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RESEARCH LETTER

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

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

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DHI/MCADAM), Scotland and by the NHS Grampian Endowment Fund (Grant Number N0042903). Samsung provided the devices and test discs and the University of Aberdeen contributed to the design and administration of the study. The funders had no role in study design, data collection, or interpretation, or the writing of the report. JGC was supported by a NHS Research Scotland Clinical Research Fellowship. KL and NLM are supported by the British Heart Foundation through a Clinical Research Training Fellowship (FS/18/25/33454) and a Chair Award, Programme Grant, and Research Excellence Award (CH/F/21/90010, RG/20/10/34966, RE/18/5/34216), respectively.

COMPETING INTEREST STATEMENT

NLM reports research grants awarded to the University of Edinburgh from Abbott Diagnostics, Siemens Healthineers and Roche Diagnostics outside the submitted work, and honoraria from Abbott Diagnostics, Siemens Healthineers, Roche Diagnostics, LumiraDx and Psyros Diagnostics. All other authors have no interests to declare.

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We would like to acknowledge the invaluable contribution of all the participating SAS paramedics and technicians as well as the support of the regional and national SAS managerial structures. We are also thankful for the involvement of numerous medical, nursing, reception and portering staff within the Emergency Department of Aberdeen Royal Infirmary, the assistance of Gary Robinson, Chaloner Chute and Susan Scotland from the DHI, and British Heart Foundation Cardiovascular Biomarker Laboratory at the University of Edinburgh.

CONTRIBUTORSHIP STATEMENT

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

ETHICAL STATEMENT

This study was approved by the National Ethics Committee (REC 14/NS/1037), registered in the Research Registry (UIN 2671), and was conducted in accordance with the Declaration of Helsinki.

DATA SHARING STATEMENT

No additional data available

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

The HEART score combines the history, electrocardiogram, age, risk factors and cardiac troponin with each component allocated 0, 1 or 2 points and scores of ≤3, 4-6 and ≥7 considered low-, intermediate-, and high-risk, respectively (1). Data pertaining to the HEAR components of the score are routinely collected by paramedics in the pre-hospital setting (2,3). Recent studies suggest paramedics may be able to use the HEART score to manage some low-risk patients without direct hospital transfer (4,5). This is attractive, with intuitive benefits for patients, ambulance services and emergency departments.

However, prospective studies of the reliability of the HEART score between different grades of clinicians have demonstrated variable results in hospital (6,7), as have two studies that have involved paramedics (8,9). A better understanding of the factors that influence risk assessment in the pre-hospital setting is necessary to ensure robust decision-making and comparable safety to rule-out myocardial infarction as in the emergency department (10).

In this prospective study we compare agreement between the HEART score and its components when performed by paramedics in the pre-hospital setting and clinicians at first assessment in hospital.

This pre-specified analysis of the Ambulance Cardiac Chest Pain Evaluation in Scotland Study (ACCESS) (2) was approved by the National Ethics Committee (REC/14/NS/1037). Consenting adult patients with chest pain suspicious for a myocardial infarction without persistent ST-segment elevation on the pre-hospital electrocardiogram had a HEAR score recorded by a study trained paramedic using their own interpretation of the history and electrocardiogram who also obtained a venous blood sample that was conveyed with the

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

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

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

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

Comparison of pre-hospital and in-hospital HEART scores

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

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

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

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

Of 281 (29%) patients identified by paramedics as low-risk (HEART ≤3), there was discordance with in-hospital clinicians in 117 (42%). Of 156 (16%) patients identified by paramedics as high-risk (HEART ≥7) there was discordance with in-hospital clinicians in 49 (31%).

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

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

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

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

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

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

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

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

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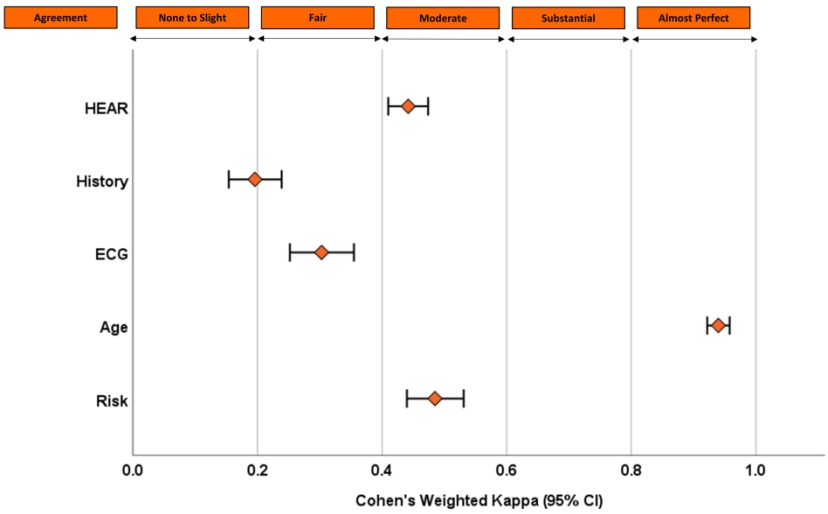
FIGURE LEGENDS

Figure 1. 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



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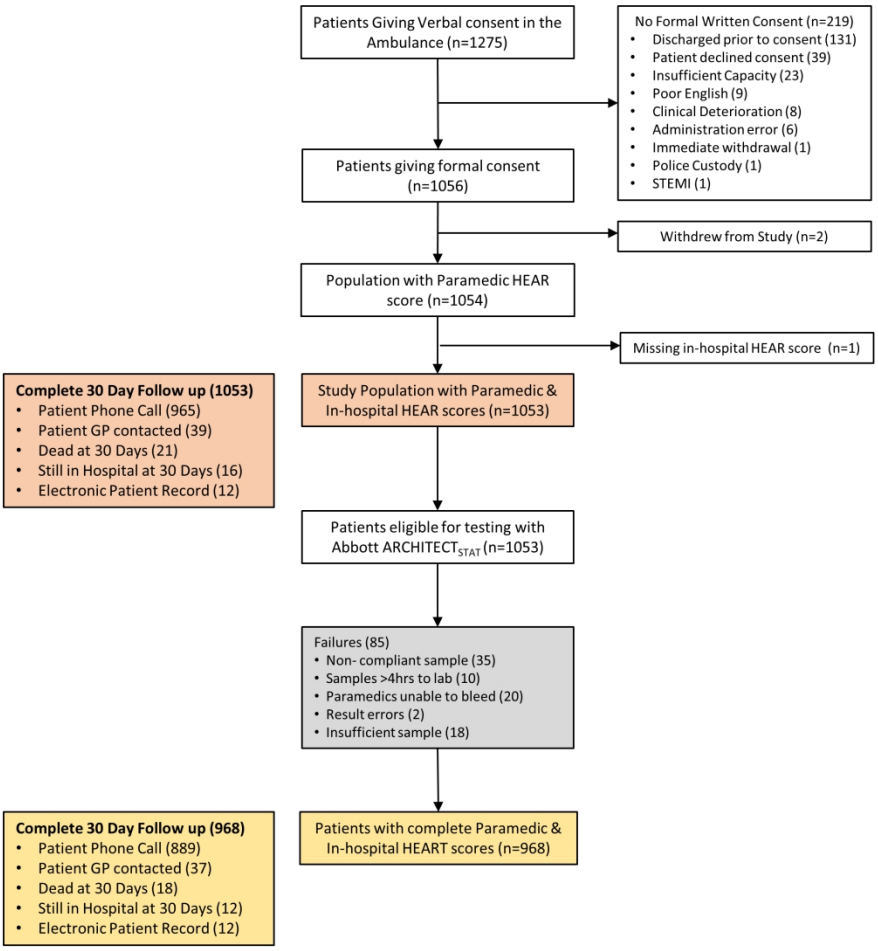

190x254mm (300 x 300 DPI)

RESEARCH LETTER

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CONTRIBUTORSHIP STATEMENT

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

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No additional data available

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However, prospective studies of the reliability of the HEART score between different grades of clinicians have demonstrated variable results in hospital (6,7)~~(6,7)~~, as have two studies that have involved paramedics (8,9). ~~(8,9).~~ A better understanding of the factors that influence risk assessment in the pre-hospital setting is necessary to ensure robust decision-making and comparable safety to rule-out myocardial infarction as in the emergency department (10)~~(10)~~.

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interpretation of the history and electrocardiogram~~)~~ who also obtained a venous blood sample that was conveyed with the patient for testing with the Abbott ARCHITECT$_{STAT}$ high-sensitivity troponin I assay (sex-specific 99th centile: 16 ng/L in women and 34 ng/L in men).

Patients were followed up for a major adverse cardiac event (MACE) comprising death, myocardial infarction, revascularisation, malignant arrhythmia, cardiac arrest, or cardiogenic shock at 30-days. All patients with myocardial injury were adjudicated independently as previously described (2)~~(2)~~. C~~Attending c~~linical staff who ~~of any grade who~~ performe~~ded~~d the first assessment in-hospital recorded a~~the~~ HEAR score were~~hilst~~ blinded to the pre-hospital score and ~~all~~ blood test result~~s~~. Patients with HEAR scores from both settings ~~available~~ were included and ~~the~~ HEART scores were calculated using the pre-hospital cardiac troponin ~~I~~ result ~~from the pre-hospital sample~~.

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

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

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

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

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

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

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

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

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

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

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

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

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FIGURE LEGENDS

Figure 1. 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