Prehospital identification of ST-segment elevation myocardial infarction and mortality (ANZACS-QI 61)

Becky Yi-Wen Liao, Mildred Ai Wei Lee, Bridget Dicker, Verity F Todd, Ralph Stewart, Katrina Poppe, Andrew Kerr

ABSTRACT

Background Early recognition of ST-segment elevation myocardial infarction (STEMI) is needed for timely cardiac monitoring and reperfusion therapy.

Methods Three anonymously linked New Zealand national datasets (July 2016–November 2018) were used to assess the utilisation of ambulance transport in STEMI cases, the concordance between ambulance initial clinical impressions and hospital STEMI diagnoses, and the association between initial paramedic clinical impressions and 30-day mortality. The St John Ambulance electronic record captures community call-outs and paramedic initial clinical impressions. The national cardiac (ANZACS-QI) registry and national administrative datasets capture all New Zealand public hospital admission diagnoses and mortality data.

Results Of 5465 patients with STEMI, 73% were transported to hospital by ambulance. For these patients, the initial paramedic impression was STEMI in 50.7%, another acute coronary syndrome (ACS) diagnosis in 19.9% and non-ACS diagnosis in 29.7%. Only 37% of the 5465 patients with STEMI were both transported by ambulance and clinically suspected of STEMI by paramedics. Compared with patients with paramedic-‘suspected STEMI’, 30-day mortality was over threefold higher for patients thought to have a non-ACS condition (10.9% and 34.9%, respectively), but after adjustment for available covariates, this was substantially ameliorated (HR 1.48, 95% CI 1.22 to 1.80).

Conclusions In this national data linkage study, only 4 out of every 10 patients with STEMI were both transported by ambulance and had STEMI suspected by paramedics. Although patients with STEMI not suspected of an ACS diagnosis by paramedics had the highest mortality rate, this is largely explained by the different risk profile of these patients.

INTRODUCTION

Timely and accurate diagnosis of ST-segment elevation myocardial infarction (STEMI) is a prerequisite for implementation of optimal evidence-based treatments including antithrombotic therapy and coronary reperfusion.1-8 The St John Ambulance service is a charity with funding from government and community donations, attends to most of the medical emergency call-outs in New Zealand (NZ). Virtually all emergency hospitalisations in NZ are admitted to public hospitals, including over 99% of acute coronary syndrome (ACS) admissions.9 In 2016, St John Ambulance implemented an electronic clinical record which contains information on patient clinical status and the paramedic initial clinical impression, including ‘suspected STEMI’ and ‘other suspected
Anonymised linkage of individual ambulance electronic records with public hospitalisation and mortality databases allows us to construct a comprehensive dataset of ambulance-to-hospital transfers, hospitalisations and outcomes for most of NZ. These linked datasets were used to investigate the utilisation of ambulance transport in STEMI cases, and to evaluate the concordance between the paramedic initial clinical impressions and the final hospital diagnoses. Our aims were to determine the proportion of patients with a final hospital diagnosis of STEMI who were transported by ambulance with a paramedic-suspected STEMI, and to assess the impact of discordance between prehospital and final STEMI diagnoses on mortality outcomes.

**METHOD**

This national data linkage study included consecutive cases captured in each of the three health datasets between 01 July 2016 and 30 November 2018.

**Terms used in this study**

The definition of ‘suspected STEMI’ in St John records required both clinical impression and ECG suggestive of STEMI by paramedics. When their initial impression is ACS or other cardiac conditions but felt not to meet the criteria for STEMI, then it is classified as ‘other suspected ACS’. The initial clinical impression is generally that of the paramedic prior to any electronic transmission of the ECG to an interventional centre. Remaining cases which do not meet either definition are classified as ‘ACS not suspected’.

**Datasets**

The St John electronic record system collects information for all ambulance call-outs, including patient demographics, clinical indications, transport times, and prehospital assessment and management. The ambulance data were obtained for the whole of NZ except for patients transported to Wellington, Hutt and Wairarapa Hospitals because they use a different ambulance service.

The All NZ Acute Coronary Syndrome Quality Improvement (ANZACS-QI) registry has captured over 99% of NZ patients with ACS investigated with coronary angiography since 2015. The dataset and methodology of the ANZACS-QI registry have been previously reported, capturing ACS diagnosis types—STEMI, non-ST-elevated ACS (NSTEACS) and non-ACS diagnoses.

The national administrative datasets include the National Minimum Dataset (NMDS) which provides International Classification of Diseases (ICD) 10AM-coded hospitalisation records, the Mortality Collection that provides mortality data, and the National Non-Admitted Patient Collection (NNAPC) which records patients presented to the emergency department who do not require hospitalisation and are discharged alive. NNAPC does not record ICD-coded diagnostic information.

**Dataset linkage and cohort construction**

Every patient in contact with NZ health system is assigned a unique identifier, the National Health Index (NHI). The NHI can be used to anonymously link multiple electronic databases using a common encrypted NHI. Admission hospitals were classified as those participating in a routine primary percutaneous coronary intervention (PCI) service, those with a catheter laboratory but without routine primary PCI availability, or rural hospitals without a catheter laboratory. For STEMI cases, ‘system time’ was from ambulance dispatch to hospital arrival.

**Statistics**

Results were presented as mean with SD and/or median with IQR for continuous variables and frequency (percentage) for categorical variables. Comparison between groups (St John initial diagnosis or St John attendance) was done using Pearson’s X^2 test for
categorical data or non-parametric Mann-Whitney U test for continuous variables as the data were not normally distributed. The significance of the difference between the final diagnosis of STEMI according to the initial St John clinical impression and method of transport to hospital was tested using log-rank test. Unadjusted Kaplan-Meier curves showed the association between final diagnosis of STEMI according to initial St John clinical impression and method of transport to hospital, and mortality. The proportional hazard assumption was tested using SAS ASSESS statement in PROC PHREG and was met. Multivariable Cox regression models were used to estimate the adjusted hazard of ambulance paramedic ‘other suspected ACS’, ‘ACS not suspected’ and ‘not attended by ambulance’ compared with ‘suspected STEMI’ for 30-day mortality. Covariates included were age (continuous), gender, ethnicity, NZDep13, modified non-cardiac Charlson Comorbidity Index, coronary intervention status and hospital. All p values were two tailed and p<0.05 was considered statistically significant. Data were analysed using SAS V.9.4 (SAS Institute), and survival plots were created using RStudio V.1.1.442.

**Patient and public involvement**

It was not appropriate to involve patients or the public in the design, conduct, reporting or dissemination plans of our research.

**RESULTS**

There were 5465 admissions with a final diagnosis of STEMI (table 1) and 3989 (73%) were transported to hospital by ambulance and 1486 (27%) self-presented. Of those transported by ambulance, 2016 (50.7%) had a prehospital clinical impression of suspected STEMI, 792 (19.9%) were suspected of another ACS diagnosis and 1181 (29.7%) were not suspected of an ACS.

For the 3989 patients transported by ambulance with a final diagnosis of STEMI, 2016 (51%) had an initial paramedic clinical impression of STEMI. As a consequence of this diagnostic sensitivity, combined with 73% of patients being transported by ambulance, only 37% of all STEMI cases were identified prehospital as a suspected STEMI (table 3). This proportion varied by age—younger patients, men and European/other patients with STEMI were most likely to be transported by ambulance with a clinically suspected STEMI (European/other 38.7% vs Māori and Pacific groups, 28.7% and 28.9%) as were those without multiple comorbidities.

In the 38 332 cases with an initial ambulance paramedic clinical impression of ‘other suspected ACS’, 792 (2.1%) were alive but did not require hospital admission. Therefore, of all the cases suspected by paramedics of having STEMI, 72% had a final cardiac diagnosis.

Table 2 shows the characteristics of those cases with a final diagnosis of STEMI according to the initial paramedic impression and the mode of presentation. Cases identified as suspected STEMI by paramedics, as opposed to another diagnosis, were more likely to be younger and male. They also had less medical comorbidity when compared with those with a non-cardiac initial impression. Māori (45%) or Pacific people (42%) with STEMI were less likely to be initially identified as having a STEMI than Indian (57%), other Asian (58%) and European/other (52%) people. Only 36% of STEMI cases transported initially to rural hospitals without catheter laboratories were suspected STEMIs prehospital compared with 53% transported to hospitals participating in a routine primary PCI service and 47% to hospitals with a catheter laboratory but without routine primary PCI. The mean time from first medical contact to hospital arrival was shorter when St John suspected a cardiac condition (54.6, 54.0 and 59.3 min for suspected STEMI, other ACS and non-ACS, respectively (p<0.001)). Self-presentation to hospital, in contrast to ambulance transfer, was more common among older patients, men and non-European/other ethnic groups (Māori (36%), Pacific (31%), European/other (24%)).

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**Table 1** Ambulance initial clinical impressions and the final diagnosis available in the Combined National Dataset for all cases

| Final diagnosis in the Combined National Dataset (column %) | STEMI | NSTEMACS | Other CHD | Non-CHD | Not admitted | Total |
|---|---|---|---|---|---|---|
| Total | 5465 | 28 304 | 14 862 | 2 184 334 | 163 426 | 2 396 391 |
| Ambulance-suspected cardiac | | | | | | |
| Suspected STEMI | 2016 (36.9) | 472 (1.7) | 86 (0.6) | 733 (0.1) | 250 (0.2) | 3557 (0.1) |
| Other suspected ACS | 792 (14.5) | 6876 (24.3) | 2484 (16.7) | 21 931 (1.0) | 6249 (3.8) | 38 332 (1.6) |
| Ambulance ‘ACS not suspected’ | 1181 (21.6) | 8785 (31.0) | 3749 (25.2) | 367 642 (16.8) | 156 927 (96.0) | 538 284 (22.5) |
| Not attended by ambulance | 1476 (27.0) | 12 171 (43.0) | 8543 (57.5) | 1 794 028 (82.1) | – | 1 816 218 (75.8) |

CHD, coronary heart disease; NSTEMACS, non-ST-elevated acute coronary syndrome; STEMI, ST-segment elevation myocardial infarction.

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Table 2  Characteristics of all cases with a STEMI diagnosis according to the ambulance service initial clinical impressions and method of transport to hospital

| Ambulance initial clinical impression | Suspected STEMI (n=2016) | Other suspected ACS (n=792) | ACS not suspected (n=1181) | P value (1 vs 2) | P value (1 vs 3) | P value (2 vs 3) | All transported by ambulance (n=3989) | Self-presented (n=1476) | P value |
|-------------------------------------|--------------------------|-----------------------------|---------------------------|----------------|----------------|----------------|--------------------------------------|-------------------------|---------|
| Age (years), mean (SD)              | 66.4 (13.5)              | 68.4 (13.9)                 | 72.7 (14.5)               | 0.001         | <0.001        | <0.001        | 68.6 (14.1)                         | 64.3 (13.5)             | <0.001  |
| Age group, n (%)                    |                          |                             |                          |               |               |               |                                      |                         |         |
| <45                                 | 106 (5.3)                | 30 (3.8)                    | 40 (3.4)                  | 0.009         | <0.001        | <0.001        | 176 (4.4)                           | 88 (6.0)                | <0.001  |
| 45–54                               | 281 (13.9)               | 107 (13.5)                  | 108 (9.1)                 | 0.009         | <0.001        | <0.001        | 496 (12.4)                          | 270 (18.3)              |         |
| 55–64                               | 534 (26.5)               | 176 (22.2)                  | 186 (15.7)                |               |               |               | 896 (22.5)                          | 391 (26.5)              |         |
| 65–74                               | 501 (24.9)               | 199 (25.1)                  | 263 (22.3)                |               |               |               | 963 (24.1)                          | 381 (25.8)              |         |
| 75–84                               | 393 (19.5)               | 171 (21.6)                  | 299 (25.3)                |               |               |               | 863 (21.6)                          | 238 (16.1)              |         |
| 85+                                 | 201 (10.0)               | 109 (13.8)                  | 285 (24.1)                |               |               |               | 595 (14.9)                          | 108 (7.3)               |         |
| Female, n (%)                       | 634 (31.4)               | 271 (34.2)                  | 514 (43.5)                | 0.158         | <0.001        | <0.001        | 1419 (35.6)                         | 440 (29.8)              | <0.001  |
| Ethnicity, n (%)                    |                          |                             |                          |               |               |               |                                      |                         |         |
| Māori                               | 184 (9.1)                | 76 (9.6)                    | 150 (12.7)                |               |               |               | 410 (10.3)                          | 232 (15.7)              |         |
| Pacific                             | 80 (4.0)                 | 29 (3.7)                    | 83 (7.0)                  |               |               |               | 192 (4.8)                           | 85 (5.8)                |         |
| Indian                              | 86 (4.3)                 | 35 (4.4)                    | 30 (2.5)                  |               |               |               | 151 (3.8)                           | 84 (5.7)                |         |
| Other Asian                         | 79 (3.9)                 | 28 (3.5)                    | 29 (2.5)                  |               |               |               | 136 (3.4)                           | 74 (5.0)                |         |
| European/other                      | 1587 (78.7)              | 624 (78.8)                  | 889 (75.3)                |               |               |               | 3100 (77.7)                         | 1001 (67.8)             |         |
| NZDep13, n (%)                      |                          |                             |                          | 0.74          | 0.536         | 0.986         | 624 (15.6)                          | 224 (15.2)              | 0.094   |
| 1–2 (least deprived)               | 327 (16.2)               | 124 (15.7)                  | 173 (14.6)                |               |               |               | 704 (17.6)                          | 251 (17.0)              |         |
| 3–4                                 | 375 (18.6)               | 135 (17.0)                  | 194 (16.4)                |               |               |               | 735 (18.4)                          | 232 (15.7)              |         |
| 5–6                                 | 385 (19.1)               | 140 (17.7)                  | 210 (17.8)                |               |               |               | 864 (21.7)                          | 291 (19.7)              |         |
| 7–8                                 | 452 (22.4)               | 164 (20.7)                  | 248 (21.0)                |               |               |               | 896 (22.5)                          | 365 (24.7)              |         |
| 9–10 (most deprived)               | 439 (21.8)               | 184 (23.2)                  | 273 (23.1)                |               |               |               | 166 (4.2)                           | 113 (7.7)               |         |
| Missing                             | 38 (1.9)                 | 45 (5.7)                    | 83 (7.0)                  | <0.001        | <0.001        | <0.001        | 2711 (68.0)                         | 1043 (70.7)             |         |
| Non-cardiac Charlson score <0.001   |                          |                             |                          |               |               |               | 1551 (76.9)                         | 1026 (70.7)             |         |
| 0                                  | 1551 (76.9)              | 541 (68.3)                  | 619 (52.4)                |               |               |               | 2711 (68.0)                         | 1043 (70.7)             |         |
| 1–2                                | 326 (16.2)               | 160 (20.2)                  | 302 (25.6)                |               |               |               | 788 (19.8)                          | 252 (17.1)              |         |
| 3+                                 | 139 (6.9)                | 91 (11.5)                   | 260 (22.0)                |               |               |               | 490 (12.3)                          | 181 (12.3)              |         |

Continued
### Table 2 Continued

| Ambulance initial clinical impression | Suspected STEMI (n=2016) | Other suspected ACS (n=792) | ACS not suspected (n=1181) | P value (1 vs 2) | P value (1 vs 3) | P value (2 vs 3) | All transported by ambulance (n=3989) | Self-presented (n=1476) | P value |
|--------------------------------------|--------------------------|-----------------------------|----------------------------|------------------|------------------|------------------|--------------------------------------|------------------------|---------|
| Hospital status, n (%)               |                          |                             |                            |                  |                  |                  |                                      |                        |         |
| Primary PCI centre                   | 1408 (69.8)              | 506 (63.9)                  | 735 (62.2)                 | <0.001           | <0.001           | 0.404            | 2649 (66.4)                         | 987 (66.9)             | 0.892   |
| Non-primary PCI centre               | 551 (27.3)               | 241 (30.4)                  | 389 (32.9)                 |                  |                  |                  | 1181 (29.6)                         | 428 (29.0)             |         |
| Rural hospital without cath lab      | 57 (2.8)                 | 45 (5.7)                    | 57 (4.8)                   |                  |                  |                  | 159 (4.0)                           | 61 (4.1)               |         |
| System time, median (IQR)            | 54.6 (42.1–74.0)         | 54.0 (40.8–71.5)            | 59.3 (44.3–80.7)           | 0.218            | <0.001           | <0.001           | 55.8 (42.4–75.9)                     | –                      | –       |
| Coronary intervention status         |                          |                             |                            |                  |                  |                  |                                      |                        |         |
| No cath                              |                          |                             |                            |                  |                  |                  |                                      |                        |         |
| Cath with intervention               | 270 (13.4)               | 177 (22.3)                  | 627 (52.7)                 | <0.001           | <0.001           | <0.001           | 1074 (26.9)                         | 381 (24.7)             | 0.512   |
| Cath without intervention            | 1574 (78.1)              | 514 (64.9)                  | 417 (35.3)                 |                  |                  |                  | 2505 (62.8)                         | 930 (64.3)             |         |
|                                       | 172 (8.5)                | 101 (12.8)                  | 137 (11.6)                 |                  |                  |                  | 410 (10.3)                          | 165 (11.0)             |         |

ACS, acute coronary syndrome; cath, catheterisation; NZDep13, New Zealand Deprivation Index 2013; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.
had a STEMI diagnosis and 18 145 (24.4%) had a diagnosis of NSTEACS or other CHD (table 1). There were 57.2% diagnosed with a non-ACS condition, and 16.3% who did not require admission and for whom no further diagnostic information is available.

Outcomes for STEMI cases according to mode of transport to hospital and the initial paramedic clinical impression are shown in table 4 and figure 1. Of the 5465 presentations with STEMI, 259 were repeat presentations which left 5206 (95.3%) first STEMI presentations for outcome analysis. The characteristics of this ‘first presentation’ cohort are similar to those shown in table 2 for all cases (online supplemental table 3).

The unadjusted 30-day mortality rates for patients with a final diagnosis of STEMI were similar for ambulance-suspected STEMI (9.0% (95% CI 7.8% to 10.3%)), suspected ‘other ACS condition’ (10.9% (95% CI 8.8% to 13.3%)) and for self-presenters (9.3% (95% CI 7.8% to 12.0%)). However, those transported by ambulance but not suspected of an ACS had the highest 30-day mortality rate (34.9% (95% CI 32.2% to 37.8%), p<0.001). After adjusting for all demographic and clinical covariates (table 4, Model C), 30-day mortality was lower for self-presenters with STEMI than for patients with STEMI identified by ambulance paramedics (HR 0.73, 95% CI 0.58 to 0.92). The risk for patients transported by ambulance but not initially suspected of an ACS was ameliorated but remained higher than for patients with STEMI identified by ambulance paramedics (HR 1.48, 1.22 to 1.80), and remained similar for ambulance-suspected ‘other ACS conditions’ (HR 0.85, 0.65 to 1.11).

**DISCUSSION**

St John Ambulance attends most of the call-outs in NZ and by combining its electronic dataset with the national datasets, we have a unique opportunity to assess both the accuracy of prehospital clinical impressions and their association with longer term outcomes. Only half of the patients with STEMI transported by ambulance were accurately identified and 20% were suspected of another ACS diagnosis, with the rest not initially thought to have an ACS. Over 60% of patients with STEMI self-presented or were not identified by paramedics and so missed out on opportunities for early reperfusion by activation of the cardiac catheterisation laboratory or receipt of prehospital fibrinolysis. The unadjusted all-cause mortality was similar for ambulance-suspected patients with STEMI or another ACS condition, and in those who self-presented, but mortality was more than three times as high in those not suspected of an ACS. After adjustment for covariates, the excess mortality risk associated with not being suspected by paramedics of having a STEMI was ameliorated, but remained 1.5 times higher than for those initially identified as having a STEMI.
Demographic differences

Māori (the indigenous population of NZ) and Pacific patients with a final hospital STEMI diagnosis were less likely to have been suspected of having a STEMI by paramedics compared with other ethnic groups. They were also more likely to have self-presented to hospital rather than called an ambulance. As a result, Māori and Pacific groups are less likely to receive timely STEMI...
therapy which is critical for improving clinical outcomes. This may contribute to their documented poorer outcomes post-MI.13

Patients with STEMI admitted to routine primary PCI-capable hospitals were more likely identified with STEMI by paramedics, compared with non-routine PCI-capable or rural hospitals (53%, 46% and 36%, respectively). While this may be due to factors such as paramedic training and appropriate utilisation of ECGs at the scene, the findings are also biased by patients with very clear STEMI in rural hospital catchments being transported directly to primary PCI-capable hospitals, leaving more equivocal cases going to rural hospitals. Prior analyses have not found differences in all-cause mortality based on the type of initial receiving hospital which may be due to appropriate identification and bypass of high-risk patients directly to primary PCI centres.14

Ambulance versus self-transport
Seventy-three per cent of the patients with STEMI were transported to hospital by ambulance. This compares favourably with international data. An observational analysis of 37,634 patients with STEMI treated at over 300 US hospitals found that emergency medical services were used for 59%-68% of patients.15-17 Nevertheless, in the current study, 27% of the STEMI cases were not attended by St John, a sizeable group without prehospital access to acute care and defibrillators. These patients will have longer time to reperfusion treatment as previously reported in the ANZACS-QI registry and from the REACT trial.18 19

Paramedic diagnostic accuracy and implications
Prehospital clinical impression of STEMI was confirmed in 57% of cases. Prior studies have reported higher diagnostic accuracies for STEMI. One study of 354 patients had suspected ACS assessed by their mobile emergency care unit (ambulance with two emergency medical staff) at 87.5% of preliminary STEMI diagnoses confirmed.20 Another Danish study similarly reported accuracy of 89%.21 A third study assessed 103 paramedics’ responses to five different settings of chest pain and ECGs, finding 93% sensitivity and 85% specificity for paramedic diagnosis of STEMI.22 In contrast, another cohort study using paramedics’ surveys reported a lower sensitivity 75% and specificity 53% for STEMI detection, including 96% correct for inferior STEMI but only 51% correct for lateral STEMI, and no correlation between paramedic training, experience and accuracy.22

Outcomes
Patients with STEMI who were transferred by ambulance but not initially suspected of an ACS had over three times the mortality risk of those initially identified by paramedics as STEMI. The adverse outcomes are in part due to covariates including age and comorbidities; and after adjustment, the excess hazard was markedly reduced to just 1.5 times excess risk. Some of this residual excess risk may be related to unmeasured and therefore unadjusted comorbidity. In particular, the national datasets do not have information about clinical acuity at the time of presentation, and it is possible that some patients with STEMI without a clear STEMI diagnosis may be more unwell. We are unable to determine, in this observational

Figure 1  Unadjusted all-cause mortality for patients with STEMI according to method of patient transport and initial ambulance paramedic clinical impression. *For patients with more than one STEMI presentation, only the first presentation was used in the outcomes analysis. ACS, acute coronary syndrome; STEMI, ST-segment elevation myocardial infarction.
study, whether some of the remaining excess risk is due to the delay in appropriate monitoring and treatment for these patients. It is also possible that patients who call an ambulance may be sicker than those who self-present. This is supported by the finding that after adjustment, self-presenters had better outcomes than ambulance-transferred patients.

Clinical implications
Increasing both the proportion transferred by ambulance and improving identification of at-risk patients by paramedics may improve prehospital STEMI identification. This may facilitate earlier reperfusion therapy whether primary PCI or fibrinolysis. Consistent and increased utilisation of prehospital ECGs may help identify at-risk patients earlier. Ongoing training of paramedics on ECG interpretation and recognition of ACS-related symptoms is needed. The relatively low positive predictive value of 57% of the ambulance clinical impression of STEMI is of concern, and needs to be addressed as prehospital fibrinolysis programmes are rolled out, to avoid patient harm related to unnecessary fibrinolysis. Strategies to increase public awareness of ACS could include media campaigns, advanced cardiac life support community courses and school programmes, with goals of shortening the time to calling an ambulance and enhancing ambulance utilisation. The data linkage methodology used for this study will allow routine audit and ongoing quality improvement initiatives.

Limitations
Patients who died prehospital were not included in this study as final diagnosis data depended on hospital admission. Some St John records in the initial dataset did not have NHiS so could not be included in this study. Records with missing NHiS were predominantly for patients not transported to hospital (personal communication, Bridget Dicker). Some patients may have developed STEMI in hospital therefore could not have been identified by St John. However, using additional data available for nearly 80% of the patients with STEMI, we could estimate how many would have had a delayed diagnosis due to the ECG findings developing after admission. Exclusion of those patients would have increased the sensitivity of the St John clinical impression from 51% to 53%. Although the available data did not record the exact proportion of patients who did not receive a prehospital ECG but prior audit from St John Ambulance has shown 99% of suspected cardiac cases had a 12-lead ECG (personal communication, Bridget Dicker). Our study results were based on real-world national experience of suspected STEMI management in NZ, with our own unique patient population and healthcare systems, therefore findings are not necessarily generalisable to other countries and healthcare systems.

**CONCLUSION**
This large national data linkage study found over 6 out of 10 patients with STEMI potentially missed out on early reperfusion due to self-presentation to hospital or not being identified by paramedics as having a STEMI. Patients with STEMI transported by ambulance but not initially suspected of having an ACS had worse prognosis, in part explained by differences in baseline demographic and clinical factors.

**Author affiliations**
1Department of Cardiology, Middlemore Hospital, Auckland, New Zealand
2Greenlane Cardiovascular Services, Auckland City Hospital, Auckland, New Zealand
3Paramedicine Research Unit, Paramedicine Department, School of Clinical Sciences, Auckland University of Technology, Auckland, New Zealand
4Clinical Audit and Research, St John New Zealand, Auckland, New Zealand
5Section of Epidemiology and Biostatistics, School of Population Health, University of Auckland, Auckland, New Zealand
6School of Medicine, University of Auckland, Auckland, New Zealand

**Acknowledgements**
We would like to thank the Clinical Audit and Research team at St John and the Middlemore Cardiac Trust for their support of this study. ANZACS-QI programme implementation, coordination and analysis: the ANZACS-QI software was developed and supported by Enigma Solutions. Programme implementation is coordinated by the National Institute for Health Innovation (NIHI) at the University of Auckland. The ANZACS-QI programme is funded by the New Zealand Ministry of Health. We thank the National Health Board Analytic Services enabling use of the national datasets. We also thank the VIEW team at the School of Population Health, University of Auckland, for the curation and linkage of the national data. ANZACS-QI Governance Group: Andrew Kerr (chair), Dean Boddington, Gary Sutcliffe, Gerry Devlin, Harvey White, John Edmond, Jonathon Tisch, Kim Marshall, Mayanna Lund, Michael Williams (deputy chair), Nick Fisher, Seif El Jack and Sue Riddle. ANZACS-QI Project management: Kristin Sutherland (project manager), Charmaine Flynn (northern coordinator) and Maxine Rhodes (southern coordinator). Data analysis: Mildred Lee. Data management: Billy Wu (SOHP), Michelle Jenkins (NIHI) and John Faatui (NIHI). We acknowledge all the New Zealand cardiologists, physicians, nursing staff, radiographers and patients who have supported and contributed to ANZACS-QI.

**Contributors**
Study design—BY-WL and AK. Data collection—all co-authors. Data analysis—BY-WL, MAWL and AK. Data interpretation—all co-authors. Manuscript writing—BY-WL and AK. Critical review of the manuscript and final approval of the manuscript—all co-authors. Guarantor—AK.

**Funding**
This work was supported by the New Zealand Health Research Council, Wellington (grant number 11/800 to AK). KP is supported by a New Zealand Heart Foundation Hynds Senior Fellowship. BY-WL and MAWL are supported by the Middlemore Hospital Cardiology Trust.

**Disclaimer**
Researchers are independent from funders, and the funders had no role in the study design, collection, analysis or interpretation of data.

**Competing interests**
None declared.

**Patient consent for publication**
Not required.

**Ethics approval**
ANZACS-QI is part of the Vascular Informatics Using Epidemiology and the Web (VIEW) programme. The VIEW programme was approved by the Northern Region Ethics Committee Y in 2003 (AKY/03/12/314), with subsequent amendments to include the ANZACS-QI registries, and with annual approval by the National Multi-region Ethics Committee since 2007 (MECO/17/EXP). The St John Ambulance service locality review approved the use of St John data in this study. All data were anonymised in the analyses so individual patient consent was not required. The corresponding author affirms that the manuscript is an honest, accurate and transparent account of the study being reported, that no important aspects of the study have been omitted.

**Provenance and peer review**
Not commissioned; externally peer reviewed.

**Data availability statement**
Data are available upon reasonable request. The data underlying this article cannot be shared publicly because they are made available to the investigators by the Ministry of Health under a Multi-region Ethics Committee...
approval. The data will be shared on reasonable request to the corresponding author and approval by the View Governance Group.

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**ORCID iDs**
Becky Yi-Wen Liao http://orcid.org/0000-0001-9910-013X
Ralph Stewart http://orcid.org/0000-0002-6167-1225
Katrina Poppe http://orcid.org/0000-0002-4418-4476

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### SUPPLEMENTARY APPENDIX

Table S1: List of ICD codes for ACS and other CHD

| ACS Type | ICD codes | Description |
|----------|-----------|-------------|
| STEMI    | I210      | Acute transmural myocardial infarction of anterior wall |
|          | I211      | Acute transmural myocardial infarction of inferior wall |
|          | I212      | Acute transmural myocardial infarction of other sites |
|          | I213      | Acute transmural myocardial infarction of unspecified site |
|          | I220      | Subsequent myocardial infarction of anterior wall |
|          | I221      | Subsequent myocardial infarction of inferior wall |
|          | I228      | Subsequent myocardial infarction of other sites |
|          | I229      | Subsequent myocardial infarction of unspecified site |
| NSTEMI   | I214      | Acute subendocardial myocardial infarction |
|          | I222      | Subsequent non-ST elevation (NSTEMI) myocardial infarction |
| USA      | I200      | Unstable angina |
| MI       | I219      | Acute myocardial infarction, unspecified |
| Unspecified |         | Angina pectoris with documented spasm |
|          | I201      | Angina pectoris with documented spasm |
|          | I208      | Other forms of angina pectoris |
|          | I209      | Angina pectoris, unspecified |
|          | I230      | Haemopericardium as current complication following acute myocardial infarction |
| Other CHD | I230      | Atrial septal defect as current complication following acute myocardial infarction |
| Code | Description |
|------|-------------|
| I231 | Myocardial infarction |
|     | Ventricular septal defect as current complication following acute myocardial infarction |
| I232 | Rupture of cardiac wall without haemopericardium as current complication following acute MI |
| I233 | Rupture of chordae tendineae as current complication following acute myocardial infarction |
| I234 | Rupture of papillary muscle as current complication following acute myocardial infarction |
| I235 | Thrombosis of atrium, auricular appendage, and ventricle as current complications following acute MI |
| I236 | Other current complications following acute myocardial infarction |
| I238 | Coronary thrombosis not resulting in myocardial infarction |
| I240 | Other forms of acute ischaemic heart disease |
| I248 | Acute ischaemic heart disease, unspecified |
| I249 | Aneurysm of heart |
| I253 | Coronary artery aneurysm |
| I254 | Ischaemic cardiomyopathy |
| I255 | Silent myocardial ischaemia |
| I256 | Cardiac arrest with successful resuscitation |
| I460 | Cardiac arrest, unspecified |

CHD: coronary heart disease
Appendix Figure 1: Flow chart summarising cohort construction

Steps which reduced the number of St John records:
- Excluding duplicate records (n=2,000)
- Keep only first record of the day if there were multiple call-outs happened on the same day (exclude n=24,276)
Total exclusions: n=25,285

Exclude those who were alive but not transported (n=127,363), or discharged pre-hospital (n=10,295), or those transferred between hospitals (n=4,761)
Total exclusions: n=133,429

St John data
n = 763,691 records in 412,736 people

Final St John dataset
n = 385,173 records in 346,199 people

Excluded patients first admitted to non-St John catchment hospitals - Wellington, Invercargill, Marlborough

ANZACS-QI ACS data
(1 Jul 2016 - 30 Nov 2018)

n = 30,618 cases in 27,738 people
from public hospitals in NZ

Final cleaned ANZACS-QI ACS data
(1 Jul 2016 - 30 Nov 2018)

n = 28,248 compliant ACS records in 28,141 cases in 25,837 people

* NS: We only use the first admission of the bundle, so the 28,141 cases in 25,837 people will be combined to NMD5 data

NMDS data
(1 Jul 2016 – 30 Nov 2018)

n = 2,718,498 records in 2,667,714 EOC bundles in 1,528,557 people

Final linked cohort for analysis n=2,196,191

Note: Of the 183,173 St John records, 163,406 records had non-matched ANZACS-QI (NS)/NMD5 data and were defined as ‘Not admitted’. They comprised 13,800 who were transported to hospital but not admitted (NMHPAC records) and 49,306 had no temporal match to any of ANZACS-QI, NMDS or NMHPAC data.

EOC, episode of care; NMDS, National minimum dataset; ACS, acute coronary syndrome.
Appendix Table 2: Characteristics of patients with a first presentation with a STEMI diagnosis according to the initial St John clinical impressions and method of transport to hospital.

|                         | St John suspected STEMI (n=1,982) | St John other suspected cardiac (n=737) | St John suspected non cardiac condition (n=1,109) | P value (1 vs 2) | P value (1 vs 3) | P value (2 vs 3) | Transported by St John (n=3,828) | Self presented (n=1,378) | P value |
|-------------------------|-----------------------------------|----------------------------------------|------------------------------------------------|----------------|----------------|----------------|---------------------------------|-------------------------|---------|
| Age (years), Mean (SD)  | 66.3 (13.5)                       | 68.4 (13.8)                            | 72.6 (14.5)                                      | <.001          | <.001          | <.001          | 68.5 (14.1)                     | 64.3 (13.6)            | <.001   |
| Age group, n (%)        |                                   |                                        |                                                |                |                |                |                                |                         |         |
| <45                     | 105 (5.3)                         | 27 (3.7)                               | 37 (3.3)                                        | 0.004          | <.001          | <.001          | 169 (4.4)                       | 84 (6.1)                |         |
| 45-54                   | 280 (14.1)                        | 101 (13.7)                             | 105 (9.5)                                       |                |                |                | 486 (12.7)                      | 256 (18.6)             |         |
| 55-64                   | 525 (26.5)                        | 160 (21.7)                             | 176 (15.9)                                      |                |                |                | 861 (22.5)                      | 365 (26.5)             | <.001   |
| 65-74                   | 493 (24.9)                        | 187 (25.4)                             | 245 (22.1)                                      |                |                |                | 925 (24.2)                      | 347 (25.2)             |         |
| 75-84                   | 386 (19.5)                        | 160 (21.7)                             | 280 (25.3)                                      |                |                |                | 826 (21.6)                      | 225 (16.3)             |         |
| 85+                     | 193 (9.7)                         | 102 (13.8)                             | 266 (24.0)                                      |                |                |                | 561 (14.7)                      | 101 (7.3)              |         |
| Female, n (%)           | 620 (31.3)                        | 254 (34.5)                             | 479 (43.2)                                      | 0.114          | <.001          | <.001          | 1353 (35.3)                     | 405 (29.4)             | <.001   |
| Ethnicity, n (%)        |                                   |                                        |                                                |                |                |                |                                |                         |         |
| Maori                   | 178 (9.0)                         | 69 (9.4)                               | 137 (12.4)                                      | 0.983          | <.001          | <.001          | 384 (10.0)                      | 217 (15.8)             | <.001   |
| Pacific                 | 76 (3.8)                          | 25 (3.4)                               | 79 (7.1)                                        |                |                |                | 180 (4.7)                       | 81 (5.9)               |         |
| Indian                  | 85 (4.3)                          | 32 (4.3)                               | 29 (2.6)                                        |                |                |                | 146 (3.8)                       | 81 (5.9)               |         |
| Other Asian             | 78 (3.9)                          | 28 (3.8)                               | 25 (2.3)                                        |                |                |                | 131 (3.4)                       | 71 (5.2)               |         |
| European/Other          | 1565 (79.0)                       | 583 (79.1)                             | 839 (75.7)                                      |                |                |                | 2987 (78.0)                     | 928 (67.3)             |         |
| NZ Dep13, n (%)         |                                   |                                        |                                                |                |                |                |                                |                         |         |
| 1-2                     | 324 (16.3)                        | 124 (16.8)                             | 172 (15.5)                                      | 0.817          | 0.570          | 0.969          | 620 (16.2)                      | 221 (16.0)             | 0.085   |
| 3-4                     | 372 (18.8)                        | 131 (17.8)                             | 193 (17.4)                                      |                |                |                | 696 (18.2)                      | 247 (17.9)             |         |
| 5-6                     | 381 (19.2)                        | 137 (18.6)                             | 209 (18.8)                                      |                |                |                | 727 (19.0)                      | 231 (16.8)             |         |
| 7-8                     | 448 (22.6)                        | 162 (22.0)                             | 247 (22.3)                                      |                |                |                | 857 (22.4)                      | 287 (20.8)             |         |
| 9-10                    | 433 (21.8)                        | 176 (23.9)                             | 269 (24.3)                                      |                |                |                | 878 (22.9)                      | 360 (26.1)             |         |
| Missing                 | 24 (1.2)                          | 7 (0.9)                                | 19 (1.7)                                        |                |                |                | 50 (1.3)                        | 33 (2.2)               |         |
| Hospital status, n (%) | Primary PCI centre | Non primary PCI centre | Rural hospital without cathlab |
|-----------------------|--------------------|------------------------|-------------------------------|
|                       | 1386 (69.9)        | 540 (27.3)             | 56 (2.8)                      |
|                       | 478 (64.9)         | 218 (29.6)             | 41 (5.6)                      |
|                       | 686 (61.9)         | 367 (33.1)             | 56 (5.0)                      |
| System time (from the first medical contact to arrival at hospital, mins) | | | |
| n                     | 1972               | 734                    | 1098                          |
| Mean (SD)             | 62.6 (33.8)        | 60.1 (29.8)            | 67.6 (35.8)                   |
|                       | 54.7 (41.9-74.0)   | 53.9 (40.7-71.6)       | 59.1 (44.3-80.9)              |
| Median (IQR)          | 54.7               | 53.9                   | 59.1                          |
| Non-cardiac Charlson | 0                  | 1-2                    | 3+                            |
| 0                     | 1546 (78.0)        | 520 (70.6)             | 595 (53.7)                    |
|                       | 317 (16.0)         | 141 (19.1)             | 281 (25.3)                    |
|                       | 119 (6.0)          | 76 (10.3)              | 233 (21.0)                    |
| 1-2                   |                    |                       |                               |
|                       |                    |                       |                               |
|                       |                    |                       |                               |
| 3+                    |                    |                       |                               |
|                       |                    |                       |                               |
| Coronary intervention status | No Cath | Cath with intervention | Cath without intervention |
| No Cath               | 208 (10.5)         | 1604 (80.9)            | 170 (8.6)                     |
|                       | 137 (18.6)         | 507 (68.8)             | 93 (12.6)                     |
|                       | 556 (50.1)         | 425 (38.3)             | 128 (11.5)                    |
| Cath with intervention|                    |                       |                               |
|                       |                    |                       |                               |
|                       |                    |                       |                               |
| Cath without intervention |        |                       |                               |
|                       |                    |                       |                               |
|                       |                    |                       |                               |

NZDep13, New Zealand deprivation index 2013; PCI, percutaneous coronary intervention; Cath, catheterisation laboratory.
Appendix Table 3: Proportion of patients with a final diagnosis of STEMI who were transported by ambulance with a paramedic suspected STEMI.

|                          | Final STEMI transported by ambulance / All final diagnoses of STEMI | Ambulance final STEMI with suspected STEMI pre-hospital / All ambulance final STEMI | Final STEMI transported by ambulance and suspected of STEMI pre-hospital / all final STEMI |
|--------------------------|---------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| All                      | 3989/5465 (73.0%)                                                   | 2016/3989 (50.5%)                                                                 | 2016/5465 (36.9%)                                                                         |
| Age group, years         |                                                                     |                                                                                    |                                                                                          |
| <45                      | 176/264 (66.7%)                                                     | 106/176 (60.2%)                                                                  | 106/264 (40.2%)                                                                          |
| 45-54                    | 496/766 (64.8%)                                                     | 281/496 (56.7%)                                                                  | 281/766 (36.7%)                                                                          |
| 55-64                    | 896/1287 (69.6%)                                                   | 534/896 (59.6%)                                                                  | 534/1287 (41.5%)                                                                         |
| 65-74                    | 963/1344 (71.7%)                                                   | 501/963 (52.0%)                                                                  | 501/1344 (37.3%)                                                                         |
| 75-84                    | 863/1101 (78.4%)                                                   | 393/863 (45.5%)                                                                  | 393/1101 (35.7%)                                                                         |
| 85+                      | 595/703 (84.6%)                                                    | 201/595 (33.8%)                                                                  | 201/703 (28.6%)                                                                          |
| Gender                   |                                                                     |                                                                                    |                                                                                          |
| Male                     | 2570/3606 (71.3%)                                                  | 1382/2570 (53.8%)                                                                | 1382/3606 (38.3%)                                                                        |
| Female                   | 1419/1859 (76.3%)                                                  | 634/1419 (44.7%)                                                                 | 634/1859 (34.1%)                                                                         |
| Ethnicity                |                                                                     |                                                                                    |                                                                                          |
| Māori                    | 410/642 (63.9%)                                                    | 184/410 (44.9%)                                                                  | 184/642 (28.7%)                                                                          |
| Pacific                  | 192/277 (69.3%)                                                    | 80/192 (41.7%)                                                                   | 80/277 (28.9%)                                                                           |
| Indian                   | 151/235 (64.3%)                                                    | 86/151 (57.0%)                                                                  | 86/235 (36.6%)                                                                           |
| Other Asian              | 136/210 (64.8%)                                                    | 79/136 (58.1%)                                                                  | 79/210 (37.6%)                                                                           |
| European/Other           | 3100/4101 (75.6%)                                                  | 1587/3100 (51.2%)                                                                | 1587/4101 (38.7%)                                                                        |
| NZ Dep13                 |                                                                     |                                                                                    |                                                                                          |
| 1-2 (least deprived)     | 624/848 (73.6%)                                                    | 327/624 (52.4%)                                                                  | 327/848 (38.6%)                                                                          |
| 3-4                      | 704/955 (73.7%)                                                    | 375/704 (53.3%)                                                                  | 375/955 (39.3%)                                                                           |
| 5-6                      | 735/967 (76.0%)                                                    | 385/735 (52.4%)                                                                  | 385/967 (39.8%)                                                                          |
| 7-8                      | 864/1155 (74.8%)                                                   | 452/864 (52.3%)                                                                  | 452/1155 (39.1%)                                                                         |
| 9-10 (most deprived)     | 896/1261 (71.1%)                                                   | 439/896 (49.0%)                                                                  | 439/1261 (34.8%)                                                                         |
| Missing                  | 166/279 (59.5%)                                                    | 38/166 (22.9%)                                                                  | 38/279 (13.6%)                                                                           |
| Hospital status          |                                                                     |                                                                                    |                                                                                          |
| Primary PCI centre       | 2649/3636 (72.9%)                                                  | 1408/2649 (53.2%)                                                                | 1408/3636 (38.7%)                                                                        |
| Non primary PCI centre   | 1181/1609 (73.4%)                                                  | 551/1181 (46.7%)                                                                  | 551/1609 (34.2%)                                                                          |
| Rural hospital without   | 159/220 (72.3%)                                                    | 57/159 (35.8%)                                                                  | 57/220 (25.9%)                                                                           |
| cathlab                        | Non-cardiac Charlson index | Coronary intervention status |
|-------------------------------|----------------------------|-----------------------------|
|                               | 0                          | No Cath                     |
|                               | 1/2                        | Cath with intervention      |
|                               | 3+                         | Cath without intervention   |
|                               | 2711/3754 (72.2%)          | 1074/1455 (73.8%)           |
|                               | 788/1040 (75.8%)           | 2505/3435 (72.9%)           |
|                               | 490/671 (73.0%)            | 410/575 (71.3%)             |
|                               | 1551/2711 (57.2%)          | 270/1074 (25.1%)            |
|                               | 326/788 (41.4%)            | 1574/2505 (62.8%)           |
|                               | 139/490 (28.4%)            | 172/410 (42.0%)             |
|                               | 1551/3754 (41.3%)          | 270/1455 (18.6%)            |
|                               | 326/1040 (31.3%)           | 1574/3435 (45.8%)           |
|                               | 139/671 (20.7%)            | 172/575 (29.9%)             |