# HEART and TIMI Scores Predict Severe Coronary Atherosclerosis in Patients With End-Stage Renal Disease

Trishna B. Parikh [1] , Moez Aziz [1] , Samuel P. Mackoff [1] , Gabriel M. Aisenberg [1]

1. Internal Medicine, University of Texas, John P and Kathrine G McGovern School of Medicine, Houston, USA

**Corresponding author:** Gabriel M. Aisenberg, gabriel.m.aisenberg@uth.tmc.edu

## Abstract

### Objectives

History, EKG, age, risk factors, and troponin (HEART) and thrombolysis in myocardial infarction (TIMI) risk calculators have been validated to predict the risk of subsequent acute coronary syndromes and in some studies, severe coronary atherosclerosis in patients with a concerning clinical history. Their performance in patients with end-stage renal disease (ESRD), a population with a high pretest probability for the condition, is unknown. We aimed to determine whether HEART and TIMI scores can predict severe coronary atherosclerosis in patients with end-stage renal disease (ESRD).

### Methods

A single-center retrospective cohort of admitted patients aged 18 years or older with ESRD on dialysis who underwent coronary angiography during admission (November 2010 to December 2017) was retrospectively reviewed. The outcome of coronary angiography was compared with the calculated HEART and TIMI scores at the time of presentation. Receiver operating characteristics and logistic regression models were used to determine optimal score cutoffs, score usefulness, and associations between outcomes, scores, and patient characteristics.

### Results

Among 231 patient encounters, the mean HEART and TIMI scores were 6±2 and 3±1 points, respectively. Patients with diabetes mellitus, those 65 years old and older, and those reported to have angina pectoris were more likely to show severe coronary artery disease (CAD) lesions. Optimal score cutoffs for determining severe coronary lesions were between six and seven (area under the curve (AUC)=0.754, confidence interval (CI): 0.682-0.826) and between three and four (AUC=0.716, CI: 0.640-0.792) for the HEART and TIMI scores, respectively.

### Conclusion

Similar to the general population, HEART and TIMI scores can predict severe coronary atherosclerosis in the complex ESRD population.

## Introduction

Cardiovascular disease accounts for 50% of mortality in patients on hemodialysis, with 52% of patients with end-stage renal disease (ESRD) suffering from an acute myocardial infarction within two years of hemodialysis initiation [1,2]. This is attributable to the high prevalence of traditional risk factors such as hypertension and diabetes mellitus and non-traditional risk factors such as vascular calcifications, endothelial dysfunction, and uremia [3-8]. Coronary angiography is the gold standard for diagnosing significant coronary atherosclerosis. While invasive techniques and other imaging modalities can be used to diagnose, risk stratify, and manage coronary artery disease (CAD) in patients with ESRD [4,6,7], acute coronary syndrome (ACS) is sometimes the initial presentation of CAD in this patient population [4]. The HEART and TIMI scores, frequently used to assist in clinical decision-making regarding ACS, use historical, clinical, and laboratory data to predict the likelihood of short-term major adverse cardiac events for patients presenting with non-ST segment elevation myocardial infarction [9-11]. However, the diagnostic evaluation of ACS in the ESRD patient population is a unique clinical challenge because patients may present without chest pain or anginal symptoms and may have abnormal electrocardiogram findings compared to the general population [3,7,8,12].

Though multiple studies have shown positive associations between the HEART and TIMI scores and the

angiographic extent of CAD and have been shown to be predictive of clinically significant CAD, none of these studies have specifically addressed patients with ESRD [13-21]. This study aims to determine whether the HEART and TIMI scores are adequate predictors of severe CAD in patients with ESRD.

## Materials And Methods

The study was undertaken at Lyndon B. Johnson Hospital, a county-based, safety-net, tertiary care center in Houston, Texas, after obtaining Institutional Review Board approval (HSC-MS-18-0047); patient consent requirements were waived. Using electronic medical records, a retrospective chart review was conducted on encounters dating from November 1, 2010, to December 31, 2017. Patients 18 years of age or older with ESRD on dialysis who were admitted to the hospital and underwent coronary angiogram during that admission were included. Those with incomplete or inaccurate records, ST-segment elevation on electrocardiogram, and outpatients with an elective indication for coronary angiogram were excluded.

From the examined medical records, the following characteristics were evaluated for each patient: age, gender, chest pain reported on presentation, whether that chest pain was interpreted as angina pectoris by the examining provider, a history of diabetes mellitus, hypertension, and hyperlipidemia, obesity, smoking history, family history of early CAD, prior coronary artery bypass graft surgery or percutaneous coronary intervention, a history of peripheral artery disease, stroke, and myocardial infarction, and dialysis schedule. The dialysis schedule was three times weekly or emergent, with the modality adopted among patients with no funding as described elsewhere [22].

We also recorded the highest troponin I level during the event (normal between 0 and 0.045 ng/mL) and description of the electrocardiogram, focusing on the presence of ST-segment depression, non-specific wave abnormalities, T-wave inversions, new Q waves, new right or left bundle branch blocks, and signs of left ventricular hypertrophy. HEART and TIMI scores were calculated based on these findings [9-11]. Coronary angiogram findings were recorded. We defined severe CAD as the presence of any stenotic lesion ≥70% without consideration of the number of affected coronary arteries or left main coronary artery disease. Patients with severe CAD were compared to those with milder or no lesions.

MedCalc Statistical Software version 18 (MedCalc Software, Ostend, Belgium) was utilized for the statistical analysis. Categorical variables were analyzed using the Fisher exact test, and discrete variables were analyzed using the Student t-test for unpaired samples. We calculated a logistic regression model including all the elements upon which the HEART and TIMI scores are built. Adjusted odds ratios (OR) are presented.

To assess the utility of the HEART and TIMI scores in delineating severe CAD, receiver operating characteristic curves were constructed for both scoring systems following existing models [23]. Areas under the curve (AUC) by polynomial regression were calculated for each receiver operating characteristic, and the optimal score cutoffs for each scoring system were determined by measuring the shortest distance from 100% sensitivity and 100% specificity. Confidence intervals were determined assuming a normal distribution. Patients with a history of percutaneous coronary intervention and coronary artery bypass graft were excluded when developing these models. A two-sided $p < 0.05$ was considered indicative of statistical significance.

## Results

Inclusion criteria were met in 231 patient encounters. Baseline characteristics are presented in Table *1*. The mean ± standard deviation HEART and TIMI scores were 6±2 and 3±1 points, respectively. In the cohort, 129 (56%) of patients had severe coronary obstructions and 102 (44%) had no or less than severe coronary obstructions. Of those who were found to have severe coronary lesions, 23 (18%) and 34 (26%) had a history of coronary artery bypass graft surgery or percutaneous coronary intervention, respectively.

| Variables | n (%) |
|---|---|
| Gender (male) | 125 (54) |
| Age (median and range) in years | 57 (28 to 82) |
| Chest pain (unspecified) | 138 (60) |
| Angina pectoris | 86 (37) |
| Previous PCI | 48 (21) |
| Previous CABG | 25 (11) |
| Diabetes mellitus | 167 (72) |
| Hypertension | 225 (97) |

| | |
|---|---|
| Hyperlipidemia | 51 (22) |
| Obesity | 47 (20) |
| Smoking | 79 (34) |
| Family history of CAD | 38 (16) |
| History of PAD, stroke, or MI | 107 (46) |
| Aspirin use within 7 days | 111 (48) |
| Scheduled dialysis (3 times/week) | 129 (55) |
| Emergent dialysis | 102 (45) |
| Elevated serum troponin I level | 179 (77) |
| Electrocardiographic abnormalities | |
|     Non-specific T wave abnormalities | 129 (56) |
|     New T wave inversion | 64 (28) |
|     Left ventricular hypertrophy | 60 (26) |
|     ST segment depression | 55 (24) |
|     New right bundle branch block | 13 (6) |
|     New Q wave | 13 (6) |
|     New left bundle branch block | 7 (3) |
| HEART score (average ± standard deviation) | 6 ± 2 |
| HEART score more than 6 | 96 (42) |
| TIMI score (average ± standard deviation) | 3 ± 1 |
| TIMI score more than 3 | 82 (35) |
| TIMI score more than 4 | 42 (18) |
| Coronary angiogram | |
|     Severe lesions | 129 (56) |
|     Less than severe lesions | 51 (22) |
|     No lesions | 51 (22) |
| Percutaneous coronary intervention | 90 (39) |

**TABLE 1: Baseline characteristics (n=231 patient encounters)**

PCI - percutaneous coronary intervention; CABG - coronary-artery bypass graft; CAD - coronary atherosclerotic disease; PAD - peripheral atherosclerotic disease; MI - myocardial infarction, TIMI - thrombolysis in myocardial infarction

The indication for obtaining a coronary angiogram was stated by the provider in 224 cases: evaluation of ACS was the most frequent (163 cases), followed by the determination of heart failure etiology (38 cases), elevated serum troponin I levels (11 cases), abnormal stress test (eight cases), and evaluation of aortic stenosis prior to valve replacement (four cases).

A comparison of the characteristics of patients with severe and non-severe or no coronary lesions is presented in Table 2. Patients with severe lesions were older, more frequently complained of angina, had a history of diabetes mellitus, had elevated serum troponin I levels and had ST-segment depression compared to those with non-severe or no lesions. HEART and TIMI scores were significantly higher among patients with severe CAD. Percutaneous coronary intervention was done following coronary angiography in 87 (67%) of patients with severe CAD.

| Variables | Severe lesions, n=129 | Less than severe or no lesions, n=102 | p-value |
|---|---|---|---|
| Gender (male), n (%) | 70 (54) | 55 (54) | 1.00 |
| Age (mean ± standard deviation) | 60 ± 10 | 52 ± 12 | <0.001 |
| Chest pain, n (%) | 81 (63) | 57 (56) | 0.34 |
| Angina, n (%) | 56 (43) | 30 (29) | 0.04 |
| Diabetes mellitus, n (%) | 106 (82) | 61 (60) | <0.001 |
| Hypertension, n (%) | 127 (98) | 98 (96) | 0.41 |
| Hyperlipidemia, n (%) | 31 (24) | 20 (20) | 0.52 |
| Obesity, n (%) | 24 (19) | 23 (23) | 0.51 |
| Smoking, n (%) | 47 (36) | 32 (31) | 0.48 |
| Family history of CAD, n (%) | 22 (17) | 16 (16) | 0.86 |
| History of PAD, stroke, or MI, n (%) | 66 (51) | 41 (40) | 0.11 |
| Aspirin use within 7 days, n (%) | 64 (50) | 47 (46) | 0.60 |
| Scheduled (versus emergent) dialysis | 65 (50) | 64 (63) | 0.06 |
| Elevated serum troponin I level | 108 (84) | 69 (68) | 0.005 |
| Electrocardiographic abnormalities | | | |
| Non-specific T wave abnormalities | 72 (56) | 57 (56) | 1.00 |
| New T wave inversion | 36 (28) | 28 (27) | 1.00 |
| Left ventricular hypertrophy | 33 (26) | 27 (26) | 0.88 |
| ST segment depression | 33 (26) | 8 (8) | <0.001 |
| New right bundle branch block | 10 (8) | 4 (4) | 0.27 |
| New Q wave | 8 (6) | 5 (5) | 0.78 |
| New left bundle branch block | 3 (2) | 4 (4) | 0.70 |
| HEART score (average ± standard deviation) | 7 ± 2 | 5 ± 2 | <0.001 |
| HEART score more than 6 | 73 (56) | 23 (23) | <0.001 |
| TIMI score (average ± standard deviation) | 4 ± 1 | 2 ± 1 | <0.001 |
| TIMI score more than 3 | 61 (47) | 21 (21) | <0.001 |
| TIMI score more than 4 | 36 (28) | 6 (6) | <0.001 |

**TABLE 2: Comparison of patients with severe coronary lesions and those with less than severe lesions or normal coronary angiograms**

CAD - coronary atherosclerotic disease; PAD - peripheral atherosclerotic disease; MI - myocardial infarction, TIMI - thrombolysis in myocardial infarction

The logistic regression model found that patients with diabetes mellitus (OR 4.00, 95% confidence interval (CI) 1.80-8.86, p<0.001), those 65 years old and older (OR 3.33, 95% CI 1.40-7.91, p=0.006), and those reported to have angina pectoris (OR 2.55, 95% CI 1.20-5.45, p=0.01) were more likely to show severe CAD lesions.

As shown in Figure 1, the optimal score cutoff for delineating severe coronary lesions was between six and seven for the HEART score and between three and four for the TIMI score. The AUC for assessing the overall usefulness of the HEART and TIMI scores in detecting severe coronary artery lesions was 0.754 (CI: 0.682-0.826) and 0.716 (CI: 0.640, 0.792), respectively. Sensitivies for HEART and TIMI scores at optimum are 67.44% and 73.64%, respectively. Specificities for HEART and TIMI scores at optimum are 68.62% and

55.88%, respectively.
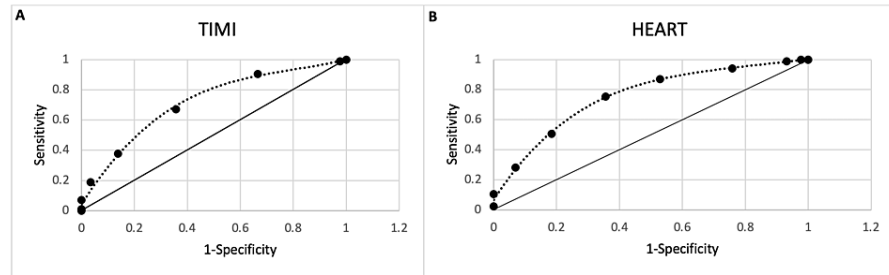


**FIGURE 1: Receiver operating characteristic curves for the TIMI score (A) and HEART score (B), estimated using polynomial regression**

TIMI - thrombolysis in myocardial infarction

## Discussion

Our study demonstrates that a HEART score between six and seven and a TIMI score between three and four are predictive of severe coronary artery lesions in patients suffering from ESRD, with AUCs demonstrating acceptable test utility of 0.754 and 0.716, respectively. The predictors used in calculating the HEART and TIMI scores have been extensively studied in the general population [24-26]; however, the specificity of these predictors may be diminished in the ESRD population [5]. For example, while troponin levels are predictive of cardiovascular events, cardiovascular mortality, and angiographic coronary obstructions in the general population, those levels have limited specificity in patients with ESRD because other cardiac and non-cardiac etiologies contribute to persistent troponin elevation [7-8]. Additionally, left ventricular hypertrophy, anemia, and electrolyte abnormalities are common in this patient population, increasing the likelihood of electrocardiogram abnormalities at baseline [8]. Non-specific electrocardiogram changes, left bundle branch block, and other findings are more prevalent among patients on dialysis with acute myocardial infarction; ST-segment elevation and Q wave changes are more common among non-dialysis patients, while ST-segment depressions are comparable [12]. These differences present a clinical challenge to the physician trying to apply criteria established for the general population to a high-risk ESRD patient population without additional data.

While there is considerable variability in study design, the HEART and TIMI scores have been shown to correlate with angiographic CAD [13-21]. To the best of our knowledge, only a few studies have evaluated the predictive value of the HEART score for obstructive CAD, with variable results [14,27,28]. However, the TIMI score predictive value has been more extensively studied [13-21]. Our findings closely align with those arising from the general population admitted to the hospital with non-ST segment elevation acute coronary syndrome in terms of AUC [13,16,28].

However, given the variability of definitions of obstructive CAD, inclusion criteria, and methods among studies, comparing the optimal TIMI score cutoffs from our study to those of the general population proved challenging. While a few studies have deemed that a TIMI score >4 has been associated with single vessel obstructive CAD [18] and a TIMI score ≤4 with normal or non-obstructive CAD [19], this score cutoff was not internally validated by computing a receiver operating characteristic or C-statistic. Interestingly, one study found a TIMI score >2 to be the optimal score cutoff in the general population; however, differences in the definition of obstructive CAD and exclusion of patients with a proven non-cardiac etiology of chest pain may explain the lower cutoff score [16]. This study also did not specify patients with ESRD.

To our knowledge, our study is the first to identify an optimal cutoff in predicting severe CAD as defined by an anatomic lesion >70% stenosis in a specific, medically complex population. However, the study has limitations. This retrospective study was done at a single center, safety-net hospital, hindering the generalizability of its findings. However, the patients at safety-net hospitals have been shown to have underutilization of invasive coronary angiography and interventions, as well as worse outcomes, compared to patients at non-safety-net hospitals presenting with an acute myocardial infarction [29]. Therefore, our findings may be more applicable to similar facilities. Additionally, the small sample size may limit statistical power. Data collection through retrospective chart review relied on the characterization of the patient's presentation by the treating physician (for example, angina pectoris). Moreover, we did not stratify the severity of CAD by the number of affected coronary arteries or involvement of the left main coronary artery. We also strictly used coronary angiography and did not consider findings from other diagnostic tools, such as computerized tomography. Finally, we did not assess for long-term outcomes which have been reported with variable results [8]. It is noteworthy that, as mentioned above, the subset of patients with end-stage renal disease is subject to a higher risk of coronary events than the general population, regardless of the

present angiographic findings. Thus, we emphasize the need for secondary prevention, including guideline-directed dietary, lifestyle, and pharmacologic recommendations.

## Conclusions

Our study establishes that, as previously described for the general population, a HEART score between six and seven, and a TIMI score between three and four adequately predict the presence of severe CAD in the ESRD patient population, presumably at higher risk for that outcome. These findings may help clinicians select the right candidates for coronary angiogram, which is especially relevant in areas with limited resources.

## Additional Information

### Disclosures

**Human subjects:** Consent was obtained or waived by all participants in this study. University of Texas Committee for the Protection of Human Subjects issued approval HSC-MS-18-0047. The study was undertaken at Lyndon B. Johnson Hospital, a county-based, safety-net, tertiary care center in Houston, Texas, after obtaining Institutional Review Board approval (HSC-MS-18-0047); patient consent requirements were waived. . **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

## References

1. Collins AJ: Cardiovascular mortality in end-stage renal disease . Am J Med Sci. 2003, 325:163-7. 10.1097/00000441-200304000-00002
2. Annual Data Report: Atlas of End-Stage Renal Disease in the United States . (2014). Accessed: May 27, 2023: https://usrds-adr.niddk.nih.gov/2022/end-stage-renal-disease/6-mortality.
3. Aoki J, Ikari Y: Cardiovascular disease in patients with end-stage renal disease on hemodialysis . Ann Vasc Dis. 2017, 10:327-37. 10.3400/avd.ra.17-00051
4. Bhatti NK, Karimi Galougahi K, Paz Y, et al.: Diagnosis and management of cardiovascular disease in advanced and end-stage renal disease. J Am Heart Assoc. 2016, 5:10.1161/JAHA.116.003648
5. Cozzolino M, Mangano M, Stucchi A, Ciceri P, Conte F, Galassi A: Cardiovascular disease in dialysis patients . Nephrol Dial Transplant. 2018, 33:iii28-34. 10.1093/ndt/gfy174
6. Dilsizian V, Gewirtz H, Marwick TH, Kwong RY, Raggi P, Al-Mallah MH, Herzog CA: Cardiac imaging for coronary heart disease risk stratification in chronic kidney disease. JACC Cardiovasc Imaging. 2021, 14:669-82. 10.1016/j.jcmg.2020.05.035
7. Hakeem A, Bhatti S, Chang SM: Screening and risk stratification of coronary artery disease in end-stage renal disease. JACC Cardiovasc Imaging. 2014, 7:715-28. 10.1016/j.jcmg.2013.12.015
8. Poli FE, Gulsin GS, McCann GP, Burton JO, Graham-Brown MP: The assessment of coronary artery disease in patients with end-stage renal disease. Clin Kidney J. 2019, 12:721-34. 10.1093/ckj/sfz088
9. Fanaroff AC, Rymer JA, Goldstein SA, Simel DL, Newby LK: Does this patient with chest pain have acute coronary syndrome?: the Rational Clinical Examination systematic review. JAMA. 2015, 314:1955-65. 10.1001/jama.2015.12735
10. Pollack CV, Jr, Sites FD, Shofer FS, Sease KL, Hollander JE: Application of the TIMI risk score for unstable angina and non-ST elevation acute coronary syndrome to an unselected emergency department chest pain population. Acad Emerg Med. 2006, 13:13-8. 10.1197/j.aem.2005.06.031
11. Van Den Berg P, Body R: The HEART score for early rule out of acute coronary syndromes in the emergency department: a systematic review and meta-analysis. Eur Heart J Acute Cardiovasc Care. 2018, 7:111-9. 10.1177/2048872617710788
12. Herzog CA, Littrell K, Arko C, Frederick PD, Blaney M: Clinical characteristics of dialysis patients with acute myocardial infarction in the United States: a collaborative project of the United States Renal Data System and the National Registry of Myocardial Infarction. Circulation. 2007, 116:1465-72. 10.1161/CIRCULATIONAHA.107.696765
13. Barbosa CE, Viana M, Brito M, et al.: Accuracy of the GRACE and TIMI scores in predicting the angiographic severity of acute coronary syndrome. Arq Bras Cardiol. 2012, 99:818-24. 10.1590/s0066-782x2012005000080
14. Cedro AV, Mota DM, Ohe LN, Timerman A, Costa JR, Castro LS: Association between clinical risk score (HEART, GRACE and TIMI) and angiographic complexity in acute coronary syndrome without ST segment elevation. Arq Bras Cardiol. 2021, 117:281-7. 10.36660/abc.20190417
15. Garcia S, Canoniero M, Peter A, de Marchena E, Ferreira A: Correlation of TIMI risk score with angiographic severity and extent of coronary artery disease in patients with non-ST-elevation acute coronary syndromes. Am J Cardiol. 2004, 93:813-6. 10.1016/j.amjcard.2003.12.015
16. Hammami R, Jdidi J, Mroua F, Kallel R, Hentati M, Abid L, Kammoun S: Accuracy of the TIMI and GRACE scores in predicting coronary disease in patients with non-ST-elevation acute coronary syndrome. Rev Port Cardiol (Engl Ed). 2018, 37:41-9. 10.1016/j.repc.2017.05.012
17. İşcanlı MD, Metin Aksu N, Evranos B, Aytemir K, Özmen MM: Comparison of TIMI and Gensini score in patients admitted to the emergency department with chest pain, who underwent coronary angiography. Med Sci Monit. 2014, 20:343-9. 10.12659/MSM.889600

18. Lakhani MS, Qadir F, Hanif B, Farooq S, Khan M: Correlation of thrombolysis in myocardial infarction (TIMI) risk score with extent of coronary artery disease in patients with acute coronary syndrome. J Pak Med Assoc. 2010, 60:197-200.
19. Mahmood M, Achakzai AS, Akhtar P, Zaman KS: Comparison of the TIMI and the GRACE risk scores with the extent of coronary artery disease in patients with non-ST-elevation acute coronary syndrome. J Pak Med Assoc. 2013, 63:691-5.
20. Mega JL, Morrow DA, Sabatine MS, et al.: Correlation between the TIMI risk score and high-risk angiographic findings in non-ST-elevation acute coronary syndromes: observations from the Platelet Receptor Inhibition in Ischemic Syndrome Management in Patients Limited by Unstable Signs and Symptoms (PRISM-PLUS) trial. Am Heart J. 2005, 149:846-50. 10.1016/j.ahj.2004.08.042
21. Roy SS, Abu Azam ST, Khalequzzaman M, Ullah M, Arifur Rahman M: GRACE and TIMI risk scores in predicting the angiographic severity of non-ST elevation acute coronary syndrome. Indian Heart J. 2018, 70:S250-3. 10.1016/j.ihj.2018.01.026
22. Cervantes L, Richardson S, Raghavan R, et al.: Clinicians' perspectives on providing emergency-only hemodialysis to undocumented immigrants: a qualitative study. Ann Intern Med. 2018, 169:78-86. 10.7326/M18-0400
23. Kirsch B, Aziz M, Kumar S, et al.: Wells score to predict pulmonary embolism in patients with coronavirus disease 2019. Am J Med. 2021, 134:688-90. 10.1016/j.amjmed.2020.10.044
24. deFilippi C, Wasserman S, Rosanio S, et al.: Cardiac troponin T and C-reactive protein for predicting prognosis, coronary atherosclerosis, and cardiomyopathy in patients undergoing long-term hemodialysis. JAMA. 2003, 290:353-9. 10.1001/jama.290.3.353
25. Khan NA, Hemmelgarn BR, Tonelli M, Thompson CR, Levin A: Prognostic value of troponin T and I among asymptomatic patients with end-stage renal disease: a meta-analysis. Circulation. 2005, 112:3088-96. 10.1161/CIRCULATIONAHA.105.560128
26. Sponder M, Fritzer-Szekeres M, Marculescu R, Litschauer B, Strametz-Juranek J: A new coronary artery disease grading system correlates with numerous routine parameters that were associated with atherosclerosis: a grading system for coronary artery disease severity. Vasc Health Risk Manag. 2014, 10:641-7. 10.2147/VHRM.S68919
27. Kolff AQ, Bom MJ, Knol RJ, van de Zant FM, van der Zee PM, Cornel JH: Discriminative power of the HEART score for obstructive coronary artery disease in acute chest pain patients referred for CCTA. Crit Pathw Cardiol. 2016, 15:6-10. 10.1097/HPC.0000000000000062
28. Shin YS, Ahn S, Kim YJ, Ryoo SM, Sohn CH, Seo DW, Kim WY: Identifying low-risk chest pain in the emergency department: obstructive coronary artery disease and major adverse cardiac events. Am J Emerg Med. 2020, 38:1737-42. 10.1016/j.ajem.2020.06.019
29. Bashar H, Bharadwaj A, Matetić A, et al.: Invasive management and in-hospital outcomes of myocardial infarction patients in United States safety-net hospitals. Cardiovasc Revasc Med. 2023, 49:7-12. 10.1016/j.carrev.2022.11.006