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CT coronary angiography assessment by coronary artery disease: Reporting and data system (CAD-RAD) as standardized lexicon

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Abstract
Background: Coronary computed tomographic angiography (CCTA) is increasingly used to examine coronary artery disease (CAD) due to its non-invasiveness, significant negative predictive value in ruling out major CAD, and recent technological advances. The purpose of this research was to compare CAD-RAD standardized vocabulary for CT coronary angiography ratings across institutions.
Methods: In this prospective research, 146 individuals of both sexes who were referred for examination by CT coronary angiography had either a clinical suspicion of or had surgery for CAD. Complete clinical history collection, physical examination, laboratory testing, coronary CT angiography, and clinical management follow-up were all standard procedures for all research participants.
Results: There was a significant relation between CAD RAD categories and age, hypertension, diabetes mellitus, hyperlipidemia, smoking, right coronary dominant (p<0.05). There was an insignificant relation between CAD RAD categories and sex, body mass index, left coronary dominant and co-dominant. There was a significant association between CAD RAD categories and coronary artery calcium score (P=0.001). There was a significant agreement between CAD- RAD correlation and follow up of patients (p<0.001).
Conclusions: The CAD-RADS score methodology was developed by professional cardiac imaging organizations that strongly advise using it as the standard reporting method for CCTA. It seems that the CAD-RADS scoring and reporting system is a good option for giving our patients a thorough and clinically useful reporting system, which might have a good effect on their treatment and diagnosis.

Keywords: CT coronary angiography, CAD, CAD-RAD, standardized lexicon

Introduction

Coronary computed tomographic angiography (CCTA) is increasingly being used as a precise method to assess coronary artery disease (CAD) since it is non-invasive and has a strong negative predictive value for ruling out serious CAD. This is owing to recent technical advancements [1].

Consequently, due to the absence of defined reporting patterns, there is a lack of consistency and uniformity in the reports. Consequently, this may lead to differences in how test findings are understood by the doctors who are treating or referring the patient, which can ultimately affect the quality of treatment provided to the patient [1]. Utilizing commonly understood language and terminology to provide a precise and accurate depiction of pathological alterations might facilitate the creation of standardized and structured reports that are readily comprehensible to the recipients [2]. Comparable methodologies have previously been implemented and validated in different domains, including breast, liver, and prostate imaging. These reporting systems facilitate the clear and efficient transmission of abnormal findings to the referring physicians, resulting in improved clinical decision-making [3, 4].

A standardized method for classifying CAD was introduced in 2016 with the publication of the CAD Reporting and Data System (CAD-RADS). Professionals from the American College of Radiology, the Society for Cardiovascular Computed Tomography (SCCT), and the North American Society for Cardiovascular Imaging (NASCI) worked together to develop this standardized reporting system for coronary computed tomography angiography (coronary CTA) [5].

The technique of classification is based on the highest degree of coronary artery stenosis seen on coronary computed tomography (CAD-RADS), which may range from 0 to 5. The CAD-RADS scoring system goes from 0 to 5. A score of 0 means that there is no plaque or stenosis, and a score of 5 means that at least one coronary channel is completely blocked. Results of coronary CTA with CAD-RADS could be communicated using modifiers. Modifiers like "non-diagnostic," "stent," "graft," and "HRP" are a part of the CAD-RADS classification system [5].
The aim of this work was to evaluate the role of CT coronary angiography assessment by CAD -RADS as standardized lexicon.

Patients and Methods
The subjects of this study were 146 male and female patients who were sent for CT coronary angiography due to a clinical suspicion of or prior surgery for CAD. After receiving approval from the Ethical Committee of Tanta University Hospitals in Tanta, Egypt, the study was carried out from November 2021 to November 2023. Patients were given the opportunity to offer their written informed consent.
Exclusion criteria included inability to sustain breath for more than 10 seconds, unstable angina necessitating rapid revascularization, heart rate over 70 beats per minute, orthopnea, renal impairment with a Creatinine level above 1.5 mg/dl, contrast allergy, pregnancy, and other medical disorders.
Each patient underwent a comprehensive evaluation, including medical history, physical examination, laboratory tests (renal function tests and lipid profile), and radiological tests (Echocardiographic examination was performed on each patient to determine the presence of resting segmental wall motion and assess the ejection fraction).

CT coronary angiography examination: A 320-row CT scanner (Aquilion one system, Toshiba Medical Systems, Tokyo, Japan) was used to examine the patients under study. All patients had multislice CT coronary angiography. Avoid consuming any meal within a 3 to 4-hour period before to the test. Refrain from consuming coffee or smoking for at least 12 hours before the examination. It is recommended to drink an adequate amount of water. Avoid engaging in any physical activity on the day of the examination. Remember to take all regular medicines as prescribed. Patients with a heart rate below 65 beats per minute were not given any drugs aimed at regulating heart rate. Patients with elevated heart rate were given oral β-blockers, as long as there were no contraindications. For patients with insufficient heart rate control, an additional 50 mg of metoprolol was administered after 60 minutes. For those who are unable to take B-blockers due to medical reasons, we administered Ivabradine orally at a dose of 5 mg one hour before to the scan. An 18G intravenous cannula was put into the patient's vein after controlling their heart rate in the patient preparation room. The patients were lying flat on the scanner table with their arms elevated above their heads. ECG electrodes were placed on the chest wall after cleaning the skin with alcohol. The ECG trace was continuously monitored to guarantee a strong R wave amplitude, which was utilized to initiate the scan. A breath holding test was conducted to prevent any distortions caused by respiratory motion artifacts. Sublingual Isosorbide dinitrate was administered at a dosage of 5 mg. A twin head powered automated injector was used to provide non-ionic contrast medium via an IV line. The patients were given a bolus of contrast medium, with a volume ranging from 60 to 90 mL, at a rate of 5 mL per second. This was then followed by the administration of 50 mL of saline solution. The scan was conducted using the bolus-tracking approach. Typically, the first stage of a CCTA evaluation was an anterior-posterior scout topogram. The maximum extent of the scanning field of vision (sFOV) was positioned slightly below the carina. To include the cardiac apex, the lower boundary of the small field of view (sFOV) should have been positioned just below the diaphragm. Typically, the subsequent stage in the CCTA process included doing a non-contrasted scan to assess calcium scoring. The bolus tracking approach was used to identify the moment that the contrast material reached the descending aorta at the level of the middle of the heart, using a trigger threshold of 230 HU. Sequential low-dose monitoring exams were conducted 10 seconds following the initiation of contrast medium injection. Once the trigger threshold was met, the scan began promptly following the order to hold one's breath. The acquisition settings include a gantry rotation period of 0.35 seconds and variable mA based on the patient's body habitus, ranging from 100 to 135 Kv. The volume scanning approach was used in conjunction with prospective ECG gating. Heart rate below 65 bpm was the standard for single heartbeat acquisition, with the scan window set at 70-80% of the RR interval. In patients with a heart rate exceeding 70 bpm, 2 heartbeat acquisition was conducted. The images were rebuilt with a slice thickness of 0.5 mm and an interval of 0.5 mm, using both smooth and sharp reconstruction kernels. The rebuilt pictures were transported to a workstation. Additionally, we acquired maximum intensity projections, using the 3D volume rendering approach, and performed curved multiplanar reconstruction. The coronary artery calcium score (CACS) is a measurement that objectively calculates the total of calcified plaque scores in all coronary arteries using the Agatston technique. To acquire an idea of the architecture of the coronary artery and the quality of the images, one may scroll through the stack of transverse images. A thorough evaluation of coronary anatomy is necessary to identify any irregularities in the coronary arteries. Curved multiplanar reformations (cMPR) and oblique interactive multiplanar reformations (MPR) were created utilizing 3D post-processing software. Coronary plaques were characterized as structures having an area of at least 1 mm2 located within and/or next to the artery lumen. These structures were easily discernible from the vessel lumen and were surrounded by pericardial tissue.
CAD-RADS N: If the research is not completely diagnostic and interpretable, segments that exhibit stenosis of less than 50% are seen. There is a possibility that there is obstructive CAD. Following the assessment of all coronary artery segments with a diameter greater than 1.5 mm for narrowings, four additional descriptors were included in the report as shown below [5]: N modifier (non-diagnostic): used when there is an uninterpretable coronary segment and a stenosis over 50% in a different segment. S modifier: The presence of at least one coronary stent was assessed, and the stent was examined for the occurrence of in-stent restenosis or occlusion. G modifier: indicates the existence of a minimum of one coronary artery bypass graft. HRP (high risk plaque) is a kind of coronary plaque that exhibits at

least two high-risk characteristics: Low attenuation plaque (LAP), Napkin ring sign, positive remodeling index (R.I), and Spotty calcification. Recommendations for Computer-Aided Design (CAD) and Radiation (RAD)The user's text is a reference to a specific point, indicated by the number 5. The CAD-RAD categories provide patient-specific therapy recommendations for both stable and acute chest pain. Patients categorized as CAD-RADS 0, 1, and 2 did not need further imaging, and other non-atherosclerotic causes of chest discomfort were taken into account. Patients categorized as CAD-RADS category 3 were advised to undergo stress testing, and if the results were positive, invasive coronary angiography (ICA) was taken into consideration. Patients with CAD-RADS classifications 4 and 5 were advised to undergo invasive coronary angiography. For groups 1-5, it was advised to undergo preventive treatment and make modifications to risk factors. Subspecialty referral: The accuracy of cardiological recommendations for assessing CAD was confirmed by comparing the findings with short-term follow-up data, namely the use of invasive coronary angiography (ICA).

Statistical analysis

The data were entered into the computer and analyzed using the IBM SPSS software application, namely Version 20.0. Quantitative data was conveyed using numerical and percentage values. The normality of the distribution of quantitative data was evaluated by the use of the Kolmogorov-Smirnov test. The data was characterized using descriptive statistics, including the range (minimum and maximum), mean, standard deviation, and median. The significance of the obtained results was evaluated using a significance level of 5%. The statistical analysis used the Chi-square test to compare different groups based on category data. The Monte Carlo modification was implemented when the projected count of cells was less than 5 for more than 20% of the instances.

Results

The mean age of the study population was 52.9 ± 10.64 years, 68 of them were male (46.6%) and 78 were female (53.4%). Approximately 54.1% were hypertensive, 34.9% were diabetic and 55.5% had hyperlipidaemia and 28% were smokers. According to CAD RAD categories as follow 17 cases were CAD RAD 0 (11.6%), 22 cases were CAD RAD1 (15.1%), 28 cases were CAD RAD 2 (19.2%), 34 cases were CAD RAD3 (23.3%), 34 cases were CAD RAD4 (23.3%), 11 cases were CAD RAD5 (7.5%). The most frequent modifier was modifier HRP found in 17 cases (11.6%) followed modifier G (8.2%), 10 cases with modifier S (7.5%), and finally 9 cases with modifier N (6.2%). Table 1

Table 1: Distribution of the studied cases according to demographics data, risk factors, coronary artery stenosis according to CAD RAD categories and CAD RAD Modifiers

		N=146
Age (years)		52.9 ± 10.64
≤ 60		112(76.7%)
>60		34(23.3%0
Sex	Male	68(46.6%)
	Female	78(53.4%)
Risk factors	Hypertensive	79(54.1%)
	Diabetic	51(34.9%)
	Hyperlipidemia	81(55.5%)
	Smoker	41(28%)
CAD RAD Categories	0	17(11.6%)
	1	22(15.1%)
	2	28(19.2%)
	3	34(23.3%)
	4	34(23.3%)
	4A	23(15.8%)
	4B	11(7.5%)
	5	11(7.5%)
CAD RAD Modifiers	N (Non diagnostic)	9(6.2%)
	HRP (High risk plaque)	17(11.6%)
	S (Stent)	10(7.5%)
	G(graft)	12(8.2%)

There was a significant relation between CAD RAD categories and age, HTN, DM, hyperlipidemia, smoking, right coronary dominant ($p<0.05$). There was an insignificant relation between CAD RAD categories and sex, BMI, left coronary dominant and co-dominant. Table 2

Table 2: Distribution of cases according to CAD RAD categories and their relation to Sociodemographic data, risk factors and coronary artery dominance of the patients

		CAD RAD 0 (n=17)	CAD RAD 1 (n=22)	CAD RAD 2 (n=28)	CAD RAD 3 (n=34)	CAD RAD 4 (n=34)	CAD RAD 5 (n=11)	P
Age (Years)		46.6±9.35	50.7±11.71	50.3±13.44	58.9±7.59	53.3±8.43	55.6±9.81	<0.001*
Sex	Male (n=68)	5(29.4%)	11(50.0%)	11(39.3%)	13(38.2%)	22(64.7%)	6(54.5%)	0.134
	Female (n=78)	12(70.6%)	11(50.0%)	17(60.7%)	21(61.8%)	12(35.3%)	5(45.5%)	
BMI		29.3±5.71	28.1±5.82	30.8±7.80	31.9±6.62	32.8±7.16	31.9±8.31	0.151
Risk factors								
HTN		4(23.5%	7(31.8%)	13(46.4%)	22(64.7%)	24(70.6%)	9(81.8%)	0.001*
DM		3(17.6%)	3(13.6%)	8(28.6%)	14(41.2%)	17(50.0%)	6(54.5%)	0.024*
Lipidemia		5(29.4%)	6(27.3%)	23(82.1%)	18(52.9%)	21(61.8%)	8(72.7%)	<0.001*
Smoking		1(5.9%)	7(31.8%)	5(17.9%)	9(26.5%)	16(47.1%)	3(27.3%)	0.037*
Coronary artery dominance								
Rt (n=95)		7(41.2%)	8(36.4%)	19(67.9%)	26(76.4%)	25(73.5%)	10(90.9%)	0.002*
Lt (n=23)		4(23.5%)	7(31.8%)	6(21.4%)	4(11.8%)	2(5.9%)	0(0.0%)	0.0578
CO (n=28)		6(35.3%)	7(31.8%)	3(10.7%)	4(11.8%)	7(20.6%)	1(9.1%)	0.136

There was a significant association between CAD RAD categories and coronary artery calcium score (P=0.001). Table 3

Table 3: Relation between coronary artery calcium score and CAD RAD categories

	CAD RAD 0 (n=17)	CAD RAD 1 (n=18)	CAD RAD 2 (n=26)	CAD RAD 3 (n=30)	CAD RAD 4 (n=31)	CAD RAD 5 (n=3)	P
CACS	0.0 (0.0 – 0.0)	3.0 (0.0 – 10.5)	24.5 (0.0 – 58.5)	61.5 (21.75 – 135.0)	172.0 (23.0 – 518.0)	356.0 (30.0 – 852.0)	**<0.001***
Zero (n=44)	17(100.0%)	8(44.4%)	10(38.5%)	4(13.3%)	5(16.1%)	0(0.0%)	
Minimal (n=9)	0(0.0%)	6(33.3%)	1(3.8%)	1(3.3%)	1(3.2%)	0(0.0%)	
Mild (n=41)	0(0.0%)	4(22.2%)	14(53.8%)	16(53.3%)	6(19.4%)	1(33.3%)	
Moderate (n=19)	0(0.0%)	0(0.0%)	1(3.8%)	8(26.7%)	9(29.0%)	1(33.3%)	
Severe (n=12)	0(0.0%)	0(0.0%)	0(0.0%)	1(3.3%)	10(32.3%)	1(33.3%)	

There is a significant agreement between CAD RAD correlation and follow up of patients (*p*<0.001). **Table 4**

Table 4: Agreement between CAD recommendations and follow up of the patients

	CAD RAD Recommendation		^{MC}p
	Agree	Disagree	
CAD RAD 0	15(88.2%)	2(11.8%)	<0.001*
CAD RAD 1	15(68.2%)	7(31.8%)	
CAD RAD 2	10(35.7%)	18(64.3%)	
CAD RAD 3	20(58.8%)	14(41.2%)	
CAD RAD 4	349(100%)	0(0.0%)	
CAD RAD 5	11(100%)	0(0.0%)	

Case 1: Male patient aged 52 years old with body mass index 30 complained of typical chest pain, referred to rule-out CAD. Figure 1

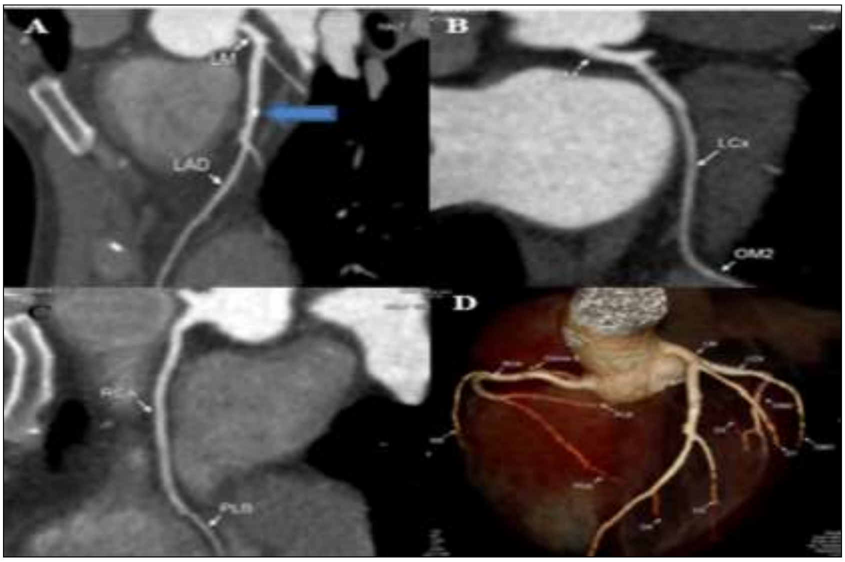

Fig 1: CT coronary angiography. (A): Curved MPR image showed an eccentric calcified plaque (blue arrow) at LAD mid segment & exerting minimal stenosis about 20% for about 6 mm, (B): Curved MPR image showed good opacification of LCx and OM branch, No coronary stenosis, (C): Curved MPR image showed good opacification of RCA, No coronary stenosis, (D): 3D VR showed normal coronary arteries

Case 2: Smoker hypertensive male patient aged 48 years old with body mass index 40 complained of exertional dyspnea, referred to rule-out CAD. Diagnosis, CAD RAD 4b/P3/V→ The patient underwent ICA that confirmed multi-vessels disease with mid LAD and RCA subtotal occlusion, moderate LM &sever LCx lesions for Coronary Artery Bypass Graft (CABG). Figure 2

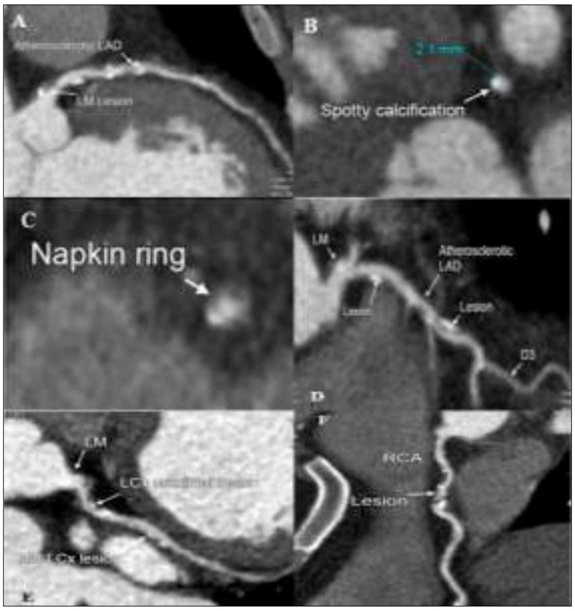

Fig 2: Coronary CT angiography reveals a short patent atherosclerotic left main artery with a mixed eccentric susceptible plaque at its distal segment, causing mild stenosis of about 50% across a length of about 4 mm. The cross-sectional images of LM lesions reveal vulnerable plaque characteristics, such as spotty calcification and the napkin ring sign. In image (D), a curved MPR image shows multiple mixed eccentric and concentric plaques in the proximal and mid-segments of the LAD, with positive remodeling. The largest plaque causes severe stenosis of approximately 70% in the mid-segment. In image (E), a curved MPR image shows a positively remodeled mixed eccentric plaque in the proximal segment of the LCx, causing moderate stenosis of about 60% over a length of 8 mm. Another mixed eccentric plaque is observed in the mid-segment of the LCx, causing mild stenosis of about 40% over a length of 9 mm. In image (F), a curved MPR image reveals multiple calcified and mixed eccentric plaques in the proximal and mid-segments of the RCA, resulting in moderate stenosis of about 50% in the proximal segment and severe stenosis of about 90% in the mid-segment.

Case3: Male patient aged 50 years old presented with body mass index 25 complained of typical chest pain referred to rule-out CAD. Diagnosis, CAD RAD 4A/P2 → the patient was refereed to ICA that showed proximal LAD lesion exerting about 90% stenosis and successful stenting of LAD was done. Figure 3

Fig 3: Coronary CT angiography: (A, B): Curved MPR images showing long atherosclerotic lesion about 30mm length, formed of mixed concentric plaques, extending from LAD ostium down to the end of its proximal segment showing severe stenosis about 90% opposite to D1 takeoff. LAD thereafter is patent and free of significant disease, (C): Curved MPR image showing patent dominant LCx ending by supplying patent posterior descending artery, LCx proximal segment showed calcified eccentric athermanous plaque exerting mild stenosis about 20%for about 6mm, (D): Curved MPR image showing average caliber patent non-dominant RCA, (E) Invasive coronary angiography showing sever proximal LAD stenosis.

Discussion

CAD has a substantial role in causing death and illness worldwide. Untreated CAD may lead to serious cardiovascular outcomes, including acute myocardial infarction, stroke, and death. These challenges often occur due to the steady development of atherosclerotic plaques, which impede blood flow in a particular region and result in stenosis [6].

It is now generally accepted that CCTA, a very successful imaging tool, is the first diagnostic test for CAD. The fact that it can identify coronary artery constriction with a negative predictive value of 90-99% and a high sensitivity makes it crucial for patient management [7].

The results are in line with those of ul Haiy *et al*. [8] and show a robust relationship between CAD-RAD categories and right coronary dominance. A correlation between the severity of CAD and dominance of the right coronary artery was shown in their investigation. More specifically, triple-vessel illness rather than single-vessel disease was more common in those with right dominance.

In line with Liaquat *et al*. [9] who reported a positive correlation between CACS and the degree of coronary artery stenosis, our research also identified a significant difference in coronary artery calcium score (p<0.001) amongst CAD RAD categories. The prevalence of severe coronary artery stenosis was shown to be low in persons whose CACS was either nonexistent or had a low value (≤100). The severity of coronary artery stenosis was directly correlated with the CACS in patients with a CACS higher than 100. Lee *et al*. [10] showed that even after taking clinical risk factors into consideration, there is a correlation between increased future risk and a CACS, higher CAD-RADS categories, and the existence of high-risk plaque.

The CAD-RADS categories may be enhanced by modifiers to indicate that a study is not completely assessable or inconclusive (N), or to highlight the presence of stents (S), grafts (G), and high-risk plaque (HRP). In our investigation, we observed 9 instances (6.2%) with modifier N, where a non-evaluable segment was present in the study, but there was >50% stenosis in another interpretable segment. These results are consistent with the study done by Morgan-Hughes *et al*. [11].

Sixty-Seven of patients were reported to have non-obstructive CAD (CAD RAD 0, 1 and 2) according to CAD RAD recommendation does not require further testing as there is a high probability that their chest pain symptoms are not due to ischemia and CTA is of high negative predictive value (9 and 20). According to previous results, Implementing these techniques may decrease the proportion of patients who undergo unneeded further examination. Consequently, this might enhance and streamline the experience of individuals with chest discomfort, while reducing expenses and potential hazards. Consistent with the findings of Boster *et al*. [12], their research provided support for The implementation of the CAD-RADS reporting template led to a decrease in the rates of further testing and referrals to cardiology for patients with non-obstructive coronary artery disease (CAD-RADS 1, 2). Therefore, CAD-RADS may influence subsequent testing in individuals for whom further testing can usually be postponed.

One of the drawbacks of our research was that it was conducted at a single location. Hence, it is necessary to get validation via bigger multi-center investigations. CAD-RADS is little used and unknown to a significant number of practitioners. A more extensive term of study is required to ensure thorough monitoring of patients, particularly those with non-obstructive lesions, due to the current time constraints. We conducted a study on a referral population that had a certain bias, since we specifically investigated symptomatic individuals who were referred for CCT due to certain indications. It is possible that the characteristics of the referral group contributed to the relatively high frequency of obstructive CAD.

Conclusions

The CAD-RADS score methodology was developed by professional cardiac imaging organizations that strongly advise using it as the standard reporting method for CCTA. It seems that the CAD-RADS scoring and reporting system is a good option for giving our patients a thorough and clinically useful reporting system, which might have a good effect on their treatment and diagnosis.

Conflict of Interest
Not available

Financial Support
Not available

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