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Pre-hospital Triage of Acute Cardiac Patients: Rationale and Design HART-c, a multicenter prospective study

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3 Adrian Aldcroft

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5 Editor in Chief

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7 BMJ Open

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9 London, UK

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11 10th of June, 2020

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14 Dear Mr. Aldcroft,

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16 I am writing to submit our manuscript entitled “*Pre-Hospital Triage of Acute Cardiac*
17 *Patients: Rationale and Design of HART-c, a multicenter prospective study*” to consider for
18 publication in BMJ Open.
19

20
21 The HART-c Study is the first study which evaluates a pre-hospital triage protocol that
22 combines paramedic’s patient assessment with a pre-hospital cardiologist consultation. To the
23 best of our knowledge, this is the first study which allows a cardiologist direct access to live
24 ambulance data, like ECG readings and vital parameters. Combined with a newly developed
25 application showing real-time hospital’s admission capacity and in-hospital patient data. The
26 aim of the study is to safely reduce unnecessary cardiac presentations at the emergency
27 departments (ED) and significantly reduce ED overcrowding.
28

29
30 Given that ED overcrowding is becoming a worldwide health care problem, we believe the
31 proposed study in this paper will appeal to cardiologists, emergency physicians, general
32 physicians, paramedics, other medical specialists and patients in the Emergency Medicine
33 community. Also, we believe publishing our study protocol before collecting and assessing
34 the final results helps in transparent and responsible science. Because we believe this triage
35 protocol would be useful outside the scope of Cardiology, the broad audience of BMJ Open
36 will allow more professionals in Emergency Medicine to benefit from the given information.
37 Furthermore, we believe this study, wherein general practitioners, paramedics, emergency
38 physicians, cardiologists, nurses and patients closely collaborate to improve healthcare for
39 acutely ill cardiac patients, is a perfect example of interdisciplinary daily clinical practice.
40

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42 Each of the authors confirms that this manuscript has not been previously published and is
43 not currently under consideration by any other journal. Additionally, all of the authors have
44 approved the contents of this paper and have agreed to the Academic Emergency Medicine’s
45 submission policies. Each named author has substantially contributed to conducting the
46 underlying research and drafting of this manuscript. Additionally, to the best of our
47 knowledge, the named authors have no conflict of interest, financial or otherwise.
48

49 Sincerely,

50 Enrico de Koning
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3 **Pre-hospital Triage of Acute Cardiac Patients: Rationale and Design HART-c, a**
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5 **multicenter prospective study**
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7

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10
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12
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ABSTRACT

Introduction: Emergency department (ED) overcrowding is a major health care problem associated with worse patient outcomes and increased costs. Attempts to reduce ED overcrowding of cardiac patients have so far focused on in-hospital triage and rapid risk stratification of chest pain patients at the ED. The HART-c study aims to safely reduce unnecessary ED visits by implementing a pre-hospital triage protocol combining paramedic assessment and expert cardiologist consultation, supported by live-monitoring of vital parameters, hospital data and real-time admission capacity.

Methods and Analysis: Patients visited by the emergency medical services (EMS) for cardiac complaints are included. EMS consultation consists of medical history, physical examination and vital signs and ECG measurements. All data is transferred to a newly developed platform for the triage cardiologist. Pre-hospital data, in-hospital medical records and real-time admission capacity are evaluated. Then a shared decision is made whether admission is necessary and, if so, which hospital is most appropriate. To evaluate safety all patients referred to their general practitioner, and their GP's, are contacted for 30-day adverse events.

Ethics and dissemination: The study is approved by the LUMC's Medical Ethics Committee. Patients are asked for consent for contacting their GP's.

Conclusion: The HART-c study evaluates the efficacy, safety and feasibility of a pre-hospital triage protocol that combines pre-hospital patient assessment and direct consultation of a cardiologist who has access to live-monitored data, hospital data and real-time hospital admission capacity. We expect this triage protocol to substantially reduce unnecessary ED visits.

ARTICLE SUMMARY

- A novel pre-hospital triage protocol is presented which aims to safely decrease unnecessary ED admissions, using telemedicine for pre-hospital decision making
- All participants, including patient representatives, were involved in the design of the study
- **Strengths and limitations:**
 - This study is a real-life reflection of interdisciplinary daily clinical practice, the retrospective cohort will reflect the control group in the best way possible
 - The HART-c Study is not a randomised controlled trial. Therefore accomplished results can only be compared retrospectively

1 INTRODUCTION

2 Emergency Department (ED) overcrowding is a worldwide health care problem associated with
3 worse patient outcomes and increased costs^{1,2}. Cardiac complaints are one of the most common
4 reasons for patients to visit the ED, with chest pain as the most frequent complaint.³ In Europe
5 and the United States, 15-20 million patients with chest pain are seen at the ED every year.⁴
6 The majority will be sent home after ruling out acute cardiovascular disease: previous studies
7 have shown that up to 80% of chest pain patients do not have an acute coronary syndrome.⁵⁻⁸
8 However, these patients substantially contribute to overcrowding of EDs and these ED visits
9 substantially increase healthcare costs.

10 Attempts to reduce ED overcrowding by cardiac patients have so far particularly focused on
11 rapid risk stratification after presentation at the ED. For example, the HEART score stratifies
12 patients as at low, intermediate or high risk of major adverse cardiac events (MACE) based on
13 history, the electrocardiogram (ECG), age, risk factors and troponin levels.⁹ However, as it
14 takes 1-2 hours for the latter to be available, patients still spend a long time at the ED after
15 which the majority can be discharged home.

16 Accordingly, interest has shifted from in-hospital to pre-hospital triage. Preventing patients
17 with cardiac complaints and a very low risk of adverse cardiac events from visiting the ED will
18 substantially help to reduce ED overcrowding. Until now, efforts to prevent ED visits are scarce
19 and especially involve single interventions such as risk score calculation by the ambulance
20 paramedic¹⁰ or pre-hospital point of care testing for troponin.¹¹ In order to improve pre-hospital
21 triage for cardiac patients in the entire chain of acute cardiac care, we developed a
22 comprehensive triage protocol entitled HART-c (“Hollands-midden Acute Regional Triage -
23 Cardiology”). This protocol combines pre-hospital patient assessment by the ambulance
24 paramedic and direct consultation of a cardiologist who has access to live-monitored data from
25 the ambulance, in-hospital data as well as real-time hospital admission capacity. By drafting

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3 26 this triage protocol, we specifically aimed to safely reduce unnecessary ED visits of patients
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5 27 with all types of cardiac complaints. In addition, we intent to provide patient-tailored care
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8 28 through pre-hospital assessment of patient specific needs and circumstances. The HART-c
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10 29 study was designed to evaluate whether the implementation of the HART-c triage protocol
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12 30 results in a reduction of unnecessary ED visits.
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17 31 **METHODS AND ANALYSIS**

18 19 32 **Study design and patient population**

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21 33 The HART-c study is a multi-center prospective study with a historical control group. The
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23 34 intervention group comprises of adult patients visited by the regional emergency medical
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25 35 services (EMS) because of cardiac complaints between 1 September 2019 and 31 August 2020
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27 36 in whom pre-hospital triage is performed according to the HART-c triage protocol. The
28
29 37 historical control group consists of adult patients visited by the regional EMS because of
30
31 38 cardiac complaints between 1 September 2018 and 31 August 2019 (1 year before the start of
32
33 39 the HART-c triage protocol). Of note, in both groups EMS consultation could have been
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35 40 requested directly by the patient, through bystanders or by the patients' general practitioner
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37 41 (GP) who refers patients through EMS. Patients in need for urgent cardiac care, patients with
38
39 42 complaints not suspected of cardiac origin as assessed by the ambulance paramedic, and
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41 43 patients unable or not willing to provide informed consent were excluded from triage according
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43 44 to the HART-c protocol. Table 1 displays the detailed inclusion and exclusion criteria.
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Table 1. Inclusion and exclusion criteria

Inclusion criteria
Patients visited by EMS for cardiac complaints
Age over 18 years
Exclusion criteria
Patients in need for urgent cardiac care because of <ul style="list-style-type: none"> - ST-elevation myocardial infarction - Hemodynamic instability - (Out of hospital) cardiac arrest - Suspected pulmonary embolism - Suspected acute aortic syndrome (thoracic or abdominal)
Patients with symptoms not suspected of cardiac origin
Unable or unwilling to provide informed consent

The HART-c study is coordinated by the Leiden University Medical Centre (LUMC) and conducted in the entire EMS region “Hollands-midden” which consists of over 600.000 inhabitants. The hospitals located in this region participate: the Leiden University Medical Centre, the Groene Hart hospital and the Alrijne hospital. The study is performed in close collaboration with the regional EMS (RAVHM) that employs 240 paramedics who are trained in pre-hospital cardiac care and 31 ambulance vehicles equipped with real-time monitoring. In addition, the study was performed and developed with the help of over regional 300 GPs.

Intervention group: Pre-hospital Triage using HART-c protocol

The intervention group consists of patients visited by the EMS because of symptoms suspected to be of cardiac origin such as chest pain, shortness of breath, palpitations or implanted cardiac device problems. In line with the National Protocol for Emergency Medical Care, patients at

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3 56 first receive standard medical care consisting of a medical history, physical examination with
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5 57 vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG.¹² In
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7 58 patients with chest pain, the pre-hospital modified HEART score (the HEART¹³ score without
8
9 59 troponin) is calculated. All acquired data are noted on a handheld device and stored on
10
11 60 AmbuSuite, an external secure database. Afterwards, the ambulance paramedic directly
12
13 61 contacts the on-call triage cardiologist. GPs can refer patients through EMS consultation,
14
15 62 however in the intervention period cardiologist consultation is possible. When a GP is in doubt
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17 63 of referral, they can request cardiologist consultation through EMS with the HART-c protocol.
18
19 64 The triage cardiologist evaluates the pre-hospital data, including, medical history, real-time
20
21 65 vital parameters and 12-lead ECG and combines them with (if present) previous medical
22
23 66 records and the actual hospital admission capacity of the regional hospitals. Based on these
24
25 67 comprehensive data, the triage cardiologist and ambulance paramedic decide, as a shared
26
27 68 decision with the patient, whether transfer to an ED is necessary and, if so, which hospital and
28
29 69 which department is most suitable. The triage decision is sent immediately to the concerning
30
31 70 ED nursing staff and the capacity of this hospital is updated automatically (Figure 2). Upon
32
33 71 arrival at the ED, cardiac assessment is based on in-house clinical decision rules as guidelines
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35 72 prescribe, 12-lead ECG and laboratory findings.⁹ The right panel in Figure 1 illustrates the
36
37 73 entire routing of patients in the intervention group.

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45 *Figure 1. Method of triage. (A) Patient routing without pre-hospital selection where patients*
46 *are referred to the nearest ED or left at home. If hospital admission capacity is insufficient,*
47 *patients are transferred to another hospital. (B) Patient routing with pre-hospital selection*
48 *using pre- and in-hospital data where a cardiologist has insight in live vital parameters and*
49 *regional hospital capacity.*
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57 *Figure 2. Mobile phone triage application: Left panel showing overview of a hospital specific*
58 *capacity. Right panel showing the ability to update capacity.*
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3 74 **Intervention group: Tempus Pro Monitor, IntelliSpace Corsium, triage platform and**
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5 75 **data handling**
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8 76 All ambulances are equipped with a Tempus Pro Monitor¹⁴ (Philips, The Netherlands) that
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10 77 allows recording of a 12-lead ECG and real-time monitoring of the following vital patient
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12 78 parameters: heart rate, blood pressure and pulse oximetry. The monitor can show trends in
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14 79 measurements and stream data for up to 10 hours. All data are encrypted and shared with the
15
16 80 on-call triage cardiologist through secure channels. The Tempus Pro Monitor is shown in
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18 81 Figure 3.
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21 *Figure 3. Image of Tempus Pro Monitor.*
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26 82 Using a secure log-in, the on-call triage cardiologist logs in to IntelliSpace Corsium (Philips,
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28 83 the Netherlands) and connects digitally with a patient specific Tempus Pro Monitor. All
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30 84 aforementioned measurements are streamed live. Once the live streaming ends, no patient
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32 85 specific data are stored on the platform. This system of data-transfer is FDA approved.^{15,16}
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35 86 A novel triage platform was developed showing real-time admission capacity of the regional
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37 87 hospitals. The nursing staff in these hospitals continuously updates their admission capacity.
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39 88 Linking these capacity data to a local electronic patient dossier (EPD-Vision; Leiden, The
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41 89 Netherlands), the on-call triage cardiologist has insight into the actual bed occupancy of each
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43 90 hospital. After consultation, the on-call triage cardiologist notes his decision and a message is
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45 91 automatically sent to the nursing staff of the chosen hospital, thereby updating their admission
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47 92 capacity immediately.
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51 93 Patient data are sent securely from Tempus Monitor to IntelliSpace Corsium. No data are stored
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53 94 on IntelliSpace Corsium. No patient data are transmitted to the mobile phone application.
54
55 95 Patient data are transferred from AmbuSuite to our EPD. All patient data and decisions are
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57 96 stored on the EPD of the coordinating hospital and are only accessible for triage cardiologists.
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97 **Historical control group: Standard care in pre-hospital setting**

98 The historical control group consists of patients visited by the EMS because of potential
99 cardiac complaints in the year before the onset of the HART-c triage protocol. Upon arrival
100 by the paramedic, standard medical care consists of medical history, physical examination
101 with vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG. All
102 acquired data are noted on a handheld device and stored on AmbuSuite (Topicus, the
103 Netherlands) which is an external secure database. Thereafter, the ambulance paramedic
104 decides, based on predefined national protocols and decision rules for diagnosis, whether
105 transfer to an ED is deemed necessary.¹² Paramedics select low risk patients for the whole
106 pallet of medical specialties, and only transport patients with cardiac complaints when in
107 doubt or if admission is deemed necessary. Of note, at the time of referral, the paramedic has
108 no insight in the previous medical records and the actual hospital admission capacity. The
109 Netherlands has a unique system, where approximately 5% of patients with cardiac
110 complaints aren't referred to a hospital after paramedic assessment, instead these patients are
111 directly referred to their GP. However, given the number of unnecessary ED visits, based on
112 expert opinion, an increase in patients not referred to a hospital is possible. After paramedic
113 assessment and hospital transport, cardiac assessment on the ED is based on in-house clinical
114 decision rules as guidelines prescribe, 12-lead ECG and laboratory findings.⁹ If evaluation at
115 the ED indicates that hospitalization is mandatory, the patient is admitted in the concerning
116 hospital. However, when admission capacity is insufficient or immediate intervention is not
117 available in the concerning hospital, ambulance transfer to another hospital is mandatory. The
118 routing of patients in the historical control group is illustrated in the left panel of Figure 1.

119 **Objective and outcome measures**

120 The HART-c study is designed to evaluate the efficacy, safety and feasibility of a novel
121 comprehensive pre-hospital triage protocol which aims to safely reduce unnecessary ED visits

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3 122 in patients with cardiac complaints. The primary outcome is the percentage of patients in who
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5 123 an ED visit can be prevented after EMS consultation. The following secondary end-points will
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8 124 be evaluated:

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10 125 - Number of ambulance transfers to an ED because of cardiac complaints
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12 126 - Number of inter-hospital transfers in cardiac patients
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14 127 - Patient, triage cardiologist and GP satisfaction with the HART-c triage protocol on a 0-
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16 128 10 scale
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18 129 - Safety of the HART-c prehospital triage protocol. This will be evaluated in intervention
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20 130 group patients who are not transferred to an ED and assessed by the occurrence of
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22 131 adverse events up to 30 days follow-up. Table 2 displays the pre-specified major and
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24 132 minor adverse events. To evaluate safety, a dedicated researcher will contact these
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26 133 patients and their GP.
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28 134 - Feasibility of the HART-c prehospital triage protocol. This will be evaluated in the
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30 135 intervention group and defined as the absence of technical problems for the ambulance
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32 136 paramedic and the triage cardiologist. This means access to the live-monitored data
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34 137 from the ambulance, hospital data and real-time hospital admission capacity are all
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36 138 available. In order to swiftly manage potential technical problems, the HART-c triage
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38 139 protocol will start during working hours. If interim analysis reveals that the protocol is
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40 140 feasible, the time frame in which HART-c triage is available could be extended.
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Table 2. Adverse events (30 days after EMS contact)

Major adverse events
Death
Acute coronary syndrome
Other adverse events
Renewed EMS visit for any cardiac complaint
Pulmonary embolism
ED visit or hospitalization for acute decompensated heart failure
Ventricular tachycardia or – fibrillation
Cerebrovascular accident (CVA) or transient ischemic attack (TIA)

141 **Statistical analysis**

142 The percentage of patients in whom an ED visit can be prevented after EMS consultation will
 143 be analyzed using a logistic regression analysis. Comparison of the total number of ambulance
 144 transfers and the number of inter hospital transfers in the intervention versus in the control
 145 group will also be evaluated using logistic regression. This study will be underpowered to
 146 detect differences in mortality and major adverse cardiac events (MACE). Accordingly, these
 147 events will only be reported and no further statistics on mortality and MACE will be done. The
 148 data will be analysed using IBM SPSS Statistics version 25. A p-value lower than 0.05 will be
 149 considered statistically significant.

150 **Patient and public involvement**

151 Patients were involved in the design of the study. During the design stage, representatives from
 152 the ‘Harteraad’, a cardiovascular patient council, were asked for input in study design, choice
 153 of outcome measures and methods of recruitment. Also, a dedicated website and e-mail address

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3 154 were created to inform the public and answer questions from professionals and patients, before
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5 155 and during the study.
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10 156 **ETHICS AND DISSEMINATION**

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12 157 The study is approved by the LUMC's Medical Ethics Committee (P18.213). Patients are
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14 158 requested to provide oral informed consent for contacting their GP at 30 days follow-up. The
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16 159 devices used in this study are FDA and/or CE approved. No manufacturer has a role in study
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18 160 design, data collection, statistical analysis or writing of the manuscript. No financial support is
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20 161 received for this study from any manufacturer.
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28 162 **DISCUSSION**

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30 163 Overcrowding of ED's is a major challenge in healthcare. The HART-c study is a multi-center
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32 164 prospective study that primarily aims to safely reduce unnecessary ED visits of patients with
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34 165 all types of cardiac complaints. If this will succeed, it will contribute to more patient-tailored
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36 166 health care and lead to improved utilization of healthcare resources.
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40 167 Although recently interest has shifted from in-hospital to pre-hospital triage, efforts to reduce
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42 168 the number of patients with cardiac complaints visiting at the ED are limited. As far as we
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44 169 know, until now only 2 study groups evaluate the added value of pre-hospital risk assessment
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46 170 in chest pain patients. The FAMOUS investigators aim to assess the effects of introducing a
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48 171 pre-hospital triage system that stratifies chest pain patients without ST segment elevation into
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50 172 1) patients at high risk for NSTEMI requiring direct transfer to a PCI hospital, 2) patients at
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52 173 intermediate risk for major adverse cardiac events who could be evaluated at the nearest non-
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54 174 PCI hospital and 3) patients at low risk for major adverse cardiac events who could have further
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56 175 evaluation at home or in a primary care setting.¹⁷ The study was divided in three phases. In the
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3 176 first phase, a venous blood sample was drawn in the ambulance for measurement of the pre-
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5 177 hospital troponin T levels, in order to establish a pre-hospital HEART score (i.e. the modified
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7 178 HEART score) and evaluate the possibility of triage at the patient's home. All patients were
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10 179 transferred to the hospital and the primary end-point was the occurrence of major adverse
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12 180 cardiac events within 30-days after presentation. Of the 1127 chest pain patients, 36% had a
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14 181 low modified HEART score and none of them developed a major adverse event. Accordingly,
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16 182 the FAMOUS authors concluded that it seemed feasible to rule out myocardial infarction at
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18 183 home in patients without ST segment elevation on the ECG.¹⁸ In the second phase, this tool
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20 184 will be externally validated. In the third phase, the risk stratification tool will be implemented
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22 185 in clinical practice. Until now, the results of the second and third phase have not been
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24 186 published.

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28 187 Another study investigating the added value of point-of-care troponin in the pre-hospital setting
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30 188 is the ARTICA¹¹ trial. This randomized trial will include patients suspected of non-ST
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32 189 elevation acute coronary syndrome in whom the modified HEAR score (the HEART score
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34 190 without troponin) is calculated by the ambulance paramedic. If the HEAR score is less than or
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36 191 equal to 3, patients will be 1:1 randomized for 1) presentation at the ED or 2) point-of-care
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38 192 troponin T measurement and transfer of care to the GP in case of a low troponin T value. The
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40 193 primary objective of the ARTICA trial will be healthcare costs at 30 days. The trial is currently
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42 194 ongoing and aims to include 866 patients in total. The total follow-up period will be 12 months.
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44 195 The similarity of the currently described HART-c study and the FAMOUS and ARTICA is that
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46 196 all three assess whether patients with cardiac complaints who are at low risk of major adverse
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48 197 events can be prevented from visiting the ED. However, while the FAMOUS and ARTICA
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50 198 study only focus on chest pain patients, the HART-c study extends this to all patients with
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52 199 cardiac complaints and could therefore be of benefit for a substantially larger cohort of patients.
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54 200 Furthermore, the HART-c triage protocol is unique as it combines pre-hospital patient
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3 201 assessment by the ambulance paramedic and direct consultation of an expert triage cardiologist
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5 202 who has access to live-monitored data from the ambulance, hospital data as well as real-time
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7 203 hospital admission capacity. If the results of current study show that the HART-c triage
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9 204 protocol is effective in safely reducing unnecessary ED visits of patients with all types of
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11 205 cardiac complaints, the next step will be to evaluate cost-effectiveness. When thereafter also
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13 206 cost-effectiveness can be demonstrated, we feel that the HART-c triage protocol can be
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15 207 expanded to other EMS regions. Furthermore, last but not least, it may potentially also be useful
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17 208 for other medical specialists aiming to optimize pre-hospital triage of non-cardiac patients.
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24 209 **CONCLUSION**

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27 210 The HART-c study is a multi-center prospective study evaluating the efficacy, safety and
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29 211 feasibility of a novel comprehensive pre-hospital triage protocol that combines pre-hospital
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31 212 patient assessment by the ambulance paramedic and direct consultation of a cardiologist who
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33 213 has access to live-monitored data from the ambulance, hospital data as well as real-time
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35 214 hospital admission capacity. If the HART-c study will succeed to safely reduce unnecessary
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37 215 ED visits of patients with all types of cardiac complaints, it may help to decrease ED
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39 216 overcrowding and ultimately reduce healthcare expenditures.
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Author statement

EK, TB, JB, CK, RAD, HS, MS and MB made a substantial contribution to the concept and design of the work. EK and MB are in charge of acquisition of data, analysis and interpretation of the data. EK, TB, SB and MB contributed to the drafting of the article. EK, SB, JB, BB, CK, RAD, MS and MB all revised the manuscript critically for important intellectual content.

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Competing interest

EK, TB, SB, JB, CK, RAD, HS, MS and MB report no conflict of interest. BB is the creator of the HEART score.

References

1. American College of Emergency Physicians Policy statements: crowding. *Annals of Emergency Medicine*. 2006;47:585.
2. A Boyle, K Beniuk, I Higginson, P Atkinson. Emergency department crowding: time *for* interventions and policy evaluations. *Emergency Medicine International*. 2012;2012:838610.
3. FA Bhuiya, SR Pitts, LF McCaig. Emergency department visits for chest pain and abdominal pain: United States, 1999-2008. *NCHS Data Brief* 2010(43):1-8.
4. EW Nawa, RW Nisk, J Xu. National Hospital Ambulatory Medical Care Survey: 2005 emergency department summary. *Advance Data* 2007; 386: 1–32.
5. S Goodacre, P Thokala, C Carroll, JW Stevens, J Leaviss, J Wang et al. Systematic review, meta-analysis and economic modelling of diagnostic strategies for suspected acute coronary syndrome. *Health Technology Assessment* 2013;17(1):v-vi, 1-188.

- 1
2
3 6. M Gorenberg M, A Marmor, H Rotstein. Detection of chest pain of non-cardiac origin
4 at the emergency room by a new non-invasive device avoiding unnecessary admission
5 to hospital. *Emergency Medicine Journal: EMJ* 2005;22(7):486-9.
6
7
- 8
9
10 7. DC Knockaert, F Buntinx, N Stoens, R Bruyninckx, H Delooz. Chest pain in the
11 emergency department: the broad spectrum of causes. *European Journal of*
12
13
14
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10. JP Stopyra, WS Harper, TJ Higgins, JV Prokesova, JE Winslow, SA Mahler et al.
Prehospital Modified HEART Score Predictive of 30-Day Adverse Cardiac Events.
Prehospital and Disaster Medicine. 2018;33(1):58–62.
11. GWA Aarts, C Camaro, RJ van Geuns, E Cramer, RRJ van Kimmenade, N van
Royen et al. Acute rule- out of non–ST- segment elevation acute coronary syndrome
in the (pre)hospital setting by HEART score assessment and a single point- of- care
troponin: rationale and design of the ARTICA randomised trial. *BMJ Open*
2020;10:e034403. doi:10.1136/ bmjopen-2019-034403
12. Ambulancezorg Nederland. *Landelijk Protocol Ambulancezorg 8.1*. Publication date:
06-2016. <https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg>

- 1
2
3 13. BE Backus, AJ Six, JC Kelder, MA Bosschaert, EG Mast, PA Doevendans. A
4
5 prospective validation of the HEART score for chest pain patients at the emergency
6
7 department. *International Journal of Cardiology*. 2013 Oct 3;168(3):2153-8
8
9
- 10 14. Tempus Pro Monitor (Philips). <https://www.rdtltd.com/>
11
12
- 13 15. IntelliSpace Corsium (Philips)
14
15 [https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
16
17 [advanced-visual-analysis](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
18
- 19 16. FDA approval IntelliSpace Corsium (Philips). FDA Primary Device ID:
20
21 05060472441331 <https://fda.report/GUDID/05060472441331>
22
23
- 24 17. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, B Dikkeschei, The FAMOUS TRIAGE
25
26 Study Group et al. Fast assessment and management of chest pain without ST-
27
28 elevation in the pre-hospital gateway: Rationale and design. *European Journal of*
29
30 *Acute Cardiovascular Care*. 2015, Vol. 4(2) 129 –136
31
32
- 33 18. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, RT Tolsma, AW van 't Hof et al. Fast
34
35 assessment and management of chest pain patients without ST-elevation in the pre-
36
37 hospital gateway (FamouS Triage): ruling out a myocardial infarction at home with
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39 the modified HEART score. *European Heart Journal: Acute Cardiovascular Care*.
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41 2018, Vol. 7(2) 102-110.
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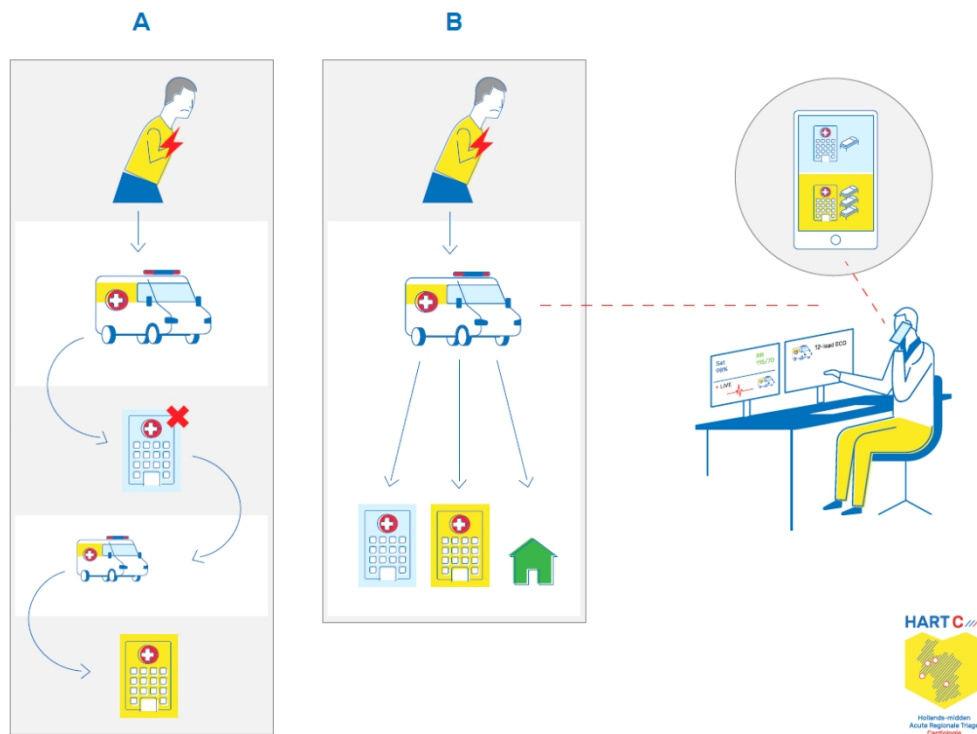


Figure 1. Method of triage

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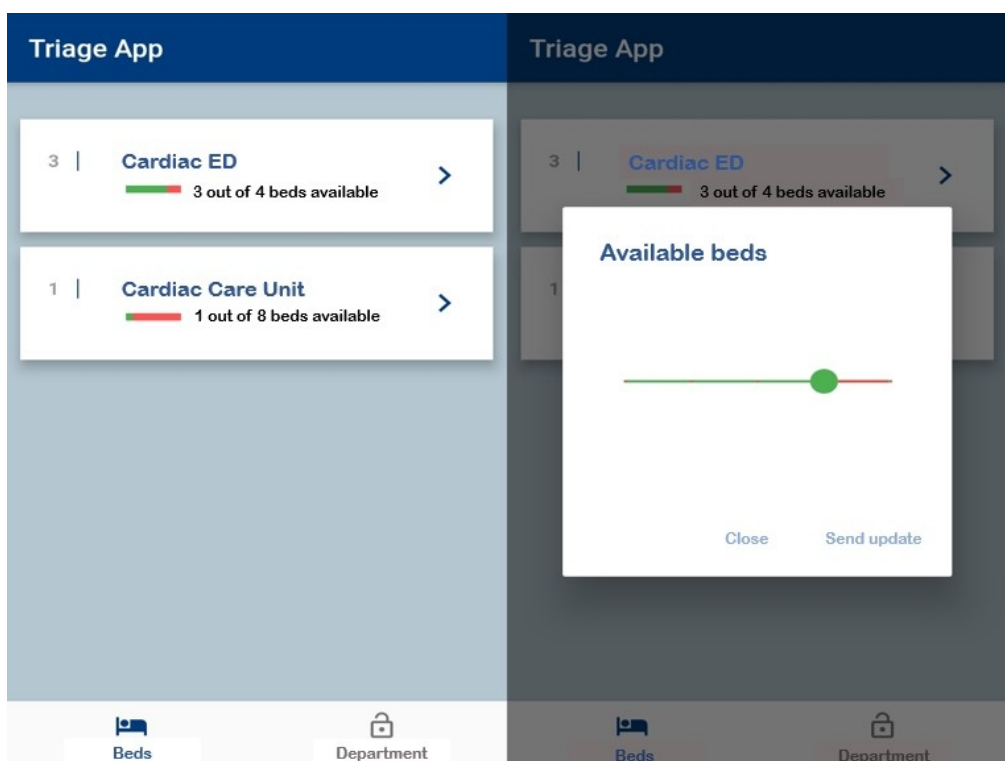


Figure 2. Mobile phone triage application
200x151mm (96 x 96 DPI)



Figure 3. Image of Tempus Pro Monitor

BMJ Open

Pre-hospital Triage of Acute Cardiac Patients: Study Protocol of HART-c, a multicenter prospective study

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3 **Pre-hospital Triage of Acute Cardiac Patients: Study Protocol of HART-c, a**
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5 **multicenter prospective study**
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ABSTRACT

Introduction: Emergency department (ED) overcrowding is a major health care problem associated with worse patient outcomes and increased costs. Attempts to reduce ED overcrowding of cardiac patients have so far focused on in-hospital triage and rapid risk stratification of chest pain patients at the ED. The HART-c study aims to safely reduce unnecessary ED visits by implementing a pre-hospital triage protocol combining paramedic assessment and expert cardiologist consultation, supported by live-monitoring of vital parameters, hospital data and real-time admission capacity.

Methods and Analysis: Patients visited by the emergency medical services (EMS) for cardiac complaints are included. EMS consultation consists of medical history, physical examination and vital signs and ECG measurements. All data is transferred to a newly developed platform for the triage cardiologist. Pre-hospital data, in-hospital medical records and real-time admission capacity are evaluated. Then a shared decision is made whether admission is necessary and, if so, which hospital is most appropriate. To evaluate safety all patients referred to their general practitioner, and their GP's, are contacted for 30-day adverse events.

Ethics and dissemination: The study is approved by the LUMC's Medical Ethics Committee. Patients are asked for consent for contacting their GP's. The main results of this trial will be disseminated in one paper.

Discussion: The HART-c study evaluates the efficacy, safety and feasibility of a pre-hospital triage protocol that combines pre-hospital patient assessment and direct consultation of a cardiologist who has access to live-monitored data, hospital data and real-time hospital admission capacity. We expect this triage protocol to substantially reduce unnecessary ED visits.

ARTICLE SUMMARY

- A novel pre-hospital triage protocol is presented which aims to safely decrease unnecessary ED admissions, using telemedicine for pre-hospital decision making
- All participants, including patient representatives, were involved in the design of the study
- **Strengths and limitations:**
 - This study is a real-life reflection of interdisciplinary daily clinical practice, the retrospective cohort will reflect the control group in the best way possible
 - The HART-c Study is a non-randomised controlled trial and therefore has risk of bias as decisions from paramedics and cardiologist can be influenced by the study.

1 INTRODUCTION

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Emergency Department (ED) overcrowding is a worldwide health care problem associated with worse patient outcomes and increased costs^{1,2}. Cardiac complaints are one of the most common reasons for patients to visit the ED, with chest pain as the most frequent complaint.³ In Europe and the United States, 15-20 million patients with chest pain are seen at the ED every year.⁴ The majority will be sent home after ruling out acute cardiovascular disease: previous studies have shown that up to 80% of chest pain patients do not have an acute coronary syndrome.⁵⁻⁸ However, these patients contribute to overcrowding of EDs and these ED visits substantially increase healthcare costs.

Attempts to reduce ED overcrowding by cardiac patients have so far particularly focused on rapid risk stratification after presentation at the ED. For example, the HEART score stratifies patients as at low, intermediate or high risk of major adverse cardiac events (MACE) based on history, the electrocardiogram (ECG), age, risk factors and troponin levels.⁹ However, as it takes 1-2 hours for the latter to be available, patients still spend a long time at the ED after which the majority can be discharged home.

Accordingly, interest has shifted from in-hospital to pre-hospital triage. Preventing patients with cardiac complaints and a very low risk of adverse cardiac events from visiting the ED will substantially help to reduce ED overcrowding. Efforts to prevent ED visits especially involve interventions focused on chest pain patients such as risk score calculation by the ambulance paramedics (for example with the modified HEART¹⁰ and HE-MACS¹¹) or pre-hospital point of care testing for troponin.¹² In order to improve pre-hospital triage for cardiac patients in the entire chain of acute cardiac care, we developed a comprehensive triage protocol entitled HART-c (“Hollands-midden Acute Regional Triage - Cardiology”).

Innovative in this protocol is the combination of pre-hospital patient assessment by the ambulance paramedic and expert consultation of a cardiologist who has access to live-

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3 26 monitored data from the ambulance, in-hospital data and real-time hospital admission capacity
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5 27 in a newly developed triage application. By drafting this triage protocol, we specifically aimed
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7 28 to safely reduce unnecessary ED visits of patients with all types of cardiac complaints. In
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9 29 addition, we intent to provide patient-tailored care through pre-hospital assessment of patient
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11 30 specific needs and circumstances. The HART-c study was designed to evaluate whether the
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13 31 implementation of the HART-c triage protocol results in a reduction of unnecessary ED visits.
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19 32 **METHODS AND ANALYSIS**

20 33 **Study design and patient population**

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22 34 The HART-c study is a multi-center prospective study with a historical control group. The
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24 35 intervention group comprises of adult patients visited by the regional emergency medical
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26 36 services (EMS) because of cardiac complaints between 1 September 2019 and 31 August 2020
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28 37 in whom pre-hospital triage is performed according to the HART-c triage protocol. The
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30 38 historical control group consists of adult patients visited by the regional EMS because of
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32 39 cardiac complaints between 1 September 2018 and 31 August 2019 (1 year before the start of
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34 40 the HART-c triage protocol). Of note, in both groups EMS consultation could have been
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36 41 requested directly by the patient, through bystanders or by the patients' general practitioner
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38 42 (GP) who refers patients through EMS. Patients in need for urgent cardiac care, patients with
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40 43 complaints not suspected of cardiac origin as assessed by the ambulance paramedic, and
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42 44 patients unable or not willing to provide informed consent were excluded from triage according
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44 45 to the HART-c protocol. Table 1 displays the detailed inclusion and exclusion criteria.
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Table 1. Inclusion and exclusion criteria**Inclusion criteria****Patients visited by EMS for cardiac complaints****Age over 18 years****Exclusion criteria****Patients in need for urgent cardiac care because of**

- **ST-elevation myocardial infarction**
- **Hemodynamic instability**
- **(Out of hospital) cardiac arrest**
- **Suspected pulmonary embolism**
- **Suspected acute aortic syndrome (thoracic or abdominal)**

Patients with symptoms not suspected of cardiac origin**Unable or unwilling to provide informed consent**

The HART-c study is coordinated by the Leiden University Medical Centre (LUMC) and conducted in the entire EMS region “Hollands-midden” which consists of over 600.000 inhabitants. The hospitals located in this region participate: the Leiden University Medical Centre, the Groene Hart hospital and the Alrijne hospital. The study is performed in close collaboration with the regional EMS (RAVHM) that employs 240 paramedics who are trained in pre-hospital cardiac care and 31 ambulance vehicles equipped with real-time monitoring. In addition, the study was performed and developed with the help of over regional 300 GPs.

Intervention group: Pre-hospital Triage using HART-c protocol

The intervention group consists of patients visited by the EMS because of symptoms suspected to be of cardiac origin such as chest pain, shortness of breath, palpitations or implanted cardiac device problems. In line with the National Protocol for Emergency Medical Care, patients at

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3 57 first receive standard medical care consisting of a medical history, physical examination with
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5 58 vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG.¹³ In
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8 59 patients with chest pain, the pre-hospital modified HEART score (the HEART¹⁴ score without
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10 60 troponin) is calculated. All acquired data are noted on a handheld device and stored on
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12 61 AmbuSuite, an external secure database. Afterwards, the ambulance paramedic directly
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14 62 contacts the on-call triage cardiologist. In total, 43 cardiologist from all three regional hospitals
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16 63 are scheduled so one cardiologist is on duty for the entire region. GPs can refer patients through
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18 64 EMS consultation, however in the intervention period cardiologist consultation is possible.
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20 65 When a GP is in doubt of referral, they can request cardiologist consultation through EMS with
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22 66 the HART-c protocol. The triage cardiologist evaluates the pre-hospital data, including,
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24 67 medical history, real-time vital parameters and 12-lead ECG and combines them with (if
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26 68 present) previous medical records and the actual hospital admission capacity of the regional
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28 69 hospitals. Based on these comprehensive data, the triage cardiologist and ambulance paramedic
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30 70 decide, as a shared decision with the patient, whether transfer to an ED is necessary and, if so,
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32 71 which hospital and which department is most suitable. The triage decision is sent immediately
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34 72 to the concerning ED nursing staff and the capacity of this hospital is updated automatically
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36 73 (Figure 2). Upon arrival at the ED, cardiac assessment is based on in-house clinical decision
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38 74 rules as guidelines prescribe, 12-lead ECG and laboratory findings.⁹ The right panel in Figure
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40 75 1 illustrates the entire routing of patients in the intervention group.
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49 *Figure 1. Method of triage. (A) Patient routing without pre-hospital selection where patients*
50 *are referred to the nearest ED or left at home. If hospital admission capacity is insufficient,*
51 *patients are transferred to another hospital. (B) Patient routing with pre-hospital selection*
52 *using pre- and in-hospital data where a cardiologist has insight in live vital parameters and*
53 *regional hospital capacity.*
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3 *Figure 2. Mobile phone triage application: Left panel showing overview of a hospital specific*
4 *capacity. Right panel showing the ability to update capacity.*
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10 **76 Intervention group: Tempus Pro Monitor, IntelliSpace Corsium, triage platform and**
11 **77 data handling**

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14 78 All ambulances are equipped with a Tempus Pro Monitor¹⁵ (Philips, The Netherlands) that
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16 79 allows recording of a 12-lead ECG and real-time monitoring of the following vital patient
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18 80 parameters: heart rate, blood pressure and pulse oximetry. The monitor can show trends in
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20 81 measurements and stream data for up to 10 hours. All data are encrypted and shared with the
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22 82 on-call triage cardiologist through secure channels. The Tempus Pro Monitor is shown in
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24 83 Figure 3.
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30 *Figure 3. Image of Tempus Pro Monitor.*
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35 84 Using a secure log-in, the on-call triage cardiologist logs in to IntelliSpace Corsium (Philips,
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37 85 the Netherlands) and connects digitally with a patient specific Tempus Pro Monitor. All
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39 86 aforementioned measurements are streamed live. Once the live streaming ends, no patient
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41 87 specific data are stored on the platform. This system of data-transfer is FDA approved.^{16,17}
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44 88 A novel triage platform was developed showing real-time admission capacity of the regional
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46 89 hospitals. The nursing staff in these hospitals continuously updates their admission capacity.
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49 90 Linking these capacity data to a local electronic patient dossier (EPD-Vision; Leiden, The
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51 91 Netherlands), the on-call triage cardiologist has insight into the actual bed occupancy of each
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53 92 hospital. After consultation, the on-call triage cardiologist notes his decision and a message is
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55 93 automatically sent to the nursing staff of the chosen hospital, thereby updating their admission
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3 95 Patient data are sent securely from Tempus Monitor to IntelliSpace Corsium. No data are stored
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5 96 on IntelliSpace Corsium. No patient data are transmitted to the mobile phone application.
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7 97 Patient data are transferred from AmbuSuite to our EPD. All patient data and decisions are
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9 98 stored on the EPD of the coordinating hospital and are only accessible for triage cardiologists.

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12 99 **Historical control group: Standard care in pre-hospital setting**

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15 100 The historical control group consists of patients visited by the EMS because of potential
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17 101 cardiac complaints in the year before the onset of the HART-c triage protocol. Upon arrival
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19 102 by the paramedic, standard medical care consists of medical history, physical examination
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21 103 with vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG. All
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23 104 acquired data are noted on a handheld device and stored on AmbuSuite (Topicus, the
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25 105 Netherlands) which is an external secure database. Thereafter, the ambulance paramedic
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27 106 decides, based on predefined national protocols and decision rules for diagnosis, whether
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29 107 transfer to an ED is deemed necessary.¹² Paramedics are able to identify low-risk patient for
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31 108 all medical specialties, and decide whether admission or ED presentation is necessary on
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33 109 every consultation. So, even in the historical cohort group only patients with cardiac
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35 110 complaints deemed severe enough for presentation are presented to the ED. Of note, at the
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37 111 time of referral, the paramedic has no insight in the previous medical records and the actual
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39 112 hospital admission capacity. The Netherlands has a unique system, where, in the historical
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41 113 cohort in our region, approximately 5% of patients with cardiac complaints aren't referred to
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43 114 a hospital after paramedic assessment, instead these patients are directly referred to their GP
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45 115 or treated at home. However, given the number of unnecessary ED visits, there is still a large
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47 116 cohort of low-risk patients in whom ED presentation could be prevented. After paramedic
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49 117 assessment and hospital transport, cardiac assessment on the ED is based on in-house clinical
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51 118 decision rules as guidelines prescribe, 12-lead ECG and laboratory findings.⁹ If evaluation at
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53 119 the ED indicates that hospitalization is mandatory, the patient is admitted in the concerning
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3 120 hospital. However, when admission capacity is insufficient or immediate intervention is not
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5 121 available in the concerning hospital, ambulance transfer to another hospital is mandatory. The
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8 122 routing of patients in the historical control group is illustrated in the left panel of Figure 1.
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12 123 **Objective and outcome measures**

14 124 The HART-c study is designed to evaluate the efficacy, safety and feasibility of a novel
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16 125 comprehensive pre-hospital triage protocol which aims to safely reduce unnecessary ED visits
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18 126 in patients with cardiac complaints. The primary outcome is the percentage of patients in who
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20 127 an ED visit can be prevented after EMS consultation. The following secondary end-points will
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22 128 be evaluated:
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26 129 - Number of ambulance transfers to an ED because of cardiac complaints.
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28 130 - Number of inter-hospital transfers in cardiac patients.
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30 131 - Patient, triage cardiologist and GP satisfaction with the HART-c triage protocol on a 0-
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32 132 10 scale.
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34 133 - Time from EMS consultation to arrival at the hospital in the both study groups.
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36 134 - Safety of the HART-c prehospital triage protocol. This will be evaluated in intervention
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38 135 group patients who are not transferred to an ED after cardiologist consultation. Safety
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40 136 will be assessed by the occurrence of adverse events up to 30 days follow-up. Table 2
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42 137 displays the pre-specified major and non-major adverse events. To evaluate safety, a
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44 138 dedicated researcher will contact these patients and their GP and evaluate on a case-by-
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46 139 case basis. If a major adverse event is deemed directly attributable to the triage protocol,
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48 140 the protocol will be adjusted or the study will be terminated prematurely.
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50 141 - Feasibility of the HART-c prehospital triage protocol. This will be evaluated in the
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52 142 intervention group and defined as the absence of technical problems for the ambulance
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54 143 paramedic and the triage cardiologist. This means access to the live-monitored data
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3 144 from the ambulance, hospital data and real-time hospital admission capacity are all
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5 145 available. In order to swiftly manage potential technical problems, the HART-c triage
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7 146 protocol will start during working hours. If interim analysis reveals that the protocol is
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9 147 feasible, the time frame in which HART-c triage is available could be extended.
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15 **Table 2. Adverse events (30 days after EMS contact)**

<u>Major adverse events</u>
Death
Acute coronary syndrome
<u>Other adverse events</u>
Renewed EMS or ED visit for cardiac complaint
Pulmonary embolism
ED visit or hospitalization for acute decompensated heart failure
Ventricular tachycardia or – fibrillation
Cerebrovascular accident (CVA) or transient ischemic attack (TIA)

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40 148 **Statistical analysis**

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42 149 The prevention of an ED visit after EMS consultation will be analysed using a logistic
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44 150 regression analysis. Ambulance transfers and inter hospital transfers in the intervention versus
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46 151 the control group will also be evaluated using logistic regression. Baseline characteristics will
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48 152 be reported as mean and standard deviation or median and interquartile range and compared
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50 153 between historical cohort and intervention. This study will be underpowered to detect
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52 154 differences in mortality and major adverse cardiac events (MACE). Accordingly, these events
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54 155 will only be reported and no further statistics on mortality and MACE will be done. The data
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3 156 will be analysed using IBM SPSS Statistics version 25. A p-value lower than 0.05 will be
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5 157 considered statistically significant.

8 158 **Patient and public involvement**

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10 159 Patients were involved in the design of the study. During the design stage, representatives from
11
12 160 the 'Harteraad', a cardiovascular patient council, were asked for input in study design, choice
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14 161 of outcome measures and methods of recruitment. Also, a dedicated website and e-mail address
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16 162 were created to inform the public and answer questions from professionals and patients, before
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18 163 and during the study.

24 164 **ETHICS AND DISSEMINATION**

25
26 165 The study is approved by the LUMC's Medical Ethics Committee (P18.213). Patients are
27
28 166 requested to provide oral informed consent for contacting their GP at 30 days follow-up. Oral
29
30 167 informed consent is requested for cardiologist consultation and study participation by
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32 168 paramedics which is then noted in AmbuSuite. Written informed consent was not deemed
33
34 169 feasible or necessary in this urgent setting. The devices used in this study are FDA and/or CE
35
36 170 approved. No manufacturer has a role in study design, data collection, statistical analysis or
37
38 171 writing of the manuscript. No financial support is received for this study from any
39
40 172 manufacturer. The main results of this trial will be disseminated in one paper.

48 173 **DISCUSSION**

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51 174 Overcrowding of ED's is a major challenge in healthcare. The HART-c study is a multi-centre
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53 175 prospective study that primarily aims to safely reduce unnecessary ED visits of patients with
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55 176 all types of cardiac complaints. By selecting the hospital best suited for every patient, this

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3 177 protocol will contribute to more patient-tailored health care and lead to improved utilization of
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5 178 all available healthcare resources in the region.

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8 179 Recently, interest has shifted from in-hospital - to pre-hospital triage. Pre-hospital cardiologist
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10 180 consultation has been standard procedure for some time in many hospitals in the Netherlands
11
12 181 for quick catheterization lab activation when paramedics suspect chest pain patients of
13
14 182 STEMI.¹⁸ For all other cardiac complaints no pre-hospital triage procedure is in place for
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16 183 emergency evaluations. However, there have been some studies assessing the possibility of
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18 184 pre-hospital triage and pre-hospital selection of low-risk cardiac patients.

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21 185 The History and ECG-only Manchester ACS (HE-MACS) decision aid was developed for pre-
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23 186 hospital triage using history, physical examination and ECG. It was derived in 796 patients and
24
25 187 validated in cohorts of 474 and 659 patients. 9.4% of all validated patients were identified as
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27 188 'very low risk' in which ACS could be 'ruled out' with a sensitivity of 99.5%. It's impact,
28
29 189 however, was not prospectively evaluated in this study.

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33 190 The FAMOUS investigators aim to assess the effects of introducing a pre-hospital triage system
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35 191 that stratifies chest pain patients without ST segment elevation into 1) patients at high risk for
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37 192 NSTEMI requiring direct transfer to a PCI hospital, 2) patients at intermediate risk for major
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39 193 adverse cardiac events who could be evaluated at the nearest non-PCI hospital and 3) patients
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41 194 at low risk for major adverse cardiac events who could have further evaluation at home or in a
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43 195 primary care setting.¹⁹ The study was divided in three phases. In the first phase, a venous blood
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45 196 sample was drawn in the ambulance for measurement of the pre-hospital troponin T levels, in
46
47 197 order to establish a pre-hospital HEART score and evaluate the possibility of triage at the
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49 198 patient's home. Of the 1127 chest pain patients, 36% had a low modified HEART score and
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51 199 none of them developed a major adverse event. Accordingly, the FAMOUS authors concluded
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53 200 that it seemed feasible to rule out myocardial infarction at home in patients without ST segment
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55 201 elevation on the ECG.²⁰ After this first phase proving feasibility, further studies have been done
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3 202 in the pre-hospital setting by the FAMOUS TRIAGE study group. In a prospective
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5 203 observational study, including 700 patients with suspected NSTEMI-ACS, 24.6 % (172 patients)
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7
8 204 were stratified as low risk with a MACE occurrence of 2.9% as opposed to 21.0% MACE
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10 205 occurrence in the intermediate to high risk group. This study showed nicely that pre-hospital
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12 206 risk stratification by ambulance paramedics using the HEART score was accurate in
13
14 207 differentiating in low and intermediate to high risk.²¹

16
17 208 Another study investigating the added value of point-of-care troponin in the pre-hospital setting
18
19 209 is the ARTICA¹² trial. This randomized trial will include patients suspected of non-ST
20
21 210 elevation acute coronary syndrome in whom the modified HEAR score (the HEART score
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23 211 without troponin) is calculated by the ambulance paramedic. If the HEAR score is less than or
24
25 212 equal to 3, patients will be 1:1 randomized for 1) presentation at the ED or 2) point-of-care
26
27 213 troponin T measurement and transfer of care to the GP in case of a low troponin T value. The
28
29 214 primary objective of the ARTICA trial will be healthcare costs at 30 days. The trial is currently
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31 215 ongoing and aims to include 866 patients in 12 months.

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35 216 The similarity of the currently described HART-c study and the HE-MACS, FAMOUS and
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37 217 ARTICA studies is that all three assess whether patients with chest pain who are at low risk of
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39 218 major adverse events can be identified before presenting to the ED. However, the HART-c
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41 219 study has some added benefit as opposed to earlier known studies. First, the HART-c study
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43 220 does not only identify patients at low-risk for events, but also aims to effectively prevent low-
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45 221 risk patients from actually visiting the ED by combining pre-hospital risk stratification by the
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47 222 paramedic and real-time cardiologist consultation with insight in live vital parameters and
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49 223 ECG. Secondly, while these studies study only focus on chest pain patients, the HART-c study
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51 224 extends this to all patients with cardiac complaints and could therefore be of benefit for a
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53 225 substantially larger cohort of patients. Furthermore, the HART-c triage protocol is unique as it
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55 226 combines pre-hospital patient assessment by the ambulance paramedic and direct consultation
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3 227 of an expert triage cardiologist who has access to live-monitored data from the ambulance for
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5 228 all cardiac patients, as opposed to only STEMI patients. Besides these novelties, the HART-c
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7 229 study incorporates hospital data as well as real-time hospital admission capacity to decide
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9 230 which regional hospital is best suited for every patient.
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12 231 If the results of current study show that the HART-c triage protocol is effective in safely
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14 232 reducing unnecessary ED visits of patients with all types of cardiac complaints, the next step
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16 233 will be to evaluate cost-effectiveness. When cost-effectiveness can be demonstrated, we feel
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18 234 that the HART-c triage protocol can be expanded to other EMS regions. Furthermore, last but
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20 235 not least, it may potentially also be useful for other medical specialists aiming to optimize pre-
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22 236 hospital triage of non-cardiac patients. Eventual improvements in pre-hospital triage, such as
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24 237 pre-hospital high sensitive Troponin sampling with a point-of-care test or newly developed and
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26 238 proven risk scores, could always be implemented in this triage protocol.
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28
29 239 To conclude, the HART-c study is a multi-center prospective study evaluating the efficacy,
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31 240 safety and feasibility of a novel comprehensive pre-hospital triage protocol that combines pre-
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33 241 hospital patient assessment by the ambulance paramedic and direct consultation of a
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35 242 cardiologist who has access to live-monitored data from the ambulance, hospital data as well
36
37 243 as real-time hospital admission capacity. If the HART-c study will succeed to safely reduce
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39 244 unnecessary ED visits of patients with all types of cardiac complaints, it may help to decrease
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41 245 ED overcrowding and ultimately reduce healthcare expenditures.
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Author statement

EK, TB, JB, CK, RAD, HS, MS and MB made a substantial contribution to the concept and design of the work. EK and MB are in charge of acquisition of data, analysis and interpretation of the data. EK, TB, SB and MB contributed to the drafting of the article. EK, SB, JB, BB, CK, RAD, MS and MB all revised the manuscript critically for important intellectual content.

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Competing interest

EK, TB, SB, JB, CK, RAD, HS, MS and MB report no conflict of interest. BB is the creator of the HEART score.

References

1. American College of Emergency Physicians Policy statements: crowding. *Annals of Emergency Medicine*. 2006;47:585.
2. A Boyle, K Beniuk, I Higginson, P Atkinson. Emergency department crowding: time *for* interventions and policy evaluations. *Emergency Medicine International*. 2012;2012:838610.
3. FA Bhuiya, SR Pitts, LF McCaig. Emergency department visits for chest pain and abdominal pain: United States, 1999-2008. *NCHS Data Brief* 2010(43):1-8.
4. EW Nawa, RW Nisk, J Xu. National Hospital Ambulatory Medical Care Survey: 2005 emergency department summary. *Advance Data* 2007; 386: 1–32.
5. S Goodacre, P Thokala, C Carroll, JW Stevens, J Leaviss, J Wang et al. Systematic review, meta-analysis and economic modelling of diagnostic strategies for suspected acute coronary syndrome. *Health Technology Assessment* 2013;17(1):v-vi, 1-188.
6. M Gorenberg M, A Marmor, H Rotstein. Detection of chest pain of non-cardiac origin at the emergency room by a new non-invasive device avoiding unnecessary admission to hospital. *Emergency Medicine Journal: EMJ* 2005;22(7):486-9.
7. DC Knockaert, F Buntinx, N Stoens, R Bruyninckx, H Delooz. Chest pain in the emergency department: the broad spectrum of causes. *European Journal of Emergency Medicine*. 2002;9(1):25-30.
8. KA Mol, BM Rahel, JG Meeder, BC van Casteren, PA Doevendans, MJ Cramer. Delays in the treatment of patients with acute coronary syndrome: Focus on pre-hospital delays and non-ST-elevated myocardial infarction. *International Journal of Cardiology*. 2016 Oct 15;221:1061-6.

- 1
2
3 9. BE Backus, AJ Six, JC Kelder, TP Mast, F van den Akker, PA Doevendans. Chest
4
5 pain in the emergency room: a multicenter validation of the HEART score. *Critical*
6
7 *Pathways in Cardiology*. 2010 Sep;9(3):164-9
8
9
- 10 10. JP Stopyra, WS Harper, TJ Higgins, JV Prokesova, JE Winslow, SA Mahler et al.
11
12 *Prehospital Modified HEART Score Predictive of 30-Day Adverse Cardiac Events.*
13
14 *Prehospital and Disaster Medicine*. 2018;33(1):58–62.
15
16
- 17 11. Alghamdi A, Howard L, Reynard C, et al. Enhanced triage for patients with suspected
18
19 cardiac chest pain: the History and Electrocardiogram-only Manchester Acute
20
21 *Coronary Syndromes decision aid.* *Eur J Emerg Med*. 2019;26(5):356-361.
22
23
- 24 12. GWA Aarts, C Camaro, RJ van Geuns, E Cramer, RRJ van Kimmenade, N van
25
26 Royen et al. Acute rule- out of non–ST- segment elevation acute coronary syndrome
27
28 in the (pre)hospital setting by HEART score assessment and a single point- of- care
29
30 troponin: rationale and design of the ARTICA randomised trial. *BMJ Open*
31
32 2020;10:e034403. doi:10.1136/ bmjopen-2019-034403
33
34
- 35 13. Ambulancezorg Nederland. *Landelijk Protocol Ambulancezorg 8.1*. Publication date:
36
37 06-2016. [https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-](https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg)
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39 [richtlijnen/landelijk-protocol-ambulancezorg](https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg)
40
41
- 42 14. BE Backus, AJ Six, JC Kelder, MA Bosschaert, EG Mast, PA Doevendans. A
43
44 prospective validation of the HEART score for chest pain patients at the emergency
45
46 department. *International Journal of Cardiology*. 2013 Oct 3;168(3):2153-8
47
48
- 49 15. Tempus Pro Monitor (Philips). <https://www.rdtltd.com/>
50
51
- 52 16. IntelliSpace Corsium (Philips)
53
54 [https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
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56 [advanced-visual-analysis](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
57
58
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2
3 17. FDA approval IntelliSpace Corsium (Philips). FDA Primary Device ID:
4
5 05060472441331 <https://fda.report/GUDID/05060472441331>
6
7
8 18. Liem SS, van der Hoeven BL, Oemrawsingh PV, et al. MISSION!: optimization of
9
10 acute and chronic care for patients with acute myocardial infarction. *Am Heart J.*
11
12 2007;153(1)
13
14 19. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, B Dikkeschei, The FAMOUS TRIAGE
15
16 Study Group et al. Fast assessment and management of chest pain without ST-
17
18 elevation in the pre-hospital gateway: Rationale and design. *European Journal of*
19
20 *Acute Cardiovascular Care.* 2015, Vol. 4(2) 129 –136
21
22
23 20. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, RT Tolsma, AW van 't Hof et al. Fast
24
25 assessment and management of chest pain patients without ST-elevation in the pre-
26
27 hospital gateway (Famous Triage): ruling out a myocardial infarction at home with
28
29 the modified HEART score. *European Heart Journal: Acute Cardiovascular Care.*
30
31 2018, Vol. 7(2) 102-110.
32
33
34 21. van Dongen DN, Tolsma RT, Fokkert MJ, et al. Pre-hospital risk assessment in
35
36 suspected non-ST-elevation acute coronary syndrome: A prospective observational
37
38 study. *Eur Heart J Acute Cardiovasc Care.* 2020;9(1_suppl):5-12.
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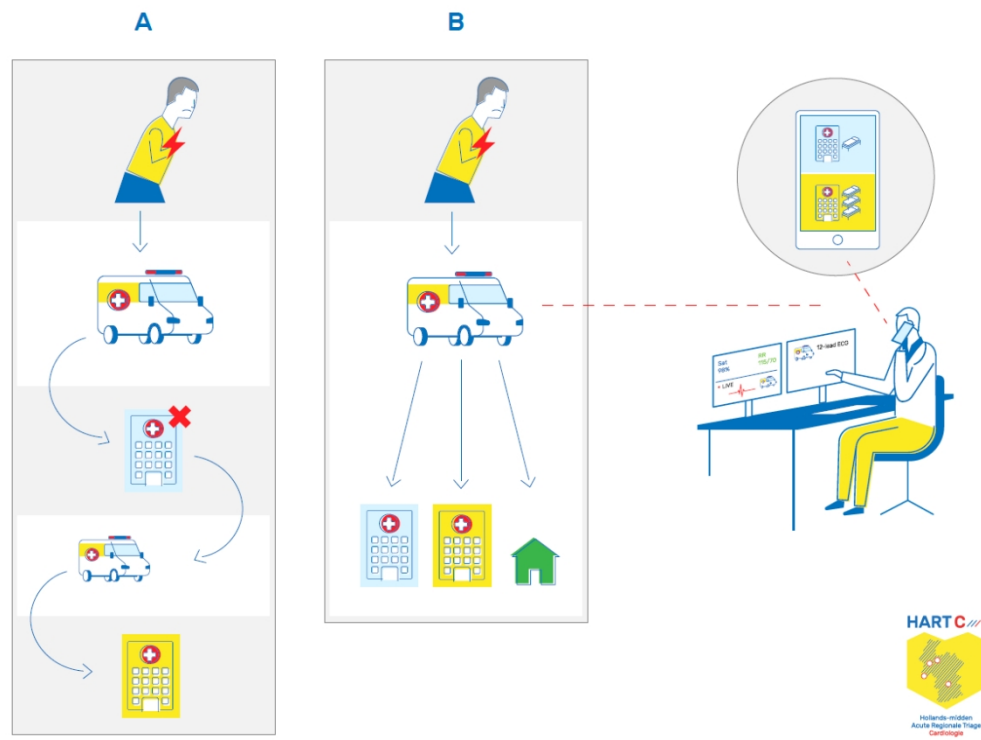


Figure 1. Method of triage

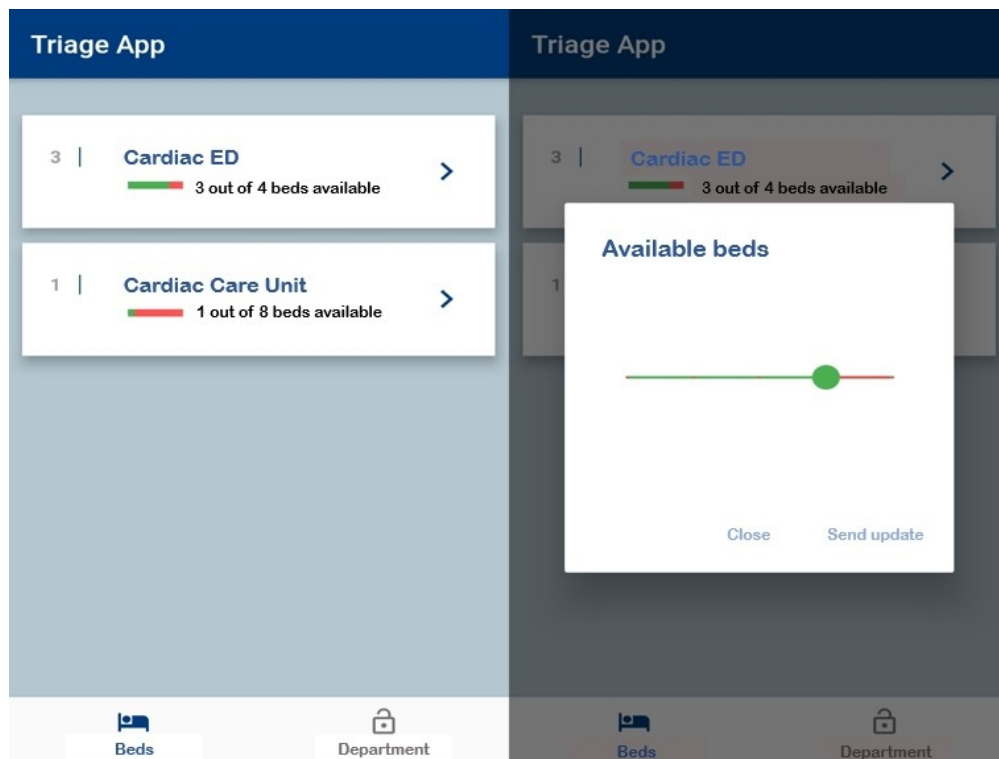


Figure 2. Mobile phone triage application

200x151mm (96 x 96 DPI)

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Figure 3. Image of Tempus Pro Monitor

BMJ Open

Pre-hospital Triage of Acute Cardiac Patients: Study Protocol of HART-c, a multicenter prospective study

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3 **Pre-hospital Triage of Acute Cardiac Patients: Study Protocol of HART-c, a**
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5 **multicenter prospective study**
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9 Medical Services, Emergency Department, overcrowding

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ABSTRACT

Introduction: Emergency department (ED) overcrowding is a major health care problem associated with worse patient outcomes and increased costs. Attempts to reduce ED overcrowding of cardiac patients have so far focused on in-hospital triage and rapid risk stratification of chest pain patients at the ED. The HART-c study aims to assess the amount of patients left at home in usual ambulance care as compared to the new pre-hospital triage protocol. This protocol combines paramedic assessment and expert cardiologist consultation using live-monitoring, hospital data and real-time admission capacity.

Methods and Analysis: Patients visited by the emergency medical services (EMS) for cardiac complaints are included. EMS consultation consists of medical history, physical examination and vital signs and ECG measurements. All data is transferred to a newly developed platform for the triage cardiologist. Pre-hospital data, in-hospital medical records and real-time admission capacity are evaluated. Then a shared decision is made whether admission is necessary and, if so, which hospital is most appropriate. To evaluate safety, all patients left at home and their GP's, are contacted for 30-day adverse events.

Ethics and dissemination: The study is approved by the LUMC's Medical Ethics Committee. Patients are asked for consent for contacting their GP's. The main results of this trial will be disseminated in one paper.

Discussion: The HART-c study evaluates the efficacy and feasibility of a pre-hospital triage protocol that combines pre-hospital patient assessment and direct consultation of a cardiologist who has access to live-monitored data, hospital data and real-time hospital admission capacity. We expect this triage protocol to substantially reduce unnecessary ED visits.

ARTICLE SUMMARY

- A novel pre-hospital triage protocol is presented which aims to safely decrease unnecessary ED admissions, using telemedicine for pre-hospital decision making
- All participants, including patient representatives, were involved in the design of the study
- **Strengths and limitations:**
 - This study is a real-life reflection of interdisciplinary daily clinical practice, the retrospective cohort will reflect the control group in the best way possible
 - The HART-c Study is a non-randomised controlled trial and therefore has risk of bias as decisions from paramedics and cardiologist can be influenced by the study.

1 INTRODUCTION

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Emergency Department (ED) overcrowding is a worldwide health care problem associated with worse patient outcomes and increased costs^{1,2}. Cardiac complaints are one of the most common reasons for patients to visit the ED, with chest pain as the most frequent complaint.³ In Europe and the United States, 15-20 million patients with chest pain are seen at the ED every year.⁴ The majority will be sent home after ruling out acute cardiovascular disease: previous studies have shown that up to 80% of chest pain patients do not have an acute coronary syndrome.⁵⁻⁸ However, these patients contribute to overcrowding of EDs and these ED visits substantially increase healthcare costs.

Attempts to reduce ED overcrowding by cardiac patients have so far particularly focused on rapid risk stratification after presentation at the ED. For example, the HEART score stratifies patients as at low, intermediate or high risk of major adverse cardiac events (MACE) based on history, the electrocardiogram (ECG), age, risk factors and troponin levels.⁹ However, as it takes 1-2 hours for the latter to be available, patients still spend a long time at the ED after which the majority can be discharged home.

Accordingly, interest has shifted from in-hospital to pre-hospital triage. Preventing patients with cardiac complaints and a very low risk of adverse cardiac events from visiting the ED will substantially help to reduce ED overcrowding. Efforts to prevent ED visits especially involve interventions focused on chest pain patients such as risk score calculation by the ambulance paramedics (for example with the HEART score¹⁰ and HE-MACS¹¹) or pre-hospital point of care testing for troponin.¹² In order to improve pre-hospital triage for cardiac patients in the entire chain of acute cardiac care, we developed a comprehensive triage protocol entitled HART-c (“Hollands-midden Acute Regional Triage - Cardiology”).

Innovative in this protocol is the combination of pre-hospital patient assessment by the ambulance paramedic and expert consultation of a cardiologist who has access to live-

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3 26 monitored data from the ambulance, in-hospital data and real-time hospital admission capacity
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5 27 in a newly developed triage application. By drafting this triage protocol, we specifically aimed
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7 28 to safely reduce unnecessary ED visits of patients with all types of cardiac complaints. In
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9 29 addition, we intent to provide patient-tailored care through pre-hospital assessment of patient
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11 30 specific needs and circumstances. The HART-c study was designed to evaluate whether the
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13 31 implementation of the HART-c triage protocol results in a reduction of unnecessary ED visits.
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19 32 **METHODS AND ANALYSIS**

20 33 **Study design and patient population**

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22 34 The HART-c study is a multi-center prospective study with a historical control group. The
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24 35 intervention group comprises of adult patients visited by the regional emergency medical
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26 36 services (EMS) because of cardiac complaints between 1 September 2019 and 31 August 2020
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28 37 in whom pre-hospital triage is performed according to the HART-c triage protocol. The
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30 38 historical control group consists of adult patients visited by the regional EMS because of
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32 39 cardiac complaints between 1 September 2018 and 31 August 2019 (1 year before the start of
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34 40 the HART-c triage protocol). Of note, in both groups EMS consultation could have been
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36 41 requested directly by the patient, through bystanders or by the patients' general practitioner
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38 42 (GP) who refers patients through EMS. Patients in need for urgent cardiac care, patients with
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40 43 complaints not suspected of cardiac origin as assessed by the ambulance paramedic, and
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42 44 patients unable or not willing to provide informed consent were excluded from triage according
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44 45 to the HART-c protocol. Table 1 displays the detailed inclusion and exclusion criteria.
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Table 1. Inclusion and exclusion criteria**Inclusion criteria****Patients visited by EMS for cardiac complaints****Age over 18 years****Exclusion criteria****Patients in need for urgent cardiac care because of**

- **ST-elevation myocardial infarction**
- **Hemodynamic instability**
- **(Out of hospital) cardiac arrest**
- **Suspected pulmonary embolism**
- **Suspected acute aortic syndrome (thoracic or abdominal)**

Patients with symptoms not suspected of cardiac origin**Unable or unwilling to provide informed consent**

The HART-c study is coordinated by the Leiden University Medical Centre (LUMC) and conducted in the entire EMS region “Hollands-midden” which consists of over 600.000 inhabitants. The hospitals located in this region participate: the Leiden University Medical Centre, the Groene Hart hospital and the Alrijne hospital. The study is performed in close collaboration with the regional EMS (RAVHM) that employs 240 paramedics who are trained in pre-hospital cardiac care and 31 ambulance vehicles equipped with real-time monitoring. In addition, the study was performed and developed with the help of over regional 300 GPs.

Intervention group: Pre-hospital Triage using HART-c protocol

The intervention group consists of patients visited by the EMS because of symptoms suspected to be of cardiac origin such as chest pain, shortness of breath, palpitations or implanted cardiac device problems. In line with the National Protocol for Emergency Medical Care, patients at

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3 57 first receive standard medical care consisting of a medical history, physical examination with
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5 58 vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG.¹³ In
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8 59 patients with chest pain, the pre-hospital modified HEART score (the HEART¹⁴ score without
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10 60 troponin) is calculated. All acquired data are noted on a handheld device and stored on
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12 61 AmbuSuite, an external secure database. Afterwards, the ambulance paramedic directly
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14 62 contacts the on-call triage cardiologist. The right panel in Figure 1 illustrates the entire routing
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16 63 of patients in the intervention group. In total, 43 cardiologist from all three regional hospitals
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18 64 are scheduled so one cardiologist is on duty for the entire region. GPs can refer patients through
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20 65 EMS consultation, however in the intervention period cardiologist consultation is possible.
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22 66 When a GP is in doubt of referral, they can request cardiologist consultation through EMS with
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24 67 the HART-c protocol. The triage cardiologist evaluates the pre-hospital data, including,
25
26 68 medical history, real-time vital parameters and 12-lead ECG and combines them with (if
27
28 69 present) previous medical records and the actual hospital admission capacity of the regional
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30 70 hospitals. Also, we developed decision aids for chest pain, dyspnoea and arrhythmia as
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32 71 guidance for triage cardiologists. These decisions aids can help the triage cardiologist in
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34 72 decision making and are added, as addendum 1 for chest pain, addendum 2 for dyspnoea and
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36 73 addendum 3 for arrhythmia, to this manuscript. Based on these comprehensive data, the triage
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38 74 cardiologist and ambulance paramedic decide, as a shared decision with the patient, whether
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40 75 transfer to an ED is necessary and, if so, which hospital and which department is most suitable.
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42 76 The triage decision is sent immediately to the concerning ED nursing staff and the capacity of
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44 77 this hospital is updated automatically (Figure 2). Upon arrival at the ED, cardiac assessment is
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46 78 based on in-house clinical decision rules as guidelines prescribe, 12-lead ECG and laboratory
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48 79 findings.⁹
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3 *Figure 1. Method of triage. (A) Patient routing without pre-hospital selection where patients*
4 *are referred to the nearest ED or left at home. If hospital admission capacity is insufficient,*
5 *patients are transferred to another hospital. (B) Patient routing with pre-hospital selection*
6 *using pre- and in-hospital data where a cardiologist has insight in live vital parameters and*
7 *regional hospital capacity.*

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12 *Figure 2. Mobile phone triage application: Left panel showing overview of a hospital specific*
13 *capacity. Right panel showing the ability to update capacity.*

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19 **80 Intervention group: Tempus Pro Monitor, IntelliSpace Corsium, triage platform and**
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21 **81 data handling**

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24 **82** All ambulances are equipped with a Tempus Pro Monitor¹⁵ (Philips, The Netherlands) that
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26 **83** allows recording of a 12-lead ECG and real-time monitoring of the following vital patient
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28 **84** parameters: heart rate, blood pressure and pulse oximetry. The monitor can show trends in
29
30 **85** measurements and stream data for up to 10 hours. All data are encrypted and shared with the
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32 **86** on-call triage cardiologist through secure channels. The Tempus Pro Monitor is shown in
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35 **87** Figure 3.

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40 *Figure 3. Image of Tempus Pro Monitor.*

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45 **88** Using a secure log-in, the on-call triage cardiologist logs in to IntelliSpace Corsium (Philips,
46
47 **89** the Netherlands) and connects digitally with a patient specific Tempus Pro Monitor. All
48
49 **90** aforementioned measurements are streamed live. Once the live streaming ends, no patient
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51 **91** specific data are stored on the platform. This system of data-transfer is FDA approved.^{16,17}

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54 **92** A novel triage platform was developed showing real-time admission capacity of the regional
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56 **93** hospitals. The nursing staff in these hospitals continuously updates their admission capacity.
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58 **94** Linking these capacity data to a local electronic patient dossier (EPD-Vision; Leiden, The
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3 95 Netherlands), the on-call triage cardiologist has insight into the actual bed occupancy of each
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5 96 hospital. After consultation, the on-call triage cardiologist notes his decision and a message is
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7 97 automatically sent to the nursing staff of the chosen hospital, thereby updating their admission
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9 98 capacity immediately.

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12 99 Patient data are sent securely from Tempus Monitor to IntelliSpace Corsium. No data are stored
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14 100 on IntelliSpace Corsium. No patient data are transmitted to the mobile phone application.
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16 101 Patient data are transferred from AmbuSuite to our EPD. All patient data and decisions are
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18 102 stored on the EPD of the coordinating hospital and are only accessible for triage cardiologists.

103 **Historical control group: Standard care in pre-hospital setting**

104 The historical control group consists of patients visited by the EMS because of potential
105 cardiac complaints in the year before the onset of the HART-c triage protocol. Upon arrival
106 by the paramedic, standard medical care consists of medical history, physical examination
107 with vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG. All
108 acquired data are noted on a handheld device and stored on AmbuSuite (Topicus, the
109 Netherlands) which is an external secure database. Thereafter, the ambulance paramedic
110 decides, based on predefined national protocols and decision rules for diagnosis, whether
111 transfer to an ED is deemed necessary.¹² Paramedics are able to identify low-risk patient for
112 all medical specialties, and decide whether admission or ED presentation is necessary on
113 every consultation. So, even in the historical cohort group only patients with cardiac
114 complaints deemed severe enough for presentation are presented to the ED. Of note, at the
115 time of referral, the paramedic has no insight in the previous medical records and the actual
116 hospital admission capacity. The Netherlands has a unique system, where, in the historical
117 cohort in our region, approximately 5% of patients with cardiac complaints aren't referred to
118 a hospital after paramedic assessment, instead these patients are directly referred to their GP
119 or treated at home. However, given the number of unnecessary ED visits, there is still a large

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3 120 cohort of low-risk patients in whom ED presentation could be prevented. After paramedic
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5 121 assessment and hospital transport, cardiac assessment on the ED is based on in-house clinical
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7 122 decision rules as guidelines prescribe, 12-lead ECG and laboratory findings.⁹ If evaluation at
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10 123 the ED indicates that hospitalization is mandatory, the patient is admitted in the concerning
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12 124 hospital. However, when admission capacity is insufficient or immediate intervention is not
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14 125 available in the concerning hospital, ambulance transfer to another hospital is mandatory. The
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17 126 routing of patients in the historical control group is illustrated in the left panel of Figure 1.

127 **Objective and outcome measures**

128 The HART-c study is designed to evaluate the efficacy and feasibility of a novel
129 comprehensive pre-hospital triage protocol which aims to safely reduce unnecessary ED visits
130 in patients with cardiac complaints. The primary outcome is the percentage of patients in who
131 an ED visit can be prevented after EMS consultation. The following secondary end-points will
132 be evaluated:

- 133 - Number of ambulance transfers to an ED because of cardiac complaints.
- 134 - Number of inter-hospital transfers in cardiac patients.
- 135 - Patient, triage cardiologist and GP satisfaction with the HART-c triage protocol on a 0-
136 10 scale.
- 137 - Time from EMS consultation to arrival at the hospital in the both study groups.
- 138 - Safety of the HART-c prehospital triage protocol. This will be evaluated in intervention
139 group patients who are not transferred to an ED after cardiologist consultation. Safety
140 will be assessed by the occurrence of adverse events up to 30 days follow-up. Table 2
141 displays the pre-specified major and non-major adverse events. To evaluate safety, a
142 dedicated researcher will contact these patients and their GP and evaluate on a case-by-
143 case basis. If a major adverse event is deemed directly attributable to the triage protocol,

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3 144 the protocol will be adjusted or the study will be terminated prematurely. The study
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5 145 will be deemed safe if the percentage of major adverse events is 1% or lower.
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8 146 - Feasibility of the HART-c prehospital triage protocol. This will be evaluated in the
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10 147 intervention group and defined as the absence of technical problems for the ambulance
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12 148 paramedic and the triage cardiologist. This means access to the live-monitored data
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14 149 from the ambulance, hospital data and real-time hospital admission capacity are all
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16 150 available. In order to swiftly manage potential technical problems, the HART-c triage
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18 151 protocol will start during working hours. If interim analysis reveals that the protocol is
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20 152 feasible, the time frame in which HART-c triage is available could be extended.
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26 **Table 2. Adverse events (30 days after EMS contact)**

27 **Major adverse events**

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31 **Death**

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33 **Acute coronary syndrome**

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35 **Other adverse events**

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38 **Renewed EMS or ED visit for cardiac complaint**

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40 **Pulmonary embolism**

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42 **ED visit or hospitalization for acute decompensated heart failure**

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44 **Ventricular tachycardia or – fibrillation**

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47 **Cerebrovascular accident (CVA) or transient ischemic attack (TIA)**
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52 **Statistical analysis**

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54 154 The prevention of an ED visit after EMS consultation will be analysed using a logistic
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56 155 regression analysis. Ambulance transfers and inter hospital transfers in the intervention versus
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58 156 the control group will also be evaluated using logistic regression. Baseline characteristics will
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3 157 be reported as mean and standard deviation or median and interquartile range and compared
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5 158 between historical cohort and intervention. This study will be underpowered to detect
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7 159 differences in mortality and major adverse cardiac events (MACE). Accordingly, these events
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10 160 will only be reported and no further statistics on mortality and MACE will be done. The data
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12 161 will be analysed using IBM SPSS Statistics version 25. A p-value lower than 0.05 will be
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14
15 162 considered statistically significant.

163 **Patient and public involvement**

164 Patients were involved in the design of the study. During the design stage, representatives from
165 the 'Harteraad', a cardiovascular patient council, were asked for input in study design, choice
166 of outcome measures and methods of recruitment. Also, a dedicated website, www.hartc.nl,
167 was created to inform the public and answer questions from professionals and patients, before
168 and during the study.

169 **ETHICS AND DISSEMINATION**

170 The study is approved by the LUMC's Medical Ethics Committee (P18.213). Patients are
171 requested to provide oral informed consent for contacting their GP at 30 days follow-up. Oral
172 informed consent is requested for cardiologist consultation and study participation by
173 paramedics which is then noted in AmbuSuite. The need for written informed consent was
174 waived by the Medical Ethics Committee. The devices used in this study are FDA and/or CE
175 approved. No manufacturer has a role in study design, data collection, statistical analysis or
176 writing of the manuscript. No financial support is received for this study from any
177 manufacturer. The main results of this trial will be disseminated in one paper.

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3 178 **DISCUSSION**
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6 179 Overcrowding of ED's is a major challenge in healthcare. The HART-c study is a multi-centre
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8 180 prospective study that primarily aims to safely reduce unnecessary ED visits of patients with
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10 181 all types of cardiac complaints. By selecting the hospital best suited for every patient, this
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12 182 protocol will contribute to more patient-tailored health care and lead to improved utilization of
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14 183 all available healthcare resources in the region.

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17 184 Recently, interest has shifted from in-hospital - to pre-hospital triage. Pre-hospital cardiologist
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19 185 consultation has been standard procedure for some time in many hospitals in the Netherlands
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21 186 for quick catheterization lab activation when paramedics suspect chest pain patients of
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23 187 STEMI.¹⁸ For all other cardiac complaints no pre-hospital triage procedure is in place for
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25 188 emergency evaluations. However, there have been some studies assessing the possibility of
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27 189 pre-hospital triage and pre-hospital selection of low-risk cardiac patients.

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30 190 The History and ECG-only Manchester ACS (HE-MACS) decision aid was developed for pre-
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32 191 hospital triage using history, physical examination and ECG. It was derived in 796 patients and
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34 192 validated in cohorts of 474 and 659 patients. 9.4% of all validated patients were identified as
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36 193 'very low risk' in which ACS could be 'ruled out' with a sensitivity of 99.5%. It's impact,
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38 194 however, was not prospectively evaluated in this study.

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41 195 The FAMOUS investigators aim to assess the effects of introducing a pre-hospital triage system
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43 196 that stratifies chest pain patients without ST segment elevation into 1) patients at high risk for
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45 197 NSTEMI requiring direct transfer to a PCI hospital, 2) patients at intermediate risk for major
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47 198 adverse cardiac events who could be evaluated at the nearest non-PCI hospital and 3) patients
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49 199 at low risk for major adverse cardiac events who could have further evaluation at home or in a
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51 200 primary care setting.¹⁹ The study was divided in three phases. In the first phase, a venous blood
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53 201 sample was drawn in the ambulance for measurement of the pre-hospital troponin T levels, in
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55 202 order to establish a pre-hospital HEART score and evaluate the possibility of triage at the
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3 203 patient's home. Of the 1127 chest pain patients, 36% had a low modified HEART score and
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5 204 none of them developed a major adverse event.²⁰ After this first phase proving feasibility,
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7 205 further studies have been done in the pre-hospital setting by the FAMOUS TRIAGE study
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10 206 group. Phase 2, a prospective observational study including 700 patients with suspected NSTE-
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12 207 ACS, showed nicely that pre-hospital risk stratification by ambulance paramedics using the
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14 208 HEART score was accurate in differentiating in low and intermediate to high risk.²¹ Recently
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16 209 the design of phase 3 has been published, where the FAMOUS study investigators aim to
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18 210 determine if use of the HEART score, including point-of-care Troponin measurement, is non-
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20 211 inferior to routine management. In this phase referral decisions are based on pre-hospital
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22 212 acquired risk stratification.²²
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24 213 Another study investigating the added value of point-of-care troponin in the pre-hospital setting
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26 214 is the ARTICA¹² trial. This randomized trial will include patients suspected of non-ST
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28 215 elevation acute coronary syndrome in whom the modified HEAR score (the HEART score
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30 216 without troponin) is calculated by the ambulance paramedic. If the HEAR score is less than or
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32 217 equal to 3, patients will be 1:1 randomized for 1) presentation at the ED or 2) point-of-care
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34 218 troponin T measurement and transfer of care to the GP in case of a low troponin T value. The
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36 219 primary objective of the ARTICA trial will be healthcare costs at 30 days. The trial is currently
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38 220 ongoing and aims to include 866 patients in 12 months.
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40 221 The similarity of the currently described HART-c study and the HE-MACS, FAMOUS and
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42 222 ARTICA studies is that all three assess whether patients with chest pain who are at low risk of
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44 223 major adverse events can be identified before presenting to the ED. However, the HART-c
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46 224 study has some added benefit as opposed to earlier known studies. First, the HART-c study
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48 225 does not only identify patients at low-risk for events, but also aims to effectively prevent low-
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50 226 risk patients from actually visiting the ED, as well as further phases from FAMOUS and
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52 227 ARTICA did, by combining pre-hospital risk stratification by the paramedic and real-time
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3 228 cardiologist consultation with insight in live vital parameters and ECG. Secondly, while these
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5 229 studies study only focus on chest pain patients, the HART-c study extends this to all patients
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7 230 with cardiac complaints and could therefore be of benefit for a substantially larger cohort of
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9 231 patients. Furthermore, the HART-c triage protocol is unique as it combines pre-hospital patient
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11 232 assessment by the ambulance paramedic and direct consultation of an expert triage cardiologist
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13 233 who has access to live-monitored data from the ambulance for all cardiac patients, as opposed
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15 234 to only STEMI patients. Besides these novelties, the HART-c study incorporates hospital data
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17 235 as well as real-time hospital admission capacity to decide which regional hospital is best suited
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19 236 for every patient.

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24 237 If the results of current study show that the HART-c triage protocol is effective in safely
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26 238 reducing unnecessary ED visits of patients with all types of cardiac complaints, the next step
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28 239 will be to evaluate cost-effectiveness. When cost-effectiveness can be demonstrated, we feel
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30 240 that the HART-c triage protocol can be expanded to other EMS regions. Furthermore, last but
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32 241 not least, it may potentially also be useful for other medical specialists aiming to optimize pre-
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34 242 hospital triage of non-cardiac patients. Eventual improvements in pre-hospital triage, such as
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36 243 pre-hospital high sensitive Troponin sampling with a point-of-care test or newly developed and
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38 244 proven risk scores, could always be implemented in this triage protocol.

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42 245 To conclude, the HART-c study is a multi-center prospective study evaluating the efficacy, and
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44 246 feasibility of a novel comprehensive pre-hospital triage protocol that combines pre-hospital
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46 247 patient assessment by the ambulance paramedic and direct consultation of a cardiologist who
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48 248 has access to live-monitored data from the ambulance, hospital data as well as real-time
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50 249 hospital admission capacity. If the HART-c study will succeed to safely reduce unnecessary
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52 250 ED visits of patients with all types of cardiac complaints, it may help to decrease ED
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54 251 overcrowding and ultimately reduce healthcare expenditures.
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Author statement

EdK, TEB, JB, CJHJK, RAD, HAMS, MS and MJB made a substantial contribution to the concept and design of the work. EdK and MJB are in charge of acquisition of data, analysis and interpretation of the data. EdK, TEB, SB and MJB contributed to the drafting of the article. EdK, SB, JB, BEB, CJHJK, RAD, MS and MJB all revised the manuscript critically for important intellectual content.

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Competing interest

EdK, TEB, SB, JB, CJHJK, RAD, HAMS, MS and MJB report no conflict of interest. BEB is the creator of the HEART score.

References

1. American College of Emergency Physicians Policy statements: crowding. *Annals of Emergency Medicine*. 2006;47:585.
2. A Boyle, K Beniuk, I Higginson, P Atkinson. Emergency department crowding: time *for* interventions and policy evaluations. *Emergency Medicine International*. 2012;2012:838610.
3. FA Bhuiya, SR Pitts, LF McCaig. Emergency department visits for chest pain and abdominal pain: United States, 1999-2008. *NCHS Data Brief* 2010(43):1-8.
4. EW Nawa, RW Nisk, J Xu. National Hospital Ambulatory Medical Care Survey: 2005 emergency department summary. *Advance Data* 2007; 386: 1–32.
5. S Goodacre, P Thokala, C Carroll, JW Stevens, J Leaviss, J Wang et al. Systematic review, meta-analysis and economic modelling of diagnostic strategies for suspected acute coronary syndrome. *Health Technology Assessment* 2013;17(1):v-vi, 1-188.
6. M Gorenberg M, A Marmor, H Rotstein. Detection of chest pain of non-cardiac origin at the emergency room by a new non-invasive device avoiding unnecessary admission to hospital. *Emergency Medicine Journal: EMJ* 2005;22(7):486-9.
7. DC Knockaert, F Buntinx, N Stoens, R Bruyninckx, H Delooz. Chest pain in the emergency department: the broad spectrum of causes. *European Journal of Emergency Medicine*. 2002;9(1):25-30.
8. KA Mol, BM Rahel, JG Meeder, BC van Casteren, PA Doevendans, MJ Cramer. Delays in the treatment of patients with acute coronary syndrome: Focus on pre-hospital delays and non-ST-elevated myocardial infarction. *International Journal of Cardiology*. 2016 Oct 15;221:1061-6.

- 1
2
3 9. BE Backus, AJ Six, JC Kelder, TP Mast, F van den Akker, PA Doevendans. Chest
4
5 pain in the emergency room: a multicenter validation of the HEART score. *Critical*
6
7 *Pathways in Cardiology*. 2010 Sep;9(3):164-9
8
9
- 10 10. JP Stopyra, WS Harper, TJ Higgins, JV Prokesova, JE Winslow, SA Mahler et al.
11
12 *Prehospital Modified HEART Score Predictive of 30-Day Adverse Cardiac Events.*
13
14 *Prehospital and Disaster Medicine*. 2018;33(1):58–62.
15
16
- 17 11. Alghamdi A, Howard L, Reynard C, et al. Enhanced triage for patients with suspected
18
19 cardiac chest pain: the History and Electrocardiogram-only Manchester Acute
20
21 *Coronary Syndromes decision aid.* *Eur J Emerg Med*. 2019;26(5):356-361.
22
23
- 24 12. GWA Aarts, C Camaro, RJ van Geuns, E Cramer, RRJ van Kimmenade, N van
25
26 Royen et al. Acute rule- out of non–ST- segment elevation acute coronary syndrome
27
28 in the (pre)hospital setting by HEART score assessment and a single point- of- care
29
30 troponin: rationale and design of the ARTICA randomised trial. *BMJ Open*
31
32 2020;10:e034403. doi:10.1136/ bmjopen-2019-034403
33
34
- 35 13. Ambulancezorg Nederland. *Landelijk Protocol Ambulancezorg 8.1*. Publication date:
36
37 06-2016. [https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-](https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg)
38
39 [richtlijnen/landelijk-protocol-ambulancezorg](https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg)
40
41
- 42 14. BE Backus, AJ Six, JC Kelder, MA Bosschaert, EG Mast, PA Doevendans. A
43
44 prospective validation of the HEART score for chest pain patients at the emergency
45
46 department. *International Journal of Cardiology*. 2013 Oct 3;168(3):2153-8
47
48
- 49 15. Tempus Pro Monitor (Philips). <https://www.rdtltd.com/>
50
51
- 52 16. IntelliSpace Corsium (Philips)
53
54 [https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
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56 [advanced-visual-analysis](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
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2
3 17. FDA approval IntelliSpace Corsium (Philips). FDA Primary Device ID:
4
5 05060472441331 <https://fda.report/GUDID/05060472441331>
6
7
8 18. Liem SS, van der Hoeven BL, Oemrawsingh PV, et al. MISSION!: optimization of
9
10 acute and chronic care for patients with acute myocardial infarction. *Am Heart J.*
11
12 2007;153(1)
13
14 19. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, B Dikkeschei, The FAMOUS TRIAGE
15
16 Study Group et al. Fast assessment and management of chest pain without ST-
17
18 elevation in the pre-hospital gateway: Rationale and design. *European Journal of*
19
20 *Acute Cardiovascular Care.* 2015, Vol. 4(2) 129 –136
21
22
23 20. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, RT Tolsma, AW van 't Hof et al. Fast
24
25 assessment and management of chest pain patients without ST-elevation in the pre-
26
27 hospital gateway (Famous Triage): ruling out a myocardial infarction at home with
28
29 the modified HEART score. *European Heart Journal: Acute Cardiovascular Care.*
30
31 2018, Vol. 7(2) 102-110.
32
33
34 21. van Dongen DN, Tolsma RT, Fokkert MJ, et al. Pre-hospital risk assessment in
35
36 suspected non-ST-elevation acute coronary syndrome: A prospective observational
37
38 study. *Eur Heart J Acute Cardiovasc Care.* 2020;9(1_suppl):5-12.
39
40
41 22. Van Dongen DN, Tolsma RT, Fokkert MJ et al. Referral decisions based on a
42
43 prehospital HEART score in suspected non-ST elevation acute coronary syndrome:
44
45 design of the Famous Triage 3 study. *Future Cardiol.* (2020) 16(4), 217-226.
46
47
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49 *Addendum 1. Decision aid for chest pain. The T stands for Triage cardiologist consultation.*
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51 *Addendum 2. Decision aid for dyspnoea. The T stands for Triage cardiologist consultation.*
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53 *Addendum 3. Decision aid for arrhythmia. The T stands for Triage cardiologist consultation.*
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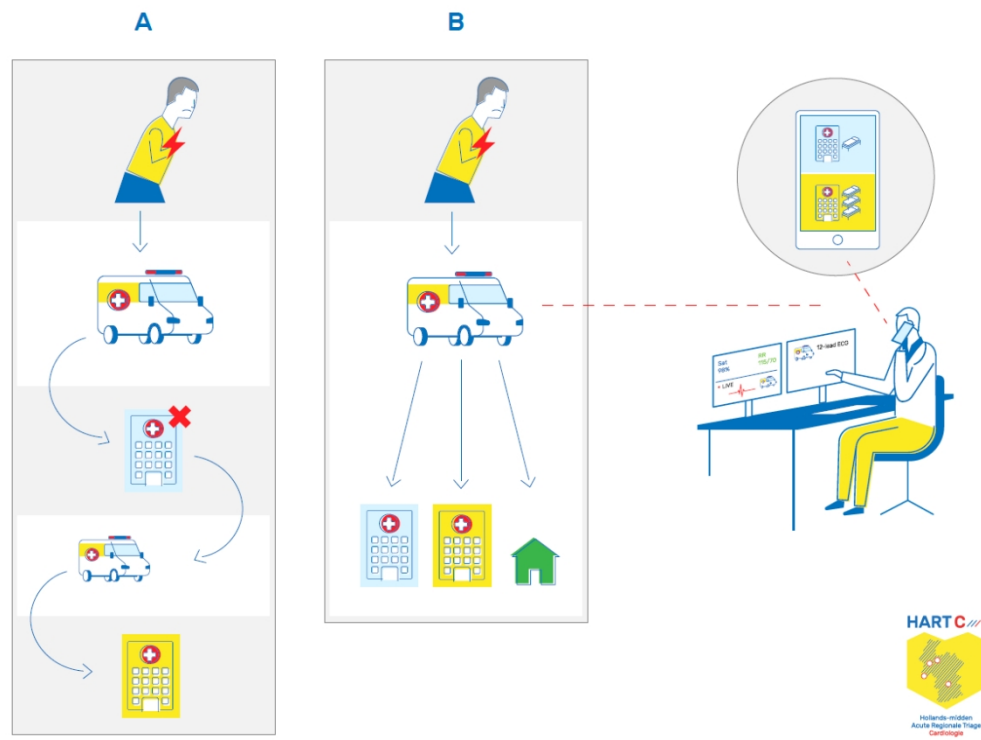


Figure 1. Method of triage

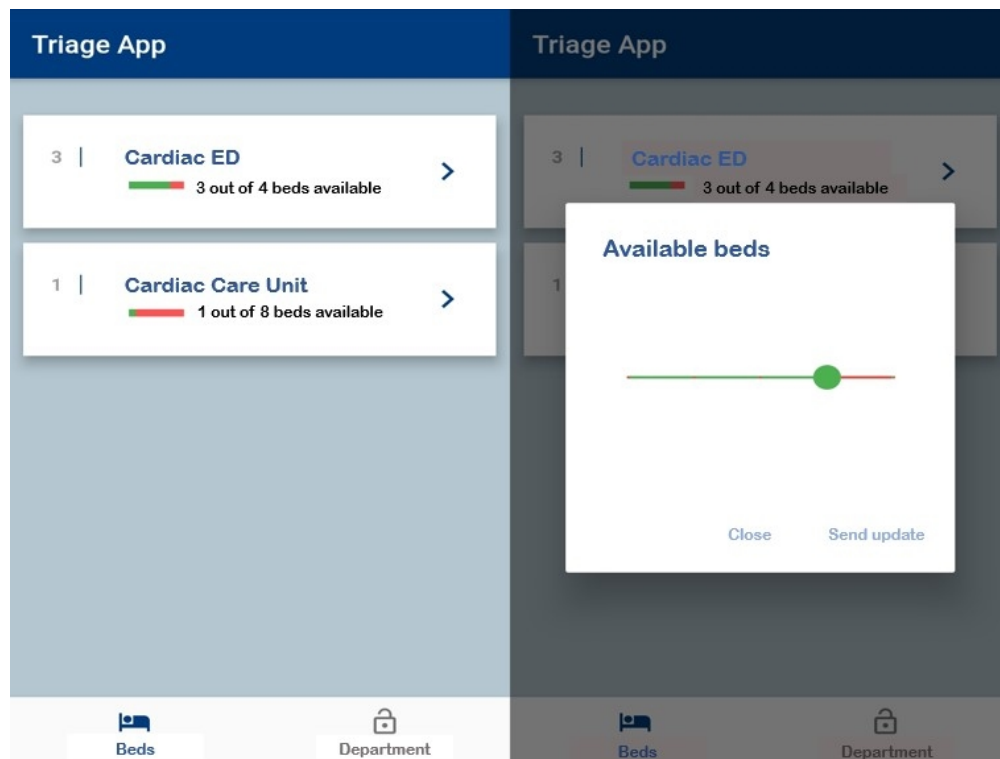


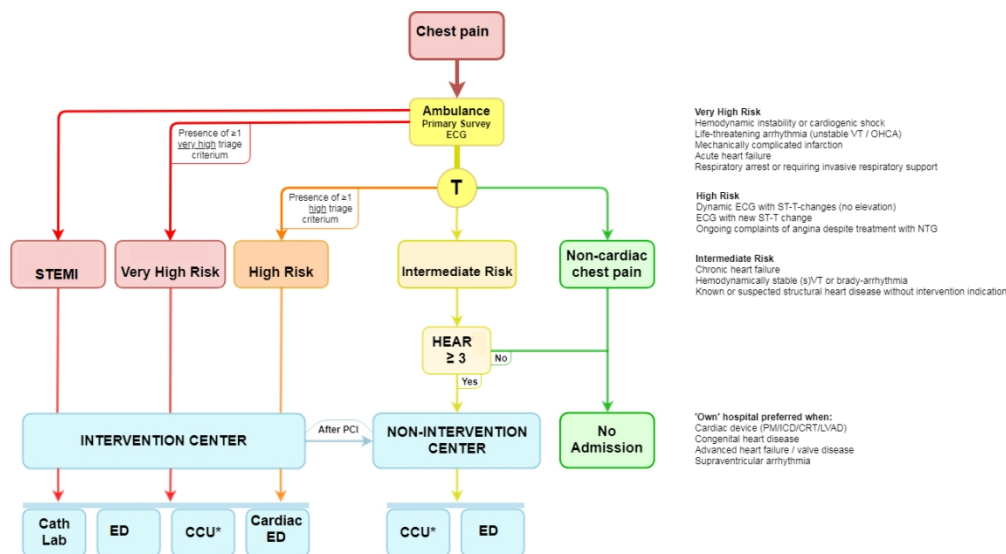
Figure 2. Mobile phone triage application

200x151mm (96 x 96 DPI)

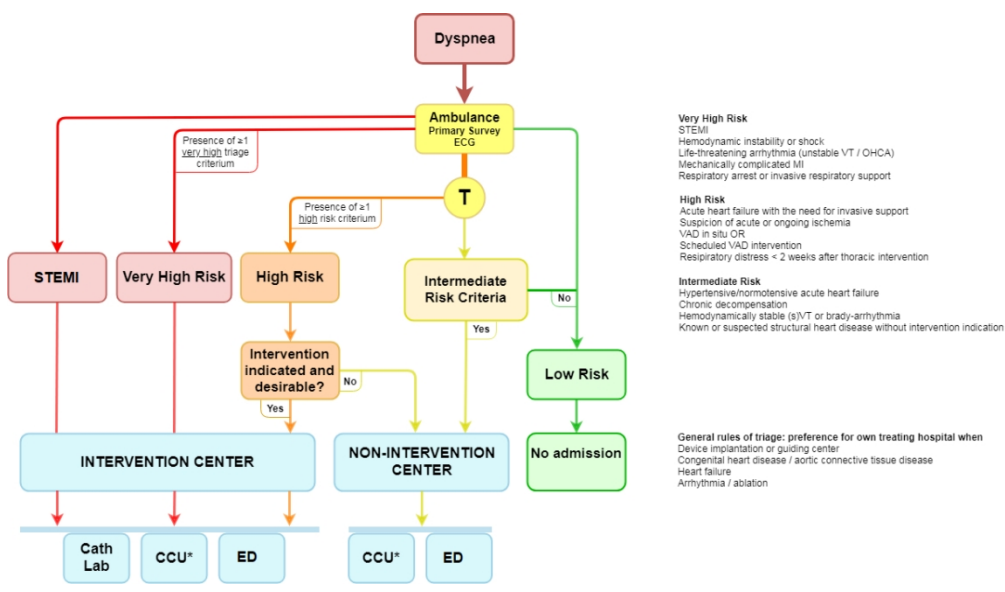
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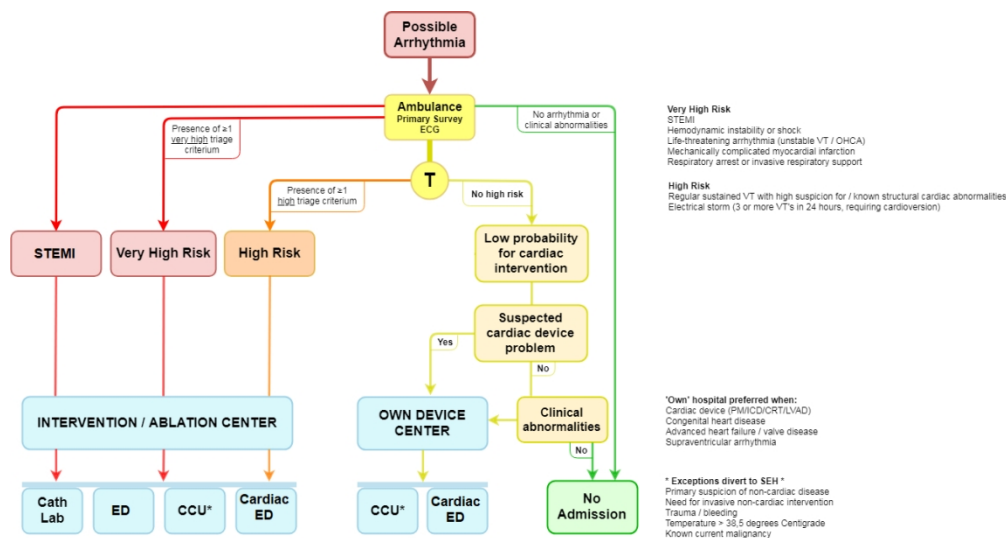


Figure 3. Image of Tempus Pro Monitor



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Pre-hospital Triage of Acute Cardiac Patients: Study Protocol of HART-c, a multicenter prospective study

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3 **Pre-hospital Triage of Acute Cardiac Patients: Study Protocol of HART-c, a**
4
5 **multicenter prospective study**
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7

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ABSTRACT

Introduction: Emergency department (ED) overcrowding is a major health care problem associated with worse patient outcomes and increased costs. Attempts to reduce ED overcrowding of cardiac patients have so far focused on in-hospital triage and rapid risk stratification of chest pain patients at the ED. The HART-c study aims to assess the amount of patients left at home in usual ambulance care as compared to the new pre-hospital triage method. This method combines paramedic assessment and expert cardiologist consultation using live-monitoring, hospital data and real-time admission capacity.

Methods and Analysis: Patients visited by the emergency medical services (EMS) for cardiac complaints are included. EMS consultation consists of medical history, physical examination and vital signs and ECG measurements. All data is transferred to a newly developed platform for the triage cardiologist. Pre-hospital data, in-hospital medical records and real-time admission capacity are evaluated. Then a shared decision is made whether admission is necessary and, if so, which hospital is most appropriate. To evaluate safety, all patients left at home and their GP's, are contacted for 30-day adverse events.

Ethics and dissemination: The study is approved by the LUMC's Medical Ethics Committee. Patients are asked for consent for contacting their GP's. The main results of this trial will be disseminated in one paper.

Discussion: The HART-c study evaluates the efficacy and feasibility of a pre-hospital triage method that combines pre-hospital patient assessment and direct consultation of a cardiologist who has access to live-monitored data, hospital data and real-time hospital admission capacity. We expect this triage method to substantially reduce unnecessary ED visits.

STRENGTHS AND LIMITATIONS

- A novel pre-hospital triage method is presented which aims to safely decrease unnecessary ED admissions, using telemedicine for pre-hospital decision making
- All participants, including patient representatives, were involved in the design of the study
- This study is a real-life reflection of interdisciplinary daily clinical practice, the retrospective cohort will reflect the control group in the best way possible
- The HART-c Study is a non-randomised controlled trial and therefore has risk of bias as decisions from paramedics and cardiologist can be influenced by the study.

1 INTRODUCTION

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Emergency Department (ED) overcrowding is a worldwide health care problem associated with worse patient outcomes and increased costs^{1,2}. Cardiac complaints are one of the most common reasons for patients to visit the ED, with chest pain as the most frequent complaint.³ In Europe and the United States, 15-20 million patients with chest pain are seen at the ED every year.⁴ The majority will be sent home after ruling out acute cardiovascular disease: previous studies have shown that up to 80% of chest pain patients do not have an acute coronary syndrome.⁵⁻⁸ However, these patients contribute to overcrowding of EDs and these ED visits substantially increase healthcare costs.

Attempts to reduce ED overcrowding by cardiac patients have so far particularly focused on rapid risk stratification after presentation at the ED. For example, the HEART score stratifies patients as at low, intermediate or high risk of major adverse cardiac events (MACE) based on history, the electrocardiogram (ECG), age, risk factors and troponin levels.⁹ However, as it takes 1-2 hours for the latter to be available, patients still spend a long time at the ED after which the majority can be discharged home.

Accordingly, interest has shifted from in-hospital to pre-hospital triage. Preventing patients with cardiac complaints and a very low risk of adverse cardiac events from visiting the ED will substantially help to reduce ED overcrowding. Efforts to prevent ED visits especially involve interventions focused on chest pain patients such as risk score calculation by the ambulance paramedics (for example with the HEART score¹⁰ and HE-MACS¹¹) or pre-hospital point of care testing for troponin.¹² In order to improve pre-hospital triage for cardiac patients in the entire chain of acute cardiac care, we developed a comprehensive triage method entitled HART-c (“Hollands-midden Acute Regional Triage - Cardiology”).

Innovative in this approach is the combination of pre-hospital patient assessment by the ambulance paramedic and expert consultation of a cardiologist who has access to live-

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3 26 monitored data from the ambulance, in-hospital data and real-time hospital admission capacity
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5 27 in a newly developed triage application. By drafting this triage method, we specifically aimed
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7 28 to safely reduce unnecessary ED visits of patients with all types of cardiac complaints. In
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9 29 addition, we intent to provide patient-tailored care through pre-hospital assessment of patient
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11 30 specific needs and circumstances. The HART-c study was designed to evaluate whether the
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13 31 implementation of the HART-c triage method results in a reduction of unnecessary ED visits.
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19 32 **METHODS AND ANALYSIS**

20 33 **Study design and patient population**

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22 34 The HART-c study is a multi-center prospective study with a historical control group. The
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24 35 intervention group comprises of adult patients visited by the regional emergency medical
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26 36 services (EMS) because of cardiac complaints between 1 September 2019 and 31 August 2020
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28 37 in whom pre-hospital triage is performed according to the HART-c triage method. The
29
30 38 historical control group consists of adult patients visited by the regional EMS because of
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32 39 cardiac complaints between 1 September 2018 and 31 August 2019 (1 year before the start of
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34 40 the HART-c triage method). Of note, in both groups EMS consultation could have been
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36 41 requested directly by the patient, through bystanders or by the patients' general practitioner
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38 42 (GP) who refers patients through EMS. Patients in need for urgent cardiac care, patients with
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40 43 complaints not suspected of cardiac origin as assessed by the ambulance paramedic, and
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42 44 patients unable or not willing to provide informed consent were excluded from triage according
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44 45 to the HART-c method. Table 1 displays the detailed inclusion and exclusion criteria.
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Table 1. Inclusion and exclusion criteria**Inclusion criteria****Patients visited by EMS for cardiac complaints****Age over 18 years****Exclusion criteria****Patients in need for urgent cardiac care because of**

- **ST-elevation myocardial infarction**
- **Hemodynamic instability**
- **(Out of hospital) cardiac arrest**
- **Suspected pulmonary embolism**
- **Suspected acute aortic syndrome (thoracic or abdominal)**

Patients with symptoms not suspected of cardiac origin**Unable or unwilling to provide informed consent**

The HART-c study is coordinated by the Leiden University Medical Centre (LUMC) and conducted in the entire EMS region “Hollands-midden” which consists of over 600.000 inhabitants. The hospitals located in this region participate: the Leiden University Medical Centre, the Groene Hart hospital and the Alrijne hospital. The study is performed in close collaboration with the regional EMS (RAVHM) that employs 240 paramedics who are trained in pre-hospital cardiac care and 31 ambulance vehicles equipped with real-time monitoring. In addition, the study was performed and developed with the help of over regional 300 GPs.

Intervention group: Pre-hospital Triage using HART-c method

The intervention group consists of patients visited by the EMS because of symptoms suspected to be of cardiac origin such as chest pain, shortness of breath, palpitations or implanted cardiac device problems. In line with the National Protocol for Emergency Medical Care, patients at

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3 57 first receive standard medical care consisting of a medical history, physical examination with
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5 58 vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG.¹³ In
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8 59 patients with chest pain, the pre-hospital modified HEART score (the HEART¹⁴ score without
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10 60 troponin) is calculated. All acquired data are noted on a handheld device and stored on
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12 61 AmbuSuite, an external secure database. Afterwards, the ambulance paramedic directly
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14 62 contacts the on-call triage cardiologist. The right panel in Figure 1 illustrates the entire routing
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16 63 of patients in the intervention group. In total, 43 cardiologist from all three regional hospitals
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18 64 are scheduled so one cardiologist is on duty for the entire region. GPs can refer patients through
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20 65 EMS consultation, however in the intervention period cardiologist consultation is possible.
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22 66 When a GP is in doubt of referral, they can request cardiologist consultation through EMS with
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24 67 the HART-c method. The triage cardiologist evaluates the pre-hospital data, including, medical
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26 68 history, real-time vital parameters and 12-lead ECG and combines them with (if present)
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28 69 previous medical records and the actual hospital admission capacity of the regional hospitals.
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31 70 Also, we developed decision aids for chest pain, dyspnoea and arrhythmia as guidance for
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33 71 triage cardiologists. These decisions aids can help the triage cardiologist in decision making
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35 72 and are added, as addendum 1 for chest pain, addendum 2 for dyspnoea and addendum 3 for
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37 73 arrhythmia, to this manuscript. Based on these comprehensive data, the triage cardiologist and
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39 74 ambulance paramedic decide, as a shared decision with the patient, whether transfer to an ED
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41 75 is necessary and, if so, which hospital and which department is most suitable. The triage
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43 76 decision is sent immediately to the concerning ED nursing staff and the capacity of this hospital
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45 77 is updated automatically (Figure 2). Upon arrival at the ED, cardiac assessment is based on in-
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47 78 house clinical decision rules as guidelines prescribe, 12-lead ECG and laboratory findings.⁹
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56 *Figure 1. Method of triage. (A) Patient routing without pre-hospital selection where patients*
57 *are referred to the nearest ED or left at home. If hospital admission capacity is insufficient,*
58 *patients are transferred to another hospital. (B) Patient routing with pre-hospital selection*
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3 using pre- and in-hospital data where a cardiologist has insight in live vital parameters and
4 regional hospital capacity.
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7 *Figure 2. Mobile phone triage application: Left panel showing overview of a hospital specific*
8 *capacity. Right panel showing the ability to update capacity.*
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14 **79 Intervention group: Tempus Pro Monitor, IntelliSpace Corsium, triage platform and**
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16 **80 data handling**

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18 81 All ambulances are equipped with a Tempus Pro Monitor¹⁵ (Philips, The Netherlands) that
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20 82 allows recording of a 12-lead ECG and real-time monitoring of the following vital patient
21
22 83 parameters: heart rate, blood pressure and pulse oximetry. The monitor can show trends in
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24 84 measurements and stream data for up to 10 hours. All data are encrypted and shared with the
25
26 85 on-call triage cardiologist through secure channels. The Tempus Pro Monitor is shown in
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28 86 Figure 3.
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35 *Figure 3. Image of Tempus Pro Monitor.*
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39 87 Using a secure log-in, the on-call triage cardiologist logs in to IntelliSpace Corsium (Philips,
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41 88 the Netherlands) and connects digitally with a patient specific Tempus Pro Monitor. All
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43 89 aforementioned measurements are streamed live. Once the live streaming ends, no patient
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45 90 specific data are stored on the platform. This system of data-transfer is FDA approved.^{16,17}
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48 91 A novel triage platform was developed showing real-time admission capacity of the regional
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50 92 hospitals. The nursing staff in these hospitals continuously updates their admission capacity.
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52 93 Linking these capacity data to a local electronic patient dossier (EPD-Vision; Leiden, The
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54 94 Netherlands), the on-call triage cardiologist has insight into the actual bed occupancy of each
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56 95 hospital. After consultation, the on-call triage cardiologist notes his decision and a message is
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3 96 automatically sent to the nursing staff of the chosen hospital, thereby updating their admission
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5 97 capacity immediately.

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8 98 Patient data are sent securely from Tempus Monitor to IntelliSpace Corsium. No data are stored
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10 99 on IntelliSpace Corsium. No patient data are transmitted to the mobile phone application.
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12 100 Patient data are transferred from AmbuSuite to our EPD. All patient data and decisions are
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14 101 stored on the EPD of the coordinating hospital and are only accessible for triage cardiologists.

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17 102 **Historical control group: Standard care in pre-hospital setting**

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19 103 The historical control group consists of patients visited by the EMS because of potential
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21 104 cardiac complaints in the year before the onset of the HART-c triage method. Upon arrival by
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23 105 the paramedic, standard medical care consists of medical history, physical examination with
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25 106 vital sign monitoring (blood pressure, heart rate, pulse oximetry) and a 12-lead ECG. All
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27 107 acquired data are noted on a handheld device and stored on AmbuSuite (Topicus, the
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29 108 Netherlands) which is an external secure database. Thereafter, the ambulance paramedic
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31 109 decides, based on predefined national protocols and decision rules for diagnosis, whether
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33 110 transfer to an ED is deemed necessary.¹² Paramedics are able to identify low-risk patient for
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35 111 all medical specialties, and decide whether admission or ED presentation is necessary on
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37 112 every consultation. So, even in the historical cohort group only patients with cardiac
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39 113 complaints deemed severe enough for presentation are presented to the ED. Of note, at the
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41 114 time of referral, the paramedic has no insight in the previous medical records and the actual
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43 115 hospital admission capacity. The Netherlands has a unique system, where, in the historical
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45 116 cohort in our region, approximately 5% of patients with cardiac complaints aren't referred to
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47 117 a hospital after paramedic assessment, instead these patients are directly referred to their GP
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49 118 or treated at home. However, given the number of unnecessary ED visits, there is still a large
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51 119 cohort of low-risk patients in whom ED presentation could be prevented. After paramedic
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53 120 assessment and hospital transport, cardiac assessment on the ED is based on in-house clinical
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3 121 decision rules as guidelines prescribe, 12-lead ECG and laboratory findings.⁹ If evaluation at
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5 122 the ED indicates that hospitalization is mandatory, the patient is admitted in the concerning
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7 123 hospital. However, when admission capacity is insufficient or immediate intervention is not
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10 124 available in the concerning hospital, ambulance transfer to another hospital is mandatory. The
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12 125 routing of patients in the historical control group is illustrated in the left panel of Figure 1.

14 15 126 **Objective and outcome measures**

16
17 127 The HART-c study is designed to evaluate the efficacy and feasibility of a novel
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19 128 comprehensive pre-hospital triage method which aims to safely reduce unnecessary ED visits
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21 129 in patients with cardiac complaints. The primary outcome is the percentage of patients in who
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23 130 an ED visit can be prevented after EMS consultation. The following secondary end-points will
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26 131 be evaluated:

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28 132 - Number of ambulance transfers to an ED because of cardiac complaints.
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30 133 - Number of inter-hospital transfers in cardiac patients.
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32 134 - Patient, triage cardiologist and GP satisfaction with the HART-c triage method on a 0-
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34 135 10 scale.
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36 136 - Time from EMS consultation to arrival at the hospital in the both study groups.
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38 137 - Safety of the HART-c prehospital triage method. This will be evaluated in intervention
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40 138 group patients who are not transferred to an ED after cardiologist consultation. Safety
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42 139 will be assessed by the occurrence of adverse events up to 30 days follow-up. Table 2
43
44 140 displays the pre-specified major and non-major adverse events. To evaluate safety, a
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46 141 dedicated researcher will contact these patients and their GP and evaluate on a case-by-
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48 142 case basis. If a major adverse event is deemed directly attributable to the triage method,
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50 143 the protocol will be adjusted or the study will be terminated prematurely. The study
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52 144 will be deemed safe if the percentage of major adverse events is 1% or lower.
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3 145 - Feasibility of the HART-c prehospital triage method. This will be evaluated in the
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5 146 intervention group and defined as the absence of technical problems for the ambulance
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7 147 paramedic and the triage cardiologist. This means access to the live-monitored data
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9 148 from the ambulance, hospital data and real-time hospital admission capacity are all
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11 149 available. In order to swiftly manage potential technical problems, the HART-c triage
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13 150 method will start during working hours. If interim analysis reveals that the method is
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15 151 feasible, the time frame in which HART-c triage is available could be extended.
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22 **Table 2. Adverse events (30 days after EMS contact)**

<u>Major adverse events</u>
Death
Acute coronary syndrome
<u>Other adverse events</u>
Renewed EMS or ED visit for cardiac complaint
Pulmonary embolism
ED visit or hospitalization for acute decompensated heart failure
Ventricular tachycardia or – fibrillation
Cerebrovascular accident (CVA) or transient ischemic attack (TIA)

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47 **152 Statistical analysis**

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49 153 The prevention of an ED visit after EMS consultation will be analysed using a logistic
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51 154 regression analysis. Ambulance transfers and inter hospital transfers in the intervention versus
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53 155 the control group will also be evaluated using logistic regression. Baseline characteristics will
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55 156 be reported as mean and standard deviation or median and interquartile range and compared
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57 157 between historical cohort and intervention. This study will be underpowered to detect
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3 158 differences in mortality and major adverse cardiac events (MACE). Accordingly, these events
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5 159 will only be reported and no further statistics on mortality and MACE will be done. The data
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7
8 160 will be analysed using IBM SPSS Statistics version 25. A p-value lower than 0.05 will be
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10 161 considered statistically significant.

12 162 **Patient and public involvement**

14 163 Patients were involved in the design of the study. During the design stage, representatives from
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16
17 164 the 'Harteraad', a cardiovascular patient council, were asked for input in study design, choice
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19 165 of outcome measures and methods of recruitment. Also, a dedicated website, www.hartc.nl,
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21 166 was created to inform the public and answer questions from professionals and patients, before
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23
24 167 and during the study.

28 168 **ETHICS AND DISSEMINATION**

30 169 The study is approved by the LUMC's Medical Ethics Committee (P18.213). Patients are
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32
33 170 requested to provide oral informed consent for contacting their GP at 30 days follow-up. Oral
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35 171 informed consent is requested for cardiologist consultation and study participation by
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38 172 paramedics which is then noted in AmbuSuite. The need for written informed consent was
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40 173 waived by the Medical Ethics Committee. The devices used in this study are FDA and/or CE
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42 174 approved. No manufacturer has a role in study design, data collection, statistical analysis or
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44 175 writing of the manuscript. No financial support is received for this study from any
45
46
47 176 manufacturer. The main results of this trial will be disseminated in one paper.

53 177 **DISCUSSION**

55 178 Overcrowding of ED's is a major challenge in healthcare. The HART-c study is a multi-centre
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58 179 prospective study that primarily aims to safely reduce unnecessary ED visits of patients with
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3 180 all types of cardiac complaints. By selecting the hospital best suited for every patient, this
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5 181 method will contribute to more patient-tailored health care and lead to improved utilization of
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8 182 all available healthcare resources in the region.

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10 183 Recently, interest has shifted from in-hospital - to pre-hospital triage. Pre-hospital cardiologist
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12 184 consultation has been standard procedure for some time in many hospitals in the Netherlands
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14 185 for quick catheterization lab activation when paramedics suspect chest pain patients of
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16 186 STEMI.¹⁸ For all other cardiac complaints no pre-hospital triage procedure is in place for
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18 187 emergency evaluations. However, there have been some studies assessing the possibility of
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20 188 pre-hospital triage and pre-hospital selection of low-risk cardiac patients.

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22 189 The History and ECG-only Manchester ACS (HE-MACS) decision aid was developed for pre-
23
24 190 hospital triage using history, physical examination and ECG. It was derived in 796 patients and
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26 191 validated in cohorts of 474 and 659 patients. 9.4% of all validated patients were identified as
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28 192 'very low risk' in which ACS could be 'ruled out' with a sensitivity of 99.5%. It's impact,
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30 193 however, was not prospectively evaluated in this study.

31
32 194 The FAMOUS investigators aim to assess the effects of introducing a pre-hospital triage system
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34 195 that stratifies chest pain patients without ST segment elevation into 1) patients at high risk for
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36 196 NSTEMI requiring direct transfer to a PCI hospital, 2) patients at intermediate risk for major
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38 197 adverse cardiac events who could be evaluated at the nearest non-PCI hospital and 3) patients
39
40 198 at low risk for major adverse cardiac events who could have further evaluation at home or in a
41
42 199 primary care setting.¹⁹ The study was divided in three phases. In the first phase, a venous blood
43
44 200 sample was drawn in the ambulance for measurement of the pre-hospital troponin T levels, in
45
46 201 order to establish a pre-hospital HEART score and evaluate the possibility of triage at the
47
48 202 patient's home. Of the 1127 chest pain patients, 36% had a low modified HEART score and
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50 203 none of them developed a major adverse event.²⁰ After this first phase proving feasibility,
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52 204 further studies have been done in the pre-hospital setting by the FAMOUS TRIAGE study
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3 205 group. Phase 2, a prospective observational study including 700 patients with suspected NSTE-
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5 206 ACS, showed nicely that pre-hospital risk stratification by ambulance paramedics using the
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7 207 HEART score was accurate in differentiating in low and intermediate to high risk.²¹ Recently
8
9
10 208 the design of phase 3 has been published, where the FAMOUS study investigators aim to
11
12 209 determine if use of the HEART score, including point-of-care Troponin measurement, is non-
13
14 210 inferior to routine management. In this phase referral decisions are based on pre-hospital
15
16 211 acquired risk stratification.²²
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18
19 212 Another study investigating the added value of point-of-care troponin in the pre-hospital setting
20
21 213 is the ARTICA¹² trial. This randomized trial will include patients suspected of non-ST
22
23 214 elevation acute coronary syndrome in whom the modified HEAR score (the HEART score
24
25 215 without troponin) is calculated by the ambulance paramedic. If the HEAR score is less than or
26
27 216 equal to 3, patients will be 1:1 randomized for 1) presentation at the ED or 2) point-of-care
28
29 217 troponin T measurement and transfer of care to the GP in case of a low troponin T value. The
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31 218 primary objective of the ARTICA trial will be healthcare costs at 30 days. The trial is currently
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33 219 ongoing and aims to include 866 patients in 12 months.
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37 220 The similarity of the currently described HART-c study and the HE-MACS, FAMOUS and
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39 221 ARTICA studies is that all three assess whether patients with chest pain who are at low risk of
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41 222 major adverse events can be identified before presenting to the ED. However, the HART-c
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43 223 study has some added benefit as opposed to earlier known studies. First, the HART-c study
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45 224 does not only identify patients at low-risk for events, but also aims to effectively prevent low-
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47 225 risk patients from actually visiting the ED, as well as further phases from FAMOUS and
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49 226 ARTICA did, by combining pre-hospital risk stratification by the paramedic and real-time
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51 227 cardiologist consultation with insight in live vital parameters and ECG. Secondly, while these
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53 228 studies study only focus on chest pain patients, the HART-c study extends this to all patients
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55 229 with cardiac complaints and could therefore be of benefit for a substantially larger cohort of
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3 230 patients. Furthermore, the HART-c triage method is unique as it combines pre-hospital patient
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5 231 assessment by the ambulance paramedic and direct consultation of an expert triage cardiologist
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8 232 who has access to live-monitored data from the ambulance for all cardiac patients, as opposed
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10 233 to only STEMI patients. Besides these novelties, the HART-c study incorporates hospital data
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12 234 as well as real-time hospital admission capacity to decide which regional hospital is best suited
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15 235 for every patient. In the future, it would be helpful to have pre-hospital information integrated
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17 236 in all hospitals electronic patient dossier. At this moment, however, that is not the case.
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19 237 If the results of current study show that the HART-c triage method is effective in safely
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21 238 reducing unnecessary ED visits of patients with all types of cardiac complaints, the next step
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24 239 will be to evaluate cost-effectiveness. When cost-effectiveness can be demonstrated, we feel
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26 240 that the HART-c triage method can be expanded to other EMS regions. Furthermore, last but
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28 241 not least, it may potentially also be useful for other medical specialists aiming to optimize pre-
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30 242 hospital triage of non-cardiac patients. Eventual improvements in pre-hospital triage, such as
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32 243 pre-hospital high sensitive Troponin sampling with a point-of-care test or newly developed and
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34 244 proven risk scores, could always be implemented in this triage protocol.
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37 245 To conclude, the HART-c study is a multi-center prospective study evaluating the efficacy, and
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39 246 feasibility of a novel comprehensive pre-hospital triage method that combines pre-hospital
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41 247 patient assessment by the ambulance paramedic and direct consultation of a cardiologist who
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43 248 has access to live-monitored data from the ambulance, hospital data as well as real-time
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45 249 hospital admission capacity. If the HART-c study will succeed to safely reduce unnecessary
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47 250 ED visits of patients with all types of cardiac complaints, it may help to decrease ED
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49 251 overcrowding and ultimately reduce healthcare expenditures.
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Author statement

EdK, TEB, JB, CJHJK, RAD, HAMS, MS and MJB made a substantial contribution to the concept and design of the work. EdK and MJB are in charge of acquisition of data, analysis and interpretation of the data. EdK, TEB, SB and MJB contributed to the drafting of the article. EdK, SB, JB, BEB, CJHJK, RAD, MS and MJB all revised the manuscript critically for important intellectual content.

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Competing interest

EdK, TEB, SB, JB, CJHJK, RAD, HAMS, MS and MJB report no conflict of interest. BEB is the creator of the HEART score.

References

1. American College of Emergency Physicians Policy statements: crowding. *Annals of Emergency Medicine*. 2006;47:585.
2. A Boyle, K Beniuk, I Higginson, P Atkinson. Emergency department crowding: time *for* interventions and policy evaluations. *Emergency Medicine International*. 2012;2012:838610.
3. FA Bhuiya, SR Pitts, LF McCaig. Emergency department visits for chest pain and abdominal pain: United States, 1999-2008. *NCHS Data Brief* 2010(43):1-8.
4. EW Nawa, RW Nisk, J Xu. National Hospital Ambulatory Medical Care Survey: 2005 emergency department summary. *Advance Data* 2007; 386: 1–32.
5. S Goodacre, P Thokala, C Carroll, JW Stevens, J Leaviss, J Wang et al. Systematic review, meta-analysis and economic modelling of diagnostic strategies for suspected acute coronary syndrome. *Health Technology Assessment* 2013;17(1):v-vi, 1-188.
6. M Gorenberg M, A Marmor, H Rotstein. Detection of chest pain of non-cardiac origin at the emergency room by a new non-invasive device avoiding unnecessary admission to hospital. *Emergency Medicine Journal: EMJ* 2005;22(7):486-9.
7. DC Knockaert, F Buntinx, N Stoens, R Bruyninckx, H Delooz. Chest pain in the emergency department: the broad spectrum of causes. *European Journal of Emergency Medicine*. 2002;9(1):25-30.
8. KA Mol, BM Rahel, JG Meeder, BC van Casteren, PA Doevendans, MJ Cramer. Delays in the treatment of patients with acute coronary syndrome: Focus on pre-hospital delays and non-ST-elevated myocardial infarction. *International Journal of Cardiology*. 2016 Oct 15;221:1061-6.

- 1
2
3 9. BE Backus, AJ Six, JC Kelder, TP Mast, F van den Akker, PA Doevendans. Chest
4
5 pain in the emergency room: a multicenter validation of the HEART score. *Critical*
6
7 *Pathways in Cardiology*. 2010 Sep;9(3):164-9
8
9
- 10 10. JP Stopyra, WS Harper, TJ Higgins, JV Prokesova, JE Winslow, SA Mahler et al.
11
12 *Prehospital Modified HEART Score Predictive of 30-Day Adverse Cardiac Events.*
13
14 *Prehospital and Disaster Medicine*. 2018;33(1):58–62.
15
16
- 17 11. Alghamdi A, Howard L, Reynard C, et al. Enhanced triage for patients with suspected
18
19 cardiac chest pain: the History and Electrocardiogram-only Manchester Acute
20
21 *Coronary Syndromes decision aid.* *Eur J Emerg Med*. 2019;26(5):356-361.
22
23
- 24 12. GWA Aarts, C Camaro, RJ van Geuns, E Cramer, RRJ van Kimmenade, N van
25
26 Royen et al. Acute rule- out of non–ST- segment elevation acute coronary syndrome
27
28 in the (pre)hospital setting by HEART score assessment and a single point- of- care
29
30 troponin: rationale and design of the ARTICA randomised trial. *BMJ Open*
31
32 2020;10:e034403. doi:10.1136/ bmjopen-2019-034403
33
34
- 35 13. Ambulancezorg Nederland. *Landelijk Protocol Ambulancezorg 8.1*. Publication date:
36
37 06-2016. [https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-](https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg)
38
39 [richtlijnen/landelijk-protocol-ambulancezorg](https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg)
40
41
- 42 14. BE Backus, AJ Six, JC Kelder, MA Bosschaert, EG Mast, PA Doevendans. A
43
44 prospective validation of the HEART score for chest pain patients at the emergency
45
46 department. *International Journal of Cardiology*. 2013 Oct 3;168(3):2153-8
47
48
- 49 15. Tempus Pro Monitor (Philips). <https://www.rdtltd.com/>
50
51
- 52 16. IntelliSpace Corsium (Philips)
53
54 [https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
55
56 [advanced-visual-analysis](https://www.philips.co.uk/healthcare/product/HC881072/intellispace-portal-90-advanced-visual-analysis)
57
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2
3 17. FDA approval IntelliSpace Corsium (Philips). FDA Primary Device ID:
4 05060472441331 <https://fda.report/GUDID/05060472441331>
5
6
7
8 18. Liem SS, van der Hoeven BL, Oemrawsingh PV, et al. MISSION!: optimization of
9 acute and chronic care for patients with acute myocardial infarction. *Am Heart J.*
10 2007;153(1)
11
12
13
14 19. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, B Dikkeschei, The FAMOUS TRIAGE
15 Study Group et al. Fast assessment and management of chest pain without ST-
16 elevation in the pre-hospital gateway: Rationale and design. *European Journal of*
17 *Acute Cardiovascular Care.* 2015, Vol. 4(2) 129 –136
18
19
20
21
22
23
24 20. M Ishak, D Ali, MJ Fokkert, RJ Slingerland, RT Tolsma, AW van 't Hof et al. Fast
25 assessment and management of chest pain patients without ST-elevation in the pre-
26 hospital gateway (Famous Triage): ruling out a myocardial infarction at home with
27 the modified HEART score. *European Heart Journal: Acute Cardiovascular Care.*
28 2018, Vol. 7(2) 102-110.
29
30
31
32
33
34
35 21. van Dongen DN, Tolsma RT, Fokkert MJ, et al. Pre-hospital risk assessment in
36 suspected non-ST-elevation acute coronary syndrome: A prospective observational
37 study. *Eur Heart J Acute Cardiovasc Care.* 2020;9(1_suppl):5-12.
38
39
40
41
42 22. Van Dongen DN, Tolsma RT, Fokkert MJ et al. Referral decisions based on a
43 prehospital HEART score in suspected non-ST elevation acute coronary syndrome:
44 design of the Famous Triage 3 study. *Future Cardiol.* (2020) 16(4), 217-226.
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50 *Addendum 1. Decision aid for chest pain. The T stands for Triage cardiologist consultation.*

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52 *Addendum 2. Decision aid for dyspnoea. The T stands for Triage cardiologist consultation.*

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55 *Addendum 3. Decision aid for arrhythmia. The T stands for Triage cardiologist consultation.*
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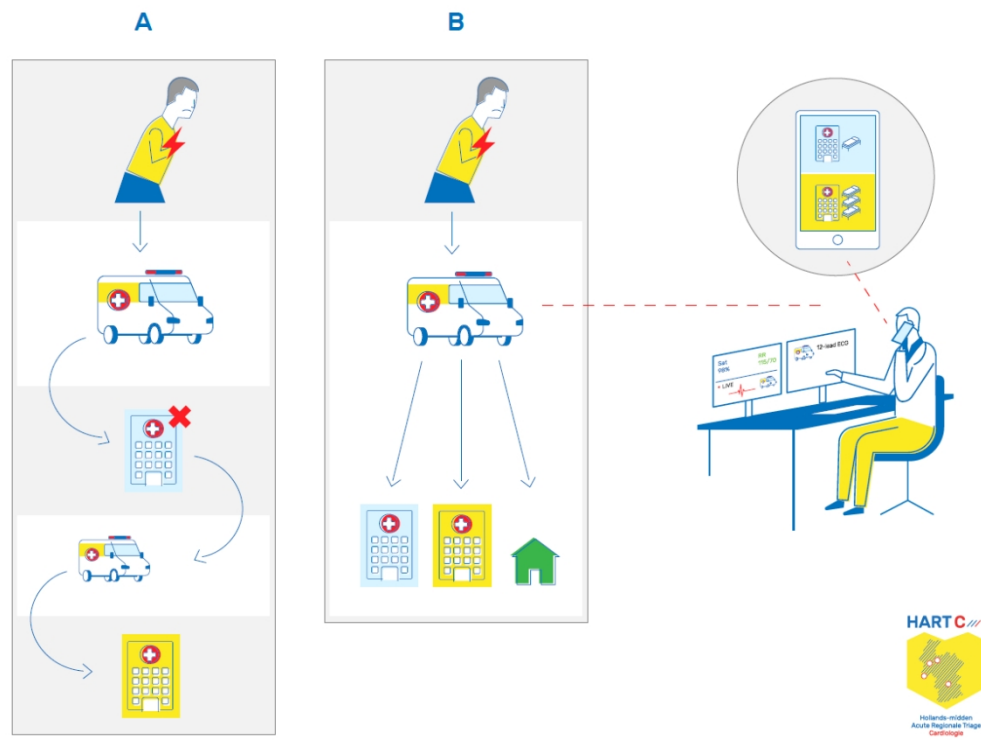


Figure 1. Method of triage

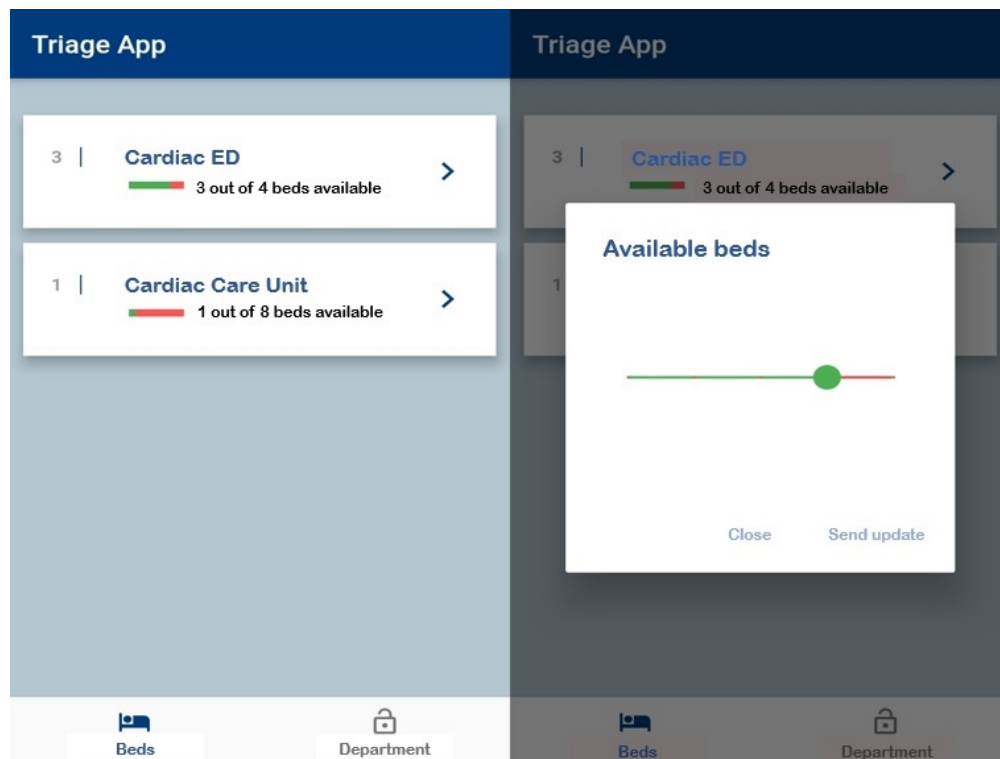


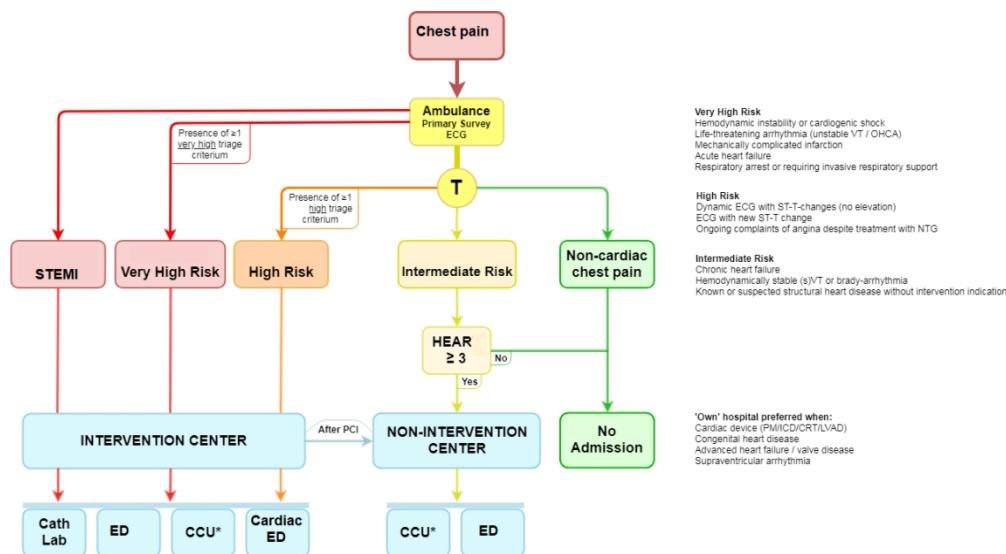
Figure 2. Mobile phone triage application

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Figure 3. Image of Tempus Pro Monitor



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