

# Implementation of a pre-hospital decision rule in general practice

## Triage of patients with suspected myocardial infarction

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**Objective** To improve pre-hospital triage of patients with suspected acute cardiac disease.

**Design** Prospective study.

**Subjects** Patients with symptoms suggestive of acute cardiac pathology, who were seen by a general practitioner, for whom acute admission into hospital was requested, and in whom a pre-hospital electrocardiogram was recorded by the ambulance service.

**Methods** The study consisted of two phases. In the first phase, a decision rule was developed based on clinical characteristics and electrocardiographic findings in 1005 patients with suspected acute cardiac pathology. In the second phase, the decision rule was prospectively validated. Symptoms were recorded by a standardized questionnaire by the general practitioner and a computerized electrocardiogram was made by the ambulance nurses at the patient's home. Three electrocardiographic outcomes were available: 'normal electrocardiogram', 'possible myocardial infarction' or 'extensive myocardial infarction'. By use of the predictive model, the general practitioner could decide if hospitalization was necessary or not.

**Main outcome measurements** Identification of patients at low (stable angina, atypical chest pain, other pathology)

and high (myocardial infarction, unstable angina) probability of acute cardiac pathology.

**Results** Among 977 patients with a complete pre-hospital evaluation in the validation phase of the study, the decision rule recommended 'no hospitalization' in 227 patients (23%). The general practitioner followed this advice in 44% of these patients. Although seven of them developed a non-Q wave myocardial infarction, no complications occurred in patients not admitted. In addition, the general practitioner did not hospitalize 19 (2%) of 750 patients for whom the decision rule recommended admission. Pre-hospital triage by the general practitioner resulted in a 12% (118 of 977 patients) reduction of the number of patients admitted to the Coronary Care Units.

**Conclusions** Pre-hospital triage by the general practitioner was facilitated using a standardized questionnaire and pre-hospital electrocardiography, and resulted in a reduction in the number of patients admitted to the Coronary Care Unit, and proved to be safe.

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**Key Words:** Predictive model, hospital admission, myocardial infarction.

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## Introduction

Many patients are admitted to the Coronary Care Unit with chest pain suggestive of myocardial infarction that is subsequently ruled out. Typically, in more than 50% of patients admitted to the Coronary Care Unit for presumed myocardial infarction, the diagnosis is not confirmed<sup>[1,2]</sup>.

In the Netherlands, most patients with suspected myocardial infarction are primarily seen by the general



**Table 1** Independent predictors of acute cardiac pathology in patients with symptoms suggestive of acute cardiac pathology

Variables	Beta	Odds ratio	95% CI‡	Probability (%)†
Intercept (a)	-2.19			
Abnormal ECG	1.42	4.1	3.0-5.7	40
Male gender	0.70	2.0	1.5-2.7	15
Radiation of chest pain to neck, left arm	0.58	1.8	1.3-2.4	15
Nausea/sweating	0.58	1.8	1.3-2.4	15
Prior cardiovascular disease*	0.41	1.5	1.1-2.0	15

\*Prior cardiovascular disease: myocardial infarction (MI), angina pectoris.

†Calculated as additional risk of acute cardiac pathology by using the beta-coefficients of the logistic regression function.

‡CI denotes confidence interval.

practitioner. However, due to the poor predictive value of the clinical information available, recognition of symptoms possibly related to acute cardiac pathology is often difficult for the general practitioner<sup>[3-5]</sup>. Because of fear of the consequences of not referring patients with acute cardiac pathology (myocardial infarction, unstable angina pectoris), the general practitioner tends to hospitalize most patients with chest pain. If guidelines could be developed to help general practitioners to distinguish acute cardiac pathology from other causes of chest pain, the number of unnecessary hospital admissions could be reduced considerably.

Previous studies of patients with chest pain in the Emergency Room or Coronary Care Unit were attempted to identify diagnostic and prognostic features of acute cardiac pathology<sup>[6-31]</sup>. Only a few studies have focussed on pre-hospital identification of chest pain patients with use of an electrocardiogram<sup>[32-34]</sup>. The purpose of the Prehospital ECG Project was to improve the selection criteria for hospital admission of patients with suspected acute cardiac pathology by increasing diagnostic accuracy. To achieve this, a decision model, including structured questions and findings from a pre-hospital computerized ECG analysis, was developed and implemented in general practice in Rotterdam.

## Methods

The Pre-hospital ECG Project consisted of two phases. In the training phase a decision rule was developed<sup>[35]</sup>. In the validation phase this decision rule was applied in general practice and prospectively validated. The outcome of the decision rule enabled the general practitioner to determine the probability of acute cardiac pathology and to reconsider the decision to refer patients to the hospital.

### Development of the decision rule

Details about the development of the decision rule have been reported elsewhere<sup>[35]</sup>. In brief, between 1 January

and 1 October 1992, 1005 patients were evaluated with symptoms suggestive of acute cardiac pathology, who were seen by a general practitioner and for whom a request for referral to hospital in the municipality of Rotterdam was made to the central ambulance post. For each patient, the general practitioner completed a standardized questionnaire, including age, sex, number of hours since the onset of pain, duration and location of the present episode of pain, response to nitroglycerin, the presence of associated symptoms (shortness of breath, sweating or nausea), previous medical history, and findings at physical examination.

After the arrival of the ambulance at the patient's home the ambulance nurse recorded a 12-lead electrocardiogram using a small portable battery-powered computer ECG device (Sicard-P, Siemens, Sweden), which was analysed by a computer program, developed by Mortara (Mortara Inc, Milwaukee, U.S.A.), and stored for later analysis<sup>[36]</sup>. Subsequently, all patients were transported to hospital.

Final discharge diagnoses were gathered from the hospital medical records or the general practitioner. Myocardial infarction was diagnosed when patients met standard history, ECG and enzyme criteria. Unstable angina was defined as a history of angina with increasing frequency and severity of symptoms or new onset angina with subsequent documentation of either ST-T changes at rest, an abnormal stress test or an abnormal coronary angiogram.

Algorithms previously proposed by other investigators to improve hospital triage of patients with or without acute cardiac disease were tested in this pre-hospital study population<sup>[11-15]</sup>. However, this evaluation was unsatisfactory in the pre-hospital setting, mainly because there was a higher incidence of acute cardiac pathology in our patients. In a multivariate analysis, six characteristics from the history as well as the ECG appeared independently and significantly associated with acute cardiac pathology (Table 1). Subsequently, a new practical model was developed that segregated patients into three groups with increasing probability of acute cardiac pathology (Table 2).



**Table 2** The decision rule

No. of positive predictors present at clinical presentation	ECG findings		
	Normal ECG	Possible or minor MI on ECG	Major MI on ECG*
0 Predictor	Home	Reconsider admission	Always
1 Predictor	Home	Admission	admission, consider
2 Predictors	Reconsider admission	Admission	starting thrombolysis
3 Predictors	Admission	Admission	
4 Predictors	Admission	Admission	

\*Sum of ST elevation/ST depression  $\geq 10$  mV in 12 leads. MI denotes myocardial infarction. Performance of the decision rule: In patients with a normal ECG and 0 or 1 positive predictor, the decision rule predicts a minimal risk of acute cardiac pathology such that hospital admission is probably not necessary. In patients with a normal ECG and two positive predictors or in patients with an abnormal ECG and no positive predictors, the risk of acute cardiac pathology is slightly increased such that a general practitioner may reconsider hospital admission, but hospital admission is not necessary. In all other conditions, hospital admission is recommended.

### Validation phase

The performance of the decision rule was validated in 1020 consecutive patients with symptoms suggestive of acute cardiac pathology from April 1993, until April 1994. The methodology of this phase was similar to that used in the first phase. Symptoms of patients suspected of myocardial infarction were recorded by the general practitioner using a standardized questionnaire, and a computerized ECG was made by the ambulance nurses. For practical purposes, the ECG interpretation was restricted to three electrocardiographic outcomes which were made available to the general practitioner: 'normal ECG', 'possible myocardial infarction' or 'extensive myocardial infarction, start thrombolytic therapy'. By use of the decision rule, the general practitioner could decide whether hospitalization was necessary or not. In the presence of unsuitable social circumstances (patient living alone or without a telephone) hospitalization was always effected. Patients not admitted were visited at home the next working day, at which occasion blood was drawn for follow-up cardiac enzyme determinations (CPK, CPK-MB,  $\alpha$ HBDH) and a follow-up ECG was recorded by technicians of the Central Doctors Laboratorium. The results of this follow-up were immediately provided to the general practitioner. Complications were recorded up to 30 days after the original visit of the general practitioner and the ambulance service. The final hospital discharge diagnoses were gathered from the hospital medical records or from the general practitioner.

### Data analysis

Clinical and electrocardiographic characteristics of hospitalized patients were compared with non-hospitalized patients. The association between findings of the decision rule and the subsequent probability of acute cardiac pathology and its complications was assessed using Student *t* and chi-square tests for continuous or

categorical variables, respectively. Two tailed *P*-values  $< 0.05$  were considered statistically significant. Receiver operator characteristics (ROC) curves were constructed to determine the ratio of true positives to false positives at different calculated probabilities of the decision rule in the training and validation set.

### Results

From April 1993 to April 1994, 1020 consecutive patients with chest pain were evaluated by the general practitioner and a pre-hospital ECG was made by the ambulance service. We obtained a final diagnosis on 977 patients and these patients constitute the present analysis. Their mean age was 65.6 years, 519 patients (53%) were of male gender, and 597 patients (61%) presented themselves to the general practitioner within 3 h after the onset of symptoms.

In 750 patients (77%) the decision rule recommended hospitalization while in 227 (23%) no hospitalization was suggested. The demographic and clinical characteristics of these patients are shown in Table 3. Compared to patients in whom no admission was recommended, patients requiring hospitalization were significantly older (67.0 vs 61.5 years,  $P < 0.05$ ), and more often of male gender (61% vs 37%,  $P < 0.05$ ). In addition, these patients received cardiac medication prior to the chest pain episode more frequently (71% vs 52%), and needed more medication by the general practitioner to relieve the chest pain.

Fifty seven per cent of the patients in the hospitalization group had a final diagnosis of acute cardiac pathology (myocardial infarction, unstable angina pectoris), compared with only 18% in the no hospitalization group (Table 4).

The general practitioners did not admit 99 of the 227 patients (44%) in whom the decision rule recommended no hospitalization (Table 3). The non-referred patients were significantly younger, and needed no or less medication to relieve their chest pain. More often



**Table 3** Baseline characteristics of patients in whom the decision rule advised admission or not and of 227 patients in whom the decision rule advised 'no admission' and who were subsequently hospitalized or not by the general practitioner

	Decision rule		GP decision	
	Hospital (%)	Home (%)	Hospital (%)	Home (%)
Total number	750 (77)	227 (23)	128 (56)	99 (44)
Mean age (years)	67.0*	61.5	63.0	59.4*
Male gender	434 (61)*	85 (37)	40 (31)	45 (45)*
Prior cardiac disease	488 (65)	62 (27)	39 (30)	23 (23)
Radiation of pain	541 (72)	101 (44)	64 (50)	37 (37)*
On cardiac medication	530 (71)*	119 (52)	72 (56)	47 (48)
Medication administered by GP	590 (79)*	149 (66)	97 (76)	52 (52)*
Pain subsides with nitrates	276 (37)	86 (38)	57 (45)	29 (29)*
Sweating/nausea	516 (69)*	93 (41)	61 (48)	32 (32)*
Clammy skin	200 (27)*	32 (14)	22 (17)	10 (10)*
Normal ECG†	131 (17)*	219 (96)	120 (94)	99 (100)*

†No ST segment abnormalities, no Q waves or other findings that hindered accurate interpretation of repolarization abnormalities.

\* $P < 0.05$ .

**Table 4** Final diagnosis and complications in 977 patients in whom the decision rule advised hospitalization or non-referral and of 227 patients in whom the decision rule advised 'no admission' and who were hospitalized by the general practitioner or not

	Decision rule		GP decision	
	Hospital (%)	Home (%)	Hospital (%)	Home (%)
Total number	750	227	128	99
Diagnosis				
Myocardial infarction	265 (35)	27 (12)	20 (16)	7 (7)
Unstable angina pectoris	162 (22)	13 (6)	12 (9)	1 (1)
Atypical chest pain	191 (25)	159 (70)	71 (55)	88 (88)
Other*	132 (18)	28 (12)	25 (20)	3 (3)
Complications				
Death	17 (2)	4 (2)	2 (2)	2 (2)
CPR	16 (2)	—	—	—
Recurrent MI	18 (2)	2 (1)	2 (1)	—
Recurrent AP	137 (18)	5 (2)	5 (4)	—
Heart failure	66 (8)	3 (1)	3 (2)	—
Rhythm disturbances†	21 (3)	3 (1)	3 (2)	—

\*Stable angina pectoris, (supra-) ventricular rhythm disturbances, heart failure or other pathology.

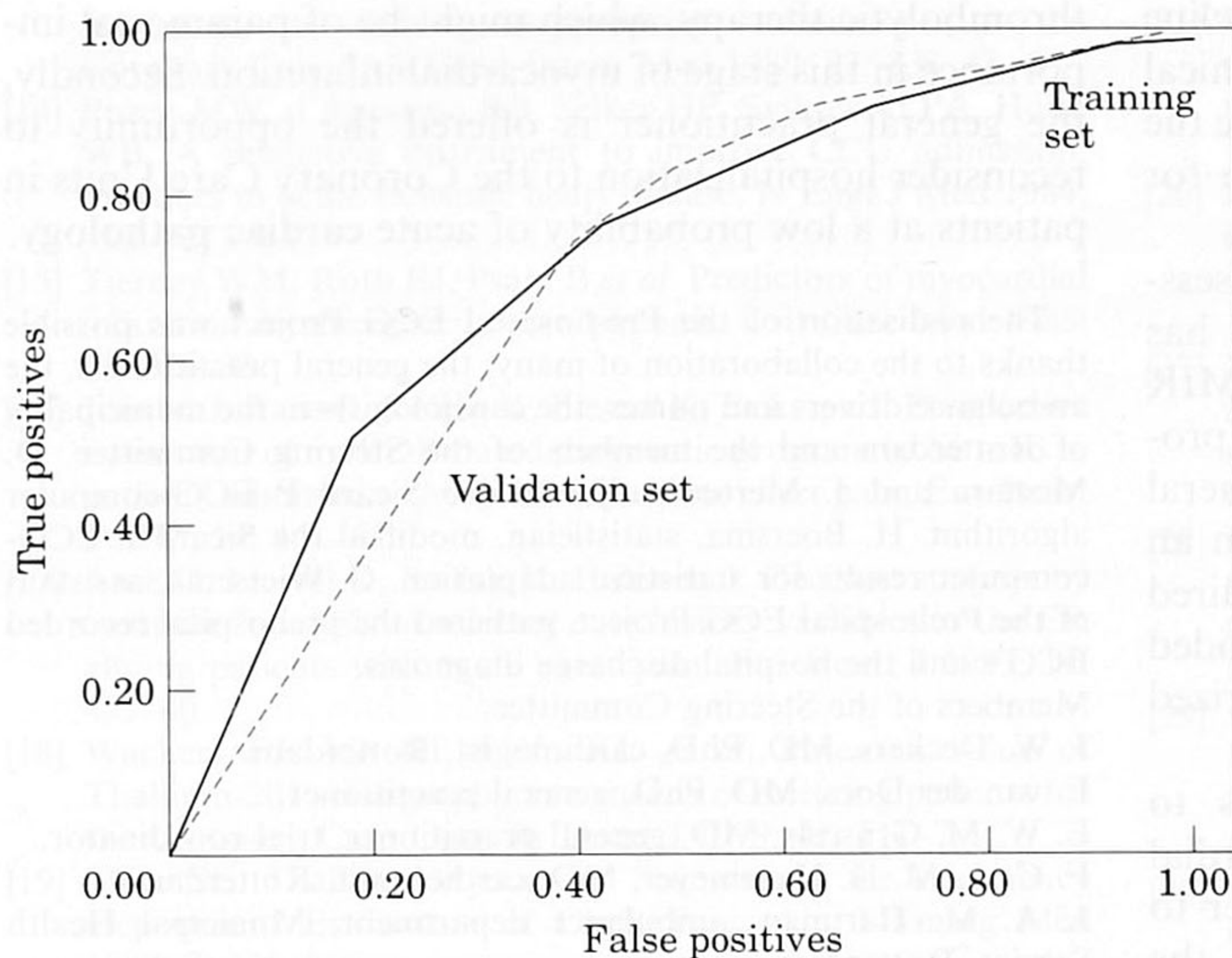
†Included (supra-) ventricular rhythm disturbances. GP=general practitioner; CPR=cardiac pulmonary resuscitation.

the chest pain subsided after the administration of sublingual nitrates. All non-hospitalized patients had a normal pre-hospital ECG.

Complications up to 30 days after the initial visit of the general practitioner (death, cardiac resuscitation, recurrent chest pain, heart failure, rhythm disturbances) occurred in 35% in the hospitalized group. In the group of patients who were hospitalized by the general practitioner, in spite of the advice of the decision rule ( $n=128$ ), acute cardiac pathology was confirmed in 25% and complications occurred in 11%. Two patients died after hospital admission: one patient died 30 min after arrival in hospital as a result of rupture of a dissecting aneurysm and the other patient developed a fatal myocardial infarction 1 h after arrival in hospital. In the 99

patients who stayed at home, acute cardiac pathology was present in 8%. In seven patients (7%) a non-Q wave myocardial infarction was detected the next working day at the follow-up visit (Table 4). These patients were subsequently hospitalized and no in-hospital complications occurred. No early death occurred, although two patients died at home during follow-up: one patient died of a malignant lung carcinoma 1 week after the original visit of the general practitioner and the other patient developed fatal pulmonary bleeding 14 days after the visit of the general practitioner. Thus the combination of the judgement of the general practitioner, aided by the decision rule, succeeded in identifying a subgroup of low risk patients in whom immediate hospitalization would not be necessary.





**Figure 1** Receiver operator characteristics (ROC) curves of the decision rule, determined in the training phase and in the validation phase.

In addition, the general practitioners did not admit 19 (2%) of 750 patients for whom the decision rule recommended admission. These patients were significantly younger in comparison with patients who were hospitalized (61.0 vs 67.1 years). Among them three developed a myocardial infarction, although no life-threatening complications occurred. Of the 19 patients, 13 (72%) had a normal pre-hospital ECG. In the other six with an abnormal pre-hospital ECG, the general practitioner decided not to hospitalize them because of social circumstances.

It is worth noting that in 95 (81%) of the 118 non-hospitalized patients this decision was made outside the official office hours. The decision not to hospitalize patients was made in 45 patients (38%) by their own general practitioner, whereas in 62% of the cases the decision was made by another general practitioner on duty.

The positive predictive value of the decision rule was 57%. Combined with the general practitioner's judgement, the positive predictive value increased to 82%. It is apparent that integrating the judgement of the general practitioner with the predictive model of the decision rule more accurately predicts the probability of acute cardiac pathology and thus the necessity of hospital admission.

Figure 1 shows the receiver-operator curve for the decision rule in the training and the validation phase. The receiver-operator curve is a way of representing the overall performance of a diagnostic test and may be used to give the optimal balance between true- and false-positives. An ideal diagnostic test would have a surface of 100% under the total area of the ROC graph. The area under the ROC curve of the decision rule in the training phase was 0.72. When applied to the validation set, the decision rule discriminated patients with a high

and a low probability of acute cardiac pathology with an ROC area of 0.70. This difference was not statistically significant.

## Discussion

A decision rule was developed as a diagnostic aid for the general practitioner to improve selection for hospital admission of patients with presumed cardiac pathology. The decision rule provides the general practitioner with an estimated risk of acute cardiac pathology and thereby the necessity of hospitalization. The risk is obtained from a structured questionnaire and the analysis of a computerized ECG. Pre-hospital triage by the general practitioner was practicable and resulted in a non-hospitalization of 118 patients (12%) who would otherwise have been admitted to the Coronary Care Unit.

The decision rule advised non-referral in 23% of the patients with chest pain. In 56% of these patients, the general practitioner deviated from this advice and these patients were hospitalized. In this group, more acute cardiac pathology and complications occurred in comparison with the non-hospitalized patients. Additional considerations in the general practitioner's judgement to hospitalize patients included the amount of medication the patient needed to relieve the chest pain, as well as abnormal findings at physical examination, including a clammy skin or an irregular heart rhythm. Integrating the general practitioner's judgement with the outcomes of the decision rule resulted in a more accurate selection for hospitalization of patients with acute cardiac pathology. Therefore, it is concluded that the decision rule is an important indicator of the probability of acute cardiac pathology, that assists the general practitioner in his (her) final diagnosis. It should be realized that the



decision rule only performs as an additional guideline for the general practitioner. Other subjective clinical factors, e.g. the amount of medicine needed to relieve the chest pain, are also influential in the final decision for hospitalization by the general practitioner.

The value of an electrocardiogram for assessment of patients with possible cardiac pathology has already been established by findings in the IMIR study<sup>3-5]</sup> and in other algorithms<sup>[11-17]</sup>. However, procuring an ECG device is not a priority for most general practitioners, since it is often not so easy to obtain an ECG at the patient's home or to maintain the required skills of ECG interpretation. This problem was avoided in the present study by implementing a computerized ECG device in the ambulance service.

Previous studies have evaluated strategies to improve the accuracy of the diagnosis of myocardial infarction in the hospital emergency rooms in order to reduce the number of unnecessary admissions to the Coronary Care Units<sup>[11-17]</sup>. Each approach identified patients at low probability of acute cardiac pathology in order to achieve more appropriate triage to the Coronary Care Units. The results are all based on similar patients with symptoms suggestive of myocardial infarction, in whom a definite diagnosis cannot be established in the first instance. In the Netherlands, the general practitioner is most important as regards selecting patients with symptoms suggestive of acute cardiac pathology, because patients usually contact their general practitioner before they are referred to hospital. The in-hospital based approaches do not tackle the difficult problem of patients who are referred to hospital and who should not have been there in the first place. The triage in hospital may therefore only minimally reduce the burden on the Coronary Care Units or the Emergency Units. Consequently, optimal diagnostic accuracy by the general practitioner is the most effective procedure to select patients for hospitalization.

A restriction of our study may be a selection bias in the development of the decision rule, because patients with abnormal physical findings, such as heart failure, were often referred to hospital by the general practitioner without completion of the pre-hospital study questionnaire during the training phase. On the other hand, patients with myocardial infarction as well as unstable angina were included in the development of the present decision rule, because we are of the opinion that both conditions need appropriate recognition and evaluation in hospital. Patients with unstable angina were excluded in the development of a predictive model in the investigations of Tierney<sup>[15]</sup> and of Goldman and co-workers<sup>[11,12]</sup>.

This study demonstrates that a pre-hospital decision rule can be used as a simple and accurate means to identify patients without acute cardiac pathology and with a low risk of complications. Use of a decision rule in the pre-hospital setting has two important implications. First, it enables the general practitioner to identify patients with an evolving myocardial infarction at a very early stage, allowing pre-hospital administration of

thrombolytic therapy, which might be of paramount importance in this stage of myocardial infarction. Secondly, the general practitioner is offered the opportunity to reconsider hospitalization to the Coronary Care Units in patients at a low probability of acute cardiac pathology.

The realisation of the Pre-hospital ECG Project was possible thanks to the collaboration of many: the general practitioners, the ambulance drivers and nurses, the cardiologists in the municipality of Rotterdam and the members of the Steering Committee. D. Mortara and J. Mertens adjusted the Sicard P ECG-computer algorithm. H. Boersma, statistician, modified the Sicard P ECG-computer results for statistical adaptation. C. Wietsema, assistant of the Prehospital ECG Project, gathered the prehospital recorded ECG's and the hospital discharge diagnoses.

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