# Acute coronary syndrome rule-out strategies in the emergency department: an observational evaluation of clinical effectiveness and current UK practice

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## ABSTRACT

**Background** Numerous strategies have been developed to rapidly rule-out acute coronary syndrome (ACS) using high-sensitivity troponin. We aimed to establish their performance in terms of emergency care length of stay (LOS) in real-world practice.

**Methods** A multicentre observational cohort study in 94 UK sites between March and April 2023. Recruitment was preferably prospective, with retrospective recruitment also allowed. Adults presenting to the ED with chest pain triggering assessment for possible ACS were eligible. Primary outcome was emergency care LOS. Secondary outcomes were index rate of acute myocardial infarction (MI), time to be seen (TTBS), disposition and discharge diagnosis. Details of ACS rule-out strategies in use were collected from local guidelines. Mixed effects linear regression models tested the association between rule-out strategy and LOS.

**Results** 8563 eligible patients were recruited, representing 5.3% of all ED attendances. Median LOS for all patients was 333 min (IQR 225, 510.5), for admitted patients was 460 min (IQR 239.75, 776.25) and for discharged patients was 313 min (IQR 221, 451). Heterogeneity was seen in the rule-out strategies with regard to recommended troponin timing. There was no significant difference in LOS in discharged patients between rule-out strategies defined by single and serial troponin timing (p=0.23 and p=0.41). The index rate of acute MI was 15.2% (1301/8563). Median TTBS was 120 min (IQR 57, 212). 24.4% (2087/8563) of patients were partly managed in a same day emergency care unit and 70% (5934/8563) of patients were discharged from emergency care.

**Conclusion** Despite heterogeneity in the ACS rule-out strategies in use and widespread adoption of rapid rule-out approaches, this study saw little effect on LOS in real-world practice. Suspected cardiac chest pain still accounts for a significant proportion of UK ED attendances. ED system pressures are likely to be explanatory, but further research is needed to understand the reasons for the unrealised potential of these strategies.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Since the introduction of high-sensitivity troponin assays, multiple acute coronary syndrome (ACS) rapid rule-out strategies have been developed aiming for reduced emergency care length of stay (LOS).
⇒ The diagnostic performance of these strategies is well established.
⇒ While implementation studies have shown an effect on LOS, these include tightly controlled conditions and specialised environments.
⇒ There is little evidence describing their effect on LOS in UK real-world practice.

### WHAT THIS STUDY ADDS

⇒ There is heterogeneity in the approach to ACS rule-out in emergency care across the UK.
⇒ This real-world assessment of the effectiveness of ACS rule-out strategies showed little difference in LOS between strategies, despite this heterogeneity.
⇒ Suspected cardiac chest pain remains a significant proportion of ED presentations, in this study accounting for 5.3% of all adult attendances.

### HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Further research should focus on why there is little difference seen between rule-out strategies and whether they can be implemented in a manner that results in the intended reduced emergency care LOS.

## INTRODUCTION

Non-traumatic chest pain is a common ED presentation. Acute coronary syndrome (ACS) is confirmed in approximately 15% of such patients[1] and is challenging to exclude with clinical gestalt alone.[2] ACS rule-out pathways have been in a continual state of development over the past decade.[3]

To support the implementation of high-sensitivity troponin (hs-cTn) assays, numerous strategies have been developed to help facilitate rapid ACS rule-out and reduce unnecessary admissions. Most have been derived from observational studies offering little insight into clinical effectiveness in terms of length of stay (LOS). Some have been tested in implementation studies, but their real-world performance may not be similar.[4 5]

There remains heterogeneity between guideline recommendations about timing of troponin tests, rule-out thresholds and risk scores.[6–9] The real-world impact of ACS rule-out strategies on emergency care LOS is yet to be explored in the context of current UK emergency care system pressures. Although the adoption of hs-cTn assays is now well



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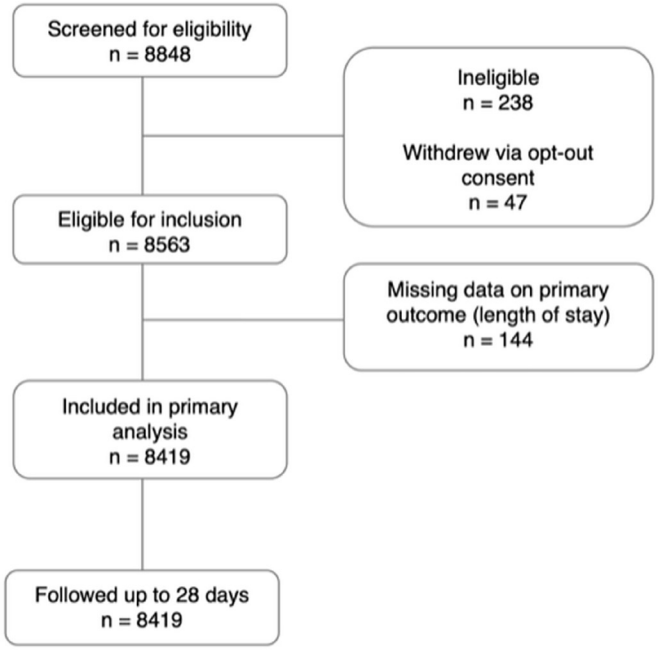


**Figure 1** Study flow chart.

established,[10] the use of, and adherence to, rapid rule-out pathways is poorly understood.

We sought primarily to describe the ACS rule-out strategies in use in the UK and establish the associations between each strategy and LOS in real-world practice. Secondary aims were to establish the frequency of acute myocardial infarction (MI) in those presenting with suspected cardiac chest pain and the distribution of alternative diagnoses.

## METHODS

### Design and setting

A multicentre observational cohort study recruiting adults presenting with suspected cardiac chest pain to 94 UK EDs. Identification of eligible patients was preferably prospective; this was also allowed retrospectively to maximise consecutive recruitment. The study was delivered by the Royal College of Emergency Medicine Trainee Emergency Research Network.

### Participants

Patients ≥18 years of age were eligible if they presented to the ED with chest pain triggering testing to rule-in or rule-out a cardiac cause. Exclusion criteria were as follows: clear non-ACS cause at presentation, another medical condition requiring admission, lacking capacity to consent, prisoners and non-English speakers where translation was unavailable.

Patients managed in a same day emergency care (SDEC) setting were included if they initially presented to the ED. Such patients were streamed to SDEC from triage or transferred after initial assessment in the ED.

Screening for eligible patients was performed by trained ED clinicians and research nurses. Clinicians confirmed eligibility where there was any doubt. Sites selected a 7-day recruitment period between 13 March and 24 April 2023. Identification of participants was preferably done prospectively by study teams within the ED, retrospective identification via ED attendance logs was also allowed to ensure identify missed cases and ensure consecutive recruitment. Recruitment was via opt-out consent with opt-out information provided during ED attendance and hospital stay or sent via mail. On receipt of an opt-out request, participants were immediately withdrawn.

**Table 1** Patient demographics and diagnoses

| Characteristic | N=8563 |
|---|---|
| Age | |
| Mean (SD) | 55 (18.2) |
| Missing n (%) | 26 (0.3) |
| Sex assigned at birth n (%) | |
| Female | 4030 (47.1) |
| Male | 4477 (52.3) |
| Other | 3 (0.0) |
| Missing | 53 (0.6) |
| Gender identity | |
| Cisgender, n (%) | 8549 (99.8) |
| Non-binary, n (%) | 10 (0.1) |
| Transgender, n (%) | 4 (0.0) |
| Ethnicity, n (%) | |
| Asian or Asian British | 659 (7.7) |
| Black, Black British, Caribbean, African | 242 (2.8) |
| Mixed or multiple ethnic groups | 66 (0.8) |
| White | 5899 (68.9) |
| Other ethnic group | 198 (2.4) |
| Missing | 1493 (17.4) |
| ACS via fourth universal definition of MI, n (%) | 1301 (15.2) |
| Clinical discharge diagnoses, n (%) | |
| Cardiovascular | |
| STEMI | 120 (1.4) |
| NSTEMI | 386 (4.5) |
| Unstable angina | 260 (3.0) |
| Unspecified ACS | 137 (1.6) |
| Stable angina | 587 (6.9) |
| Non-specific chest pain | 342 (4.0) |
| Other cardiac | 930 (10.9) |
| Aortic dissection | 9 (0.1) |
| Respiratory | |
| PE | 116 (1.4) |
| LRTI/Pneumonia | 481 (5.6) |
| Pneumothorax | 11 (0.1) |
| Other respiratory | 157 (1.8) |
| Gastrointestinal | 799 (9.3) |
| Musculoskeletal | 1298 (15.2) |
| Haematology/Oncology/Dermatology | 38 (0.4) |
| Psychiatric/Toxicology | 319 (3.7) |
| No abnormality detected | 1648 (19.2) |
| Other | 794 (9.3) |
| Missing | 131 (1.5%) |

ACS, acute coronary syndrome; LRTI, lower respiratory tract infection; MI, myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction; PE, pulmonary embolism; STEMI, ST-elevation myocardial infarction.

### Outcome measures

The primary outcome was emergency care (ED and SDEC) LOS. The secondary outcomes were frequency of acute MI as per the fourth universal definition of MI,[11] clinical discharge diagnosis as recorded in the patient's notes, time to be seen (TTBS) and disposition from the ED.

The central study team determined which participants, across the whole cohort regardless of disposition, met the fourth

**Table 2** ACS rule-out strategies in use

| Serial troponin strategy: recommended time between tests | Single troponin strategy: minimum time from symptoms | Sites N (%) |
|---|---|---|
| 0–1 hour | 0 hour | 7 (7.4) |
| | 3 hours (a) | 13 (13.8) |
| | 6 hours | 2 (2.1) |
| 0–2 hours | 0 hour | 1 (1.1) |
| | 1 hour | 4 (4.3) |
| | 3 hours (b) | 4 (4.3) |
| | 6 hours | 1 (1.1) |
| | 12 hours | 1 (1.1) |
| | No single rule-out recommendation in guideline | 3 (3.2) |
| 0–3 hours | 0 hour (c) | 5 (5.3) |
| | 1 hour | 3 (3.2) |
| | 2 hours (d) | 16 (17.0) |
| | 3 hours | 10 (10.6) |
| | 6 hours (e) | 14 (14.9) |
| | 12 hours | 1 (1.1) |
| | No single rule-out recommendation in guideline | 3 (3.2) |
| 0–6 hours | 6 hours | 1 (1.1) |
| | No single rule-out recommendation in guideline | 2 (2.1) |
| 0–12 hours | No single rule-out recommendation in guideline | 1 (1.1) |
| 0 variable | 3 hours | 1 (1.1) |
| No guideline | No guideline | 1 (1.1) |

Single troponin strategies are grouped by minimum time from symptom onset after which ACS could be ruled out with a single sufficiently low troponin. Serial troponin strategies are grouped by recommended time between tests.
Rule-out guidelines: (a) ESC 0–1 hour algorithm, (b) ESC 0–2 hours algorithm, (c) T-MACS (Troponin-only Manchester Acute Cornary Syndromes Decision Aid), (d) High-STEACS (High-Sensitivity Troponin in the Evaluation of patients with suspected Acute Coronary Syndrome), (e) ESC 0–3 hours algorithm.
ACS, acute coronary syndrome; ESC, European Society of Cardiology.

universal definition from troponin results, symptoms, ECG and further investigation findings such as echocardiography, angiography and cardiac imaging collected by site teams. A rise or fall of 50% of the 99th centile for the troponin assay used was considered significant.[12]

## Data sources

Local study teams collected LOS, TTBS and clinical discharge diagnoses from ED systems and discharge summaries. Investigation results, including troponin results, and ECG findings were collected from pathology reporting systems and patient records. Anonymised patient data were entered into Research Electronic Data Capture, a General Data Protection Regulation compliant database.[13]

Sites submitted guidelines and completed a site-level survey from which two members of the central study team extracted rule-out strategy details including troponin assay, intended troponin timings and risk scores. Local teams examined patient notes to determine whether a risk score result was documented. Sites also submitted the overall number of adult ED attendances during their recruitment period. To report LOS in relation to ACS rule-out strategy, sites were grouped in terms of single and serial troponin rule-out approach. Single troponin strategies were grouped by minimum time from symptom onset after which ACS could be ruled out with a single sufficiently low troponin. Serial troponin strategies were grouped by recommended time between tests.

Participants were followed up to 28 days after ED presentation to collect results of investigations such as angiography and to record discharge diagnosis for those admitted to hospital. Working diagnosis at 28 days was recorded from hospital notes for those still admitted.

## Study size

No sample size calculation was included in the study design. Based on engagement with previous TERN studies, we aimed to recruit from 100 EDs. Chest pain has previously been estimated to account for 6% of UK ED attendances.[1] It was estimated that 100 sites would therefore recruit 10 500 patients.

## Statistical methods

Patient characteristics are reported using number (n) and proportion (%) for categorical variables and median and IQR for continuous variables. LOS was defined as time from arrival to discharge or admission in minutes and summarised using median and IQR for each single and serial troponin rule-out strategy for all patients and separately by disposition. Patients were excluded from the LOS analysis if they had missing disposition, emergency care LOS equivalent to hospital stay or emergency care LOS was missing.

Linear mixed effects models were used to assess the association between rule-out strategies and LOS, with random effects to account for clustering of patients within sites. LOS was log-transformed to address non-normality of model residuals. Two models were applied. Model 1 assessed the association between initial troponin timing strategy and LOS in patients with a single troponin measure. Model 2 assessed association between serial troponin timing strategy and LOS in patients who underwent more than one troponin test.

Troponin timing strategy was entered as an unordered categorical variable in both models. In model 1, this variable represented the minimum time from symptoms after which ACS could be ruled out with a single sufficiently low troponin. In model 2, this variable represented the recommended time between serial troponin tests. Both models also included patient disposition (admitted or discharged), and the interaction between troponin timing and disposition as fixed effects to allow the effect of troponin timing on LOS to be assessed separately for admitted and discharged patients.

Estimated marginal mean (and 95% CIs) was calculated from the resulting model for each rule-out strategy, separately for admitted and discharged patients. The marginal means represent the mean LOS for each strategy adjusted for other factors in the model to allow for comparison between groups. Marginal means, their CIs and p values were calculated on the log scale and back-transformed to the original scale. Post hoc tests were used to identify which pairs of rule-out strategies had significantly different LOS. P values from the post hoc tests were adjusted for multiple comparisons using Tukey's method.

All analyses were conducted using R V.4.2.3. Study findings are reported in line with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[14]

## Missing data

Sites were contacted to complete key missing or clearly erroneous data. Apart from disposition, participants were not excluded from the analysis based on missing data.

## RESULTS

### Participants

In total, 8610 patients met inclusion criteria at 94 UK sites (online supplemental table 1) and 47 patients opted out. 8563 eligible patients were therefore recruited and 8419 included in the primary LOS analysis (figure 1). Patient demographics are shown in table 1.

### ACS rule-out strategies

Almost all sites used an hs-cTn assay, with hs-cTn-T used at 50 (53.2%) sites and hs-cTn-I at 43 (45.8%). One site used a point-of-care troponin assay in an urgent care centre linked to a type 1 ED. Further detail on troponin assays is included in online supplemental table 2.

There was heterogeneity in the serial troponin rule-out strategies (table 2,online supplemental table 3). A 0–1 hour strategy was in use at 22 (23.4%) sites, all using the ESC algorithm.[8] A 0–2 hour strategy was in use at 12 (12.8%) sites, four (4.3%) using the 99th centile and eight using the ESC algorithm.[8] A 0–3 hour strategy was in use at 54 (57.4%) sites, 47 (50.0%) using the 99th centile as part of either the European Society of Cardiology (ESC) algorithm[15] or the High-STEACS pathway,[16] five (5.3%) using the T-MACS pathway.[17] Three (3.2%) sites used 0–6 hours troponin timings with the 99th centile as the rule-out threshold. One (1.1%) site used 0–12 hours with the 99th centile as the rule-out threshold.

There was similar heterogeneity in the single troponin rule-out strategies (table 2, online supplemental table 3 online supplemental file 1). Eight (8.5%) sites allowed rule-out regardless of time from symptom onset with a troponin below (or near) the limit of detection (LOD). Seven (7.4%) sites used the LOD at ≥1 hour; 16 (17.0%) sites used the LOD at ≥2 hours; 27 (28.7%) sites allowed rule-out at ≥3 hours, 24 (25.5%) using the LOD and three (3.2%) using the 99th centile; 17 (18.1%) sites allowed rule-out at ≥6 hours, three (3.2%) using the LOD and 14 using the 99th centile. Two (2.1%) sites used the 99th centile at ≥12 hours. Five (5.3%) sites used the T-MACS pathway. Four (4.3%) sites did not have guidelines including recommendations on single troponin rule-out.

One (1.1%) site had no guideline and both serial and initial troponin rule-out strategy was left to the discretion of the assessing clinician.

A risk score was included in the guideline at 55 (58.5%) sites, from which 5668 patients were recruited. The most commonly used was the HEART score[18] (History, ECG, Age, Risk factors and Troponin, 42 sites, 44.7%), followed by T-MACS[17] (Troponin-only Manchester Acute Coronary Syndrome Decision Aid, five sites, 5.3%), TIMI[19] (Thrombolysis in Myocardial Infarction, four sites, 4.3%), Angina score (locally developed, two sites, 2.1%) and EDACS[20] (Emergency Department Assessment of Chest Pain Score, two sites, 2.1%). No score was documented in 77.5% of these patients (4390/5668, missing data in 424).

### Disposition from the ED

Discharge from emergency care (ED or SD) occurred in 69.3% (5934/8563) of patients (figure 2). A single troponin test was performed in 59.1% (5058/8563) and 48.8% (4179/8563) were discharged after only one troponin. 24.4% (2087/8563) were managed in an SDEC setting having been streamed there from triage or transferred after initial ED assessment.

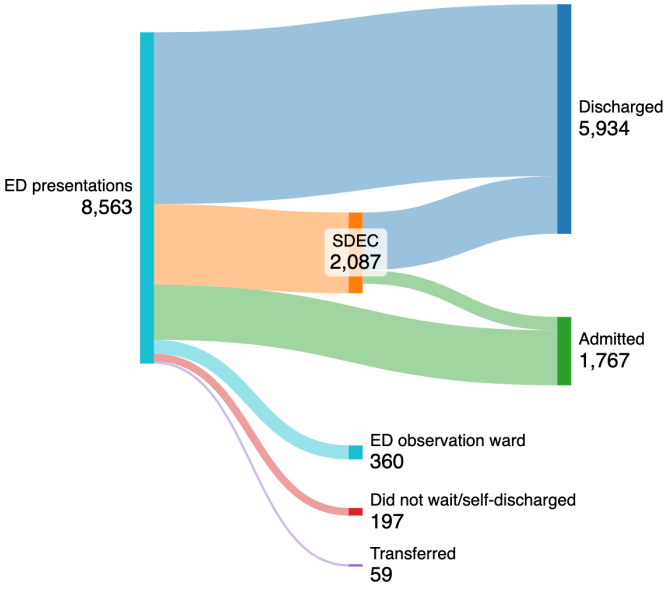


**Figure 2** Sankey diagram: patient disposition and same day emergency care (SDEC) setting use.

### Emergency care length of stay

Median LOS was 333 min (n=8419 IQR 225–510.5) for all patients, 313 min (n=6201, IQR 221–451) for those discharged and 460 min (n=2166, IQR 239.75–776.25) for those admitted. Median TTBS was 120 min (n=8086, IQR 57–212).

Median LOS and TTBS are shown in table 3 and visualised in figure 3. Considering single troponin rule-out strategies by minimum time from symptoms to first troponin test, median LOS was as follows: 0 hour; 287 min (IQR 206–434), 1 hour; 344.5 min (IQR 233–571.75), 2 hours; 306 min (IQR 211–455), 3 hours; 345 min (IQR 230–533), 6 hours; 346 min (IQR 233–512.75), 12 hours; 287 min (IQR 207.5–392), T-MACS; 379 min (IQR 250–602.5), no guideline; 339 min (IQR 234.5–512.75). Considering serial troponin strategies by intended time between troponins, median LOS was as follows: 0–1 hour; 313 min (IQR 216–492), 0–2 hours; 324 min (IQR 224–503), 0–3 hours; 344 min (IQR 229–523), 0–6 hours; 327.5 min (IQR 224–513.25), 0–12 hours; 266.5 min (IQR 190–527.25), 0 variable; 344.5 min (IQR 262–467), no guideline; 322 min (IQR 229–449).

In patients requiring only a single troponin test (n=4968), mixed effects modelling identified an association between initial troponin strategy and ED LOS in admitted (p<0.001) but not discharged (p=0.23) patients. In patients requiring two or more troponin tests (n=2942), the model to assess the association between serial troponin strategy and LOS revealed no evidence of an association between serial troponin strategy and ED LOS in admitted (p=0.20) nor discharged patients (p=0.41). Estimated means and model coefficients are included in online supplemental tables 4-6.

Median TTBS was 120 min (IQR 57–212) and median time from arrival to the receipt of the first sample in the laboratory was 87 min (IQR 54–141).

### Diagnoses

The fourth universal definition of MI was met in 15.2% (1301/8563) of patients. ACS, or probable ACS, was the clinical discharge diagnosis or working diagnosis at 28 days in 10.5% (903/8563) (table 1).

**Table 3** Emergency care LOS (in minutes) and time to be seen by rule-out strategy

| | Sites n | Patients n | LOS missing n | LOS overall Median (IQR) | LOS admitted Median (IQR) | LOS, discharged Median (IQR) | Time to be seen Median (IQR) |
|---|---|---|---|---|---|---|---|
| Single troponin rule-out strategies | | | | | | | |
| Time from onset | | | | | | | |
| 0 hour | 8 | 905 | 18 | 287 (206, 434) | 378 (216, 662.75) | 270.5 (203.75, 387.5) | 103 (54, 168) |
| 1 hour | 7 | 552 | 6 | 344.5 (233, 571.75) | 327.5 (195, 822.25) | 345 (251.5, 513.75) | 95 (47.5, 202.5) |
| 2 hours | 16 | 1430 | 20 | 306 (211, 455) | 429 (227.25, 682.75) | 279 (208, 396.5) | 91.5 (35, 177.75) |
| 3 hours | 27 | 2245 | 41 | 345 (230, 533) | 481 (275.5, 880.5) | 317 (221, 469) | 132 (66, 238) |
| 6 hours | 20 | 1906 | 35 | 346 (233, 512.75) | 437.5 (239, 771) | 332 (230.75, 465.25) | 129 (68, 217) |
| 12 hours | 2 | 115 | 0 | 287 (207.5, 392) | 415 (262, 700) | 245.5 (192.75, 345) | 125 (50, 177.75) |
| T-MACS | 5 | 672 | 6 | 379 (250, 602.5) | 584 (347.25, 957.75) | 360 (240, 518.5) | 151.5 (74, 277) |
| No guideline | 9 | 594 | 18 | 339 (234.5, 512.75) | 514 (327, 817.5) | 312 (223, 450) | 125.5 (54, 220.75) |
| Serial troponin rule-out strategies | | | | | | | |
| Timing of serial samples | | | | | | | |
| 0–1 hour | 22 | 2160 | 59 | 313 (216, 492) | 449 (266.25, 772) | 291 (210.75, 427.25) | 111 (56, 192) |
| 0–2 hours | 12 | 802 | 7 | 324 (224, 503) | 360 (196.5, 652) | 322 (235, 444.25) | 89 (44.5, 161.5) |
| 0–3 hours | 54 | 5022 | 70 | 344 (229, 523) | 484 (252, 813) | 322 (224, 460.25) | 127 (60, 226.5) |
| 0–6 hours | 3 | 228 | 4 | 327.5 (224, 513.25) | 456 (254.5, 699.25) | 308.5 (208.5, 487.25) | 146.5 (81, 290.75) |
| 0–12 hours | 1 | 22 | 2 | 266.5 (190, 527.25) | 938 (728, 1363) | 218 (181, 337) | 96 (45, 151.75) |
| 0 variable | 1 | 94 | 2 | 344.5 (262.25, 466.5) | 328 (193, 514.5) | 354.5 (280.5, 438) | 134 (28, 229) |
| No guideline | 1 | 91 | 0 | 322 (228.5, 449) | 466 (319, 599) | 297 (221.5, 402) | 185 (86, 227.5) |

Single troponin rule-out strategies are grouped by minimum time from symptoms after which ACS could be ruled out with a single sufficiently low troponin. Serial troponin rule-out strategies are grouped by intended time between tests.
ACS, acute coronary syndrome; LOS, length of stay.

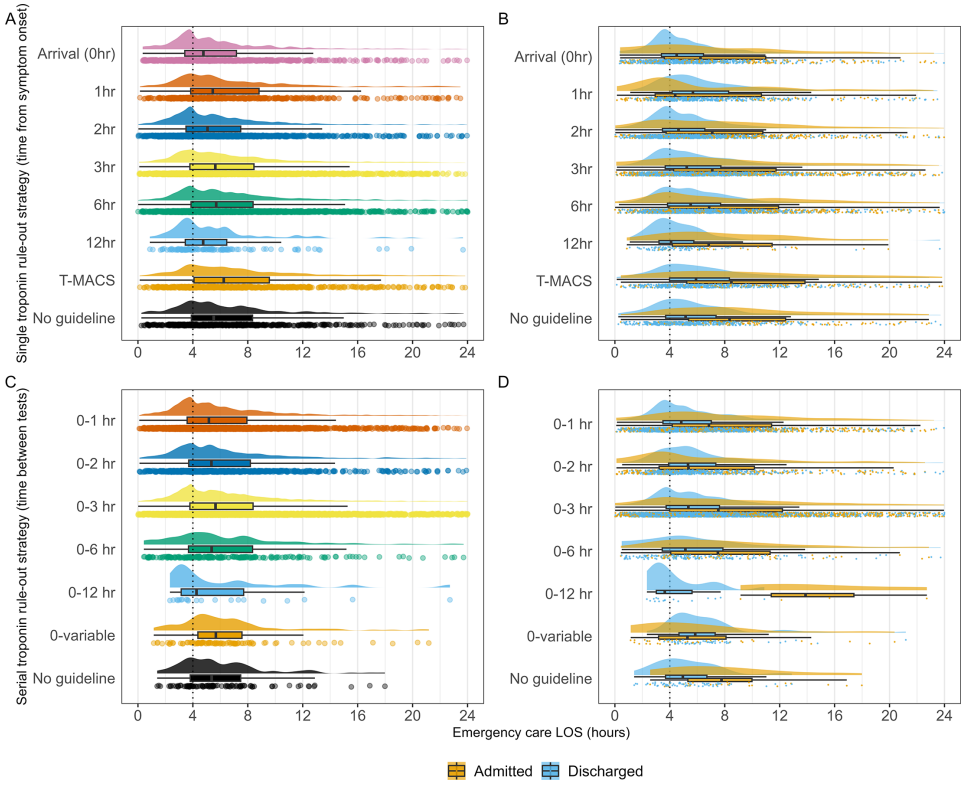


**Figure 3** Emergency care length of stay by rule-out strategy visualised as raincloud plots. Box and whisker plots show median and IQR. Single troponin rule-out strategies are grouped by minimum time from symptoms after which ACS could be ruled out with a single sufficiently low troponin. Serial troponin rule-out strategies are grouped by intended time between tests. (A) Single troponin rule-out strategies, all patients. (B) Single troponin rule-out strategies by disposition (admitted or discharged). (C) Serial troponin rule-out strategies, all patients. (D) Serial troponin rule-out strategies by disposition (admitted or discharged).

## DISCUSSION

Our study of ACS rule-out strategies in 94 UK EDs saw widespread adoption of hs-cTn assays and rapid rule-out strategies with heterogeneity in recommended troponin timings. There was little difference in median LOS between strategies. The mixed effects models described a significant difference in LOS among admitted patients only, who, given the study design, will not have had ACS successfully ruled out. The median LOS was just over 5.5 hours overall and just under 5.5 hours for those discharged. A representative cohort was recruited, with a similar proportion of patients meeting MI diagnostic criteria and the study cohort accounting for a similar proportion of overall ED attendances as previously seen.[1]

This study demonstrates continued adoption of hs-cTn and rapid ACS rule-out strategies. A survey of English hospitals published in 2020 reported 84% using hs-cTn and 75% employing rapid rule-out serial troponin approaches (60% 0–3 hours, 4% 0–2 hours, 9% 0–1 hours).[10] In comparison, our study reports near-universal hs-cTn use and 94% of sites employing rapid rule-out serial troponin approaches (57.4% 0–3 hours, 12.8% 0–2 hours, 23.4% 0–1 hour). Our study also reports widespread adoption of single troponin discharge guidelines (89.4%) with 8.5% of sites allowing ACS rule-out based on an arrival troponin below the LOD regardless of symptom timing. Rapid rule-out approaches appear widely acceptable to clinicians with 69.3% of patients discharged from the ED or SDEC, 48.8% after a single troponin.

Previous studies assessing the impact of rapid rule-out strategies have seen effects on LOS; however, these were not UK based and included specialised settings such as a chest pain assessment units.[21] These studies have demonstrated a reduced LOS with the introduction of hs-cTn within 0–3 hours strategies and further reductions with 0–2 hours and 0–1 hour strategies.[21–24] Median LOS as low as 2.5 hours has been seen with the ESC 0–1 hour strategy, notably in the context of good pathway adherence and median time between collection of first and second troponin sample of 65 min.[22]

The lack of difference in LOS between rule-out strategies in our study likely reflects system pressures and ED crowding. Delays in seeing a clinical decision-maker and difficulties in achieving intended troponin timings are likely contributory factors. Median TTBS was 120 min (IQR 57–212) and median time from arrival to the receipt of the first sample in the laboratory was 87 min (IQR 54–141). Initial troponin was collected as early as 22 min after arrival in a German study testing the ESC 0–1 hour strategy.[25] Adherence to intended troponin timings has been an issue with implementation of this strategy in the UK.[26] UK NHS laboratories are equally subject to intense demand and experience delays in analysis. Variation in TTBS in our study between rule-out strategies may confound the mixed effect model LOS analysis, although the model included a random effect for site which will partly mitigate this. The impact of system pressures was recognised in the LoDED study, a UK randomised controlled trial (RCT) considering single troponin rule-out based on an arrival test irrespective of symptom onset time.[4] A UK-based RCT as part of the High-STEACS study did however see a reduction in median LOS of up to a third in all patients and by half in those discharged.[5] The low rate of risk score documentation potentially implies pathway non-adherence alongside the issue of system pressures.

Our study saw only 30.1% of patients with a LOS below the current UK 4-hour target. The influence of this target is noticeable in the visualisation of LOS, with a spike at, or just before 4 hours, especially among discharged patients, across rule-out strategies (figure 2). The LOS visualisation also demonstrates a shorter LOS in those attending the site with a 0–12 hour strategy likely due to higher rates of inpatient admission for serial testing. This site accounted for a small number of patients (n=22) and LOS was not seen to be significantly different to other strategies in the mixed effects modelling.

While our study did not assess diagnostic performance, both serial and single troponin rapid rule-out approaches using hs-cTn have been seen to be highly sensitive with low false negative rates.[4 5 27 28]

A highly cited single-centre UK study published in 2005 reported chest pain accounting for 6.0% of ED attendances with ECG evidence of ACS in 11.0% and clinically diagnosed ACS in 34.5%.[1] Our study provides a more current and generalisable estimate of these figures. We observed suspected cardiac chest pain accounting for 5.3% (8563/160 669) of adult ED attendances, 15.2% meeting the fourth universal definition of MI and a clinical discharge diagnosis of ACS in 10.5%.

Future research should explore why ACS rule-out strategies are not performing as intended, the impact of ED crowding and whether pathway non-adherence contributes. Researchers and clinical teams should consider whether rapid rule-out strategies can be implemented in a manner that results in reduced LOS, including the role of SDEC. The health economic impact of the widespread adoption of rapid rule-out strategies should also be considered.

### Limitations and strengths

Our study did not measure major adverse cardiovascular events beyond initial presentation or assess rule-out strategy safety. Follow-up was limited to diagnostic investigations relevant to the fourth universal definition of MI. ECGs were not centrally reviewed and local senior clinician consensus was relied on. MI diagnostic rates were similar to those in a comparable cohort.[1] The study recruited over 6 weeks and therefore may be affected by seasonal variation in emergency care activity.

Due to the strength of the TERN model, our study recruited from a large number of UK EDs and is therefore highly generalisable within UK settings. To maximise consecutive recruitment, our study used flexible recruitment dates and prospective and retrospective identification of participants, consistent with other observational studies recruiting high-frequency ED presentations.[29] The proportion of overall presentations recruited was consistent with previous similar work despite a greater number of sites.[1]

## CONCLUSIONS

There is heterogeneity in ACS rule-out in the UK with widespread adoption of a variety of rapid rule-out strategies. Despite this heterogeneity, little difference is seen in LOS between approaches, and the median LOS is over 5.5 hours. Suspected cardiac chest pain continues to represent a significant proportion of ED attendances with the majority of patients discharged from the ED and SDEC. Future research should consider why rapid rule-out strategies are underperforming and whether they can be implemented in a manner that results in the intended reduced LOS.

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## REFERENCES

1 Goodacre S, Cross E, Arnold J, *et al*. The health care burden of acute chest pain. *Heart* 2005;91:229–30.
2 Body R, Cook G, Burrows G, *et al*. Can emergency physicians "rule in" and "rule out" acute myocardial infarction with clinical judgement? *Emerg Med J* 2014;31:872–6.
3 National Institute of Clinical Excellence. *High-sensitivity troponin tests for the early rule out of NSTEMI*. 2020.
4 Carlton EW, Ingram J, Taylor H, *et al*. Limit of detection of troponin discharge strategy versus usual care: randomised controlled trial. *Heart* 2020;106:1586–94.
5 Shah ASV, Anand A, Strachan FE, *et al*. High-sensitivity troponin in the evaluation of patients with suspected acute coronary syndrome: a stepped-wedge, cluster-randomised controlled trial. *Lancet* 2018;392:919–28.
6 Amsterdam EA, Wenger NK, Brindis RG, *et al*. 2014 AHA/ACC guideline for the management of patients with non-ST-elevation acute coronary syndromes: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation* 2014;130:2354–94.
7 National Institute of Clinical Excellence. *Recent-onset chest pain of suspected cardiac origin: assessment and diagnosis*. 2016.
8 Collet J-P, Thiele H, Barbato E, *et al*. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. *Eur Heart J* 2021;42:1289–367.
9 Chew DP, Scott IA, Cullen L, *et al*. National Heart Foundation of Australia & Cardiac Society of Australia and New Zealand: Australian Clinical Guidelines for the Management of Acute Coronary Syndromes 2016. *Heart Lung Circ* 2016;25:895–951.
10 Thapa S, Wong R, Goodacre S. Implementation of rapid rule out of myocardial infarction using high-sensitivity troponin: cross-sectional survey of English hospitals. *Emerg Med J* 2020;37:229–31.
11 Thygesen K, Alpert JS, Jaffe AS, *et al*. Fourth Universal Definition of Myocardial Infarction (2018). *J Am Coll Cardiol* 2018;72:2231–64.
12 Reichlin T, Irfan A, Twerenbold R, *et al*. Utility of absolute and relative changes in cardiac troponin concentrations in the early diagnosis of acute myocardial infarction. *Circulation* 2011;124:136–45.
13 Harris PA, Taylor R, Thielke R, *et al*. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377–81.
14 von Elm E, Altman DG, Egger M, *et al*. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* 2007;147:573–7.
15 Roffi M, Patrono C, Collet J-P, *et al*. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2016;37:267–315.
16 Chapman AR, Anand A, Boeddinghaus J, *et al*. Comparison of the Efficacy and Safety of Early Rule-Out Pathways for Acute Myocardial Infarction. *Circulation* 2017;135:1586–96.
17 Body R, Carlton E, Sperrin M, *et al*. Troponin-only Manchester Acute Coronary Syndromes (T-MACS) decision aid: single biomarker re-derivation and external validation in three cohorts. *Emerg Med J* 2017;34:349–56.
18 Six AJ, Backus BE, Kelder JC. Chest pain in the emergency room: value of the HEART score. *Neth Heart J* 2008;16:191–6.
19 Antman EM, Cohen M, Bernink PJ, *et al*. The TIMI risk score for unstable angina/non-ST elevation MI: A method for prognostication and therapeutic decision making. *JAMA* 2000;284:835–42.
20 Than M, Flaws D, Sanders S, *et al*. Development and validation of the Emergency Department Assessment of Chest pain Score and 2 h accelerated diagnostic protocol. *Emerg Med Australas* 2014;26:34–44.
21 Stoyanov KM, Hund H, Biener M, *et al*. RAPID-CPU: a prospective study on implementation of the ESC 0/1-hour algorithm and safety of discharge after rule-out of myocardial infarction. *Eur Heart J Acute Cardiovasc Care* 2020;9:39–51.
22 Twerenbold R, Costabel JP, Nestelberger T, *et al*. Outcome of Applying the ESC 0/1-hour Algorithm in Patients With Suspected Myocardial Infarction. *J Am Coll Cardiol* 2019;74:483–94.
23 Twerenbold R, Jaeger C, Rubini Gimenez M, *et al*. Impact of high-sensitivity cardiac troponin on use of coronary angiography, cardiac stress testing, and time to discharge in suspected acute myocardial infarction. *Eur Heart J* 2016;37:3324–32.
24 Than MP, Pickering JW, Dryden JM, *et al*. ICare-ACS (Improving Care Processes for Patients With Suspected Acute Coronary Syndrome): A Study of Cross-System Implementation of a National Clinical Pathway. *Circulation* 2018;137:354–63.
25 Neumann JT, Sörensen NA, Schwemer T, *et al*. Diagnosis of Myocardial Infarction Using a High-Sensitivity Troponin I 1-Hour Algorithm. *JAMA Cardiol* 2016;1:397–404.
26 Couch LS, Sinha A, Navin R, *et al*. Rapid risk stratification of acute coronary syndrome: adoption of an adapted European Society of Cardiology 0/1-hour troponin algorithm in a real-world setting. *Eur Heart J Open* 2022;2:oeac048.
27 Wildi K, Boeddinghaus J, Nestelberger T, *et al*. Comparison of fourteen rule-out strategies for acute myocardial infarction. *Int J Cardiol* 2019;283:41–7.
28 Chiang C-H, Chiang C-H, Lee GH, *et al*. Safety and efficacy of the European Society of Cardiology 0/1-hour algorithm for diagnosis of myocardial infarction: systematic review and meta-analysis. *Heart* 2020;106:985–91.
29 McLatchie R, Reed MJ, Freeman N, *et al*. Diagnosis of Acute Aortic Syndrome in the Emergency Department (DAShED) study: an observational cohort study of people attending the emergency department with symptoms consistent with acute aortic syndrome. *Emerg Med J* 2024;41:136–44.
30 Smith J, Keating L, Flowerdew L, *et al*. An Emergency Medicine Research Priority Setting Partnership to establish the top 10 research priorities in emergency medicine. *Emerg Med J* 2017;34:454–6.