CLINICAL STUDY

Comparison of six decision aid rules for diagnosis of acute myocardial infarction in elderly patients presenting to the emergency department with acute chest pain

HRECKO Juraj, DOKOUPIL Jiri, PUDIL Radek

The 1st Department of Internal Medicine – Cardioangiology, Medical Faculty of Charles University in Hradec Králové and University Hospital Hradec Králové, Hradec Králové, Czech Republic. **juraj.hrecko@fnhk.cz**

ABSTRACT

OBJECTIVE: This study aimed to evaluate the accuracy and effectiveness of different strategies for the diagnosis of acute myocardial infarction (AMI) in the elderly in real-life clinical practice.

METHODS: Patients older than 70 years presenting to the emergency department with chest pain were included. The performance of six decision aid rules (T-MACS, HEART, EDACS, TIMI, GRACE, and ADAPT) and solo troponin T strategy for diagnosing AMI was evaluated by calculating sensitivity, specificity, odds ratios, negative and positive predictive values.

RESULTS: A total of 250 patients, with a mean age of 78.5 years, were enrolled. Forty-eight patients (19.2 %) had an acute myocardial infarction in a 30 day follow-up period. The sensitivity for ruling-out AMI was 100 % for T-MACS, HEART, and ADAPT; 97.9 % for EDACS, 93.8 % for TIMI, and 81.3 % for GRACE and solo TnT strategy. For ruling-in AMI, the specificity was 97.5 % for T-MACS, 95 % for TIMI, 83.2 % for HEART, 81.7 % for GRACE, and 46 % for ADAPT.

CONCLUSION: T-MACS decision aid had the best performance for rule-out and rule-in diagnostics of AMI. Risk stratification of patients with suspected acute coronary syndrome based on decision aid rules can be used in real-life practice, even in the population of the elderly *(Tab. 6, Fig. 1, Ref. 17).* Text in PDF *www.elis.sk*

KEY WORDS: decision aid rules, acute myocardial infarction, elderly.

Abbreviations: ACS – acute coronary syndrome; AUC – area under the curve; ADAPT – Accelerated Diagnostic Protocol to Assess Patients With Chest Pain Symptoms; AMI – acute myocardial infarction; CABG – coronary artery bypass graft surgery; CI – confidence interval; EDACS – Emergency Department Assessment of Chest Pain Score; ECG – electrocardiogram; ESC – European Society of Cardiology; HEART – HEART (History, ECG, Age, Risk factors, and Troponin concentration) score; hs-TnT – high-sensitive Troponin T; IQR – interquartile range; MACE – major adverse cardiac events; NPV – negative predictive value; LR+ – positive likelihood ratio; LR– – negative likelihood ratio; OR – odds ratio; PCI – percutaneous coronary intervention; PPV – positive predictive value; ROC – receiver operator characteristics; TIMI – Thrombolysis in Myocardial Infarction risk score for unstable angina/ non-ST elevation myocardial infarction; T-MACS – Troponin-only Manchester Acute Coronary Syndrom Score Decision Aid Rule; TnT – troponin T.

The 1st Department of Internal Medicine – Cardioangiology, Medical Faculty of Charles University in Hradec Králové and University Hospital Hradec Králové, Czech Republic

Address for correspondence: Juraj HRECKO, MD, The 1st Department of Internal Medicine – Cardioangiology, Medical Faculty of Charles University in Hradec Králové and University Hospital Hradec Králové, Sokolská 581, CZ-500 05 Hradec Králové, Czech Republic.
Phone: +420.722.191997, Fax: +420.495.832006

Introduction

Chest pain is a common reason for the visit to the emergency department. A broad spectrum of underlying causes can be masked in this symptom. A spectrum of examination possibilities can be used to reach accurate diagnosis – starting with an evaluation of the patient's history, rapid assessment of symptoms and physical findings, electrocardiography, cardiac imaging, and biochemical analysis. Typical chest pain with persisting ST-segment elevation on an electrocardiogram is an unquestionable indication for emergent coronary angiography. However, an approach to the chest pain patient without ST-segment elevation is not so clear. A misdiagnosis of such diseases as acute myocardial infarction (AMI), pulmonary embolism, or acute aortic dissection could lead to severe life harm or even death.

Current guidelines for the management of acute coronary syndromes without ST-segment elevation recommend serial troponin testing (1). The introduction of high-sensitive troponin assays resulted in the higher sensitivity of this approach with earlier de-

Tab. 1. Summary of chosen decision aids – evaluated variables, clinical outcomes in original trials, risk stratification, and value of age for prediction of ACS/ MACE.

Protocol	T-MACS	HEART	EDACS	TIMI	GRACE	ADAPT
Variables	ECG ischemia	History	Age	Age ≥ 65	Age	Abnormal troponin at 0 or 2 hours
	Crescendo angina	ECG	Sex	≥ 3 risk factors for CAD	Heart Rate	Ischemic changes on ECG
	Pain radiating to shoulder	Age	Known CAD or ≥ 3 risk factors for CAD	Know CAD	Systolic Blood Pressure	Age ≥ 65
	Pain associated with vomiting	Risk factors	Diaphoresis	ASA use	Creatinine	≥ 3 risk factors for CAD
	Sweating observed	Initial Troponin	Pain radiating to arm, shoulder, neck, or jaw	Severe angina	Cardiac Arrest at Admission	Know CAD
	Hypotension		Pain worsened with inspiration	ECG ischemic changes	ST-segment deviation	ASA use
	Initial Troponin		Pain reproduced by palpation	Positive cardiac marker	Abnormal cardiac enzymes	Severe angina
					Killip class	
Outcomes	30 days ACS or MACE[a]	6 weeks MACE[a]	30 days MACE[b]	14 days MACE[a]	6 months death	30 days MACE[b]
Risk stratification	Very low risk (0–1%)	Low risk (score 0–3)	Low risk (score <16)	Low risk (score 0–1)	Low risk (< 109 pts)	Low risk (normal TnT, normal ECG and TIMI 0)
	Low risk (2–4%)	Moderate risk (score 4–6)	Not-low risk (score ≥ 16)	Moderate risk (score 2–5)	Medium risk (109–140 pts)	Intermediate (normal TnT, normal ECG, and TIMI 1)
	Moderate risk (5–94%)	High risk (score >6)		High risk (score 6–7)	High risk (> 140 pts)	High (abnormal TnT or abnormal ECG, any TIMI)
	High risk (>94%)					
Value of age on total score	none*	age ≥ 65: 2 pts	70 years: 12 pts	age ≥65: 1 pt	70–79 years: 73 pts	age ≥ 65 counts for TIMI score ≥ 1
			71–75 years: 14 pts			
			76–80 years: 16 pts		> 79 years: 91 pts	
			81–85 years: 18 pts			
			≥ 86 years: 20 pts			
Maximum score	100%	10 points	38 points	7 points	340 points	NA

ACS – acute coronary syndrome; AIM – acute myocardial infarction; ASA – acetylsalicylic acid; CAD – coronary artery disease; ECG – electrocardiogram; MACE – major adverse cardiac event; MACE[a] – a composite of acute myocardial infarction, myocardial revascularization, and all-cause death (applicable for T-MACS, HEART, and TIMI); MACE[b] – a composite of acute myocardial infarction, myocardial revascularization, cardiac death, cardiogenic shock, cardiac arrest, ventricular arrhythmia and high-grade atrioventricular block (applicable for EDACS and ADAPT); NA – not applicable; pts – points in the scoring system; * age is not involved in the calculation

tection of minimal myocardial necrosis. However, we must not forget that even a slight myocardial injury can be caused by many non-coronary cardiac states, non-cardiac, or even physiological conditions. This strategy contributes to higher costs, staff over-occupancy, and prolonged stay at emergency departments, leading to adverse patient outcomes such as increased morbidity and mortality (2).

Older patients frequently have atypical symptoms, which prolongs the time to correct diagnosis and proper treatment. Visual and auditory impairment and cognitive deterioration contribute to delayed arrival to the emergency department and even misinterpretation of symptoms by the patient himself. Patients at high age, in many cases, have more associated diseases, which independently increase the risk for coronary events. Comorbidities, associated states, medication, and their interactions may also affect electrocardiographical findings and troponin levels.

Many protocols were tested to make the diagnostic process efficient. This study evaluates six decision aid rules: T-MACS, HEART, EDACS, TIMI, GRACE, and ADAPT; and a strategy of the decision based only on a single troponin T value with a cut-off at 95th percentile upper reference limit (solo TnT strategy). These six risk stratification scores were validated in large multicentre trials and had shown great sensitivity and negative predictive value, especially in the ability to rule-out acute myocardial infarction. Using these decision aids is not common in our region, so we decided to evaluate their accuracy and effectiveness in everyday clinical practice. We chose the selected population of the elderly because they are often neglected in clinical trials, and the proper diagnostics of acute myocardial infarction in this group remains a challenge.

Methods

Study design and participants

The study was performed at a single centre – University Hospital in Hradec Králové, which serves as a regional hospital for a district of around 160 thousand inhabitants. We enrolled patients examined in the emergency department of our hospital for one year (from January 1 to December 31, 2016). The ethical committee of University Hospital approved the study. The trial was conducted following the principles of the Declaration of Helsinki. The inclusion criteria were chest pain as a dominant symptom, age above 70 years, twelve lead electrocardiogram (ECG) recorded, and at least one blood sample for high sensitive troponin T (hs-TnT) analyzed. We excluded patients with apparent ST-segment elevations on the ECG (these were recommended for acute coronary angiography) and those unable to follow up.

Data collection

Demographic data, chest pain characteristics, ECG findings, past medical history, and hs-TnT concentrations for every patient were gathered from the hospital information

Tab. 2. Baseline characteristics of included patients.

Baseline characteristics	
Total (n)	250
Age, median (IQR)	78 (73–84)
Men, n (%)	126 (50.4)
Personal history	
Coronary artery disease, n (%)	106 (42.4)
Peripheral artery disease, n (%)	23 (9.2)
TIA/ stroke, n (%)	25 (10.0)
Dyslipidaemia, n (%)	146 (58.4)
Hypertension, n (%)	209 (83.6)
Diabetes mellitus, n (%)	73 (29.2)
Current smoking, n (%)	73 (29.2)
Chest pain characteristics	
Typical angina, n (%)	97 (38.8)
Propagation to arm, n (%)	40 (16.0)
Relief after nitrates, n (%)	62 (24.8)
Nausea/ vomiting, n (%)	24 (9.6)
Sweating observed, n (%)	23 (9.2)
Produced by palpation, n (%)	49 (19.6)
Worsened with inspiration, n (%)	26 (10.4)
ECG and biochemical findings	
No new ischemic ECG changes, n (%)	183 (73.2)
hs-TnT at arrival ng/L, median (IQR)	16 (10–25)
creatinine μmol/L, median (IQR)	93 (80–112)
CKD-EPI eGFR ml/min/1.73m2, median (IQR)	59.4 (46.2–70.2)
Decision aids average score for the whole population	
T-MACS, median (IQR)	6% (3–26.8%)
HEART, median (IQR)	5 (4–7)
EDACS, median (IQR)	20 (16–23)
TIMI, median (IQR)	3 (2–4)
GRACE, median (IQR)	116 (102–136)
Others	
Hospital admissions, n (%)	99 (39.6)
Coronary angiography performed, n (%)	39 (15.6)
Revascularization (CABG/PCI), n (%)	28 (11.2)
Acute myocardial infarction, n (%)	48 (19.2)
Deaths, n (%)	4 (1.6)
Major adverse cardiac events, n (%)	55 (22.0)

CABG – coronary artery bypass graft surgery; CKD-EPI eGFR – Chronic Kidney Disease Epidemiology Collaboration estimated glomerular filtration rate equation; ECG – electrocardiogram; hs-TnT – high-sensitive Troponin T concentration; IQR – interquartile range; New ischemic ECG changes – new or presumably new horizontal or descending ST-segment depression ≥ 0.5 mm or T wave inversion in at least two adjacent leads; PCI – percutaneous coronary intervention; TIA – transient ischemic attack

Tab. 3. Risk stratification – total number and proportion of patients with acute myocardial infarction in each risk group for evaluated decision aid rules and solo TnT strategy.

T-MACS	total, n	%	AMI, n	%
Very Low	11	4.4	0	0.0
Low	95	38.0	3	3.2
Moderate	130	52.0	36	27.7
High	14	5.6	9	64.3
HEART	total, n	%	AMI, n	%
Low	35	14.0	0	0.0
Moderate	148	59.2	15	10.1
High	67	26.8	33	49.3
EDACS	total, n	%	AMI, n	%
Low risk	54	21.6	1	1.9
Not-low risk	196	78.4	47	24.0
TIMI	total, n	%	AMI, n	%
Low	49	19.6	3	6.1
Moderate	183	73.2	37	20.2
High	18	7.2	8	44.4
GRACE	total, n	%	AMI, n	%
Low	99	39.6	9	9.1
Moderate	94	37.6	19	20.2
High	57	22.8	20	35.1
ADAPT	total, n	%	AMI, n	%
Low	0	0.0	0	0.0
Intermediate	96	38.4	3	3.1
High	154	61.6	45	29.2
Solo TnT strategy	total, n	%	AMI, n	%
TnT < 15ng/L	113	45.2	9	8.0
TnT ≥ 15ng/L	137	54.8	39	28.5

AMI – acute myocardial infarction; TnT – concentration of high-sensitive Troponin T at arrival to the emergency department

system retrospectively. They were used to calculate T-MACS, HEART, EDACS, TIMI, GRACE, and ADAPT scores.

Laboratory analysis

Upon arrival to the emergency department, the blood sample was taken from a peripheral vein and immediately sent to the local laboratory for analysis. We analyzed blood samples for the concentration of high sensitivity troponin T (hs-TnT) with the assay Elecsys from Roche Diagnostics (99th percentile upper reference limit of 14ng/L for men and women, coefficient of variation < 10 % at 13 ng/L).

Decision aid rules

Each of these chosen aids uses different clinical, electrocardiographical, or biochemical variables. According to the predicted probability of acute myocardial infarction calculated by the test score, patients were divided into different risk groups. Original decision aid rule authors proposed managing the patient at the emergency department following the calculated risk. For example, safe discharge from the emergency department for low-risk groups, admission to the ward and invasive approach for high-risk groups, and additional examination such as serial troponin testing or stress/ imaging tests for moderate-risk groups (3). Table 1 shows the summary of the selected decision aids.

Troponin-only Manchester Acute Coronary Syndrom Score Decision Aid Rule (T-MACS) operates with six dichotomous variables and one single hs-TnT concentration (measured at the time of arrival to the emergency department) (4). Patients could be divided into four groups according to their probability of acute coronary syndrome or 30-days major adverse cardiac events (MACE) – very low-risk, low, medium, or high risk. This protocol can essentially exclude MACE in the very low-risk patients (rule-out diagnostics) and predicts MACE in high-risk patients (rule-in diagnostics) with high probability (5).

HEART is the acronym for History, ECG, Age, Risk factors, and Troponin concentration. This model predicts the 6-week risk of MACE. Low-risk patients (score 0–3) should be discharged from emergency, moderate-risk patients (score 4–6) are recommended

for further examination during a hospital stay, and patients with high risk (score above 6) should undergo early invasive coronary angiography (6).

Emergency Department Assessment of Chest Pain Score (EDACS) identifies chest pain patients with a low risk for major cardiac events in 30 days. Risk stratification is based on age, sex, coronary artery disease risk factors, and symptoms and signs of myocardial ischemia. In the initial evaluation, troponin testing is not required. However, patients who do not meet the low-risk criteria should be ruled out for acute myocardial infarction with usual chest pain protocols with serial troponin testing (7, 8). Only low-risk patients (score < 16) without ischemic changes on ECG and with negative troponins are safe for early discharge.

GRACE (Global Registry of Acute Coronary Events) is an extensive multicentre international database (9). Formerly, the GRACE score was studied to estimate in-hospital mortality of patients with confirmed acute coronary syndrome and is still recommended in current ESC guidelines for the management of acute coronary syndrome without ST-segment elevations (1). In this study, we hypothesized about its predictive value in a general population of chest pain patients. We used an improved version GRACE 2.0, which involves eight variables (age, pulse, systolic blood pressure, ECG ischemia, abnormal cardiac enzymes, creatinine value, cardiac arrest at admission, and Killip class) (10, 11).

TIMI (Thrombolysis in Myocardial Infarction) risk score for unstable angina/ non-ST elevation myocardial infarction is one of the first widely implemented chest pain decision rules. Seven variables - age 65 years or older, at least three risk factors for coronary artery disease, prior coronary stenosis of 50 % or more, ST-segment deviation on the electrocardiogram at presentation, at least two anginal events in last 24 hours, use of aspirin, and elevated serum cardiac markers – were identified from huge international database using multivariate logistic regression. The score predicts a percentual risk of 14-days MACE (all-cause mortality, myocardial revascularization, or myocardial infarction) (12). Patients with a score of zero or one point are at low risk of adverse outcomes. High-risk score patients (6 and 7 points) require aggressive pharmacological treatment and an early invasive approach.

Accelerated Diagnostic Protocol to Assess Patients with Chest Pain Symptoms (ADAPT) evaluates electrocardiogram, 0-hour and 2-hour troponin value, and TIMI score. Initially, this protocol was created to identify patients at low risk for 30 days MACE, suitable for rapid discharge from the emergency department (13). A combination of normal troponin, normal ECG and TIMI score of zero represents the low-risk population; abnormal troponin or abnormal ECG constitutes a high-risk group.

Solo Troponin T (TnT) strategy: we hypothesized about the accuracy of strategy using only one variable - single high-sensitivity Troponin T (hs-TnT) concentration with the cut-off value at the 99th percentile upper reference limit for used assay (14ng/L for men and women) for determination. Patients with a hs-TnT value below 15ng/L were identified as low-risk, others as high-risk.

Outcomes

As in most of the original trials of decision aid rules mentioned above, we followed patients for one month. The primary endpoint was an occurrence of acute myocardial infarction (AMI) and major adverse cardiac events (MACE). MACE includes composite of AMI, myocardial revascularization, and all-cause mortality. The diagnosis of AMI was based on the presence of myocardial necrosis assessed by multiple troponin samples testing and at least one of the following: typical chest pain symptoms, ECG signs of myocardial ischemia, and/ or the presence of significant stenosis (> 60 %) or occlusion of the coronary vessel on coronary angiography; as recommended in the current guidelines (1, 14).

Statistical analysis

Categorical data were presented as proportions and percentages, continuous data as median and interquartile range. Selected patient characteristics between the groups

Tab. 4. Comparison between patients with and without AMI during the follow-up period.

	With AMI	Without AMI	p
Total, n	48	202	
Age, median (IQR)	81 (73–85.8)	77 (73–83)	0.101
Male sex, n (%)	35 (72.9)	89 (44.1)	**< 0.001**
CAD, n (%)	22 (45.8)	84 (41.6)	0.592
PAD, n (%)	8 (16.7)	15 (7.4)	**0.046**
Stroke, n (%)	5 (10.4)	20 (9.9)	0.915
Dyslipidemia, n (%)	23 (47.9)	123 (60.9)	0.101
Hypertension, n (%)	40 (83.3)	169 (83.7)	0.956
Diabetes mellitus, n (%)	19 (39.6)	54 (26.7)	0.078
Current smoker, n (%)	21 (43.8)	52 (25.7)	**0.014**
Typical angina, n (%)	39 (81.3)	58 (28.7)	**< 0.001**
Propagation do arm, n (%)	8 (16.7)	32 (15.8)	0.889
Relief after nitrates, n (%)	24 (50.0)	38 (18.8)	**< 0.001**
Nausea/ vomiting, (%)	9 (18.8)	15 (7.4)	**0.017**
Sweating observed, n (%)	6 (12.5)	17 (8.4)	0.379
Pain produced by palpation, n (%)	2 (4.2)	47 (23.3)	**0.003**
Pain worsened with inspiration, n (%)	1 (2.1)	25 (12.4)	**0.036**
ECG without ischemia, n (%)	23 (47.9)	160 (79.2)	**< 0.001**
hs-TnT at time 0 ng/L, median (IQR)	26.5 (16.3–61.8)	14 (10–22)	**< 0.001**
hs-TnT at time 1 ng/L, median (IQR)	59 (27–120)	20 (14–30)	**< 0.001**
Creatinine μmol/L, median (IQR)	92.5 (81–106.3)	93 (78–114)	0.961
T-MACS %, median (IQR)	34 (13–90)	4 (2–16)	**< 0.001**
HEART score, median (IQR)	7 (6–8)	5 (4–6)	**< 0.001**
EDACS score, median (IQR)	22 (20–25)	19 (14–22)	**< 0.001**
TIMI score, median (IQR)	4 (2–5)	3 (2–4)	**0.002**
GRACE score, median (IQR)	132 (116–148.5)	111.5 (100–130.3)	**< 0.001**
ADAPT high risk, n (%)	45 (93.8)	109 (54.0)	**< 0.001**
Hospital admissions, n (%)	46 (95.8)	53 (26.2)	**< 0.001**
CAG performed, n (%)	27 (56.3)	12 (5.9)	**< 0.001**

AMI – acute myocardial infarction; CAD – coronary artery disease; CAG – coronary angiography; ECG without ischemia – no new or presumably new horizontal or descending ST-segment depression ≥ 0.5mm or T wave inversion in at least two adjacent leads; hs-TnT at time 0 – concentration of high-sensitivity troponin T in ng/L in arrival; hs-TnT at time 1 – concentration of high-sensitivity troponin T in ng/L after 3,6, or 12 hours after initial evaluation (available only in 150 patients); PAD – peripheral arterial disease

of patients with and without AMI were compared, the continuous data were tested with the Mann-Whitney U test and categorical data with the Pearson's Chi-square test for independence. The diagnostic accuracy of decision aid rules was evaluated by calculating sensitivity, specificity, odds ratios, negative and positive predictive values with respected 95 % confidence intervals and constructing the receiver operator characteristics (ROC) curves. Sensitivities and specificities of decision aids were compared using McNemar`s test. Statistical analysis was performed using M.S. Office Excel (Microsoft, Redmont, Washington, USA) and open-source software SOFA Statistics v1.4.6 (Paton-Simpson & Associates Ltd).

Results

A total of 250 patients were enrolled. The median age was 78 years (70–94 years), 50 % were males. During 30 days follow-up period, a total of 48 patients (19.2 %) were diagnosed with acute myocardial infarction, 55 patients (22 %) had a major cardiac event (MACE), 28 patients (11.2 %) underwent myocardial revascularization (coronary artery bypass graft surgery in 4 patients, percutaneous revascularization in 24 patients) and four patients died.

In the population of patients with confirmed AMI, 46 patients (96 %) were diagnosed during an initial presentation in the emergency department. The remaining two patients experienced myocardial infarction within the following 30 days. The first patient was initially evaluated as having stable angina pectoris, but a few days later, he returned with chest pain at rest and underwent acute surgical revascularization. In the second patient, chest pain was evaluated as musculoskeletal (repeatedly normal troponin levels),

with hemodynamically moderate aortic stenosis and atrial fibrillation. However, 20 days later, the patient returned with typical chest pain and extensive myocardial infarction, which led to fatal heart failure. Table 2 demonstrates the baseline characteristics of the included participants.

The highest prevalence of acute myocardial infarction (64.3 % and 49.3 %, respectively) was in high-risk groups identified by T-MACS and HEART score. There was no acute myocardial infarction (AMI) in the low-risk groups pointed by these decision aids. The proportion of patients with AMI in each risk group for the selected decision aid rule is in Table 3.

The spectrum of diagnosis in patients without AMI was broad. Most of the patients (n = 174; 83.3 %) had musculoskeletal pain. In 13 patients, chest pain was secondary due to an arrhythmia (mainly atrial fibrillation), and 12 had chest pain due to heart failure. Other causes of chest pain were newly diagnosed severe aortic stenosis in 3 patients and lung cancer in 2 patients. Pulmonary embolism, acute aortic dissection, pleuropneumonia, cholecystitis and myopericarditis were less common, each occurring just in one patient.

We found a significant difference in the incidence of peripheral arterial disease, active smoking, typical angina, and hs-TnT concentration at arrival in patients with AMI compared to those without AMI. Worsening of pain by respiration, pain produced by palpation, and the absence of new ischemic changes on ECG seem to be protective factors. Analysis of risk factors possibly contributing to the occurrence of AMI shows Table 4.

The diagnostic accuracy of each protocol is represented in table 5. Separately, we rated competence to rule out AMI by comparing low-risk and non-low risk groups identified by each deci-
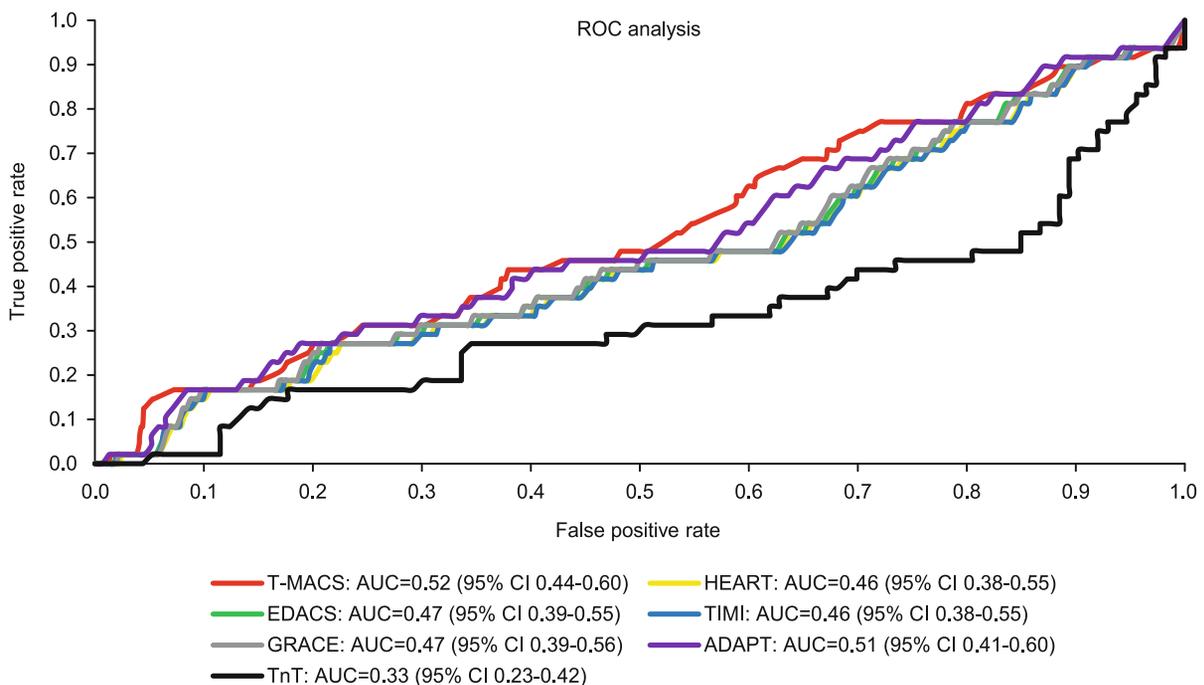

Fig. 1. Receiver operator characteristics (ROC) analysis of studied decision aid rules for the diagnosis of acute myocardial infarction.

Tab. 5. Diagnostic accuracy of decision aid rules in rule-out and rule-in diagnostics of acute myocardial infarction.

Rule-Out	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Accuracy, %	LR +	LR –	OR (95% CI)
T-MACS	100.0 (100–100)	5.4 (2.3–8.6)	20.1 (15.0–25.2)	100.0 (100–100)	23.6	1.1	0.0	NA
HEART	100.0 (100–100)	17.3 (12.1–22.6)	22.3 (16.8–27.9)	100.0 (100–100)	33.2	1.2	0.0	NA
EDACS	97.9 (93.9–100.0)	26.2 (20.2–32.3)	24.0 (18.0–30.0)	98.1 (94.6–100.0)	40.0	1.3	0.1	16.7 (2.3–124.2)
TIMI	93.8 (86.9–100.0)	22.8 (17.0–28.6)	22.4 (16.6–28.2)	93.9 (87.2–100.0)	36.4	1.2	0.3	4.4 (1.3–14.9)
GRACE	81.3 (70.2–92.3)	44.6 (37.7–51.4)	25.8 (18.9–32.8)	90.9 (85.3–96.6)	51.6	1.5	0.4	3.5 (1.6–7.6)
ADAPT	100.0 (100–100)	0.0	19.2 (14.3–24.1)	NA	19.2	1.0	NA	NA
Solo TnT	81.3 (70.2–92.3)	51.5 (44.6–58.4)	28.5 (20.9–36.0)	92.0 (87.0–97.0)	57.2	1.7	0.4	4.6 (2.1–10.0)
Rule-In	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Accuracy, %	LR +	LR –	OR (95% CI)
T-MACS	18.8 (7.7–29.8)	97.5 (95.4–99.7)	64.3 (39.2–89.4)	83.5 (78.7–88.2)	82.4	7.6	0.8	9.1 (2.9–28.6)
HEART	68.8 (55.6–81.9)	83.2 (78.0–88.3)	49.3 (37.3–61.2)	91.8 (87.8–95.8)	80.4	4.1	0.4	10.9 (5.3–22.2)
TIMI	16.7 (6.1–27.2)	95.0 (92.1–98.0)	44.4 (21.5–67.4)	82.8 (77.9–87.6)	80.0	3.4	0.9	3.8 (1.4–10.3)
GRACE	41.7 (27.7–55.6)	81.7 (76.4–87.0)	35.1 (22.7–47.5)	85.5 (80.5–90.5)	74.0	2.3	0.7	3.2 (1.6–6.3)
ADAPT	93.8 (86.9–100.0)	46.0 (39.2–52.9)	29.2 (22.0–36.4)	96.9 (93.4–100.0)	55.2	1.7	0.1	12.8 (3.9–42.5)

CI – 95% confidence interval; LR+ – positive likelihood ratio; LR– – negative likelihood ratio; NA – not applicable (because of division by zero); NPV – negative predictive value; OR – odds ratio; PPV – positive predictive value

sion aid model. T-MACS, HEART, and ADAPT had the highest sensitivity, however, with very poor specificity. On the other hand, we measured the ability to rule in AMI by comparing high-risk groups and non-high-risk groups. HEART and ADAPT protocols showed the highest sensitivity with decent specificity. EDACS decision aid and solo TnT strategy were reviewed only in the rule-out part because of their dichotomous character (low-risk and not low-risk; below and above upper reference limit, respectively). Head-to-head comparison of sensitivity and specificity of decision protocols in the rule-out and rule-in diagnostics of AMI are presented in table 6.

The receiver operator characteristics (ROC) and area under the curve (AUC) analysis of chosen diagnostic protocols shows Figure 1. The areas under the curve (AUC) were comparable for every decision rule. T-MACS had the highest AUC (0.52), and solo TnT strategy had the lowest AUC (0.33).

Discussion

This single-centre study evaluated the diagnostic accuracy of six decision aids and the single troponin value strategy in the rule-out and rule-in diagnostics of acute myocardial infarction in everyday practice in the emergency department in a selected population of the elderly. Our results suggest that these protocols can be used even in this group with similar results. As far as we

know, there are not enough studies that evaluated the use of decision aids in the selected population of the elderly and compared these protocols in-between. We hope that the publication of these results could lead to a change of practice and hopefully even better care in this field. To our knowledge, this study is unique because of the mean age of participants included and the number of decision protocols used.

In our study, T-MACS and HEART scores have 100 % sensitivity and 100 % negative predictive value for ruling out AMI between selected decision aid rules. T-MACS rule also has an excellent performance in rule-in diagnostics for AMI in the high-risk group with 97.5 % specificity and 64.3 % positive predictive value – the highest from evaluated risk stratification protocols. The HEART score had slightly lower specificity (83.2 %, p < 0.001 for difference) and identified a lower proportion of AMI patients in the high-risk group compared to T-MACS score (49.3 % vs 64.3 %).

The EDACS score had very high sensitivity and negative predictive value for ruling-out AMI (97.9 % and 98.2 %, respectively), missing just one patient with acute myocardial infarction classified in low-risk groups. Because of its dichotomous character (low-risk versus not low-risk), we have not tested its performance in rule-in diagnostics.

In the ability to rule out AMI, GRACE score and solo TnT strategy had the weakest performance with the lowest sensitivity

(around 80 %) between selected decision aids with specificities around 50 % and a negative predictive value of 90.9 % and 92 %. When used to rule in AMI, GRACE score also had low specificity and positive predictive value (81.7 % and 35.1 %, respectively). Further, the solo TnT strategy was not tested in the rule-in part for the same reasons as the EDACS protocol. We proved that the single parameter decision rule (the solo TnT strategy with a cut-off at the upper reference limit) is just not good enough for the risk stratification of patients with the suspected acute coronary syndrome. It seems that the conjunction of clinical, biochemical, and ECG markers gives better results. However, the GRACE score is the model with the most parameters used than other decision aid rules.

Results of ADAPT protocol are conflicting due to the inability to choose any patients as low risk. Patients over 65 years could be determined just as moderate or high risk because of the age restrictions used in this model. Nevertheless, we decided not to exclude this decision aid rule from the study to show the real-life practice.

When looking at the performance in rule-in diagnostics of AMI in high-risk patients, the T-MACS score had the best results with the highest specificity (97.5 %) and positive predictive value (64.3 %). TIMI also has excellent specificity (95 %) but with a lower positive predictive value. In contrast, ADAPT had the highest sensitivity and negative predictive value (almost 94 %

and 97 %, respectively) with the most significant proportion of high-risk patients (63 %), however, with no low-risk patients – as discussed above.

It is known that age is an independent variable for the incidence of acute myocardial infarction and major adverse cardiovascular events. Age played a crucial role in the risk stratification in ADAPT protocol in this trial. Age higher than 64 years old means non-low risk score. As opposed, in the T-MACS model, age is not even evolved. Moreover, this could be one of the reasons for excellent performance on this protocol in our trial. Age above 70 years old presents 20 % of total possible score points acquired in the HEART model, 14 % in the TIMI protocol, 21–26 % in the GRACE score (for septuagenarians and octogenarians, respectively), and the highest proportion of maximum possible points in the EDACS protocol (31–52 % points according to the age).

Some trials evaluated different risk stratification protocols in diagnosing acute myocardial infarction in patients with suspected acute coronary syndrome without apparent ST-segment elevations. A retrospective study of Sun et al (15) compared HEART and TIMI risk scores for prediction of MACE (all-cause death, acute myocardial infarction, and urgent revascularization) in 8255 patients with suspected acute coronary syndrome presenting to nine emergency departments between years 1999–2001. They found lower sensitivity and positive predictive value for TIMI and

Tab. 6. Comparison of sensitivities and specificities of decision aid rules.

Rule Out AMI	Protocol 1 sensitivity, %	Protocol 2 sensitivity, %	p	Protocol 1 specificity, %	Protocol 2 specificity, %	p
T-MACS vs HEART	100.0	100.0	NS	5.4	17.3	< .001
T-MACS vs EDACS	100.0	97.9	NS	5.4	26.2	< .001
T-MACS vs TIMI	100.0	93.8	NS	5.4	22.8	< .001
T-MACS vs GRACE	100.0	81.3	NS	5.4	44.6	NS
T-MACS vs ADAPT	100.0	100.0	NS	5.4	0.0	NS
T-MACS vs solo TnT	100.0	81.3	NS	5.4	51.5	< .001
HEART vs EDACS	100.0	97.9	NS	17.3	26.2	0.016
HEART vs TIMI	100.0	93.8	NS	17.3	22.8	0.046
HEART vs GRACE	100.0	81.3	NS	17.3	44.6	< .001
HEART vs ADAPT	100.0	100.0	NS	17.3	0.0	< .001
HEART vs solo TnT	100.0	81.3	NS	17.3	51.5	< .001
EDACS vs TIMI	97.9	93.8	NS	26.2	22.8	0.42
EDACS vs GRACE	97.9	81.3	NS	26.2	44.6	< .001
EDACS vs ADAPT	97.9	100.0	NS	26.2	0.0	< .001
EDACS vs solo TnT	97.9	81.3	NS	26.2	51.5	< .001
TIMI vs GRACE	93.8	81.3	0.25	22.8	44.6	< .001
TIMI vs ADAPT	93.8	100.0	0.25	22.8	0.0	< .001
TIMI vs solo TnT	93.8	81.3		22.8	51.5	< .001
GRACE vs ADAPT	81.3	100.0	NS	44.6	0.0	NS
GRACE vs solo TnT	81.3	81.3	NS	44.6	51.5	< .001
ADAPT vs solo TnT	100.0%	81.3%	NS	0.0%	51.5%	< .001
Rule In AMI	Test 1 sensitivity, %	Test 2 sensitivity, %	p	Test 1 specificity, %	Test 2 specificity, %	p
T-MACS vs HEART	18.8	68.8	< .001	97.5	83.2	< .001
T-MACS vs TIMI	18.8	16.7	NS	97.5	95.0	NS
T-MACS vs GRACE	18.8	41.7	NS	97.5	81.7	< .001
T-MACS vs ADAPT	18.8	93.8	< .001	97.5	46.0	< .001
HEART vs TIMI	68.8	16.7	< .001	83.2	95.0	< .001
HEART vs GRACE	68.8	41.7	< .001	83.2	81.7	< .001
HEART vs ADAPT	68.8	93.8	< .001	83.2	46.0	< .001
TIMI vs GRACE	16.7	41.7	NS	95.0	81.7	< .001
TIMI vs ADAPT	16.7	93.8	< .001	95.0	46.0	< .001
GRACE vs ADAPT	41.7	93.8	< .001	81.7	46.0	< .001

HEART, but higher specificity compared to our results (sensitivity for TIMI 62.8 % vs 93.8 %; specificity 63.8 % vs 22.77 %; NPV 96.3 % vs 93.9 %; PPV 10.2 % vs 22.4 %; sensitivity for HEART 85.8 % vs 100 %, specificity 51.2 % vs 17.33 %; NPV 98.2 % vs 100 %; and PPV 10.3 % vs 22.3 %).

Compared with the study of Body et al (6), we found similar results for sensitivities of T-MACS (100 % vs 99.2 %) and EDACS (97.9 % vs 96.2 %), we had higher sensitivity of HEART (100 % vs 91.8 % in Body's trial) and lower sensitivity of TIMI score (93.8 % vs 97.5 %). Our C-statistics were much lower, 0.52 vs 0.96 for T-MACS, 0.46 vs 0.78 for HEART, and 0.46 vs 0.69 for TIMI. Unlike our study, Body's trial was prospective, multi-centric, included much more patients (999 pts) but of younger age (mean age 58.1 years), and evaluating just four decision aids (T-MACS, HEART, TIMI, and EDACS) and troponin-only strategy using a value 3 ng/L of the high-sensitivity troponin I assay as a cut-off.

Carlton et al (17) compared five risk scores (TIMI, HEART, GRACE, modified Goldman and Vancouver Chest Pain Rule) and two high sensitivity troponin assays in the ability to rule out myocardial infarction quickly. Almost a thousand patients with a mean age of 58 years were included. Their results were similar to ours: sensitivity for HEART score 98.7 % vs 100 % in our trial; for GRACE 92.3 % vs 81.25 %; for TIMI 94.9 % vs 93.8 %; and 83.5 % vs 81.3 % for single hs-TnT value with cut-of at 14 ng/L – same as in our trial.

Study limitations

The first limitation of this study is its retrospective course. Data were collected from the hospital information system as described by treating physicians who were not using risk stratification protocols. The authors of this study personally overviewed all electrocardiograms for signs of ischemia and calculated risk scores. However, we believe that due to the short follow-up period, there should not be severe errors between prospective and retrospective forms of evaluation.

Secondly, a study was conducted in a single centre and included fewer patients than the trials mentioned above. This could lead to a lack of patients in low/very-low risk groups and the low specificity of studied protocols in ruling-out AMI in this trial.

Finally, we evaluated a highly selected population of the elderly. Patients with high age have their specific features. It was reflected in higher comorbidity rates, fewer typical symptoms, and electrocardiographical signs of ischemia. However, there are not many global trials evaluating data about this specific group.

Conclusions

We evaluated decision aid rules for diagnostics of acute myocardial infarction in very old patients in the emergency department with the suspected acute coronary syndrome. T-MACS decision aid had the best performance with 100 % sensitivity and 100 % negative predictive value for ruling-out AMI, 97.5 % specificity, and 64.3 % positive predictive value for ruling-in AMI. The HEART score was excellent in ruling-out AMI (100 % sensitivity and 100 % NPV) but with lower specificity for ruling in AMI

(83.2 %). Other evaluated protocols and solo TnT strategy were less accurate. ADAPT protocol should be used with caution to rule out AMI in very old patients. This study proves that risk stratification of patients with suspected acute coronary syndrome based on decision rule aids can be used in real-life practice, even in the population of the elderly.

Learning points

1. The diagnosis of acute myocardial infarction in older patients is problematic because of atypical symptoms, no ischemic changes on electrocardiogram and elevated levels of cardiac troponins from multiple cardiac and non-cardiac conditions.
2. Decision aid rules could make the diagnostic process more effective by stratifying the risk of coronary events in an individual patient.
3. Decision making based just on troponin testing is insufficient, complex evaluation of symptoms, patient's history, electrocardiogram and blood analysis is more efficient. The single troponin strategy in this study had worse performance in diagnosing acute myocardial infarction than more complex decision aid protocols with multiple parameters used.
4. Troponin-only Manchester Acute Coronary Syndrom Score Decision Aid Rule (T-MACS) had the best performance and results for diagnosing acute myocardial infarction in our population of very old patients with the suspected acute coronary syndrome at the emergency department.

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