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Medical consumption compared for TIMI and HEART score in chest pain patients at the emergency department: a retrospective cost analysis

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ABSTRACT

Objective: To investigate which risk score (TIMI score or HEART score) identifies the largest population of low-risk patients at the emergency department (ED). Furthermore, we retrospectively calculated the corresponding expected decrease in medical consumption if these patients would have been discharged from the ED.

Methods: We performed analyses in two hospitals of the multicentre prospective validation study of the HEART score, executed in 2008 and 2009. Patients with chest pain presenting to the ED were included and information was collected on major adverse cardiac events (MACEs) and on hospital admissions and diagnostic procedures within 6 weeks. The TIMI and HEART score were calculated for each patient.

Results: We analysed 640 patients (59% male, mean age of 60, cumulative incidence of MACE 17%). An estimated total of €763 468 was spent during follow-up on hospital admission and diagnostic procedures. In total, 256 (40%) patients had a HEART score of 0–3 and were considered low risk (miss rate 1.6%), a total of €64 107 was spent on diagnostic procedures and hospital admission after initial presentation in this group. In comparison, 105 (16%) patients with TIMI score of 0 were considered low risk (miss rate 0%), with a total of €14 670 spent on diagnostic procedures and initial hospital admission costs. With different cut-offs for low risk, HEART 0–2 (miss rate 0.7%), would have resulted in a total of €25 365 in savings, compared with €71 905 when an alternative low risk cut-off for TIMI of TIMI≤1 would be used (miss rate 3.0%).

Conclusions: The HEART score identifies more patients as low risk compared with the TIMI score, which may lead to a larger reduction in diagnostic procedures and costs in this low-risk group. Future studies should prospectively investigate whether adhering to the HEART score in clinical practice and early discharge of low-risk patients is safe and leads to a reduction in medical consumption.

Strengths and limitations of this study

- Data from a prospective, multicentre validation study of the HEART score were used including a broad population of patients with chest pain. The overall MACE incidence in our population largely corresponds with existing literature, suggesting that our patient selection is representative for the larger group of patients with chest pain.
- In each patient, the TIMI and HEART score were calculated leading to a paired analysis which is more valid and more powerful to detect differences.
- This study concerns a retrospective analysis of costs within a prospective study from 2008. Another disadvantage is the use of contemporary cardiac troponin instead of the increasingly used high-sensitive cardiac troponin.
- The decision-making process of performing a diagnostic procedure in a patient is a subjective one that was carried out by different physicians based on their personal opinion or preference. Likewise, both risk scores contain the subjective element of 'history', which possibly results in inter-rating variance.
- By selecting a subsample of a larger cohort study, we might have introduced some form of selection bias into our analysis. However, the incidence of the outcome of major adverse cardiac events in our subsample was similar to that of the original study population.

BACKGROUND

Each year, an estimated 6% of presentations at emergency departments (EDs) are attributed to symptoms suspicious of acute coronary syndrome (ACS).[1 2] Of all these patients, the majority has chest pain due to non-cardiac causes and only 15–20% of patients have an ACS.[3] Differentiating between low-risk and high-risk patients for ACS remains a diagnostic challenge, since a normal ECG and initially negative biomarkers do not exclude ACS. Therefore, the majority of low-risk patients are currently admitted to the hospital to undergo further

testing, regardless of low pretest probability. However, often results of these performed tests are normal.[4] The question remains whether this conservative approach leads to better clinical outcomes for patients and there is discussion on optimal management in patients who are deemed safe to discharge from the ED.[5]

Several risk stratification tools and prediction models have been developed over time. Currently, international cardiac guidelines recommend the use of a risk score for risk stratification.[6 7] The current study investigates two of these risk scores, namely the thrombosis in myocardial infarction (TIMI) score and the HEART score.

First, the TIMI risk score was developed in 2000 to stratify risk in patients with chest pain admitted to the cardiac care unit (CCU) and can be used to predict 30-day outcomes of mortality, myocardial infarction (MI) and severe recurrent ischaemia requiring urgent revascularisation.[8 9] The TIMI score is composed of seven elements as shown in table 1. It is one of the two risk scores that is implemented in current international guidelines and well known by most clinicians.[10]

Second, the HEART score was developed in 2007 and has been validated to stratify the risk of short-term adverse cardiac events in patients with chest pain at the ED.[9 11–16] The HEART score is an acronym for History, ECG, Age, Risk factors and Troponin. These components can be rated 0, 1 or 2 points each and results in a total HEART score between 0 and 10, as shown in table 2. It has been specifically developed for patients with chest pain and previous prospective studies indicated the HEART score as valid for patient stratification, especially in identifying a low-risk group of patients without compromising safety. Such a low-risk group can then be considered for early discharge from the ED.[9 11 14 15 17–19] In a previous study by Mahler *et al*,[14] the HEART score identified 20% (95% CI 18% to 23%) as low risk (HEART score 3 or lower) with a corresponding sensitivity of 99% (95% CI 97% to 100%) for ACS. A recent study suggests that a TIMI score of 0 and HEART score of ≤3 with high-sensitivity troponin I could achieve a negative predictive value ≥99.5% while identifying more than 30% of patients as suitable for immediate discharge.[20]

Although both risk scores have been validated for use in a low-risk ED population, they are mostly not yet actively used; that is, no policy decision is made based on the individual risk score of a patient. Furthermore, none of these previous studies mentioned secondary outcome measurements such as clinical course or medical consumption.

A pilot study of 122 patients by Six *et al*[17] analysed medical consumption of patients with chest pain with a HEART score at the ED. It concluded that, if the HEART score would be routinely applied on patients with chest pain, diagnostic pathways for low-risk patients could be shortened which could lead to cost reduction. However, these were small numbers in a small non-academic hospital.

Our goal is to investigate the medical consumption in the low-risk TIMI and HEART score categories. Furthermore, we assessed which risk score is more efficient in identifying the largest number of low-risk patients, without compromising safety.

Table 1 The thrombosis in myocardial infarction (TIMI) score for unstable angina/NSTEMI

Age≥65 years	0 1
≥3 risk factors for CAD	0 1
Known CAD	0 1
Aspirin use in past 7 days	0 1
Recent severe angina	0 1
Elevated cardiac markers	0 1
SD≥0.5 mm	0 1
TOTAL	0–7

CAD, Coronary artery disease; NSTEMI, non-ST-segment elevation myocardial infarction.

Table 2 The HEART score for patients with chest pain

History	
Highly suspicious	2
Moderately suspicious	1
Slightly or non-suspicious	0
ECG	
Significant ST-depression	2
Non-specific repolarisation disturbance	1
Normal	0
Age (years)	
≥65	2
>45 to <65	1
≤45	0
Risk factors	
≥3 risk factors, or history of atherosclerotic disease	2
1 or 2 risk factors	1
No risk factors known	0
Troponin	
≥3× normal limit	2
>1–<3 normal limit	1
≤ Normal limit	0
Total	0–10

METHODS

Study population

This is an additional analysis of 680 patients in two hospitals, using the data of a multicentre prospective validation study in 10 hospitals of the HEART score, which included a total of 2388 patients between 2008 and 2009.[15] The ethics committee of the University Medical

Centre Utrecht approved the study. Since it was an observational study and patients received standard care, at that time informed consent procedures were waived. Patients were informed of the registration of data and the follow-up policy and data were processed anonymously. Any patient with acute chest pain admitted to the (cardiac) ED was eligible, regardless of age or prehospital suspicion. Patients with ST-elevation MI (STEMI) were immediately taken to the coronary intervention room, and therefore excluded.

Two hospitals were chosen for our additional study on diagnostic procedures, as it was anticipated that for these hospitals patient information of sufficient quality would be available. The first one is a general hospital with a large specialised cardiology department, the second one an academic hospital. Both are intervention centres and perform percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG).

Calculation of the TIMI and HEART score

ED residents of participating hospitals were instructed to fill out the case record form (CRF), which consisted of patient history, cardiovascular risk factors, medication, physical examination and past medical history. Laboratory results, including contemporary Troponin I or T, and the admission to ECG were added to the CRF. The ECG was blindly classified afterwards by independent, experienced cardiologists.

The HEART score predicts the 6-week incidence of major adverse cardiac events (MACE), stratifying patients into a low-risk (HEART score 0–3), intermediate-risk (4–6) and high-risk (7–10) group.[12 15 16] The incidence of MACE in the previous validation studies has been 1.7% in low-risk patients, 16.6% in intermediate-risk patients and 50.1% in high-risk patients.[15] The classification into the different risk categories can be used to make a direct clinical decision for further patient evaluation. In the current study, the HEART score was calculated by the resident at the ED, without actively using the score for further management. Each of the five elements in the HEART score was given 0, 1 or 2 points, resulting in a score between 0 and 10, see table 2.

The TIMI score was developed for prediction at the CCU for 30-day outcomes of mortality, MI and severe recurrent ischaemia requiring urgent revascularisation, with the following occurrence rates: 4.7% for TIMI 0/1, 8.3% for 2, 13.2% for 3, 19.9% for 4, 26.2% for 5 and 40.9% for 6–7.[8] Previous research reported a TIMI score of 0 to identify low-risk patients to be safely discharged home from the ED without further testing.[19] More recent studies including high-sensitive troponin suggest also a TIMI score of 1 to be low risk and thus suitable for discharge.[21] Therefore, we analysed the results for both these cut-off values for TIMI. The TIMI score consists of seven elements and takes into account age, risk factors as well as occurrence of coronary artery disease (CAD), use of drugs containing aspirin, severe angina (defined by the original authors of the TIMI score as 2 or more severe episodes of angina within 24 hours), ECG changes as well as cardiac markers. The scoring of these dichotomous elements results in a score between 0 and 7; as shown in table 1. In current study, the TIMI score was calculated from the admission data by an algorithm specifically designed for this study. This algorithm operated without interpretations by the investigators.

Outcome measures

Six-week occurrence of MACE

Information on the primary outcome of MACE was already collected during the original study.[15] The definition of MACE consisted of AMI, PCI, CABG, stenosis managed conservatively, and death due to any cause. The duration of follow-up was 6 weeks in all patients. The diagnosis of AMI was diagnosed by an adjudication committee according to the applicable guidelines at that time.[10] Further information on definition and assessment of MACE can be found in the main publication.[15]

Occurrence of MACE in low-risk group

Since we were particularly interested in the low-risk population, we defined these groups according to cut-off values originally reported by the original investigators of the HEART score and TIMI, namely a low-risk group of patients with a HEART score from 0 to 3, and for the TIMI score this low-risk group consisted of patients with a TIMI score of 0.[8 15] Furthermore, we analysed the results for alternative cut-off values for TIMI≤1 and HEART 0–2.

Admission, readmission, ED revisits, outpatient clinic visits and diagnostic procedures

Additionally, information on whether or not patients were admitted after the initial presentation, length of admission, readmissions, ED revisits, outpatient clinic visits and diagnostic procedures within 6-weeks after initial presentation was collected. All information was retrieved from electronic patient files. Information on the following diagnostic procedures was collected: bicycle stress testing with exercise ECG, myocardial scintigraphy, cardiac MRI, coronary CT angiography (CCTA) and coronary angiography (CAG). Standard (thoracic) CT scans were not included, since these were mostly requested in the context of pulmonary disease.

Costs

Costs of diagnostic procedures were based on rates as provided by a university medical centre.[22] These costs were up to date as of 1 January 2015. Costs of hospital admission and ED visits were based on Dutch guidelines for medical cost analysis.[23]

Statistical analysis

Continuous variables are presented as means (±SD) or medians (IQR), while categorical variables are presented as numbers (percentage). From contingency tables, the incidence of MACE and distribution of the use of

healthcare resources were extracted. Of the incidence of MACE, the corresponding 95% CIs were calculated. All analyses were performed using Statistical Package for the Social Sciences for Windows 20.0 (SPSS Incl. Chicago, Illinois, USA).

RESULTS

Study population

The current study included 680 patients of two hospitals (28.5% of the initial study population). Attempts were made to track down follow-up data for patients receiving their follow-up in different hospitals than the study hospitals, however, in 25 patients (3.7%) we were unsuccessful and thus these patients were lost to follow-up. Additionally, 15 (2.2%) patients were included twice in the original study and we considered only their first presentation. For an overview of patient selection with inclusion and exclusion, see figure 1. Eventually, 640 patients remained for analysis. Mean age was 60 years and 59% was male. Baseline characteristics are depicted in table 3.

6-week Occurrence of MACE

A total of 110 (17.2%) patients out of the 640 were diagnosed with MACE. Figure 1 and table 4 give an overview of the distribution of the different conditions within MACE. Most common was the performance of PCI in 65 patients (59.1%). A diagnosis of AMI was made in 36 patients (32.7%), 24 patients received a CABG (21.8%) and 14 patients (12.7%) had a stenosis on CAG that could be managed conservatively. One patient died (0.9%) with a HEART score of 10 and a TIMI score of 7. This 85-year-old male with non-ST-segment elevation MI (NSTEMI) was managed conservatively because of high age and comorbidity; however developed new cardiac ischaemia and died shortly after.

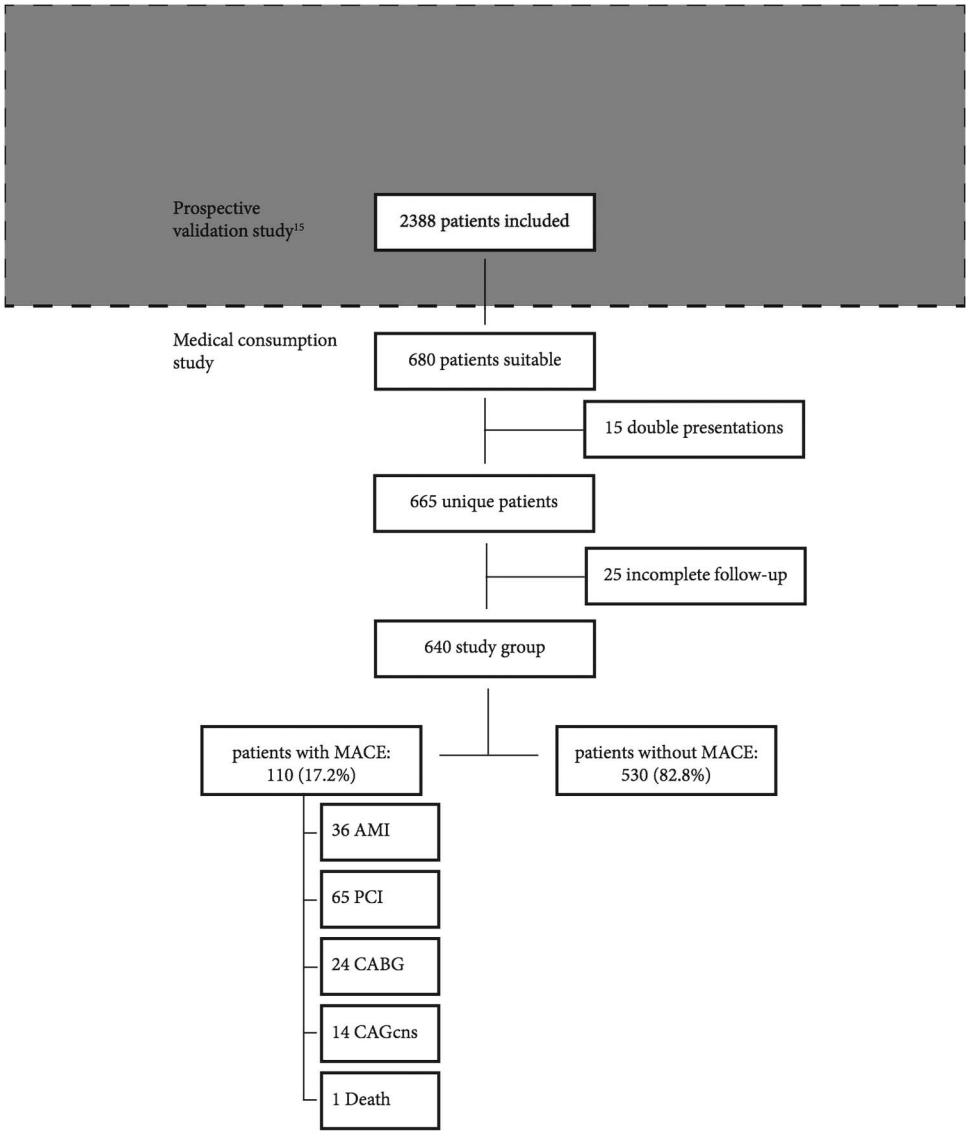

Figure 1 Patient flow chart.

Table 3 Baseline characteristics

	Total		Patients without MACE		Patients with MACE	
	mean/n	SD/%	mean/n	SD/%	mean/n	SD/%
Demographics						
Study group	640		530	83%	110	17%
Age in years	60.0	15	59	16	67	11
Male	376	59%	298	56%	81	74%
Vital signs at presentation						
Heart rate	76.5	19	77	19	76	17
Systolic blood pressure	139.0	22	138	21	142	23
Diastolic blood pressure	81.9	34	82	37	81	14
Cardiovascular risk factors						
Diabetes mellitus	105	16%	84	16%	4	4%
Hypertension	277	44%	225	42%	54	49%
Hypercholesterolemia	235	37%	183	35%	55	50%
Smoking	207	32%	167	32%	40	36%
Family history of CVD	254	40%	202	38%	52	47%
Obesity	131	21%	107	20%	24	22%
History of cardiovascular disease						
Myocardial infarction	118	19%	89	17%	31	28%
CABG	60	9%	43	8%	18	16%
PCI	131	21%	97	18%	35	32%
CVA	241	38%	181	34%	63	57%
PAD	23	4%	16	3%	7	6%
Mean HEART score	4.2	2	4	2	7	2
Mean TIMI score	2.4	2	2	2	4	1

CABG, coronary artery bypass grafting; CVA, cerebrovascular accident; CVD, cardiovascular disease; MACE, major adverse cardiac event; PAD, peripheral arterial disease; PCI, percutaneous coronary intervention; TIMI, thrombosis in myocardial infarction.

Occurrence of MACE across risk score categories

In table 4, the occurrence of MACE is depicted with a low-risk group of patients with a HEART score of 0–3 (n=256, cumulative MACE incidence in this low-risk group: 1.6%; 95% CI 0.6% to 4.0%) or TIMI score of 0 (n=105, cumulative MACE incidence in this low-risk group: 0%; 95% CI 0% to 3.5%). When an alternative cut-off of TIMI of ≤1 was used, the cumulative incidence of MACE was 3.0%; 95% CI 1.5% to 6.2%. The alternative cut-off value of HEART of 0–2 resulted in a cumulative incidence of MACE of 0.7%; 95% CI 0.1% to 3.7%.

Admission, readmission, ED revisits and diagnostic procedures

A total of 226 patients (35%) were admitted to the hospital after presentation at the ED, a total of 57 patients (9%) were readmitted and 49 patients (8%) revisited the ED within 6 weeks. In total, 246 exercise ECG tests were performed, 41 myocardial scintigraphies, 8 cardiac MRIs, 5 CCTAs and 89 CAGs.

Within the low-risk TIMI group (TIMI=0), 5 patients (5%) were admitted after ED presentation, compared with 28 patients (11%) in the low-risk HEART group (HEART 0–3). Furthermore, within 6 weeks 10 patients (10%) revisited the ED 11 times within the low-risk TIMI group, and 22 patients (9%) from the low-risk HEART group revisited the ED 27 times.

Within the low-risk TIMI group (TIMI=0), 44 exercise ECG tests (42%), 2 myocardial scintigraphies (2%), 1 cardiac MRI (1%), 1 CCTA (1%) and no CAGs were administered. In the low-risk HEART group (HEART 0–3), 106 bicycle stress tests (41%), 5 myocardial scintigraphies (2%), 4 cardiac MRIs (2%), 4 CCTAs (2%) and 7 CAGs (3%) were performed. Further information on use of healthcare resources is found in tables 5 and 6.

Costs

In total, an estimated €763 468 was spent during the 6 weeks of follow-up on 640 patients, of which €544 287 (71%) on hospital admission and readmission costs and €219 181 (29%) on diagnostic procedures (table 7). This €544 287 consisted of admissions at initial ED visit by 226 patients being admitted for a total of 1191 days. The total costs of diagnostic procedures consisted of costs for the bicycle stress tests (€36 654; 17%), myocardial scintigraphy (€29 725; 14%), cardiac MRI (€3384; 2%), CCTA (€1500; 1%) and CAG (€147 918; 67%).

Concerning the costs in the low-risk population, in the low-risk HEART patients (HEART score 0–3), a total of €33 945 was spent on diagnostic procedures and an additional €30 162 on admission during initial presentation, resulting in a total cost of €64 107 (8.4% of the mentioned total costs of €763 468). A more conservative approach, which classifies HEART 0–2 as low risk (miss

Table 4 Components of MACE for each TIMI and HEART score and cumulative frequency of all patients with MACE and all patients in risk group

		Components of MACE*					Cumulative frequency of all patients with MACE and all patients in risk group			
	N patients	AMI	PCI	CABG	CAG cons	Death	Total patients with MACE	Cum. frequency of all patients with MACE (%)	Cum. frequency MACE of all patients in risk group (%)	Cumulative N patients
TIMI										
0	**105**	0	0	0	0	0	0	0	0	105
1	**125**	2	7	0	0	0	7	6.4	3.0	230
2	**120**	7	9	3	1	0	16	20.1	6.6	350
3	**112**	7	14	5	6	0	24	42.7	10.2	462
4	**98**	5	11	5	3	0	20	60.9	12.0	560
5	**55**	11	16	7	3	0	29	87.3	15.6	615
6	**23**	3	8	3	1	0	12	98.2	17.0	638
7	**2**	1	0	1	0	1	2	100	17.2	640
Total	**640**	36	65	24	14	1	110	100	17.2	640
HEART										
0	**18**	0	0	0	0	0	0	0	0	18
1	**46**	0	0	0	0	0	0	0	0	64
2	**85**	1	1	0	0	0	1	0.9	0.7	149
3	**107**	0	2	1	0	0	3	3.6	1.6	256
4	**105**	2	6	0	2	0	8	10.9	3.3	361
5	**103**	2	9	4	0	0	15	24.5	5.8	464
6	**76**	8	12	7	1	0	24	46.4	9.4	540
7	**56**	11	14	8	9	0	31	74.5	13.8	596
8	**29**	5	14	2	2	0	18	90.9	16.0	625
9	**10**	4	6	0	0	0	6	96.4	16.7	635
10	**5**	3	1	2	0	1	4	100	17.2	640
Total	**640**	36	65	24	14	1	110	100	17.2	640

*Total components of MACE can exceed the total number of patients with MACE, since 1 patient can have >1 MACE.
AMI, acute myocardial infarction; CABG, coronary arterial bypass grafting; CAG, coronary angiography; MACE, major adverse cardiac event; PCI, percutaneous coronary intervention; TIMI, thrombosis in myocardial infarction.

rate MACE: 0.7% (1/149 patients)), would have resulted in saving of €12 112 in diagnostic procedures and €13 253 in admissions, with a total of €25 365 in savings (3.3% of the mentioned total costs of €763 468).

On the other hand, in the low-risk TIMI patients (TIMI=0), a total of €8729 was spent on diagnostic procedures and €5941 on hospital admission, resulting in potential savings of €14 670 (1.9% of total costs). Additionally, had TIMI≤1 been used as the cut-off for low risk (miss-rate MACE: 3.0%, 7/230 patients)), a total of €39 001 could have been saved in diagnostic procedures, €32 904 in admissions, amounting to €71 905 (9.4% of the mentioned total costs of €763 468).

DISCUSSION

This additional analysis on medical consumption in 640 patients with chest pain shows that admission, readmission and ED revisit rates increase with higher TIMI and HEART scores. Diagnostic procedure rates were similar

Table 5 Admission, ED revisit and readmission rates compared for low TIMI scores and low HEART scores

		Initial presentation			Readmissions			ED revisits		
	Patients (n)	Admitted		Days (sum)	Patients	Re-admissions (n)	Days (sum)	Patients		Revisits (n)
Low-risk TIMI (0)	105	5	5%	13	1	1%	1	2	10	10%	11
Not low-risk TIMI (1–7)	535	221	41%	1178	56	10%	70	367	39	7%	47
Low-risk HEART (0–3)	256	28	11%	66	5	2%	8	41	22	9%	27
Not low-risk HEART (4–10)	384	198	52%	1125	52	14%	61	328	27	7%	31
Total all patients	640	226	35%	1191	57	9%	69	369	49	8%	58

ED, emergency department; TIMI, thrombosis in myocardial infarction.

Table 6 Comparison of diagnostic procedures within 6 weeks for low HEART scores and low TIMI scores

		Diagnostic procedures									
	Patients (n)	Stress bicycle test		Myocard scintigraphy		Coronary CT-angiography		Cardiac MRI		Coronary angiography	
Low-risk TIMI (0)	105	44	42%	2	2%	1	1%	1	1%	0	0%
Not low-risk TIMI (1–7)	535	202	38%	39	7%	4	1%	7	1%	89	17%
Low-risk HEART (0–3)	256	106	41%	5	2%	4	2%	4	2%	7	3%
Not low risk HEART (4–10)	384	140	36%	36	9%	1	0.3%	4	1%	82	21%
Total all patients	640	246	38%	41	6%	5	1%	8	1%	89	56%

TIMI, thrombosis in myocardial infarction.

Table 7 Overview of the total costs on initial hospital admission and diagnostic procedures for low HEART scores and low TIMI scores

	Costs of performed diagnostic procedures (€)						Costs of initial admission (€)	Total costs of diagnostic procedures and initial admission (€)
	Stress bicycle	Myocard scintigraphy	CCTA	Cardiac MRI	CAG	Total	Admission costs	
Low risk TIMI (0)	6556	1450	300	423	0	8729	5941	14 670
Not low risk TIMI (1–7)	30 098	28 275	1200	2961	147 918	210 452	538 346	748 798
Low risk HEART (0–3)	15 794	3625	1200	1692	11 634	33 945	30 162	64 107
Not low risk HEART (4–10)	20 860	26 100	300	1692	136 284	185 236	514 125	699 361

CAG, coronary angiography; CCTA, coronary CT angiography.

between HEART and TIMI within low-risk, intermediate-risk and high-risk groups. Only the use of bicycle stress tests declined as TIMI and HEART increased, whereas use of CAG increased with increasing scores. However, the HEART score with a score between 0 and 3 identifies more low-risk patients at the ED than the TIMI score with a score of 0.

In the current study, 40% of patients with chest pain received a low HEART score of 0–3, with a cumulative incidence of MACE of 1.6%. It remains unsure whether diagnostic procedures with limited predictive values are going to detect this 1.6% population. In this specific group with a low pretest probability, reduction of diagnostics could diminish patient burden and hospital costs. The same holds for the low-risk TIMI group; however, the reduction of diagnostics is limited using the TIMI score as only 105 (16%) patients receive a score of 0 and are considered as low risk. This is due to the conservative nature of the TIMI score, resulting in a MACE incidence of 0% in its low-risk group. When including TIMI scores of 1 into the low-risk group, the number of patients will increase from 105 to 230 (36%), however, the occurrence of MACE will increase as well from 0% to 3.0%. It is to be debated what is an acceptable yet achievable missed event rate for patients with chest pain in our current healthcare system with ED overcrowding.[5]

Our findings are consistent with other studies in terms of demonstrated safety of the HEART score for risk-stratification and its possible use in determining further policy to reduce medical consumption, especially in low-risk patients.[9 11 14 15 18 19 24] However, literature discussing TIMI and its incidence of MACE shows some discrepancy with our results. The TIMI low-risk group in this study consisted of patients with TIMI 0 and had an incidence of MACE of 0% within 6 weeks of follow-up. Several studies found that even with a TIMI score of 0, patients did experience a risk of MACE up to 2.4%.[9 25]

Patients with chest pain often receive multiple diagnostic tests, with a risk of iatrogenic damage and furthermore are prone to false-positive or false-negative results, especially the exercise ECG test. Especially, low-risk patients are a group in which medical consumption could be reduced. In our study, a total of €33 945 could have been saved on diagnostic procedures alone and an additional €30 162 could have been saved if patients with a HEART score of 0–3 had been reassured and discharged early from the ED. The possible total cost reduction amounted to €64 107 (8.4% of the mentioned total costs of €763 468). If the TIMI score would have been used to stratify risk categories and the low-risk TIMI group be discharged with reassurance, a total of €8729 would have been saved in diagnostic procedures and another €5941 in hospital admission costs, resulting in potential savings of €14 670 (1.9% of total costs). Extrapolating our results from two hospitals to all hospitals, with a total of 200 000 patients presenting with chest pain each year in the Netherlands, the implementation of the HEART score as a risk-stratifying tool (with early discharge of the patients with HEART score 0 to 3, conservatively estimated at 25% of all patients) could result in yearly national savings of €12 520 898, compared with a yearly national saving of €1 879 593 when the TIMI score would be used and patients with TIMI=0 would be discharged from the ED.

When discharging patients based solely on a score to reduce redundant medical consumption, it remains the question whether the rate of missed MACE is acceptable (see limitations). In this study, four patients in the low-risk HEART score group experienced MACE within 6 weeks. The first of these patients (HEART score 3) had already been scheduled for CABG prior to presentation. The other two patients with a HEART score of 3, as well as the one patient with HEART 2, were diagnosed immediately with ACS at the ED and received elective PCIs in a later stage, indicating mild severity of disease in these patients. These cases show that the HEART score should not be blindly followed, but rather be used as a risk stratification tool.

Limitations

First, any decisions on diagnostic testing and admissions were left to the clinicians. This should be taken into account when interpreting the results. However, because of the observational nature of our research question, this is surmountable. Likewise, attending clinicians also filled out the CRF. Some of the elements in both scores are subjective, which allows for inter-rater differences. The inter-rater agreement has not been investigated. However, as both risk scores contain subjective elements, these inter-rater differences are likely to be comparable between the TIMI and HEART score.

Second, since our analyses are based on a selection of patients from a larger sample, it makes making estimates less certain, especially in terms of safety. However, all patients who met the initial inclusion criteria were included in the original study, making selection bias unlikely.

Third, we could have underestimated medical consumption in two ways. There may have been patients who received follow-up in other hospitals than where they had their initial presentation. Nevertheless, we assume that most patients would mention cotreatment in other hospitals to their physician at the ED, who reports this in the discharge letter, and thus was apparent to us. Additionally, we did not consider any medicolegal costs that could have resulted from missed MACE as such cases are rare in the Netherlands. Including these costs would sequentially lead to a higher cost in both the low-risk HEART and TIMI patients. It could be important to take such costs into account in other countries where medicolegal cases are more prevalent.

Fourth, we adhered to the definition of low-risk MACE as intended by the original investigators of the HEART score and the TIMI score.[8 11] Other cut-offs have been suggested, especially in the current era of high-sensitive

troponin. Additionally, a survey conducted by Than *et al*[26] in 2012 showed that most clinicians prefer diagnostic strategies to have a miss rate of <1%. Although this threshold is desired by clinicians, the article also mentioned a study by Kline *et al* that had found a miss rate of 2% would be more desirable. Otherwise, the harm of false-positive tests would outweigh the harm of untreated disease.[26 27] Had a 1% threshold been applied in our cohort, the HEART score would still have identified more low-risk patients (score 0–2, n=149, miss rate 0.7%) than the TIMI score (score 0, n=105, miss rate 0%); however, the total potential savings of the HEART score would have been lower.

Fifth, in this study a contemporary troponin assay was used, since high-sensitive troponin was not yet introduced during the original study. Addition of a high-sensitive troponin assay (at 0 and 2 hour) allowed for TIMI 0–1 patients to be classified as low risk.[21] Carlton *et al*[20] showed that TIMI would be the more effective risk score, but neither HEART nor TIMI reached a 1% miss rate for AMI with addition of either high-sensitive troponin. Additionally, in this study only AMI was included as an outcome measure. Therefore, it is difficult to extrapolate these findings to our results using a broader definition of MACE.

Last, as it was beyond the scope of our research question, this study did not investigate the possible benefits of the use of the TIMI or HEART score concerning intermediate-risk or high-risk patients. However, it is important to identify high-risk patients for targeted care, while intermediate-risk patients might benefit from a more observational approach. Therefore, future research should also look into specific diagnostic pathways for these two risk categories and possible savings that might result from their implementation.

Our findings support previous studies that the HEART score aids medical decision-making in terms of risk stratification. The HEART score identifies more patients as low risk compared with the TIMI score, which may lead to a reduction in diagnostic procedures and hospital admission in this low-risk group and thus in possible savings. Future studies should prospectively investigate whether adhering actively to the HEART score with an early discharge from the ED of low-risk patients, is indeed safe and leads to a reduction in the use of healthcare resources.

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