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Implementation of the ESC 0 h/1h algorithm and the HEART score in the emergency department: A prospective cohort study

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A B S T R A C T

Background: The European Society of Cardiology (ESC) 0 h/1h algorithm is the preferred diagnostic strategy for chest pain patients in the emergency department (ED). It is suggested that adding clinical information to the algorithm improves its diagnostic performance. This study evaluates implementation of the ESC 0 h/1h algorithm in the ED and investigates the potential advantages of combining it with a clinical decision rule, which might be especially relevant in the heterogenous observation category.

Methods: In this prospective cohort study, chest pain patients in whom the ESC 0 h/1h algorithm was applied were enrolled. HEART score components were collected. Diagnostic characteristics were determined for the algorithm with and without addition of the HEART score. Primary endpoint was a composite endpoint at 30-day follow-up, consisting of myocardial infarction and death.

Results: A total of 668 patients were enrolled. The rule-in and rule-out categories consisted of 8.2% and 54.9% of the patients, respectively. Positive predictive value and specificity of the rule-in category were 67.3% and 97.1%, respectively. Negative predictive value (NPV) and sensitivity of the rule-out category were both 100%. In the observation category, a HEART score ≤ 3 yielded a NPV and sensitivity of 97.1% and 93.8%, respectively.

Conclusion: The ESC 0 h/1h algorithm yielded a NPV and sensitivity of 100% for myocardial infarction and death at 30-day follow-up. Addition of the HEART score did not provide clinically relevant advantages. Although the HEART score can be used to guide diagnostic testing in the observation category, a low HEART score did not yield an NPV of $> 99\%$.

1. Introduction

Emergency department (ED) overcrowding is a global phenomenon and associated with worse patient outcomes [1,2]. Since chest pain is one of the main complaints in the ED, accounting for over 10% of all ED visits, reducing the time to cardiac diagnosis (e.g. acute coronary syndrome [ACS]) could have a significant impact on ED overcrowding [3–5]. The use of high-sensitivity cardiac troponin (hs-cTn) assays in a 0 h/1h algorithm to rule-in or rule-out non ST elevation acute coronary syndrome (NSTE-ACS) is now recommended by the European Society of Cardiology (ESC) [6]. The performance of the ESC 0 h/1h algorithm has been investigated in several studies and it turns out to be an excellent diagnostic tool with a very high rule-out safety [7–11]. Moreover, application of the ESC 0 h/1h algorithm resulted in less functional cardiac testing and shorter length of stay (LoS) in the ED, which leads to lower costs and might help preventing ED overcrowding [6,8,11]. However, around 25% of the chest pain patients do not qualify for early rule-in or rule-out and comprise the observation category [11]. The observation category is a heterogenous population in which additional testing is required and in which (non)invasive imaging might be considered. Although this category is associated with poor prognosis, there is currently no sufficient tool to stratify or guide management of these patients. [8,12] While the addition of clinical information to the ESC 0 h/1h algorithm improves rule-in and rule-out performance, no data is available on the additional value of clinical information to the observation category [13]. The HEART score, which consists of History, Electrocardiogram (ECG), Age, Risk factors and Troponin, is a validated diagnostic tool for risk stratification in chest pain patients in the ED with a high degree of reproducibility and an excellent interoperator agreement in both nurses and doctors [14–16]. This tool combines clinical information into a quantifiable surrogate marker for the physician's clinical judgment. The addition of the HEART score may aid physicians to further classify patients in the observation category as low- or high-risk for myocardial infarction (MI).

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We adopted the ESC 0 h/1h algorithm in the ED of our tertiary referral hospital and present the performance of this ESC 0 h/1h algorithm with regards to 30-day outcomes, its applicability and the effects on LoS. Moreover, we present the potential additional diagnostic value of the HEART score.

2. Methods

2.1. Study design and population

This is a prospective cohort study of consecutive patients with chest pain or an ischemic equivalent (such as dyspnea) presenting to the cardiac ED of the Radboudumc (Nijmegen, the Netherlands) from April 2019 through February 2020. In April 2019, the ESC 0 h/1h algorithm was introduced to the cardiac ED of this tertiary academic medical centre and all staff involved in the cardiac ED was instructed to use the algorithm in patients with chest pain or an ischemic equivalent suspected for ACS. The patients in whom the ESC 0 h/1h algorithm was followed, were included in the current registry. Whether the ESC 0 h/1h algorithm was followed, was registered by the nurses in the cardiac ED. Patients with ST-segment elevation on the electrocardiogram were excluded. Inclusion of patients was halted due to the COVID-19 pandemic. The study was approved by the local Central Committee on Research Involving Human Subjects.

2.2. Patient and public involvement

This research was done without patient involvement. Patients were not involved in the study design and the writing or editing of this document.

2.3. Clinical assessment and patient management

All patients underwent routine clinical assessment according to the prevailing guidelines, including medical history, physical examination, 12-lead ECG and routine laboratory measurements (including hs-cTn). Hs-cTn measurement was performed with the Elecsys high-sensitivity Troponin T assay on the cobas e801 system (Roche Diagnostics, Basel, Switzerland), which has a limit of detection of 3 ng/L. Further (non–) invasive management of the patients was left to the discretion of the treating physicians and all physicians were free to overrule the algorithm if necessary, based on the clinical presentation.

2.4. Heart score

If the HEART score was not reported by the treating physician, medical records were reviewed retrospectively by two study investigators to assess the History, ECG, Age and Risk factors (HEAR) components of the HEART score for each patient. While assessing the HEAR components, the study investigators were blinded for the hs-cTn concentrations and endpoints. In case of uncertainty, a third study investigator was consulted. According to previous studies, patients with a HEART score of ≤ 3 were defined as the low-risk patients and patients with a HEART score of ≥ 7 were defined as the high-risk patients [14,15,17].

2.5. Endpoints and follow-up

Medical records were reviewed by two study investigators for occurrence of endpoints and adjudication of the final diagnosis. In case of uncertainty, a third study investigator was consulted. After 30 days, patients were contacted by telephone to account for occurrence of endpoints outside of our hospital. If a patient was hospitalized, records were checked for potential outcomes. Moreover, follow-up information was obtained from the patients' medical records and the national registry on mortality. The primary endpoint was the occurrence of a composite endpoint at 30-day follow-up, including the index event. The composite endpoint was defined as the occurrence of all-cause mortality or MI. MI was defined as a detection of rise and/or fall in hs-cTn with at least one hs-cTn concentration above the 99th percentile of the upper reference limit, in combination with a clinical setting of myocardial ischemia, according to the fourth universal definition of MI [18]. Secondary endpoints included the occurrence of the composite endpoint at index visit, MI at index visit, MI at 30-day follow-up, all-cause mortality at index visit, all-cause mortality at 30-day follow-up, revascularization at index visit and revascularization at 30-day follow-up.

2.6. Diagnostic characteristics

To test the rule-out safety of the ESC 0 h/1h algorithm, sensitivity and negative predictive value (NPV) for the composite endpoint at 30-day follow-up in patients in the rule-out category were calculated, with and without addition of the HEART score. To test rule-in accuracy of the ESC 0 h/1h algorithm, specificity and positive predictive value (PPV) for the composite endpoint at 30-day follow-up in patients in the rule-in category were calculated, with and without addition of the HEART score. To test the diagnostic performance of the HEART score in the observation category, sensitivity and NPV were calculated for patients with a HEART score ≤ 3, whereas specificity and PPV were calculated for patients with a HEART score ≥ 7.

2.7. Patients in whom the ESC 0 h/1h algorithm was not followed

Patients were not included in the current registry if the ESC 0 h/1h algorithm was not followed. Therefore, in these patients, the medical records were not studied and follow-up was not performed. However, in order to gain insight in both the study population and the excluded population, basic characteristics (age and gender) and final diagnosis of non-ST segment elevation myocardial infarction (NSTEMI) were extracted from the electronic health record system.

2.8. Length of stay (LoS)

In order to assess the LoS, time of admission to the ED and time of discharge from the ED were extracted from the electronic health record system for both the patients in the study and the patients in whom the algorithm was not followed. The LoS was calculated as the difference between these registered moments, in minutes.

2.9. Statistical analysis

All study data were collected in Castor Electronic Data Capture. The diagnostic performance of the ESC 0 h/1h algorithm was assessed with and without addition of the HEART score. Continuous variables were described as median with interquartile range [IQR], categorical variables as numbers and percentages. Differences in baseline characteristics were assessed using the Kruskal-Wallis test for continuous variables and the Pearson Chi-square test or Fisher's exact test for categorial variables, whichever appropriate. The 95% confidence intervals (CI) of the NPVs and PPVs were calculated by the Clopper Pearson exact method. The sensitivities and specificities were calculated by construction of two by two contingency tables. A p-value of < 0.05 was considered statistically significant. Analyses were performed using SPSS V.25 (IBM Corp.).

3. Results

From April 2019 to February 2020, 668 patients were included in this study. Baseline characteristics of these patients are summarized in Table 1.

In the total population, MI at index presentation occurred in 7.5% (50/668). Since no patients died during the index presentation, the composite endpoint at index presentation was also 7.5% (50/668).

Table 1
Baseline characteristics. MI = myocardial infarction, PCI = percutaneous coronary intervention, CABG = coronary artery bypass grafting.

Baseline characteristics	All patients (n = 668)	Rule-in (n = 55)	Observation (n = 246)	Rule-out (n = 367)	P-value
Age, years	66 (55–74)	70 (60–77)	72 (63–79)	60 (51–68)	<0.001
Male	357 (53.4%)	34 (61.8%)	149 (60.6%)	174 (47.4%)	0.003
Risk factors					
Hypertension	329 (49.3%)	24 (43.6%)	136 (55.3%)	169 (46.0%)	0.056
Hypercholesterolemia	200 (29.9%)	9 (16.4%)	88 (35.8%)	103 (28.1%)	0.009
Current smoking	94 (14.1%)	10 (18.2%)	21 (8.5%)	63 (17.2%)	0.007
History of smoking	299 (44.8%)	26 (47.3%)	103 (41.9%)	170 (46.3%)	0.513
Positive family history	245 (36.7%)	21 (38.2%)	72 (29.3%)	152 (41.4%)	0.009
Diabetes mellitus	110 (16.5%)	11 (20.0%)	62 (25.2%)	37 (10.1%)	<0.001
History					
Coronary artery disease	291 (43.6%)	25 (45.5%)	136 (55.3%)	130 (35.4%)	<0.001
Previous MI	180 (26.9%)	16 (29.1%)	90 (36.6%)	74 (20.2%)	<0.001
Previous PCI	217 (32.5%)	19 (34.5%)	98 (39.8%)	100 (27.2%)	0.005
Previous CABG	69 (10.3%)	6 (10.9%)	41 (16.7%)	22 (6.0%)	<0.001
Peripheral artery disease	94 (14.1%)	6 (10.9%)	48 (19.6%)	40 (10.9%)	0.009

Revascularization at index presentation was performed in 7.2% (48/668) of the patients.

Complete 30-day follow-up data were available for 99.9% (667/668) of the patients. During follow-up, MI occurred in two patients who had no MI at index presentation, one patients died and revascularization was performed in one patient. The composite endpoint at 30-day follow-up occurred in 7.9% (53/667) of the patients, with 0.1% (1/667) deaths and 7.8% (52/667) MI. At 30-days follow-up, revascularization was performed in 7.3% (49/667) of the patients.

3.1. Performance of the ESC 0 h/1h algorithm

As shown in Fig. 1, the rule-in category, the observation category and the rule-out category consisted of 8.2% (55/668), 36.8% (246/668) and 54.9% (367/668) of the patients, respectively.

The incidences of the primary and secondary endpoints are shown in Fig. 1.

The specificity and PPV of the rule-in category for 30-day composite endpoint were 97.1% (95 %CI 95.5–98.2%) and 67.3% (95 %CI 53.3–79.3%), respectively. All of the events in the rule-in category occurred at index presentation, none during follow-up.

The sensitivity and NPV of the rule-out category for 30-day composite endpoint were 100% and 100% (95 %CI 99.0–100.0%), respectively.

3.2. The HEART score

In the total population, 35.8% (239/668) of the patients had a HEART score of ≤ 3, 54.9% (367/668) of the patients had a HEART score of 4–6 and 9.3% (62/668) had a HEART score of ≥ 7.

In the patients with a HEART score of ≤ 3, 4–6 and ≥ 7, the composite endpoint at 30-day follow-up occurred in 0.4% (1/238), 6.5% (24/367) and 45.2% (28/62) of the patients, respectively.

3.3. The ESC 0 h/1h algorithm in combination with the HEART score

As shown in Fig. 2, the high-risk combination of the rule-in category and a HEART score of ≥ 7 consisted of 4.0% (27/668) of the patients,

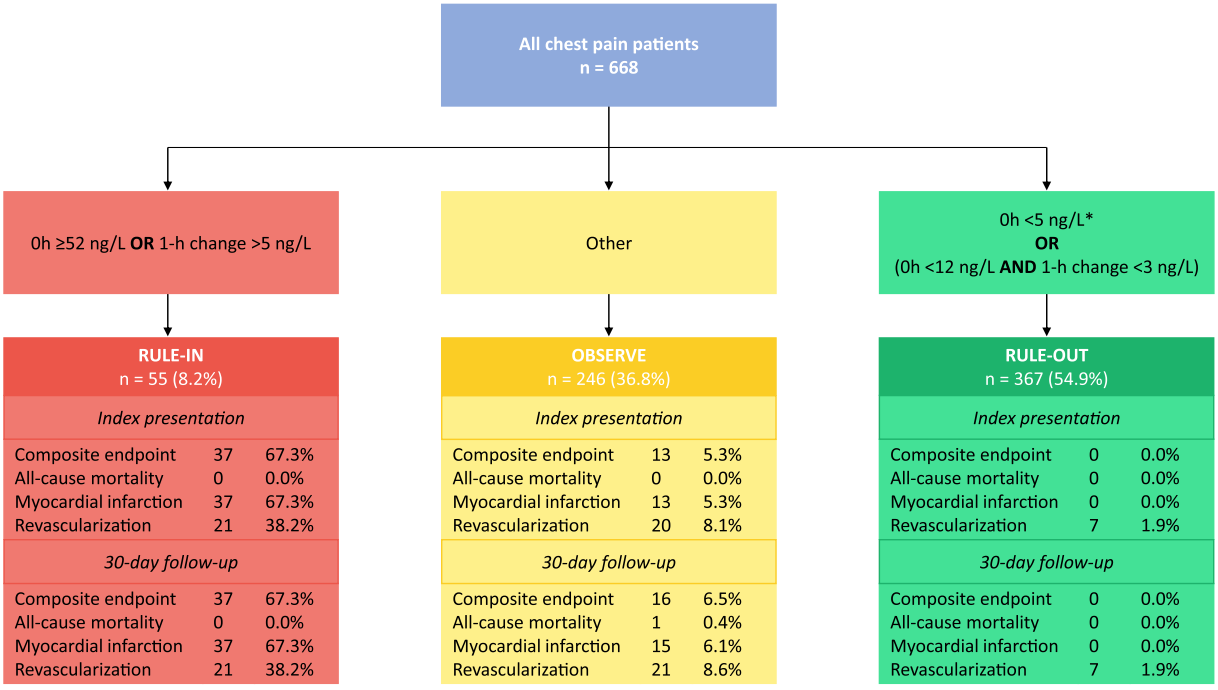

Fig. 1. The ESC 0 h/1 h algorithm for (30-day) composite endpoint, all-cause mortality, myocardial infarction and revascularization.

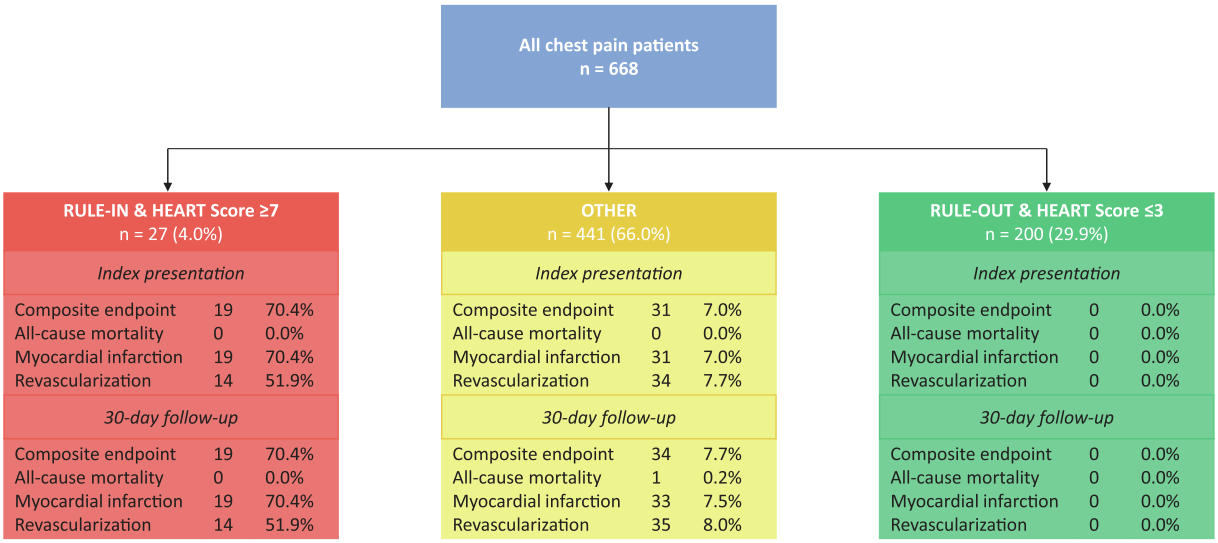

Fig. 2. The ESC 0 h/1 h algorithm in combination with the HEART score for (30-day) composite endpoint, all-cause mortality, myocardial infarction and revascularization.

while the low-risk combination of the rule-out category and a HEART score of ≤ 3 consisted of 29.9% (200/668) of the patients.

The high-risk combination of the rule-in category and a HEART score of ≥ 7 yielded a specificity of 98.7% (85 %CI 97.6–99.4%) and a PPV of 70.4% (95 %CI 49.8–86.2%) for 30-day composite endpoint.

The low-risk combination of the rule-out category and a HEART score of ≤ 3 yielded a sensitivity of 100% and a NPV of 100% (95 %CI 98.2–100.0%) for 30-day composite endpoint.

As shown in Table 2, addition of the HEART score to the ESC 0 h/1h algorithm also provides diagnostic information in the observation category. In the observation category, a HEART score of ≤ 3 yielded a sensitivity of 93.8% (95 %CI 75.3–99.6%) and NPV of 97.1% (95 %CI 85.1–99.9%) for 30-day composite endpoint. A HEART score of ≤ 3 yielded a sensitivity and NPV for index presentation composite endpoint of 100% and 100% (95 %CI 90.0–100.0%), respectively. A HEART score of ≥ 7 in the observation category yielded a specificity of 89.5% (95 %CI 85.1–93.0%) and a PPV of 27.3% (95 %CI 13.3–45.5%) for 30-day composite endpoint. Additional (non–)invasive testing (coronary angiography, coronary CT angiography, echocardiography and cardiac stress testing) was performed in 24.0% (59/246) of the patients in the observation category. In patients in the observation category with a HEART score of ≤ 3, 4–6 and ≥ 7, additional testing was performed in 11.1%, 20.3% and 57.6% of the patients, respectively.

3.4. Patients in whom the ESC 0 h/1h algorithm was not followed

The ESC 0 h/1h algorithm was not followed in a total of 653 chest pain patients. These patients had a median age of 62 (IQR 51–73), 51.9% were male and NSTEMI at index presentation occurred in 10.4%. In comparison with the study population, p-values for differences in age, gender and NSTEMI at index presentation were 0.003, 0.578 and 0.076, respectively.

3.5. Length of stay in the ED

The median LoS in the 668 patients treated according to the ESC 0 h/1h algorithm was 226 (IQR 181–301) minutes, whereas the median LoS in the 653 patients in whom the ESC 0 h/1h algorithm was not followed was 244 (IQR 182–320), which was not a significant difference (p-value 0.127). In the rule-in category, the observation category and the rule-out

Table 2
Primary and secondary endpoints of the ESC 0 h/1 h algorithm in combination with the HEART score.

		Rule-in N = 55			Observe N = 246			Rule-out N = 367		
	All patients N = 668	HEART 0–3 N = 3	HEART 4–6 N = 25	HEART 7–10 N = 27	HEART 0–3 N = 36	HEART 4–6 N = 177	HEART 7–10 N = 33	HEART 0–3 N = 200	HEART 4–6 N = 165	HEART 7–10 N = 2
Index presentation										
Composite	50	0 (0.0%)	18 (72.0%)	19 (70.4%)	0 (0.0%)	5 (2.8%)	8 (24.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
endpoint	(7.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
All-cause	0 (0.0%)	0 (0.0%)	18 (72.0%)	19 (70.4%)	0 (0.0%)	5 (2.8%)	8 (24.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
mortality	50	0 (0.0%)	7 (28.0%)	14 (51.9%)	1 (2.8%)	10 (5.6%)	9 (27.3%)	0 (0.0%)	7 (4.2%)	0 (0.0%)
Myocardial	(7.5%)									
infarction	48									
Revascularization	(7.2%)									
30-day follow-up										
Composite	53	0 (0.0%)	18 (72.0%)	19 (70.4%)	1 (2.9%)	6 (3.4%)	9 (27.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
endpoint	(7.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
All-cause	1 (0.1%)	0 (0.0%)	18 (72.0%)	19 (70.4%)	0 (0.0%)	6 (3.4%)	9 (27.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
mortality	52	0 (0.0%)	7 (28.0%)	14 (51.9%)	1 (2.9%)	11 (6.2%)	9 (27.3%)	0 (0.0%)	7 (4.2%)	0 (0.0%)
Myocardial	(7.8%)									
infarction	49									
Revascularization	(7.3%)									

category, the LoS were 230 (IQR 184–368) minutes, 248 (IQR 197–312) minutes and 212 (IQR 171–275) minutes, respectively.

4. Discussion

After incorporation of the ESC 0 h/1h algorithm to our tertiary referral centre ED, we have the following important findings. First, the ESC 0 h/1h algorithm rapidly identifies rule-in patients with a PPV for 30-day composite endpoint (the occurrence of myocardial infarction or death) of 67.3% and rule-out patients with a NPV for 30-day composite endpoint of 100%. Second, the LoS was a median of 226 min. Third, in the observation category, a HEART score ≤ 3 resulted in a high negative predictive value of 97.1%.

4.1. Rule-in efficacy of the ESC 0 h/1h algorithm

In the rule-in category in our study, the PPVs for 30-day composite endpoint and MI were both 67.3%. The PPV for MI in patients in the rule-in category in our study was therefore similar to the 62–75% that was shown in previous studies [9,10,19,20]. In the rule-in category in our study, 67.3% of the patients were hospitalized in a monitored unit and 58.2% of the patients underwent early coronary angiography, while in the study by Twerenbold et al. 46% and 67% of the patients were hospitalized in a monitored unit and underwent early coronary angiography, respectively [11]. Possibly, these differences are due to the differences in study populations. Twerenbold et al. included patients with a suspected NSTEMI, while our study population consisted of a less selected pool of chest pain or ischemic equivalent patients, which is reflected by final other cardiac diagnoses, such as atrial fibrillation, pericarditis and congestive heart failure in 23.1% of the patients. This represents the real-world use of the ESC 0 h/1h algorithm.

4.2. Rule-out safety of the ESC 0 h/1h algorithm

Several large validation studies have shown that using the ESC 0 h/1h algorithm in patients with suspected NSTE-ACS leads to a NPV for MI of over 99% in patients assigned to the rule-out category [6,9–11]. With a NPV for MI at index presentation and 30-day follow-up of 100% in the rule-out category, our study is in line with other studies and confirms the safety of the ESC 0 h/1h algorithm. However, 1.9% of the patients in the rule-out category of our study underwent coronary revascularization. All of these patients had a diagnosis of unstable angina, which highlights the importance of using the ESC 0 h/1h algorithm in combination with the physician's clinical judgment.

4.3. Combination of the ESC 0 h/1h algorithm and the HEART score

In our study, 49.2% of the patients in the rule-in category had a HEART score of ≥ 7, resulting in a high-risk combination of the rule-in category and a high HEART score in 4.0% of the total study population. In this high-risk combination, the composite endpoint occurred in 70.4%, both at index presentation and 30-day follow-up.

Although the observation category consists of a heterogenous population, addition of the HEART score did help identification of the low-risk patients in this category. The NPV for 30-day composite endpoint was 97.1% for a HEART score of ≤ 3 in the observation category. Since a NPV of $\geq$ 99% is considered sufficient for the clinical use as a rule-out strategy [21], application of the HEART score in the observation category does not result in a rapid rule-out strategy with sufficient safety. However, application of the HEART score in the observation category does provide important diagnostic information and might be used to guide the type of further testing needed.

The PPV for 30-day composite endpoint of a HEART score of ≥ 7 in the observation category was 27.3%, which is too low for rapid rule-in and reflects the heterogeneity of the patients in the observation category. This heterogeneity is highlighted by the high number of patients with a HEART score of ≥ 7 in the observation category requiring additional (non–)invasive testing, which was 57.6%.

In the total population, 35.8% of the patients had a HEART score ≤ 3, with a NPV for 30-day composite endpoint of 99.6% (95 %CI 97.7–100.0%). In the rule-out category, 54.5% of the patients had a HEART score of ≤ 3, resulting in a low-risk combination of the rule-out category and a low HEART score in 29.9% of the total study population. No primary or secondary endpoints occurred in the patients with a low HEART score in the rule-out category. However, since 45.5% of the patients in the rule-out category had a HEART score of ≥ 4, almost half of the patients in the rule-out category had to be ruled towards the observation category to identify this low-risk population (HEART score ≤ 3) within the rule-out category. Therefore, in our study, this low-risk combination was able to identify the patients who were eligible for rapid discharge and who would not require revascularization, at the cost of a rise in the number of patients ruled towards the observation category. This has previously been observed by Cortes et al [22]. The recent study by Allen et al showed a NPV of 98.4% for 30-day major adverse cardiac events (MACE, defined as cardiac death, MI and revascularization) of a low HEART score in the rule-out category. This NPV was lower than the NPV in our study, which was 100% if the same definition for MACE was used [23].

To summarize, addition of the HEART score just marginally increased the rule-in efficacy and rule-out safety of the ESC 0 h/1h algorithm, at the cost of a rise in the number of patients ruled towards the observation category. In the observation category, the HEART score enabled identification of low-risk patients. Although the NPV was not sufficient enough to use it as a safe rule-out strategy, it might be used to guide further diagnostic testing.

4.4. Length of stay

In our study, the median LoS of the patients treated according to the ESC 0 h/1h algorithm was 3.8 h (226 min), which is substantially shorter than the reported LoS of over 5 h in studies using the 0 h/3h algorithm [24,25]. However, the LoS in our study is longer than the reported 2.5 h in the study by Twerenbold et al [11]. Moreover, the LoS in our study was not significantly shorter than the LoS of the chest pain patients who were excluded from our study because the ESC 0 h/1h algorithm was not followed. This could partly be explained by the fact that our study started directly after implementation of the ESC 0 h/1h algorithm into our ED. We expect that the LoS will be shorter after everyone involved in the ED is used to application of the ESC 0 h/1h algorithm. In our population, the LoS was mostly influenced by the time between the last troponin result (the first or second measurement, depending on the algorithm) and discharge or transfer from the ED. Therefore, further education of the staff involved in the ED might accelerate decision making and subsequently reduce LoS.

4.5. Limitations

This study has some limitations. First, not all chest pain patients visiting the ED were included in the study, since logistical objections (delays in the hs-cTn measurements and drawing of the blood samples) prevented the ESC 0 h/1h algorithm from being applied in every patient. If the second blood sample was not drawn within 75 min, the nurses in the ED were instructed to revert to the ESC 0 h/3h algorithm. However, comparison between the study patients and the patients in whom the ESC 0 h/1h algorithm was not followed, revealed no significant difference in the occurrence of NSTEMI. Second, adjudication of the patients to the three triage categories (rule-in, observation and rule-out) for the analyses in this study, was solely based on the hs-cTn concentration in the patients' medical records. Since the actual adjudication towards rule-in or rule-out strategies is based on the physician's clinical judgment and not just the hs-cTn concentration, the actual rule-in or rule-out strategies might have differed from the presented categories. This is also

true for the HEART score, which was calculated retrospectively in the majority of patients, if the treating physician did not report the HEART score. Unfortunately, after data collection it turned out to be unclear whether the components of the HEART score were assessed by the treating physician or were interpreted by the study investigators while extracting the data. Thus, specifically the efficacy and safety of the ESC 0 h/1h algorithm in combination with the HEART score, as assessed by the treating physician, need to be prospectively evaluated in the setting of implementation into clinical practice.

5. Conclusion

The European Society of Cardiology 0 h/1h algorithm is a diagnostic tool for ruling out myocardial infarction in chest pain patients presenting to the emergency department, with a negative predictive value and sensitivity of both 100% at 30-day follow-up. The algorithm helps shortening the length of stay in the emergency department. Combining the HEART score and the European Society of Cardiology 0 h/1h algorithm marginally improves triage in the emergency department. In the observation category, addition of the HEART score provided important diagnostic information, but did not result in a negative predictive value of $>$ 99% for the composite endpoint of myocardial infarction or death after 30 days.

Contributorship statement

GA, CC and PD conceived the study. GA, NV and JK performed the data collection. GA conducted data management, conducted the analyses and wrote the first draft. CC, NV, JK, AH, EC, RVK, NVR, RVG and PD reviewed and commented on all drafts of the manuscript. GA, CC and PD are responsible for the overall content as guarantors.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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