low or intermediate risk of developing cardiovascular events [8].

Hypertension was the most common risk factor among the studied population. Statistically, it was significantly least prevalent in the normal group, with no differences among the Non-OCAD and the OCAD groups.

That was concordant with (Reda et al. 2021) study that reported that hypertension was the second commonest risk factor after abdominal obesity among Egyptian patients presenting with ACS [6].

Also (Eyuboglu et al. 2020) stated that the genesis and progression of coronary atherosclerosis, from endothelial dysfunction to symptomatic obstructive CAD, were consistently linked to elevated blood pressure. Hypertension was the most significant modifiable risk factor for these connections [7].

Smoking statistically was significantly less prevalent in the normal group than in the diseased group, with no differences among the non-OCAD and other groups.

HDL statistically was highest in the normal group with no differences among non-OCAD and OCAD groups.

These were concordant with Roth et al. (2021), who underwent a review article about the last 30-year global burden of cardiovascular disease and risk factors and concluded that high HDL was least associated with the

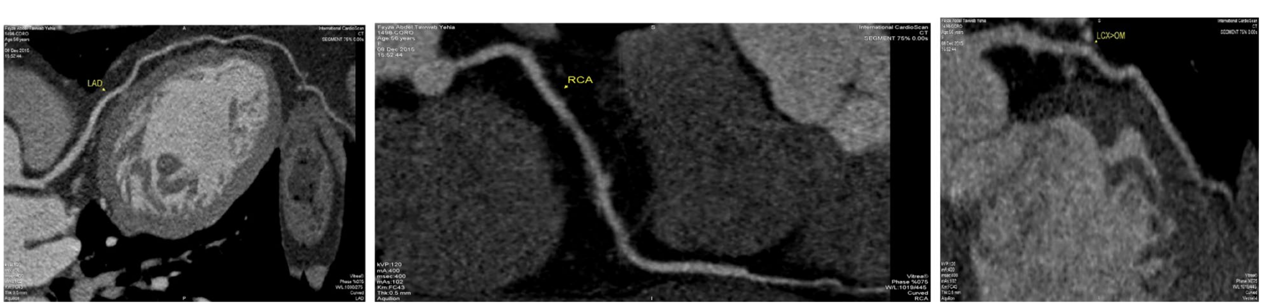

Fig. 3 Shown is a CT coronary angiogram of a female patient, 54-year old, hypertensive, dyslipidemic with negative family history for CAD. She experienced recurrent attacks of non-specific chest pain that occasionally radiate to her left arm. Resting ECG had no ischemic changes. Multislice Computed Tomography Coronary Angiogram (MSCT-CA) was requested to rule out significant coronary artery disease. HeartScore = 1 (moderate risk), MSCT shows normal coronaries

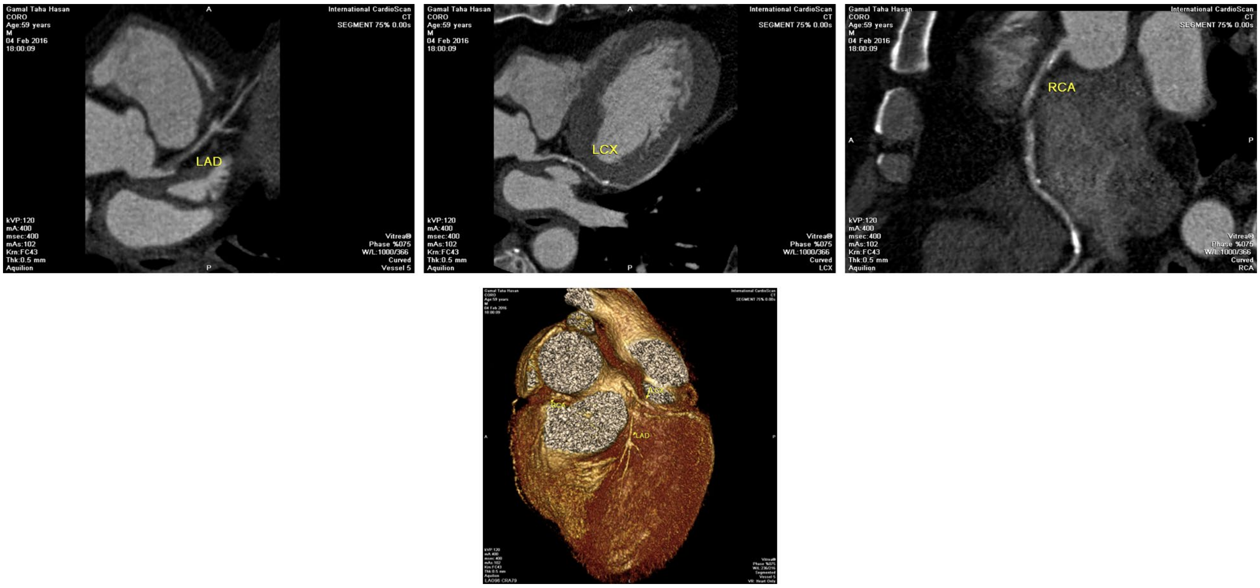

Fig. 4 Shown is a CT coronary angiogram of a 60-year-old male patient chronic heavy smoker, dyslipidemic, and hypertensive. For the previous few months, he experienced recurrent attacks of retro-sternal chest pain that were precipitated by effort and relieved by rest. Resting ECG had no ischemic changes. HeartScore = 24 (very high risk) and CACS = 215.MSCT-CA images show significant distal left main and significant proximal LAD. RCA and LCX are free from significant disease

disease and seemed protective while smoking was highly associated with it [9].

LDL levels showed no statically significant difference between normal and abnormal studied cases.

That was concordant with (Fujimoto et al. 2015), who studied asymptotic 2238 consecutive studied cases without known coronary artery disease who underwent coronary CT angiography and CACS to screen for CAD and reported that low-density lipoprotein cholesterol level, a well-known risk factor of cardiac event, was not predictor [10].

Our study showed that the ability of the HeartScore and the CACS to predict CAD (differentiate normal and diseased) was good with the best cutoff: HeartScore < 2 (for disease exclusion) and CACS > 6 (for disease inclusion). (receiver operating characteristic area below the curve is 0.8 for both).

70% of the patients in the normal coronary angiogram group had low and moderate HeartScore while 80% of the diseased group had at least a high HeartScore (if not very high).

This was in accordance with (García-Lledó et al. 2016), who studied 582 patients for the relation between risk-scoring models and coronary atherosclerosis detected on MSCT-CA and reported that studied cases with no lesions had much lower HeartScore risk than those with those diseased "any extent of coronary disease" and he reported that the ability of the HeartScore risk and CACS to predict CAD was accepted [8].

Breuckmann et al. (2016), who studied 618 patients, average age 75, presented with atrial fibrillation and chest pain, and after cardioversion, all had MSCT-CA and CACS, and he reported that calcium score might be used as a surrogate marker of risk detection in studied cases with chest pain [11].

In addition (Michaud et al. 2021) studied postmortem coronary artery calcium scores in cases of myocardial infarction and reported that 0 or low CACS on unenhanced Postmortem CT could not exclude ACAD and CACS rises significantly with years old (p value < 0.05) and did not find a relationship with sex, body weight, body mass index, and heart weight [12].

Williams et al., who studied 14,759 asymptomatic patients referred for assessment of CAC scanning using electron beam tomography and followed up for about six years, informed that mortality was positively associated with an increasing calcification [13].

Adelhoefer et al. 2020 worked through the CAC Consortium study and established that while studied cases with a CAC score higher than 1000 represent a distinct high-risk group (i.e., good positive) and on the other hand, a CAC score of Zero could be a reliable negative risk factor for developing cardiovascular disease and for disease-specific mortality, this could be explained by two reasons: first, the group studied was a random sample of asymptomatic healthy individuals, second, all had a mean follow up of 12 years [14].

Our study demonstrated that the HeartScore and the CACS couldn't differentiate between OCAD and Non-OCAD. (receiver operating characteristic area below the curve for HeartScore and CACS were 0.6 and 0.5, respectively, and there was not a static cutoff.)

This was in accordance with (García-Lledó et al. 2016), who reported that Although variations were negligible and even nonsignificant, the estimated risk of studied cases with obstructive lesions was higher than those with nonobstructive lesions [8].

That was in concordance with Cherukuri et al. (2021), who ran a review of the literature on CACS and reported that calcium score has low specificity for diagnosing obstructive CAD [15].

On the other hand, (Breuckmann et al. 2016) stated that CACS had been shown to discriminate among those studied cases with and without obstructive lesions. Still, that study was done on only 73 German patients who presented with chest pain which makes it already a higher risk group also statically cutoff value and negative predictive value were not provided. In addition, the definition of "obstructive" was not declared [11].

Our study demonstrated that both the HeartScore nor the CACS could not differentiate SVD and MVD. (receiver operating characteristic area below curve were 0.5 and 0.6 respectively).

That was concordant with (Gupta et al. 2022), who reviewed CAC and radiological assessment methods concerning plaque composition and stated that CAC scoring techniques do not take into account risk conferred by the number of lesions [16].

Also (Kamínek et al. 2015) studied 164 studied cases without known CAD, 123 (seventy-five percent) men and sixty (thirty-seven percent) women having type II diabetes, renal insufficiency, left ventricular dilatation, and other cardiac problems. The mean age of these patients was 61 ± 12 years. They reported that as regard recognition of multivessel CAD, the sensitivity of CAC was low (41%) [17].

Hence to conclude the answers of the three main research questions, ability of HeartScore and CACS to differentiate normal from diseased is moderate but their ability was poor to differentiate OCAD and Non-OCAD and also in differentiation between Single vessel disease and Multivessel Disease.

Limitations

Data are dependent on a single-center, observational research. The number of patients involved is considered small. Risk factors are dynamic (changes in the blood pressure level and minor alterations in lipids from one day to another can change studied cases' risks by a couple of percentage points, up or down). This renders detection of the score level from which it is proposed to start or change treatment very challenging. In addition, there is no long-term follow-up.

Conclusions

From a clinical point of view, our research suggests that HeartScore and CACS have moderate value in predicting CAD.

Abbreviations

CVD	Cardiovascular disease
CAD	Coronary Artery Disease
SCORE	Systematic COronary Risk Evaluation
CAC	Coronary Artery Calcium
CACS	Coronary Artery Calcium Score
ECG	Electrocardiograph
MSCT	Multi-Slice Computed Tomography
MSCT-CA	Multi-Slice Computed Tomography Coronary Angiogram
MVD	Multivessel Disease
OCAD	Obstructive Coronary Artery Disease
Non-OCAD	Non- Obstructive Coronary Artery Disease
PCI	Percutaneous Coronary Intervention
CABG	Coronary Artery Bypass Graft
HbA1c	Glycated hemoglobin
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
HDL	High-Density Lipoprotein
LDL	Low-Density Lipoprotein
ROC	Receiver Operating Curve
	Syntax Synergy between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery

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Author contributions

AE, AT, and YE conceived of the presented idea. AE and AT developed the theory and performed the computations. NO and YE verified the analytical methods. NO encouraged AE to collect the data and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript. All authors have read and approved the manuscript.

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Availability of data and materials

The authors confirm that all data supporting the finding of the study are available within the article and the raw data supporting the findings were generated and available at the corresponding author on request.

Declarations

Ethics approval and consent to participate

Informed written consents were taken from the patients, the study was approved by ethical committee of Ain Shams University, faculty of medicine (2018-11-17).

Consent for publication

All participants included in the research gave written consent to publish the data included in the study. Authors accepted to publish the paper.

Competing interests

The authors declare that they have no competing of interests.

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References

1. World Health Organization. June 11, 2021. "Cardiovascular Diseases (CVDs)". https://HeartScore.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)
2. https://HeartScore.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)
3. Piepoli MF, Hoes AW, Agewall S, Albus C, Brotons C, Catapano AL, Cooney MT, Corra U, Cosyns B, Deaton C, Graham I (2016) 2016 European Guidelines on cardiovascular disease prevention in clinical practice. Kardiologia Polska (Polish Heart Journal) 74(9):821–936
4. Kenfield SA, Stampfer MJ, Rosner BA, Colditz GA (2008) Smoking and smoking cessation in relation to mortality in women. JAMA 299:2037–2047
5. Willett WC, Manson JE, Stampfer MJ et al (1995) Weight, weight change, and coronary heart disease in women. Risk within the 'normal' weight range. JAMA 273:461–465
6. Reda A, Bendary A, Elbahry A, Farag E, Mostafa T, Khamis HEARTSCORE, Wadie M, Bendary M, Azeem BA, Salah R (2020) Prevalence of atherosclerosis risk factors in Egyptian patients with acute coronary syndrome: final data of the nationwide cross-sectional 'CardioRisk'project. J Public Health Africa 11(2):1368
7. Eyuboglu M, Karayakalı M, Karaman K, Arısoy A, Celık A (2020) Utility of Systematic Coronary Risk Evaluation (SCORE) system to predict coronary artery disease severity in low to moderate risk hypertensive patients undergoing elective coronary angiography. Arterial Hypertension 24(3):128–134
8. García-Lledó A, Moya-Mur JL, Ponz-Mir V, Novo-Aparicio S, Sanz-Barrio A, Álvarez-Sanz C, de Santiago-Nocito A (2016) Relationship among risk SCORE systems and coronary atherosclerosis determined by multislice computed tomography. Clin Cardiol 39(10):603–607
9. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, Barengo NC, Beaton AZ, Benjamin EJ, Benziger CP, Bonny A, Brauer M, Brodmann M, Cahill TJ, Carapetis J, Catapano AL, Chugh SS, Cooper LT, Coresh J, Criqui M, DeCleene N, Eagle KA, Emmons-Bell S, Feigin VL, Fernández-Solà J, Fowkes G, Gakidou E, Grundy SM, He FJ, Howard G, Hu F, Inker L, Karthikeyan G, Kassebaum N, Koroshetz HEARTSCORE, Lavie C, Lloyd-Jones D, Lu HS, Mirijello A, Temesgen AM, Mokdad A, Moran AE, Muntner P, Narula J, Neal B, Ntsekhe M, Moraes de Oliveira G, Otto C, Owolabi M, Pratt M, Rajagopalan S, Reitsma M, Ribeiro ALP, Rigotti N, Rodgers A, Sable C, Shakil S, Sliwa-Hahnle K, Stark B, Sundström J, Timpel P, Tleyjeh IM, Valgimigli M, Vos T, Whelton PK, Yacoub M, Zuhlke L, Murray C, Fuster V; GBD-NHLBI-JACC Global Burden of Cardiovascular Diseases Writing Group. Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019: Update From the GBD 2019 Study. J Am Coll Cardiol. 2020 Dec 22;76(25):2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010. Erratum in: J Am Coll Cardiol. 2021 Apr 20;77(15):1958–1959.
10. Fujimoto S, Kondo T, Kumamaru KK, Shinozaki T, Takamura K, Kawaguchi HEARTSCORE, Matsumori R, Hiki M, Miyauchi K, Daida HEARTSCORE, Rybicki FJ (2015) Prognostic value of coronary computed tomography (CT) angiography and coronary artery calcium SCORE performed before revascularization. J Am Heart Assoc 4(8):e002264
11. Breuckmann F, Olligs J, Hinrichs L, Koopmann M, Lichtenberg M, Böse D, Fischer D, Eckardt L, Waltenberger J, Garvey JL (2016) Coronary artery calcium as an independent surrogate marker in the risk assessment of patients with atrial fibrillation and an intermediate pretest likelihood for coronary artery disease admitted to a German chest pain unit. Clin Cardiol 39(3):157–164
12. Michaud K, Magnin V, Faouzi M et al (2021) Postmortem coronary artery calcium score in cases of myocardial infarction. Int J Legal Med 135:1829–1836
13. Williams M, Shaw LJ, Raggi P et al (2008) Prognostic value of number and site of calcified coronary lesions compared with the total SCORE. JACC Cardiovasc Imaging 1(1):61–69
14. Adelhoefer S, Uddin SMI, Osei AD, Obisesan OH, Blaha MJ, Dzaye O (2020) Coronary artery calcium scoring: new insights into clinical interpretation—lessons from the CAC Consortium. Radiol Cardiothorac Imaging 2(6):e200281
15. Cherukuri L, Birudaraju D, Budoff MJ (2021) Coronary artery calcium SCORE: pivotal role as a predictor for detecting coronary artery disease in symptomatic patients. Coron Artery Dis 32(6):578–585
16. Gupta A, Bera K, Kikano E, Pierce JD, Gan J, Rajdev M, Ciancibello LM, Gupta A, Rajagopalan S, Gilkeson RC (2022) Coronary artery calcium scoring: current status and future directions. Radiographics 42:947–967
17. Kamínek M, Metelková I, Budíková M, Koranda P, Henzlova L, Havel M, Sovová E, Kincl V (2015) Diagnosis of high-risk patients with multivessel coronary artery disease by combined cardiac gated SPET imaging and coronary calcium SCORE. Hell J Nucl Med 18(1):31–34

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