Neth Heart J (2012) 20:499–504
DOI 10.1007/s12471-012-0322-6

ORIGINAL ARTICLE

Consumption of diagnostic procedures and other cardiology care in chest pain patients after presentation at the emergency department

A. J. Six · B. E. Backus · A. Kingma · S. I. Kaandorp

Published online: 23 October 2012

Abstract
Objective The HEART score serves risk stratification of chest pain patients at the emergency department (ED). Quicker and more solid decisions may be taken in these patients with application of this score. An analysis of medical consumption of 122 acute chest pain patients admitted before the introduction of this score may be indicative of possible savings.
Methods Numbers of cardiology investigations and clinical admission days were counted. Charged cost of medicine was divided into three categories: ED, in-hospital, and outpatient clinic.
Results The total cost of care was € 469,631, with an average of € 3849 per patient. Seventy-five percent of this cost was due to hospitalisation under the initial working diagnosis of acute coronary syndrome (ACS). This diagnosis was confirmed in only 29/122 (24 %) of the patients. The low-risk group (41 patients with HEART scores 0–3) included one patient with a previously scheduled CABG. In the remaining 40 patients, hospitalisation occurred in 12/40 (30 %) patients and 30/40 (75 %) patients visited the outpatient clinic. The total cost of medical care after presentation of these 40 patients was € 37,641; there were no cases where a new diagnosis of coronary artery disease was made. When medical care in this subgroup is declared redundant, major savings on national medical care budgets could be made.
Conclusion If the HEART score were to be routinely applied, diagnostic pathways could be shortened and costs reduced, in particular in low-risk patients.

Keywords HEART score · Medical consumption · Costs · Chest pain · Emergency department · Risk stratification

A. J. Six
Department of Cardiology, Hofpoort Hospital,
Woerden, the Netherlands

B. E. Backus
Department of Cardiology, University Medical Centre Utrecht,
Utrecht, the Netherlands

A. Kingma
University of Utrecht, Department of Cardiology, University Medical Centre Utrecht,
Utrecht, the Netherlands

S. I. Kaandorp
Faculteit Natuurwetenschappen, Wiskunde en Informatica,
University of Amsterdam,
Amsterdam, the Netherlands

A. J. Six (✉)
Sterrenburg 1,
Utrecht 3511, the Netherlands
e-mail: jacobsix@zonnet.nl

Introduction

The acute coronary syndrome (ACS) is a complex of symptoms caused by a –possibly threatening- occlusion of a coronary artery. However, in the majority of the cases chest pain is caused by various other cardiac and non-cardiac conditions [1].

In order to improve risk stratification in chest patients without overt acute coronary syndrome (ACS) at presentation on the one hand and to place relative arguments for ACS into perspective on the other hand, we developed the HEART score for chest pain patients at the emergency department (ED) [2]. The score was based on clinical experience and medical literature and designed to be as easy to use as the Apgar score for newborns. HEART is an acronym of its components: History, ECG, Age, Risk factors and Troponin. Each of these may be scored with 0 (symptom absent), 1 (symptom doubtful) or 2 points (symptom present). The HEART score has been validated in various studies. The first validation study was a pilot retrospective

analysis in 122 acute chest pain patients of a single hospital. This study was extended with patient data from three other hospitals to compose the first multicentre validation study in 880 patients [3]. This was followed by a prospective validation study in 10 hospitals in the Netherlands [4]. An external validation study in 2906 patients in 14 hospitals in the Asia-Pacific region has recently been completed [5]. The data of all these studies are remarkably consistent and show both high negative and high positive predicted values for outcome.

As a first step in the implementation process of the HEART score, an analysis of medical consumption was made in patients admitted before the introduction of this score. The results may be indicative of possible savings when the score becomes part of clinical decision-making.

Methods

The study population consisted of a complete series of all patients with acute chest pain who presented at the emergency room (ED) of the Hofpoort Hospital in Woerden in the first quarter of 2006. Clinical characteristics were published previously in this Journal [2]. The average age of the patients was 61.2±15.4 years.

The HEART score was calculated according to Table 1. Details of the criteria are given in a previous publication [3].

Major adverse cardiac event (MACE) was defined as the six-week occurrence of an acute myocardial infarction (AMI), percutaneous coronary interventions (PCI), coronary arterial bypass graft operations (CABG) and death due to any cause.

Table 1 The HEART score for chest pain patients at the emergency department

History (=anamnesis)	Highly suspicious	2
	Moderately suspicious	1
	Slightly or not suspicious	0
ECG	Significant ST depression	2
	Nonspecific repolarisation disturbance	1
	Normal	0
Age	≥ 65 years	2
	45 – 65 years	1
	≤ 45 years	0
Risk factors	≥ 3 risk factors, *or*	2
	History of atherosclerotic disease	
	1 or 2 risk factors	1
	No risk factors known	0
Troponin	≥ 3x normal limit	2
	1-3x normal limit	1
	≤ normal limit	0
Total		

The quantification of medical consumption was based on a combination of medical files and a complete series of hospital invoices. Both sources were combined into a new database. Distinction was made for each item as to whether it had taken place at the ED, cardiology clinic or outpatient clinic. The focus of the investigation was on cardiology diagnostics. Therefore, invoices for non-cardiology medical care such as consultation fees for other medical specialists, abdominal echocardiography and microbiology were not included. Charges from other hospitals after referral of the patient, in particular costs due to treatments such as PCI and CABG, were also ignored. The same holds true for drug therapies. Results are given as mean±SD.

As a measure of precision of average costs, we calculated the 95 % confidence intervals by means of bootstrapping with 10,000 replicates because a priori, a normal distribution was not anticipated.

Results

Clinical admissions

The distribution of the HEART scores and the numbers of MACE in each category are given in Table 2. The risk of MACE during 6 weeks after presentation increased with the HEART score. Twenty-nine of the 122 patients (24 %) had a total of 38 MACE.

Seventy-nine of the 122 patients (65 %) were hospitalised. This resulted in a total of 567 hospitalisation days. Fifty-six patients stayed on the coronary care unit (CCU), with an average length of stay of 2.2±2.6 days. Additional data on numbers of hospitalisations in each HEART category are given in Table 3.

Costs

Charges of the ED, clinic, outpatient clinic and totals are given in Table 4.

The total cardiology-related costs were € 469,631. The mean cost of presentation at the ED was € 276± 108 per patient. The cost of presentation accounts for 7 % of the total cost. The cost of clinical observations was € 350,945, accounting for 75 % of the total. The clinical charges consist of cost of hospitalisations for 84 % and diagnostics, cardiology consultation fees and laboratory investigations for 16 %. In 2006, the day charge was € 1574 for the CCU and € 255 for the clinic. The cost of clinical admission was € 4442 on average per patient. The total cost of later outpatient visits for all patients was € 85,056, reflecting 18 % of all costs, and on average € 1198 per outpatient.

Numbers of cardiology investigations are given in Table 5.

Table 2 Numbers of patients in each HEART score and the occurrence of major adverse cardiac events (MACE)

HEART score	N patients	AMI	Revascularisation		Death	MACE (pts)	MACE (%)
			PCI	CABG			
0	3	0	0	0	0	0	0 %
1	10	0	0	0	0	0	0 %
2	16	0	0	1	0	1	6 %
3	12	0	0	0	0	0	0 %
4	28	2	2	0	0	3	11 %
5	20	4	3	0	0	5	25 %
6	11	3	2	1	0	4	36 %
7	10	3	3	2	0	7	70 %
8	7	2	3	0	2	5	71 %
9	4	2	0	2	0	3	75 %
10	1	0	1	0	0	1	100 %
	122	16	14	6	2	29	24 %

AMI acute myocardial infarction, *PCI* percutaneous coronary intervention, *CABG* coronary bypass graft, *MACE* major adverse coronary event

Low-risk group

In the group with a HEART score of 0–3, 15/41 (37 %) patients were admitted for clinical observation. The observation period consisted of 23 days on the CCU and 28 days at the cardiology clinic. Charges for hospitalisation only were € 36,202 and € 9016, respectively. The total cost of hospitalisation plus clinical investigations was € 50,553. The average duration of hospitalisation was 3.9±1 days. The average cost of hospitalisation was € 3370 per hospitalised patient. One patient reached an endpoint, a CABG occurring a couple of weeks after presentation. The index presentation of this patient was a visit to the ED due to a haematoma after an elective diagnostic coronary angiography. He also reported chest pain due to his previously documented stable angina. Therefore, this case was included in the analysis. The coronary revascularisation was already scheduled before the presentation to the ED. In this low-risk group exercise testing was performed in 13/41 (32 %) patients. The total charge for these tests was € 1079. Coronary ischaemia was not diagnosed in any of these tests. An echocardiogram was taken in 7/41 (17 %) patients, for a total charge of € 868. Myocardial scintigraphy was not done in this subgroup. Two of 41 (4 %) patients underwent coronary angiography. The cost of these was € 3168 in total. Neither of these patients had significant stenosis. Thirteen of 41 patients (32 %) returned to the outpatient clinic after discharge. The total cost of outpatient care was € 9998, reflecting € 769 per outpatient.

Intermediate-risk group

In the intermediate-risk group, with HEART scores of 4–6, 43/59 (69 %) patients were observed clinically. The total cost of hospitalisation was € 136,985. The observation period was 41 days at the CCU, with a total charge of € 64,534 for cost of hospitalisation. In addition, these patients were hospitalised at the cardiology department for 212 days. The cost of hospitalisation was € 3186 per hospitalised patient. The average duration of hospitalisation was 5.8 days (SD=3.4). In this subgroup 37/59 (68 %) patients had an exercise test, at a total charge of € 3320. An echocardiogram was taken in 21/59 (37 %) patients, at a total charge of € 2728. In 1/59 (2 %) patients myocardial scintigraphy was performed at a charge of € 950. Eight of the 59 (14 %) patients underwent an elective coronary angiography. The cost of these was € 7600. In addition, six patients were referred for emergency invasive strategies (cost not included in this analysis). Significant stenosis was seen in 9/14 (64 %) patients. In this intermediate-risk group, 39/59

Table 3 Numbers of hospitalised patients and hospitalisation days at the coronary care unit (CCU) and the clinical cardiology department in each HEART score

HEART score	N patients	CCU		Clinic		Total CCU and or clinic		
		Patients	Days	Patients	Days	Patients	% admissions	Days
0	3	0	0	0	0	0	0 %	0
1	10	0	0	1	4	1	10 %	3
2	16	5	17	7	18	7	38 %	30
3	12	5	6	7	14	7	50 %	18
4	28	13	21	19	75	19	71 %	85
5	20	9	10	14	80	15	65 %	79
6	11	7	10	9	57	9	73 %	55
7	10	7	19	9	99	9	90 %	112
8	7	5	15	7	50	7	100 %	70
9	4	4	17	3	23	4	100 %	39
10	1	1	9	1	21	1	100 %	29
Total	122	56	124	77	443	79	65 %	567

CCU coronary care unit

Table 4 Cost in € of presentation, clinic and outpatient clinic

HEART score	N patients	ED €	Clinical admission €	Outpatient €	Total cost €	Total per patient €	95 % CI
0	3	609	0	0	609	203	54-311
1	10	2530	1263	92	3885	386	204-697
2	16	4399	34,960	3756	43,115	2695	812-5811
3	12	2994	14,330	6150	23,474	1956	1040-3018
4	28	8558	59,061	12,632	80,251	2866	2034-3787
5	20	5566	43,611	11,935	61,112	3056	1952-4261
6	11	2969	34,313	6378	43,660	3969	2592-5320
7	10	2613	67,605	24,573	94,791	9479	5434-14,392
8	7	1885	40,376	10,686	52,947	7564	4284-11,275
9	4	1165	35,274	8736	45,175	11,294	5656-19,034
10	1	342	20,152	118	20,612	20,612	NA
Total	122	33,630	350,945	85,056	469,631	3849	3010-4772

ED emergency department, *NA* not applicable

95 % CI is NA when only 1 patient is in that group

(66 %) patients visited the outpatient clinic after clinical discharge. The total charges for outpatient care were € 30,945 or € 793 per outpatient.

High-risk group

In the group of patients with HEART scores of 7–10, one patient was immediately referred to an intervention centre elsewhere for emergency invasive treatment. The other 21/22 (95 %) patients were admitted for clinical observation. Altogether, these patients stayed on the CCU for 60 days, with a total charge of € 94,446, and 193 days in the clinical cardiology department. A total of € 163,407 was charged for all clinical costs. Clinical cost was € 7781 per hospitalised patient. The average duration of hospitalisation was 12.0± 6.4 days.

Exercise testing was performed in 13/22 (63 %) patients, at a total cost of € 1162. An echocardiogram was taken in 13/22 (86 %) patients, at a total charge of € 2356. In one of the 22 patients (5 %) myocardial scintigraphy was done, at a cost of € 950. Seven of the 22 patients (32 %) underwent elective coronary angiography, at a total cost of € 10,836. In addition, six patients were referred at some point for emergency diagnostic and/or therapeutic coronary intervention (cost of these not included). In the high-risk group 18/22

Table 5 Numbers of cardiology investigations

HEART score	N patients	Exercise test	Echocardio-graphy	Scintigraphy	Coronary angiography	
					In hospital	After referral[a]
0	3	0	0	0	0	0
1	10	1	1	0	0	0
2	16	7	2	0	1	0
3	12	5	4	0	1	0
4	28	22	4	1	3	0
5	20	12	11	0	3	4
6	11	6	7	0	2	2
7	10	9	8	0	5	2
8	7	4	5	1	2	1
9	4	1	6	0	0	2
10	1	0	0	0	0	1
Total	122	67	48	2	17	12
Per procedure (€)	83	124	950	1548		
Total (€)	5561	5952	1900	26,316		

PCI percutaneous coronary intervention, *CABG* coronary artery bypass graft

[a]Cost after referral not included

(82 %) patients visited the outpatient clinic. The cost of outpatient care was € 44,113 which was € 2450 per patient.

Discussion

The evaluation of chest pain patients at the ED is complex and requires many diagnostic procedures. The HEART score allows reliable risk stratification, without additional diagnostics within 1 h upon arrival of the patient [2–5]. Therefore, it can quickly be determined which diagnostic pathways may be useful or redundant once the HEART score is known.

This study is an analysis of medical consumption in 122 acute chest pain patients. Seventy-nine of these 122 patients (65 %) were admitted for clinical observation under the suspected diagnosis of ACS. The diagnosis was confirmed in only 29 of these 79 cases (37 %) in terms of the occurrence of at least one MACE. In the remaining 63 % of those patients this diagnosis was not confirmed. This fact may be interpreted as over-diagnosis in roughly two thirds of these patients.

Reduction of diagnostics

According to generally accepted methodological principles, diagnostic tests do not add any value in case of low pretest likelihood, in particular when the testing methods used result in many false-positive and false-negative results. Reduction of redundant diagnostics has the potential of reducing iatrogenic damage. In this context iatrogenic damage may consist of complications due to procedures, medication errors, radiation damage, hospital infections and possible traumatic experiences due to the hospital stay. Unfortunately, iatrogenic damage is hard to measure. By means of the measurement of diagnostic consumption we may get an impression of what savings can be made for patients and the health care system.

About one third of the patients in our four validation studies have HEART scores of 0–3. In these groups the risk of MACE is 1-2 %. Classical exercise testing has a sensitivity of only 65-70 % and a specificity of 75-80 % [6]. Also advanced ischaemia detection by means of myocardial scintigraphy, CT scan and MRI have limited positive and negative predictive values for significant coronary artery disease. Therefore, it is very questionable whether these diagnostic procedures are useful in a setting of a 1 % risk.

About half the patients had moderate HEART scores (4–6), indicating a risk of 12–20 %. In this setting, the HEART score does not help the clinician very much in choosing the best diagnostic policy, other than the decision to admit the patient for clinical observation and to perform diagnostic procedures.

HEART scores of 7–10, indicating risks of MACE up to 100 %, occurred in 17 % of the patients. This study group is relatively small as the majority of high-risk patients never reach the ED but are immediately transported to the intervention room. As far as these patients do reach the ED, a case may be made for immediate referral to the intervention room.

Savings

In the current study in 41 low-risk patients, a total of € 60,551 was spent on all kinds of medical costs after presentation at the ED. One of these was the patient with a scheduled CABG before presentation, at a cost of € 22,910. The other 40 patients were evaluated at a total cost of € 37,641, without disease being confirmed in any of these cases. When extrapolating this figure for the entire year 2006, savings of € 150,564 could theoretically have been made in a 265-bed hospital by declaring all diagnostic procedures redundant in low HEART score patients. When further extrapolating this figure to all 45,000 hospital beds in the Netherlands, this may theoretically translate into national savings of € 26 millions in 2006. When assuming an annual cost increase of 4 %, this implies theoretical savings of over € 32 million in the current 2012 situation.

A similar figure was presented by Mahler et al. after analysis of 1070 chest pain patients (904 low risk, 166 high-risk) in a third referral centre in the United States [7]. This study showed an occurrence of MACE of 0.6 % in low-risk patients (HEART score≤3). It was suggested that annual savings of $ 112,000–204,000 could be made in a single hospital by reduction of diagnostic procedures in the low-risk group.

The cost analysis in patient groups with moderate or high HEART scores does not bring us clear messages. One of the most important observations is that the cost in these patients is dominated by hospitalisation in a therapeutic setting such as patients with a myocardial infarction or clinical recovery after CABG.

Acceptable risk

When a policy of early discharge of low-risk patients is proposed, and consequently, medical consumption is considered redundant, the question arises as to what rate of missed diagnoses is acceptable. This issue was previously raised by Pope et al. [1]. These investigators observed a risk of inappropriate discharge of patients with AMI of 2.1 %, in the era before the introduction of troponin assays for clinical use. According to Schull et al. [8], 2.1 % of patients with AMI and 2.3 % of patients with unstable angina are misdiagnosed. In the HEART validation studies we found a rate of false negatives, in terms of MACE, ranging from 0.99 %–

2.56 % [2–5]. Therefore, the HEART score study group has suggested a policy of early discharge of patients with HEART scores≤3 without further work-up. In 2006, this idea was already addressed by Christensen et al. [9] who published the Vancouver prediction rule. This clinical tool was developed to identify a group of chest pain patients with a risk of ACS of<2 % in whom early discharge would be favourable. A similar policy was proposed by Mahler et al. [7], who suggested reduction of diagnostic procedures in the low-risk patients (HEART score≤3) with an occurrence of MACE of 0.6 %.

Therefore, it is questionable whether additional diagnostic work-up makes sense in an on average 60-year-old patient population that has a documented risk of MACE of≤2.5 %. A prolonged stay in the cardiology clinic and additional diagnostic procedures are rather likely to increase the number of false positives (resulting in even more redundant medicine) than to reduce the number of false negatives.

Strengths and limitations

The study population concerns patients who were admitted in the first quarter 2006. Consequently, the data are 6 years old. On the other hand, strong aspects are that the clinical data are published, the HEART score did not influence the clinical policy and detailed financial data for all clinical procedures are available.

Since 2006 cardiology has developed further. Practically all hospitals in the Netherlands now have a specialised Cardiology Emergency Department (Eerste Hart Hulp, EHH). In addition, many sites have equipment for cardiac CT and MRI. In the study by Mahler, conducted in the USA in 2008–2010, (mentioned above), CT scans were performed in one third of the patients [7]. These developments have resulted in further rise in medical consumption, although the diagnostic benefit of the modern diagnostic procedures is not undisputed.

Last but not least, the focus of this analysis was to investigate whether the diagnostic HEART score helps in reducing diagnostic procedures. Therefore, the therapeutic costs were intentionally ignored. These occur in particular after referral to specialised centres for cardiac catheter interventions and thoracic surgery. The incidence of such procedures increases with higher HEART scores.

All limitations mentioned above result in relative underestimation of medical consumption in today's practice.

Conclusions

The HEART score is helpful to be enable better medical decisions to be taken quickly with regards to diagnostic and treatment options for chest pain patients at the ED. In particular in patients with low HEART scores, hospital admissions and specific diagnostic procedures may be reduced. When avoiding redundant medical care, iatrogenic damage may be reduced and savings of tens of millions of Euros may be made for the national health care system.

Acknowledgements Words of gratitude are expressed to Elsbeth Klop from the finance department of the Hofpoort Hospital, who supplied the billing history of the patients in this study.

References

1. Pope JH, Aufderheide TP, Ruthazer R, et al. Missed diagnoses of acute cardiac ischemia in the emergency department. N Engl J Med. 2000;342:1163–70.
2. Six AJ, Backus BE, Kelder JC. Chest pain in the emergency room: value of the HEART score. Neth Heart J. 2008;16:191–6.
3. Backus BE, Six AJ, Kelder JC, et al. Chest pain in the emergency room. A multicenter validation of the HEART score. Crit Pathways Cardiol. 2010;9:164–9.
4. Backus BE, Six AJ, Kelder JC, et al. A prospective validation of the heart score for chest pain patients at the ER. Eur Heart J 2011;32 (abstract supplement), 952, abstract 5220
5. Backus BE, Six AJ, Cullen L, et al. The HEART score for chest pain patients at the emergency department validated in a multi centre Asia-Pacific population. Eur Heart J 2012;33:59 (abstract).
6. Diamond GA, Forrester JS. Analysis of probability as an aid in the clinical diagnosis of coronary artery disease. N Engl J Med. 1979;300:1350–8.
7. Mahler SA, Hiestand BC, Goff DC, et al. Can the HEART score safely reduce stress testing and cardiac imaging in patients at low risk for major adverse cardiac events? Crit Pathways Cardiol. 2011;10:128–33.
8. Schull MJ, Vermeulen MJ, Stukel TA. The risk of missed diagnosis of acute myocardial infarction associated with emergency department volume. Ann Emerg Med. 2006;48:647–55.
9. Christenson J, Innes G, McKnight D, et al. A clinical prediction rule for early discharge of patients with chest pain. Ann Emerg Med. 2006;47:1–10.