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Comparison of pre-hospital and in-hospital HEART scores in patients with possible myocardial infarction

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Manuscripts

Comparison of pre-hospital and in-hospital HEART scores

1 RESEARCH LETTER

2 **Comparison of pre-hospital and in-hospital HEART scores**
3 **in patients with possible myocardial infarction**

4

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41

42 PRESENTATION

43 The results held within this article have not yet been presented.

44

45 FUNDING AND DECLARATIONS

46 The study was funded by the Digital Health & Care Institute (DHI) (Reference

Comparison of pre-hospital and in-hospital HEART scores

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 48 N0042903). Samsung provided the devices and test discs and the University of Aberdeen
 49 contributed to the design and administration of the study. The funders had no role in study
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55 COMPETING INTEREST STATEMENT

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 59 Psyros Diagnostics. All other authors have no interests to declare.

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68 CONTRIBUTORSHIP STATEMENT

69 JGC, JF, KJL and EMD conceived the study and its design. JGC, JF, LAD, KMMB, KJL and
 70 JLH developed and delivered the paramedic training. JGC, LAD, AJC, KMMB, JLH, EMD,
 71 TF, KKL, AA and ASVS acquired the data. JGC, NWS and AJL performed the analysis.
 72 JGC, JF, NWS, AJL and NLM interpreted the data. JGC and NLM drafted the manuscript.
 73 All authors reviewed the manuscript critically for intellectually important content and
 74 provided their final approval of the version to be submitted. All authors are accountable for
 75 the work.

76 ETHICAL STATEMENT

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82 No additional data available

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 92 **Figures/Tables** 1
 93 **References** 10

Comparison of pre-hospital and in-hospital HEART scores

94 Chest pain suspicious for myocardial infarction is a common reason for ambulance transfer to
95 hospital where the HEART score may be used to identify those at low-risk and potentially
96 suitable for early discharge (1).

97 The HEART score combines the history, electrocardiogram, age, risk factors and
98 cardiac troponin with each component allocated 0, 1 or 2 points and scores of ≤ 3 , 4-6 and ≥ 7
99 considered low-, intermediate-, and high-risk, respectively (1). Data pertaining to the HEAR
100 components of the score are routinely collected by paramedics in the pre-hospital setting
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104 However, prospective studies of the reliability of the HEART score between different
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109 In this prospective study we compare agreement between the HEART score and its
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112 This pre-specified analysis of the Ambulance Cardiac Chest Pain Evaluation in Scotland
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114 Consenting adult patients with chest pain suspicious for a myocardial infarction without
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Comparison of pre-hospital and in-hospital HEART scores

118 patient for testing with the Abbott ARCHITECT_{STAT} high-sensitivity troponin I assay (sex-
119 specific 99th centile: 16 ng/L in women and 34 ng/L in men).

120 Patients were followed up for a major adverse cardiac event (MACE) comprising
121 death, myocardial infarction, revascularisation, malignant arrhythmia, cardiac arrest, or
122 cardiogenic shock at 30-days. All patients with myocardial injury were adjudicated
123 independently as previously described (2). Clinical staff who performed the first assessment
124 in-hospital recorded a HEAR score were blinded to the pre-hospital score and blood test
125 result. Patients with HEAR scores from both settings were included and HEART scores were
126 calculated using the pre-hospital cardiac troponin result.

127 The primary outcome was the inter-rater agreement between the HEAR and HEART
128 scores determined pre-hospital by paramedics and in-hospital by attending clinicians. This
129 analysis was conducted across all possible values of HEAR (0-8) and HEART (0-10) scores,
130 calculated using Cohen's weighted kappa (κ_w) and repeated for the individual components of
131 the HEAR score. Discrimination of pre-hospital and in-hospital HEAR and HEART scores
132 for MACE at 30-days was expressed using the area under the receiver operator curve
133 (AUROC) with 95% confidence intervals (CI) and compared for statistical significance using
134 DeLong's test. Agreement was also compared for those classified as low- (HEART ≤ 3) and
135 high-risk (HEART ≥ 7). Statistical analysis was undertaken using IBM SPSS (version 28.0;
136 IBM Corp., Armonk, NY) and Stata (version 17.0; StataCorp LLC, College Station, TX).

137 A total of 1,053 patients (mean age 64 [SD 15] years, 42% women) had complete pre-
138 hospital and in-hospital HEAR scores. Follow-up at 30 days was complete in all patients with
139 284 (27%) experiencing a MACE and 192 (18%) a type 1 myocardial infarction
140 (*Supplemental Figure 1*).

Comparison of pre-hospital and in-hospital HEART scores

141 The average HEAR score was 4.4 (SD 1.7) and 4.7 (SD 1.8) in the pre-hospital and
142 in-hospital setting, respectively. Discrimination for MACE at 30 days was significantly lower
143 for the HEAR score determined pre-hospital compared to in-hospital (AUROC 0.70, 95% CI
144 0.67 to 0.73 *versus* 0.75, 95% CI 0.72 to 0.78, P=0.001).

145 Pre-hospital and in-hospital HEAR scores were the same in only 289 (27.4%)
146 patients. When this was broken down into the components the score was the same for the
147 history in 459 (43.6%) patients, the electrocardiogram in 630 (59.8%), age in 1,010 (95.9%),
148 and risk factors in 696 (66.1%).

149 Overall agreement between pre-hospital and in-hospital HEAR scores was moderate
150 (κ 0.44, 95% CI 0.41 to 0.47). Agreement between the components was almost perfect for
151 age (κ 0.94, 95% CI 0.92 to 0.96), moderate for risk factors (κ 0.49, 95% CI 0.44 to 0.53),
152 fair for the electrocardiogram (κ 0.30, 95% CI 0.25 to 0.36) and poor for the history (κ
153 0.20, 95% CI 0.15 to 0.24) (**Figure 1**).

154 There were 968 (92%) patients with a pre-hospital cardiac troponin result to
155 determine the pre-hospital and in-hospital HEART score. Discrimination for MACE at 30
156 days of the HEART score was better than for the HEAR score but was significantly worse
157 when determined pre-hospital compared to in-hospital (AUROC 0.78, 95% CI 0.75 to 0.81
158 *versus* 0.82, 95% CI 0.79 to 0.85, P=0.002). Pre-hospital and in-hospital HEART scores were
159 the same in only 262 patients (27%) and overall agreement was moderate (κ 0.49, 95% CI
160 0.46 to 0.53).

161 Of 281 (29%) patients identified by paramedics as low-risk (HEART \leq 3), there was
162 discordance with in-hospital clinicians in 117 (42%). Of 156 (16%) patients identified by
163 paramedics as high-risk (HEART \geq 7) there was discordance with in-hospital clinicians in 49
164 (31%).

Comparison of pre-hospital and in-hospital HEART scores

165 In a large prospective study of patients with possible myocardial infarction, we
166 observed important differences in the application of the HEAR and HEART scores performed
167 by paramedics pre-hospital and clinicians in hospital. Discrimination for MACE was
168 moderate in both settings but significantly worse when scores were determined in the pre-
169 hospital setting. Agreement between paramedics and in-hospital clinical staff was moderate
170 with just 1 in 4 patients having the same score, and particularly poor for the subjective history
171 and electrocardiogram components.

172 Previous prospective evaluations of HEART score inter-rater agreement have been
173 inconsistent in both the emergency department, (6,7) and pre-hospital setting (8,9). We
174 observed moderate agreement overall between pre-hospital and in-hospital HEAR (κ 0.44)
175 and HEART (κ 0.49) scores, lower than previous studies in the emergency department
176 (6,7), but similar to prior comparisons of agreement between the pre-hospital and in-hospital
177 setting (8,9).

178 That agreement should be worse on the more interpretable history and
179 electrocardiogram components of the HEART score, than age, risk factors or cardiac
180 troponin, is intuitive, and has been demonstrated before, though with substantial variation
181 across studies (6-9). Previous observational studies have provided pre-hospital practitioners
182 with a pre-recorded video and website access to aid HEART score calculation (9) or the
183 option to contact a cardiologist for electrocardiograph opinion (8), though without discernible
184 improvement in agreement within in-hospital assessment compared to our study (which relied
185 on trained paramedic interpretation alone), which was poor and fair for history and
186 electrocardiogram components, respectively. We observed only moderate agreement between
187 pre-hospital and in-hospital evaluation of the risk factor component, consistent with prior
188 studies (8,9).

Comparison of pre-hospital and in-hospital HEART scores

189 Some aspects of our study design may have influenced the finding that in-hospital
190 scores were more discriminatory for MACE than those calculated in the pre-hospital setting.
191 In-hospital evaluation took place about two hours after paramedic assessment, allowing time
192 for the history, response to treatment, and electrocardiographic features to evolve.
193 Furthermore, in-hospital clinicians have access to ambulance data and also the full patient
194 record including previous electrocardiograms. We did not account for the experience of the
195 clinician completing the in-hospital HEAR score, but all would have had direct access to
196 senior clinicians, potentially influencing scores. There was even disagreement in 1 in 20
197 patients for the age component of the score, confirming that correct entry of fixed values in
198 the calculation of HEART score cannot be assumed (6,9).

199 In addition, we acknowledge that incorporation of a laboratory based high-sensitivity
200 cardiac troponin test into a pre-hospital risk assessment is theoretical and that the relatively
201 high incidence of MACE may indicate selection bias explained by recruitment at the
202 discretion of the attending paramedic.

203 The main priority of pre-hospital research is to identify low-risk patients who can be
204 managed without direct transfer to hospital with comparable safety to the emergency
205 department (10). Recent work from the Netherlands demonstrates paramedics can identify
206 some patients with a pre-hospital HEART score ≤ 3 who do not require hospital transfer, but
207 even with augmented safety netting, 1 in 4 were still transferred (4). Further, management of
208 patients determined by paramedics as 'low-risk' with a HEAR score ≤ 3 and a point-of-care
209 troponin below a threshold nearly 3 x the 99th centile without hospital conveyance may be
210 cost-effective in the Dutch healthcare system, though clinical safety remains unproven (5).

211 The drive to transfer diagnostic assessment to ambulance services will continue, but
212 methods that work in hospital may not be directly applicable or appropriate for use in the pre-

Comparison of pre-hospital and in-hospital HEART scores

213 hospital setting. Regarding patients with suspected myocardial infarction, those overseeing
214 the training and education of paramedics should focus on evaluation of the paramedic
215 perspective of pre-hospital decision making, particularly how interpretable components can
216 be better protocolized and on what decision support may help. Other important goals are
217 better pre-hospital access to the electronic patient record and previous electrocardiograms,
218 along with access to new high-sensitivity cardiac troponin tests at the point-of-care. If risk
219 scores are to be employed in the pre-hospital setting, they should be based on objective
220 measures wherever possible, with automated electronic imputation of data to optimise
221 reliability.

For Review Only

Comparison of pre-hospital and in-hospital HEART scores

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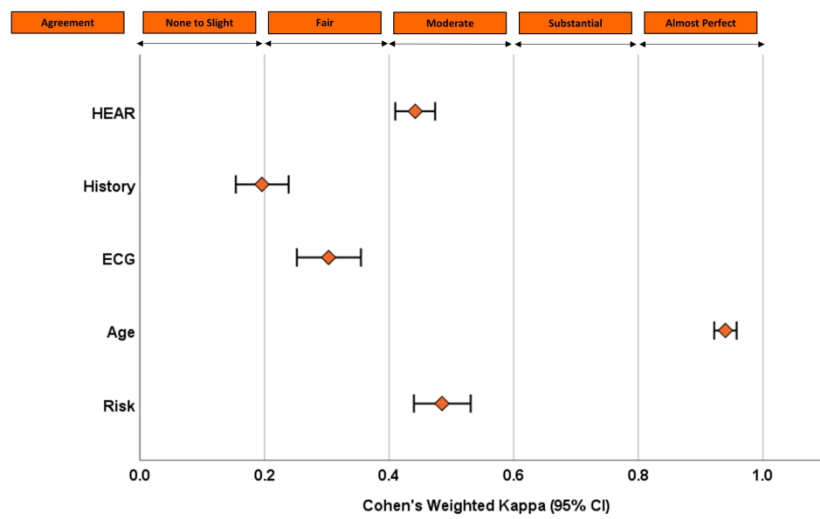
255

256 FIGURE LEGENDS

257 **Figure 1.** Forest Plot of Weighted Cohen's Kappa statistic (with 95% confidence intervals) of
 258 agreement between pre-hospital and in-hospital HEAR scores and the individual components

259 Abbreviations: CI= confidence interval; ECG = electrocardiogram; HEAR = Heart,

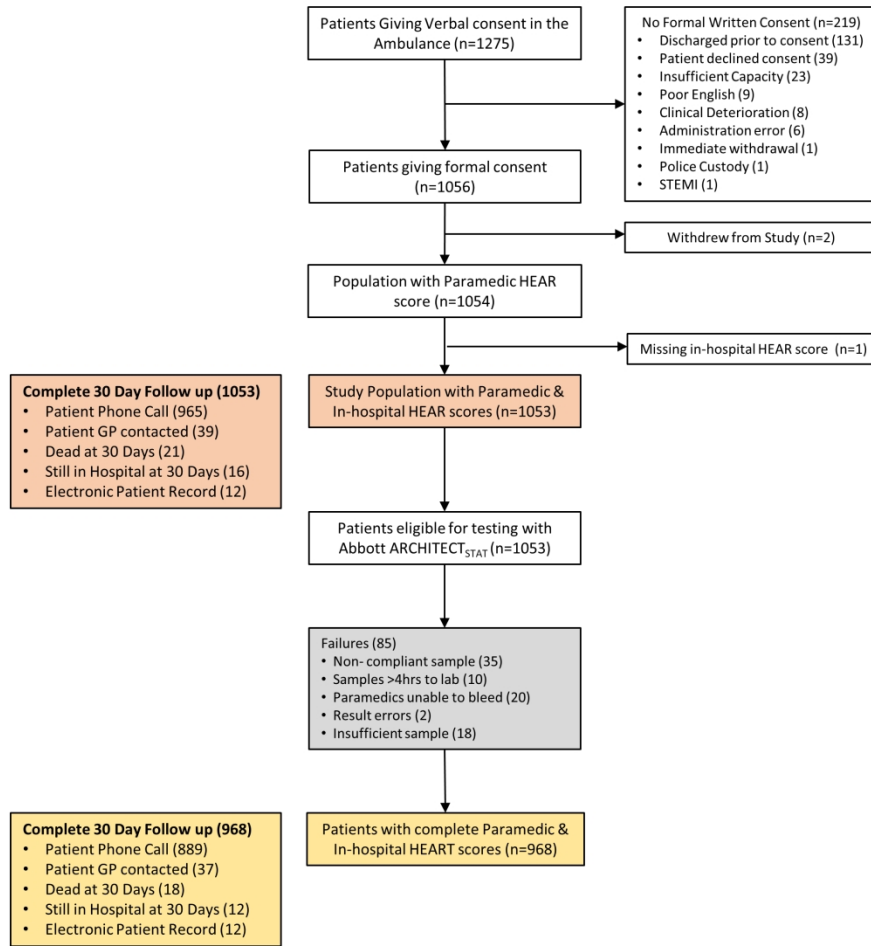
260 Electrocardiogram, Age and Risk Factors score



Forest Plot of Weighted Cohen's Kappa statistic (with 95% confidence intervals) of agreement between pre-hospital and in-hospital HEAR scores and the individual components

Abbreviations: CI= confidence interval; ECG = electrocardiogram; HEAR = Heart, Electrocardiogram, Age and Risk Factors score

338x190mm (300 x 300 DPI)



190x254mm (300 x 300 DPI)

Comparison of pre-hospital and in-hospital HEART scores

RESEARCH LETTER

**Comparison of pre-hospital and in-hospital HEART scores
in patients with possible myocardial infarction**

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PRESENTATION

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124 independently as previously described (2)(2). ~~C~~Attending-clinical staff ~~who of any grade who~~
125 ~~performed~~ the first assessment in-hospital recorded ~~at~~ the HEAR score ~~were~~ ~~while~~ blinded to
126 the pre-hospital score and ~~all~~ blood test results. Patients with HEAR scores from both settings
127 ~~available~~ were included and ~~the~~ HEART scores were calculated using the pre-hospital cardiac
128 troponin I-result ~~from the pre-hospital sample~~.

129 The primary outcome was the inter-rater agreement between the HEAR and HEART
130 scores determined pre-hospital by paramedics and in-hospital by attending clinicians. This
131 analysis was conducted across all possible values of HEAR (0-8) and HEART (0-10) scores,
132 calculated using Cohen's weighted kappa (κ_w) and repeated for the individual components of
133 the HEAR score. Discrimination of pre-hospital and in-hospital HEAR and HEART scores
134 for MACE at 30-days was expressed using the area under the receiver operator curve
135 (AUROC) with 95% confidence intervals (CI) and compared for statistical significance using
136 DeLong's test. Agreement was also compared for those classified as low- (HEART ≤ 3) and
137 high-risk (HEART ≥ 7). Statistical analysis was undertaken using IBM SPSS (version 28.0;
138 IBM Corp., Armonk, NY) and Stata (version 17.0; StataCorp LLC, College Station, TX).

139 A total of 1,053 patients (mean age 64 [SD 15] years, 42% women) had complete pre-
140 hospital and in-hospital HEAR scores. Follow-up at 30 days was complete in all patients with

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141 284 (27%) experiencing a MACE and 192 (18%) a type 1 myocardial infarction
142 (*Supplemental Figure 1*).

143 The average HEAR score was 4.4 (SD 1.7) and 4.7 (SD 1.8) in the pre-hospital and
144 in-hospital setting, respectively. Discrimination for MACE at 30 days was significantly lower
145 for the HEAR score determined pre-hospital compared to in-hospital (AUROC 0.70, 95% CI
146 0.67 to 0.73 *versus* 0.75, 95% CI 0.72 to 0.78, $P=0.001$).

147 Pre-hospital and in-hospital HEAR scores were the same in only 289 (27.4%)
148 patients. When this was broken down into the components the score was the same for the
149 history in 459 (43.6%) patients, the electrocardiogram in 630 (59.8%), age in 1,010 (95.9%),
150 and risk factors in 696 (66.1%).

151 Overall agreement between pre-hospital and in-hospital HEAR scores was moderate
152 (κ 0.44, 95% CI 0.41 to 0.47). Agreement between the components was almost perfect for
153 age (κ 0.94, 95% CI 0.92 to 0.96), moderate for risk factors (κ 0.49, 95% CI 0.44 to 0.53),
154 fair for the electrocardiogram (κ 0.30, 95% CI 0.25 to 0.36) and poor for the history (κ
155 0.20, 95% CI 0.15 to 0.24) (*Figure 1*).

156 There were 968 (92%) patients with a pre-hospital cardiac troponin result to
157 determine the pre-hospital and in-hospital HEART score. Discrimination for MACE at 30
158 days of the HEART score was better than for the HEAR score but was significantly worse
159 when determined pre-hospital compared to in-hospital (AUROC 0.78, 95% CI 0.75 to 0.81
160 *versus* 0.82, 95% CI 0.79 to 0.85, $P=0.002$). Pre-hospital and in-hospital HEART scores were
161 the same in only 262 patients (27%) and overall agreement was moderate (κ 0.49, 95% CI
162 0.46 to 0.53).

163 Of ~~the~~ 281 (29%) patients identified by paramedics as low-risk ($\text{HEART} \leq 3$), there
164 was discordance with in-hospital clinicians in 117 (42%) ~~patients~~. Of ~~the~~ 156 (16%) patients

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165 identified by paramedics as high-risk (HEART ≥ 7) there was discordance with in-hospital
166 clinicians in 49 (31%) ~~patients~~.

167 In a large prospective study of patients with possible myocardial infarction, we
168 observed important differences in the application of the HEAR and HEART scores performed
169 by paramedics pre-hospital and clinicians in hospital. Discrimination for MACE was
170 moderate in both settings but ~~was~~ significantly worse when scores were determined in the
171 pre-hospital setting. Agreement between paramedics and in-hospital clinical staff was
172 moderate with just 1 in 4 patients having the same score, and ~~was~~ particularly poor for the
173 subjective history and electrocardiogram components.

174 Previous prospective evaluations of HEART score inter-rater agreement ~~between~~
175 ~~raters of the HEART score~~ have been inconsistent in both the emergency department,
176 ~~(6,7)(6,7)~~ and pre-hospital setting (8,9). We observed moderate agreement overall between
177 pre-hospital and in-hospital HEAR (κ 0.44) and HEART (κ 0.49) scores, lower than
178 previous studies in the emergency department ~~(6,7)(6,7)~~, but similar to prior comparisons of
179 agreement between the pre-hospital and in-hospital setting (8,9).

180 That agreement should be worse on the more interpretable history and
181 electrocardiogram components of the HEART score, than age, risk factors or cardiac
182 troponin, is intuitive, and has been demonstrated before, though with substantial variation
183 across studies (6-9). ~~Previous observational studies~~ Interpretation of the history can be
184 ~~difficult, is subjective and influenced by experience. have provided pre-hospital practitioners~~
185 with a pre-recorded video and website access to aid HEART score calculation (9) or the
186 option to contact a cardiologist for electrocardiograph opinion (8), though without discernible
187 improvement in agreement within in-hospital assessment compared to our study (which relied
188 on trained paramedic interpretation alone), which was poor and fair for history and

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189 ~~electrocardiogram components, respectively. Despite training on what should be scored 0, 1~~
 190 ~~and 2, agreement on the electrocardiographic component was only slightly better, and w~~
 191 observed only moderate agreement between pre-hospital and in-hospital evaluation of the risk
 192 factor component, consistent with prior studies (8,9).

193 Some aspects of our study design may have influenced the finding that in-hospital
 194 ~~HEAR~~ scores were more discriminatory for MACE ~~than those calculated when documented~~
 195 ~~in hospital than in the in the~~ pre-hospital setting. In-hospital evaluation took place about two
 196 hours after paramedic assessment, allowing time for the history, response to treatment, and
 197 electrocardiographic features to evolve. Furthermore, in-hospital clinicians have access to
 198 ~~both~~ ambulance data ~~and~~ also the full patient record including previous
 199 electrocardiograms. We did not account for the experience of the clinician completing the in-
 200 hospital HEAR score, but all would have had direct access to senior clinicians, potentially
 201 influencing scores. ~~T~~Remarkably, there was even disagreement in 1 in 20 patients for the age
 202 component of the score, confirming that correct entry of fixed values in the calculation of
 203 HEART score cannot be assumed. The assumption that fixed values will always be entered
 204 correctly in the calculation of the HEART score has been shown to be false before (6,9).
 205 ~~(6,9).~~

206 In addition, we acknowledge that incorporation of a laboratory based high-sensitivity
 207 cardiac troponin test into a pre-hospital risk assessment is theoretical and that the relatively
 208 high incidence of MACE may indicate selection bias explained by recruitment at the
 209 discretion of the attending paramedic.

210 The main priority of pre-hospital research is to identify low-risk patients who ~~are low-~~
 211 ~~risk and can be~~ managed without direct transfer to hospital with comparable safety to ~~that~~
 212 ~~expected in~~ the emergency department (10)(40). Recent work from the Netherlands

Commented [JC1]: Camaro - 12-lead ECG was performed and evaluated by ambulance paramedics and if there was any doubt, the ECG could be transmitted for immediate evaluation by an independent cardiologist. The patients were screened by ambulance paramedics, after which the patients were invited to participate in the study by the ambulance paramedics. In order to aid the ambulance paramedics in informing the patients, an animated version of the trial information for patients was available in all ambulances

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213 demonstrates ~~paramedics can identify that~~ some patients with a pre-hospital HEART score ≤ 3
214 ~~who do~~ not require hospital transfer, but even with augmented safety netting, 1 in 4 were
215 still transferred (4)(4). Further, management of patients determined by paramedics as ‘low-
216 risk’ with a HEAR score ≤ 3 ~~and a in addition to a~~ point-of-care troponin below a threshold
217 nearly 3 x the 99th centile without hospital conveyance may be cost-effective in the Dutch
218 healthcare system, though clinical safety remains unproven (5)(5).

219 The drive to transfer diagnostic assessment to ambulance services will continue, but
220 methods that work in hospital may not be directly applicable or appropriate for use in the pre-
221 hospital setting. Regarding patients with suspected myocardial infarction, those overseeing
222 the training and education of paramedics should focus on evaluation ~~Future work should~~
223 ~~include an evaluation~~ of the paramedic perspective of pre-hospital decision making,
224 particularly how interpretable components can be better protocolized and on what decision
225 support may help. ~~Other important goals are berequired, better~~ pre-hospital access to the
226 electronic patient record and previous electrocardiograms, along with ~~and~~ access to new high-
227 sensitivity cardiac troponin tests at the point-of-care. If risk scores are to be employed in the
228 pre-hospital setting, ~~then~~ they should be based on objective measures wherever possible, with
229 automated electronic imputation of data to optimise reliability.

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263

264 **FIGURE LEGENDS**

265 **Figure 1.** Forest Plot of Weighted Cohen's Kappa statistic (with 95% confidence intervals) of
 266 agreement between pre-hospital and in-hospital HEAR scores and the individual components
 267 Abbreviations: CI= confidence interval; ECG = electrocardiogram; HEAR = Heart,
 268 Electrocardiogram, Age and Risk Factors score