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Rapid rule-out of acute myocardial infarction using the 0/1-hour algorithm for cardiac troponins in emergency primary care: the OUT-ACS implementation study

Tonje R. Johannessen[1,2*], Sven Eirik Ruud[2], Anne Cecilie K. Larstorp[3,4], Dan Atar[4,5], Sigrun Halvorsen[4,5], Beate Nilsen[2] and Odd Martin Vallersnes[1,2]

Abstract

Background Acute chest pain has a high hospital referral rate due to the limited ability to exclude acute myocardial infarction (MI) in primary care. We aimed to evaluate the effectiveness of implementing the European Society of Cardiology (ESC) 0/1-hour algorithm for high-sensitivity cardiac troponin T (hs-cTnT) testing in emergency primary care.

Methods In a prospective study (April-October 2023), the ESC 0/1-hour algorithm for hs-cTnT was implemented at the main emergency primary care clinic in Oslo, Norway. All consecutive patients ≥ 18 years with acute non-traumatic chest pain having hs-cTnT measurements done were registered. The patients were assigned to MI rule-out, rule-in, or further observation using the algorithm. Patients in the observation group had a 4-hour hs-cTnT measurement done. The outcome measures were the proportion of patients conclusively assessed by the protocol, personnel adherence, reduction in length of stay (LOS) compared to the previous 0/4-hour protocol (historical cohort), and disposition.

Results During six months, hs-cTnT measurements were conducted in 32.6% (995/3053) of chest pain patients (median age 58 years (IQR 45–68); 50.6% female). A single hs-cTnT measurement assigned 24.1% ($n = 240/995$) towards MI rule-out, suitable for early discharge, increasing to 63.8% after adding a 1-hour measurement. The observation group (319/995, 32.1%) was reduced to 23.0% (229/995) after a 4-hour measurement. A total of 77.0% of the patients were conclusively assigned to either rule-out or rule-in group. The personnel adhered well to the new protocol, with a median 1-hour sampling interval of 63 min (IQR 60–66) and 4.6 h (IQR 4.1–5.5) for the 4-hour sample. The protocol was misinterpreted or overruled in 8.6% of the cases. Compared to the previous 0/4-hour protocol, LOS was reduced by -2.2 h (95% confidence intervals − 2.6 to -1.7). After completed assessment at the clinic, 14.8% were transferred to hospital, where 20 patients were diagnosed with an MI. The remaining patients were sent home or managed in the outpatient setting; any occurrence of MIs in this group is unknown.

*Correspondence:
Tonje R. Johannessen
t.r.johannessen@medisin.uio.no

Full list of author information is available at the end of the article

Conclusions The ESC 0/1-hour algorithm effectively assesses low-risk acute chest pain in emergency primary care, reinforcing its gatekeeper role by managing these patients at a lower level of care.

Keywords Primary care, Acute myocardial infarction, Biomarkers, Diagnostics, Troponin, Chest pain

Background

The current heavy burden on emergency services results in overcrowding, especially in hospital emergency departments (ED) [1]. Acute chest pain is one of the most common symptoms that results in ED visits [2, 3]. As Norway has referral-based access to hospital EDs, almost 60% of patients with acute myocardial infarction (MI) will initially be assessed by a primary care physician [4]. However, the initial chest pain assessment often results in hospital referrals for additional diagnostic assessment due to the limited ability to provide a safe MI rule-out in the pre-hospital setting provide [5]. In the ED, serial measurement of cardiac troponins with a high-sensitivity assay can be used to rule out myocardial injury and MI [6, 7]. After hospital assessment, more than half of these patients are discharged with a non-cardiac chest pain diagnosis [2–4]. Many of these patients could have been ruled out at a lower level of care if appropriate diagnostic tools were available outside the hospital EDs.

Troponin measurement in primary care has been debated over the last decade, primarily due to safety concerns about delayed recognition and hospital referral of non-ST-segment elevation acute coronary syndrome (NSTE-ACS), but also logistical challenges in performing the serial measurements needed to distinguish acute from chronic troponin elevation [6–9]. At the main emergency primary care clinic in Oslo, Norway, cardiac biomarkers have been used since the late 1990s, introducing high-sensitivity cardiac troponin T (hs-cTnT) testing in 2009. Troponin measurement was available for patients not requiring immediate hospital admission, and the samples were sent to the hospital laboratory nearby for analysis. The troponin protocol involved two measurements, collected at a 4-6-hour interval, and was quite resource-demanding due to the prolonged observation time while waiting for the results.

In the 2015 NSTE-ACS guidelines from the European Society of Cardiology (ESC) [10], a rapid 0/1-hour algorithm for hs-cTnT interpretation was recommended to assess chest pain in the EDs [11]. In the observational OUT-ACS (One-hoUr Troponin in a low-prevalence population of Acute Coronary Syndrome) study, conducted at the clinic from 2016 to 2018, we validated the novel 0/1-hour algorithm in our low-risk cohort [12]. By applying the algorithm, we showed that 3 out of 4 patients were assigned to the large MI rule-out group with high safety (sensitivity 98.4% and negative predictive value 99.9%) [12]. With reduced ED referrals and shortened length of stay, the 0/1-hour algorithm also proved cost-effective, with almost 1800 EUR saved for each patient conclusively assessed in primary care [13]. Since then, the high safety and efficacy of the algorithm have been extensively confirmed in large multicentre studies [14–18], as well as being recommended as a preferred clinical decision pathway for assessing chest pain [7, 9]. Therefore, implementing this safe and effective approach was the preferable next step in improving chest pain assessment at the emergency primary care clinic in Oslo.

To our knowledge, the real-world application of the ESC 0/1-hour algorithm outside hospitals has not yet been investigated. In this study, we aimed to evaluate the effectiveness, personnel adherence, and patient disposition after implementing the ESC 0/1-hour algorithm in emergency primary care.

Materials and methods

Design

A six-month prospective implementation study was started on 24 April 2023, when the previously used 0/4-hour hs-cTnT protocol was replaced by the ESC 0/1-hour algorithm for hs-cTnT at the Oslo Accident and Emergency Outpatient Clinic (OAEOC), the main emergency primary care clinic in Oslo, Norway. The study was conducted as a quality improvement evaluation after implementing the new routine.

Setting

The Department of Emergency Primacy Care at the OAEOC is staffed by nurses and general practitioners on a fixed clinical rotation. It is open 24/7, with approximately 85,000 consultations annually. During the implementation study, the clinic was located four kilometres from Oslo University Hospital, with laboratory transport every four hours (03-07-11 am/pm). Patients needing supplementary blood tests for medical clearance but not needing urgent hospital admission were kept waiting at the clinic while blood samples were sent to the hospital for analysis.

Following clinical examination and an electrocardiogram (ECG), the treating physician first decides whether the chest pain has an evident non-cardiac cause (i.e., hs-cTn testing not considered relevant), or if immediate hospital referral is required (i.e., hs-cTn not performed to avoid pre-hospital delay). Patients having hs-cTnT measurements done at the clinic are typically pain-free or have resolved presenting symptoms, where either the medical history, clinical examination, or the initial ECG comprise some cardiac-suspect elements requiring

troponin measurement for a safe MI rule-out before discharge. In most cases, these patients would have been referred to a hospital ED if troponin measurements had not been available. Patients having hs-cTnT measurements were kept at the clinic in case of recurrent symptoms while awaiting the results. They would either stay in a designated waiting area or were admitted to the OAEOC observation unit, which has a capacity of 18 patients.

Participants and data collection

All consecutive patients ≥ 18 years of age having troponin measurements done at the clinic during the first six months following the implementation were included and anonymously registered for study purposes. Data were retrospectively collected from the electronic patient records, including age, sex, date/time variables, troponin results, registered diagnosis codes from the International Classification of Primary Care 2nd version (ICPC-2) [19] or International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) [20], and final disposition. We defined the ICPC-2 codes A11, K01, K74-76, L04, and R02 as chest pain-related. We also registered the diagnosis of MI from hospital discharge documents among the hospitalised patients. Due to the waiver of written informed consent, we were unable to register the occurrence of acute MIs in patients who were discharged or managed as outpatients.

Troponin measurement

For hs-cTnT measurement, venous blood samples were collected by nurses using 5 mL serum tubes by Greiner Bio-One. While awaiting the transport courier to the hospital laboratory, samples were stored at room temperature (i.e., approximately 20 °C) for a minimum of 30 min before being centrifuged at 3700 rpm for 10 min. The samples were then stored in a refrigerator until transportation.

At the Department of Medical Biochemistry at Oslo University Hospital, Ullevaal, the samples were analysed using the Cobas 8000 e801 Module Analyzer by Roche Diagnostics, Switzerland. The Elecsys Troponin T hs STAT assay has a 99th percentile upper reference limit (URL) of normal at 14 ng/L with a coefficient of variation ≤ 10% and a limit of detection and blank at 2–5 ng/L and 2.5-3 ng/L, respectively [21, 22].

The previous hs-cTnT protocol

The previous hs-cTnT protocol at the clinic involved at least two hs-cTnT measurements with a minimum sampling interval of 4–6 h. The 99th percentile of the URL of normal (i.e., > 14 ng/L for hs-cTnT) had been used as a threshold for myocardial injury in accordance with the *Third-* and later the *Fourth Universal Definition of Myocardial Infarction* [6, 23]. A significant relative change between two hs-cTnT measurements could indicate acute myocardial ischaemia (i.e., a 4-hour change > 50% if the 0-hour concentration was at or below the 99th percentile, or a change exceeding 20% if the 0-hour sample was above the 99th) [6, 23]. After considering relevant differential diagnoses, patients without elevated troponins or a significant change were considered low-risk and potentially suitable for discharge.

A historical cohort (The OUT-ACS study) [12] was used to compare the previous hs-cTnT protocol and the novel 0/1-hour algorithm when evaluating the differences in length-of-stay and efficiency.

Transition to the ESC 0/1-hour algorithm

Preparations for transitioning to the new protocol for troponin measurement were conducted over three months in close collaboration with the end-users at the clinic (i.e., nurses without laboratory expertise and primary care physicians working on fixed rotation at the clinic) and the Department of Medical Biochemistry at Oslo University Hospital, Ullevaal. Feedback on the new protocol, information material, patient flow, and potential implementation barriers was collected from the end-users. Necessary adjustments were made accordingly. With turnaround times (i.e., time from blood sampling to available lab results) typically ranging from 1.5 to 2 h, the nurses were to repeat the sampling one hour after the initial draw, ensuring the 1-hour window was not missed. The hospitals in the Oslo region were informed of the transition to the new protocol before implementation.

As the 0/1-hour algorithm uses assay-specific criteria, the 99th percentile URL was abandoned as a clinical threshold. By applying the 0/1-hour criteria, patients were assigned to either rule-out (i.e., low probability of MI; potentially suitable for early discharge), rule-in (high probability of MI; hospitalisation recommended), or the observation group (intermediate MI risk; additional testing required before decision) [7]. According to local recommendations (Fig. 1), all patients in the observation group should be considered for hospitalisation or have a third hs-cTnT measurement collected at the clinic before discharge. In the OUT-ACS protocol, the third hs-cTnT measurement was interpreted using criteria derived by Lopez-Ayala et al. [24], which previously have been externally validated in the OUT-ACS cohort [25].

Outcome measures

The primary outcome measure of this study was the effectiveness (proportion of patients triaged towards rule-out or rule-in) when applying the ESC 0/1-hour algorithm in emergency primary care. Secondary measures were staff adherence to the protocol (timing of blood samples, cases of not following the algorithm), length of stay (LOS; i.e.,

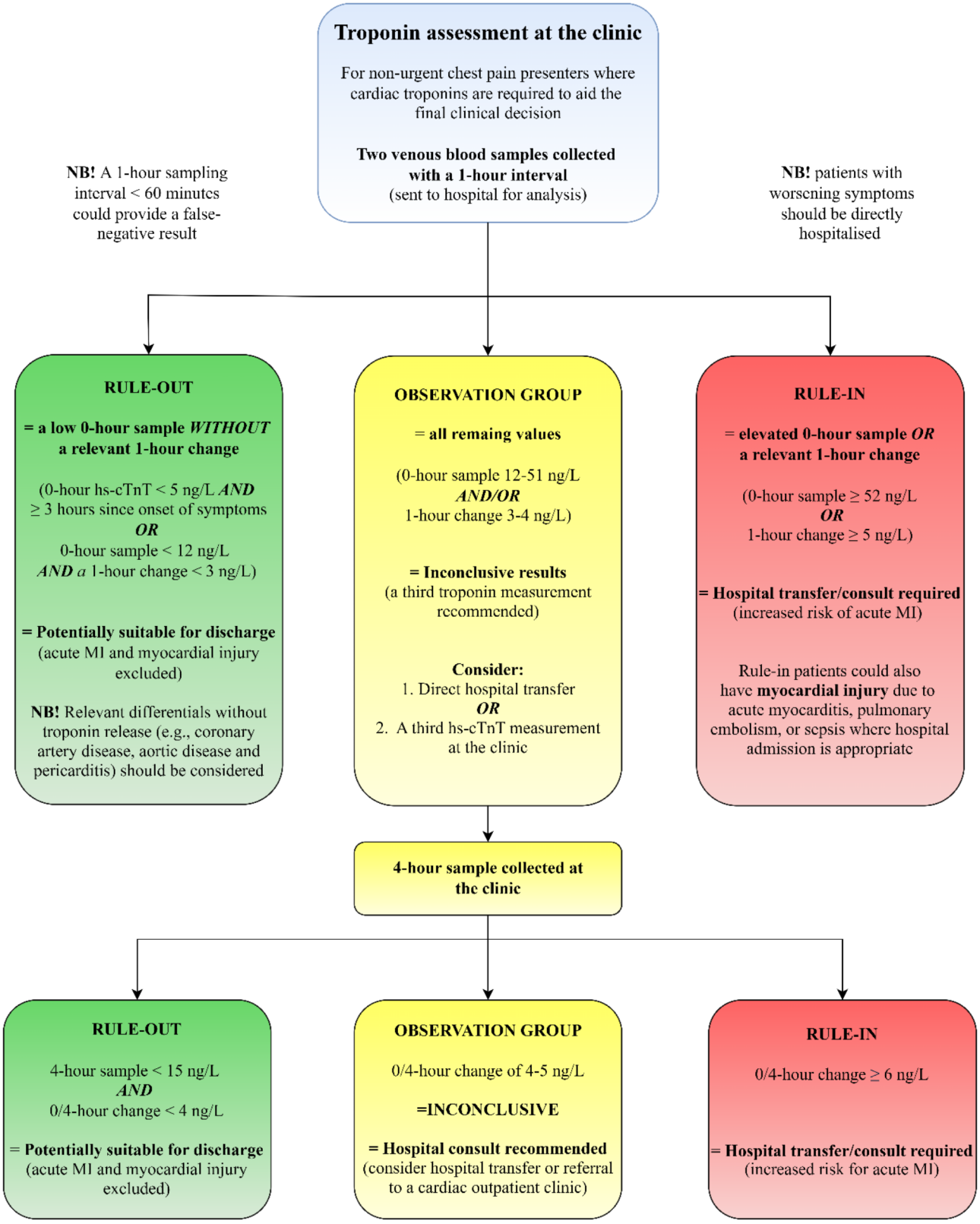

Fig. 1 The OUT-ACS protocol at the emergency primary care clinic in Oslo
hs-cTnT: high-sensitivity cardiac troponin T; MI: myocardial infarction

time from arrival to discharge), and patient disposition after conclusive assessment.

Statistical analyses

All numbers are presented as frequencies and percentages, and medians and interquartile ranges (IQR) as appropriate. Linear regression analyses, adjusted for age and sex, were performed to compare total LOS between the previous 0/4-hour protocol (i.e., the historical OUT-ACS cohort) [12] and the implemented 0/1-hour algorithm. IBM SPSS version 26.0 and MedCalc were used in the analyses. The Sankey charts were made using SankeyMATIC.com.

Results

During the first six months following the implementation, 3053 patients presented at the clinic with chest pain-related complaints, where hs-cTnT measurements were requested in 33.3% (1018/3053) of the patients. A total of 11.9% (121/1018) waited in the designated waiting area while the samples were sent to the central laboratory for analysis. The remaining patients (88.1%; 897/1018) were admitted to the observation unit, comprising 41.0% (897/2188) of all patient-stays at the observation unit during the study period.

Twenty-three patients (2.3%) had troponin measured after an electric trauma. As the aetiology of their chest complaints is not considered a potential NSTE-ACS, these patients were excluded from the remaining analyses, yielding 995 included patients. Median age was 58 years (IQR 45–68), and 50.6% ($n = 503$) were female. The included patients presented to the clinic a median of 4.2 h (IQR 1.5–17.6 h) after the onset of symptoms (Table 1).

A single troponin measurement

By applying the 0-hour criteria (Fig. 1), a single troponin measurement classified 24.1% ($n = 240$) of the patients into the direct rule-out group, potentially allowing for early discharge (Fig. 2). Among the 13 patients in this group who were sent to the hospital, none were discharged with an MI diagnosis. Conversely, 32 patients (3.2%) would have been assigned to the direct rule-in group due to an elevated cardiac troponin. The median time from the onset of symptoms to the first blood draw was 7.8 h (IQR 4.6–20.4).

The 0/1/4-hour OUT-ACS protocol

By applying the 0/1-hour criteria, 63.8% ($n = 635$ patients) were assigned to the rule-out group. A total of 4.1% ($n = 41$) ended up in the rule-in group, amongst whom 16 were diagnosed with an acute MI during hospitalisation. The remaining 32.1% ($n = 319$) of patients were triaged to the indecisive observation group, where further testing was recommended. Of these, 38 were directly hospitalised after the 1-hour result, and 26 patients were sent home against the protocol recommendations. This resulted in a third troponin measurement being collected at the clinic in 255/319 (80.0%) of the observation group patients. The 4-hour sample resulted in 111/255 additional patients being assigned towards rule-out and 11/255 more towards rule-in, leaving 133 (13.4%) patients in the observation group at the end.

Table 1 Comparison between the previous 0/4-hour protocol vs. the 0/1/4-hour OUT-ACS protocol

	Historical cohort (0/4-hour protocol) 2016–2018 [12]	**OUT-ACS implementation study cohort 2023**		
	Total *n* = 1711	**Total *n* = 995**	**0/1-hour rule-in/rule-out cases *n* = 676**	**0/1-hour observation group cases *n* = 319**
Female	47.7% ($n = 816$)	50.6% ($n = 503$)	51.5% ($n = 348$)	48.6% ($n = 155$)
Age	56 years (45–68)	58 years (46–72)	53 years (42–63)	73 years (58–83)
Symptom onset to arrival	3.8 h (1.5–12.4)	4.2 h (1.5–17.6)	4.1 h (1.5–18.3)	4.4 h (1.6–16.4)
Arrival to first blood draw	2.1 h (1.5-3.0)	2.6 h (1.8–3.7)	2.6 h (1.8–3.7)	2.6 h (1.8–3.6)
Symptom onset to first blood draw	6.6 h (4.0-14.8)	7.8 h (4.6–20.4)	7.8 h (4.5–21.7)	7.8 h (4.8–18.9)
Minutes between 0- and 1-hour sample	65 min (60–70)	63 min (60–66)	63 min (60–66)	63 min (60–65)
Hours between 0- and 4-hour sample	4.3 h (4.1–4.9)	4.6 h (4.1–5.5)	4.2 h (4.0-4.9)‡	4.6 h (4.1–5.6)
Troponin assessment time	9.5 h (7.7–13.5)	7.0 h (4.1–11.6)	6.0 h (3.9–10.0)	9.3 h (5.8–15.7)
Total LOS at the clinic	11.9 h (9.8–16.1)	9.9 h (6.8–14.8)	9.0 (6.5–12.7)	12.3 h (8.7–18.4)
Diagnosed MI	3.6% ($n = 61$)*	2.0% ($n = 20$)†	$n = 17$	$n = 3$

* Adjudicated MI diagnosis, based on all available data collected during the OUT-ACS study[12]

† Based on hospital discharge documents (occurrence of MIs among those who were not admitted were not available)

‡ $n = 38$ patients, including rule-in patients having a 4-hour measurement at the clinic and rule-out patients who were subject to unnecessary 4-hour measurements

LOS: length of stay; MI: myocardial infarction; OUT-ACS: One-hoUr Troponin in a low-prevalence population of Acute Coronary Syndrome

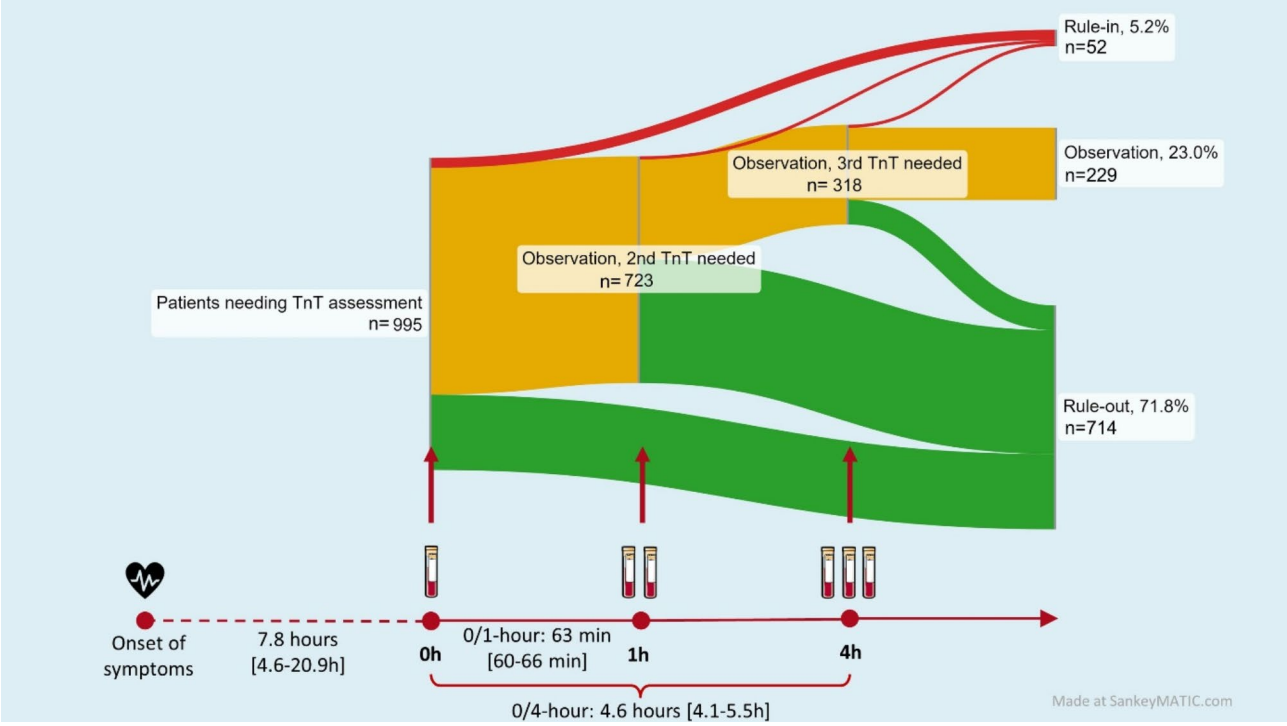

Fig. 2 Triage of patients according to the OUT-ACS protocol. The timeline below the Sankey Chart illustrates the time from the onset of symptoms to the first blood draw and the timing of the 0-, 1- and 4-hour samples

However, those triaged to the observation group who did not receive a complete 0/1/4-hour assessment (i.e., directly hospitalised ($n = 38$) or incorrectly discharged after the 0-hour ($n = 32$) or 1-hour samples ($n = 26$)), have been added to the final observation group in Fig. 2, as these were not further risk stratified at the clinic. Consequently, according to the OUT-ACS protocol (0/1/4-hour algorithm), 71.8% ($n = 714/995$) were triaged as rule-out, 5.2% ($n = 52$) as rule-in, and 23.0% ($n = 229$) remained in the observation group (Fig. 2). Hence, the total effectiveness of the algorithm (i.e., patients being conclusively assigned to either the rule-out group or rule-in group) after the 0-, 1- and 4-hour sample, where 27.3%, 68.0% and 77.0%, respectively (Fig. 2).

Length of stay

After arriving at the clinic, the median waiting time was 1.2 h (IQR 0.7–2.1 h) before the initial evaluation by the physician. The median time spent at the clinic before the first blood sampling was 2.6 h (IQR 1.8–3.7 h; Table 1). Timeline comparisons between the previous 0/4-hour protocol used at the clinic and the new 0/1/4-hour protocol are shown in Table 1. Implementing the 0/1-hour algorithm resulted in a significantly reduced LOS at the clinic compared to the previous 0/4-hour protocol. The coefficient from linear regression showed an average reduction of -2.19 h (95% CI: -2.63 to -1.75) when adjusted for age and sex. Among patients triaged as rule-out or rule-in ($n = 676/996$; 67.9%) by the 0/1-hour algorithm, the reduction was even larger (i.e., -3.10 h (95% CI -3.58 to -2.62)).

Disposition

After the final decision, 14.8% of the patients were transferred to a hospital for further observation and treatment (Fig. 3), where 20 patients were diagnosed with an acute MI (19 triaged as rule-in, and 1 to the observation group). The remaining patients were sent home or managed in the outpatient setting: 39.9% without further follow-up, 39.2% were advised to see their regular general practitioner (GP), 1.1% were admitted at the local municipal short-term facility, and 5.0% were referred to a hospital cardiovascular outpatient clinic.

Personnel adherence

The personnel adhered well to the algorithm, with a median sampling interval of 63 min (IQR 60–66) and 4.6 h (IQR 4.1–5.5) for the 1- and 4-hour measurements, respectively (Fig. 2; Table 1).

The algorithm was ignored, misinterpreted, or overruled in 8.6% ($n = 86$) of the cases discharged home. According to the OUT-ACS protocol, 25 of these patients were assigned to the rule-out group, 57 to the observation group, and 4 to the rule-in group. Further details and comments are described in Table 2:

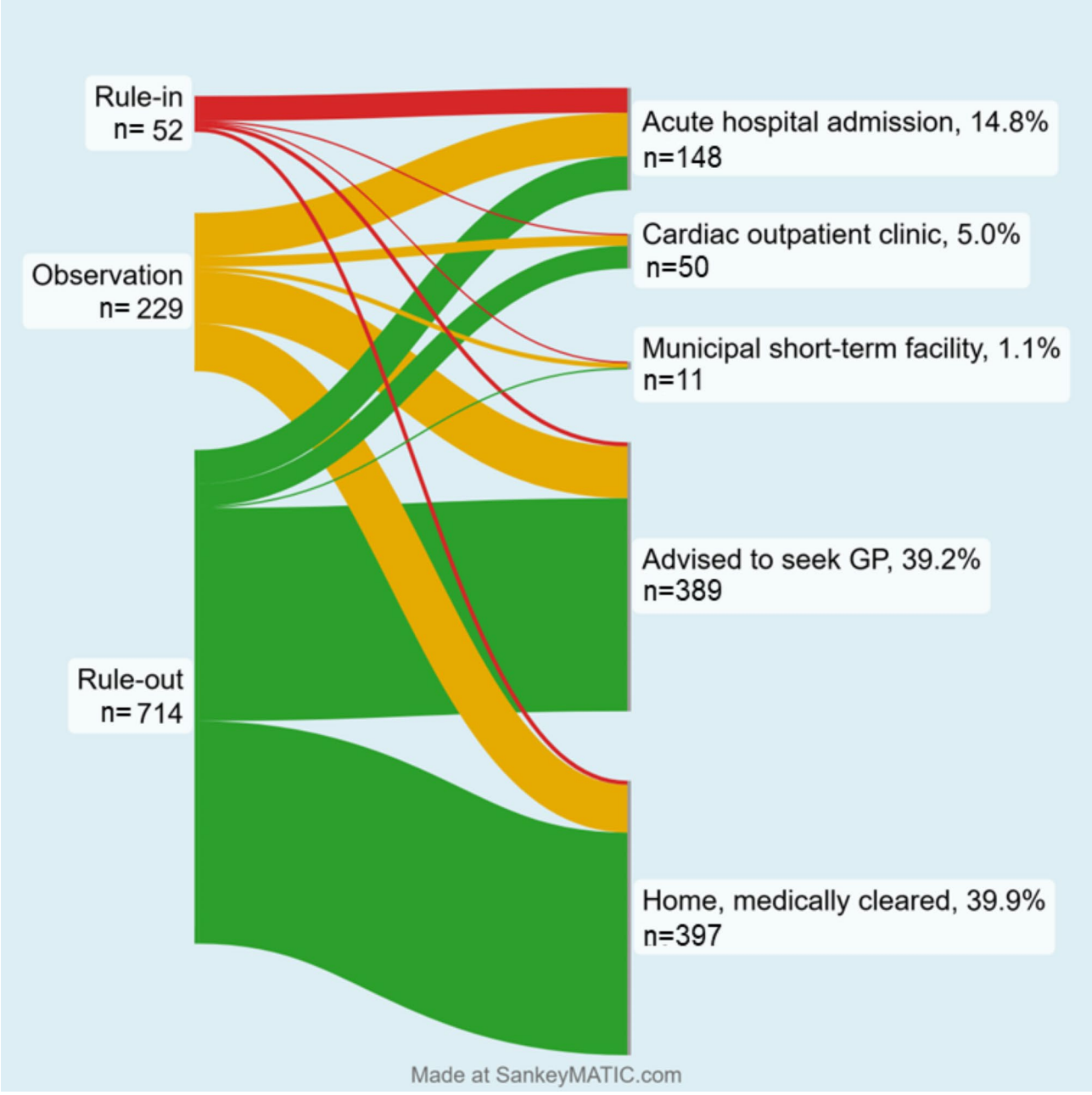

Fig. 3 Patient disposition categorised by the three triage categories
GP: general practitioner

Even though the local recommendations encouraged serial measurement whenever troponins were requested, the physicians ordered a single troponin measurement in 12.3% ($n = 122$) of the patients. This resulted in 38 patients being called back to the clinic for a repeat measurement after being discharged home, and 32 patients did not have a recommended 1-hour measurement performed (Table 1). The remaining patients were conclusively ruled in or ruled out by a single measurement or sent to the hospital for further observation and treatment.

Discussion

Summary of main findings

The implemented OUT-ACS strategy, which comprises the ESC 0/1-hour algorithm and an additional 4-hour sample for patients in the observation group, conclusively assigned 27.3%, 68.0%, and 77.0% to either rule-out or rule-in after the 0-, 1-, and 4-hour sample, respectively. The median sampling interval was 63 min for the 1-hour measurement and 4.6 h for the 4-hour measurement, and the protocol was misinterpreted or overruled

Table 2 Deviations from the 0/1/4-hour OUT-ACS protocol ($n=86$)

Rule-out group ($n=25$)	**4-hour hs-cTnT collected without indication ($n=25$)** • Subject to unnecessary repeated testing after being ruled out by the 0/1-hour samples. • Resulted in prolonged observation and delayed time before conclusive decision.
Observation group ($n=57$)	**1-hour hs-cTnT missing ($n=32$)** • 0-hour < 12 ng/L ($n=25$) o Potentially rule-out cases if a 1-hour sample had been collected. • 0-hour 12–14 ng/L ($n=1$) • 0-hour above the 99th percentile URL; >14 ng/L ($n=6$) o Median hs-cTnT 18 ng/L (IQR 15–23) o Patients with myocardial injury. Without the 1-hour measurement, it was not possible to distinguish acute from chronic injury (i.e., a potential safety issue). **4-hour hs-cTnT missing ($n=26$)** • Median hs-cTnT 12 ng/L (IQR 11–16) • Most had stable 0/1-hour measurements above the rule-out threshold of 11 ng/L (e.g., 0/1-hour hs-cTnT pairs of 12–12 ng/L, 17–17 ng/L, or 16–16 ng/L).
Rule-in group ($n=4$)	**4-hour hs-cTnT missing ($n=4$)** • Discharged home after being discussed with the on-call hospital specialist. • The elevated hs-cTnT levels were interpreted as habitual or non-ischaemic before being advised against further testing.

hs-cTnT: high-sensitivity cardiac troponin T, IQR: interquartile range; OUT-ACS: One-hoUr Troponin in a low-prevalence population of Acute Coronary Syndrome; URL: upper reference limit

in only 8.6% of the cases. After the final decision, 14.8% were transferred to hospital. The remaining patients were discharged home or referred to outpatient management. Implementing the 0/1-hour algorithm significantly reduced the LOS compared to the previous 0/4-hour protocol, indicating successful integration by staff into routine care.

Evaluation of the implementation

Implementing a rapid diagnostic algorithm based on hs-cTn measurements, we found that the gatekeeper function of primary care was strengthened, as less than 15% of the patients required hospital transfer after assessment at the clinic. Without the hs-cTn measurement, nearly all these patients would probably have been sent to a hospital ED due to clinical uncertainty. In a previous cost-effectiveness analysis, we found that almost 1800 EUR would be saved per low-risk patient conclusively assessed by hs-cTnT measurements in emergency primary care compared to routine hospital management [13].

More rapid evaluation leads to better utilisation of resources at the clinic and shorter waiting times for a final decision, which may result in less anxiety for the patients involved and faster identification and hospital transfer for those with an atypical MI presentation. With the new protocol, 68% of the patients received a conclusive troponin assessment 3.3 h earlier than those in the observation group, requiring the traditional 4-hour sample before a final decision (Table 1). Still, as the clinic used fixed time intervals for laboratory couriers during the study, the full potential of the protocol was not used. However, after the clinic moved to a new location close to Oslo University Hospital, Aker, in November 2023, pneumatic tubes have allowed continuous access to hospital laboratory testing immediately after a blood draw. This has reduced the total length of stay even further.

Personnel adherence was satisfactory, with impressive sampling intervals and adherence to the protocol in more than 9 of 10 cases after implementation. This demonstrates the feasibility and applicability of this approach also when used by non-laboratory personnel outside hospital EDs. The applicability of the algorithm was comparable to what was found in an ED implementation study by Twerenbold et al., reporting protocol violations in only 6% of the cases and a median 1-hour sampling interval of 65 min [14]. In our study, most of the protocol deviations were either related to (1) patients in the 0/1-hour rule-out group having an unnecessary 4-hour hs-cTnT measured, which contributes to overuse of care and prolonged length of stay, although without comprising safety, and (2) repeated measurements recommended by the protocol not being done (Table 2). Choosing to perform single hs-cTn sampling before sending the patient home resulted in logistical challenges, callbacks, delayed 1-hour measurements, and potential safety issues, especially among those few with an elevated hs-cTnT who did not have a repeated measurement. Even in our low-prevalence setting, 73% of the patients would not have been conclusively triaged by a single troponin measurement, illustrating the need for serial testing also in emergency primary care when using hs-cTnT measurements.

A common criticism of the 0/1-hour algorithm has been that it cannot provide a clear recommendation for patients assigned to the observation group. In our study, most of these patients were either hospitalised or kept for a 4-hour sample and prolonged observation at the clinic, including a more thorough examination and investigation of relevant differential diagnoses. Four of these patients were subsequently diagnosed with an MI when hospitalised. Previous publications have shown that these patients are older and have increased cardiovascular risk [12, 24, 26, 27], justifying the prolonged observation before discharge.

By implementing an algorithm designed to meet high safety requirements [7], the new 0/1-hour protocol is now safer than the previous one, which relied on the 99th percentile and relative changes in hs-cTn concentrations (pooled sensitivity 99.1% vs. 93.7%, respectively) [17]. Also, a recent publication investigating hs-cTn measurements performed in primary care in the Amsterdam

region between 2011 and 2021 identified a considerable safety issue (sensitivity 78%) when the 99th percentile of the URL of normal was chosen as the clinical threshold for a single hs-cTnT/I measurement [28]. As the acceptable MI miss-rate among GPs and ED physicians has been reported to be < 1% [29, 30], a preferred diagnostic decision aid for MI should achieve a rule-out sensitivity of 99% but also adequate specificity to avoid too many referrals of patients with non-cardiac chest pain [7, 9, 30]. This could be achievable using serial hs-cTn measurements and more targeted, assay-specific thresholds optimised to meet these criteria. Hence, the OUT-ACS protocol, using the ESC 0/1-hour algorithm, may be able to provide these standards for emergency primary care clinics if a hospital laboratory is located within proximity.

Strengths and limitations

It is a strength that the study comprises all consecutive Tn measurements during the first six months following implementation. It is also a major strength that the OUT-ACS protocol was prospectively validated for the specific low-risk setting before being implemented at the clinic rather than relying on results from hospital studies, which include a different mix of patients and a higher disease prevalence. In addition, the study was performed by non-laboratory personnel with great adherence and with only a few deviations from the recommended protocol. This illustrates the importance of involving staff and collaborators in every phase of the implementation process, as was done in this study.

Given the waiver for written informed consent, the study strictly adhered to data minimisation protocols. Consequently, baseline characteristics, including symptoms, clinical findings, and cardiovascular risk profiles, were not recorded. Furthermore, we did not have consent for linkage with national registries to collect cardiovascular endpoints. As a result, the study lacks comprehensive data on total cardiovascular events among participants at the index episode and the subsequent days. Hence, we could not register the occurrence of MIs among the patients who were not referred to the hospital. As a result, we could not assess the true safety or predictive performance (i.e., the sensitivity, specificity, or predictive values) of the protocol. Despite this limitation, the safety of the 0/1-hour algorithm has been extensively validated in numerous studies, including our prior research, leading us to consider it safe for implementation [12, 14–17, 25]. What this study adds is novel insights regarding its impact on patient flow, clinical routine, personnel adherence, and feasibility when implemented in a real-world emergency primary care setting.

External validity

Another limitation of the OUT-ACS protocol is that it requires direct access to a central laboratory assay for hs-cTn analysis. Due to significant geographical variations, this strategy is not generalisable to most emergency primary care clinics in Norway. Implementing a protocol that shifts hospital-based diagnostic tests to primary care also necessitates several organisational changes regarding patient flow, lab transport routines, and staff [31], which might be considered too resource-demanding. Still, in our previous health-economic evaluation, we demonstrated that this strategy would be highly cost-effective [13], which could be used as an argument for strengthened resources in emergency primary care if such a strategy is being considered.

However, the future looks promising with the recent advancements in whole blood hs-cTnI assays analysed on point-of-care (POC) instruments [32–35]. These instruments have been demonstrated to provide a valid result in less than 20 min, allowing GPs to act on a single troponin result before obtaining subsequent samples. In addition, the whole-blood hs-cTnI assays have been shown to achieve a higher proportion of single-sample rule-out cases [32, 33] than we found when using hs-cTnT in this study. Therefore, we anticipate these developments will enhance the assessment of patients with chest pain in emergency primary care, and also in the more remote areas. We intend to investigate this further in the upcoming OUT-POC (One-hoUr Troponin using a high-sensitivity Point-Of-Care assay in emergency primary care) study, which may broaden the application of the OUT-ACS strategy outside of hospital EDs.

Conclusion

In times when hospital EDs are overcrowded with patients, proper and timely decision-making is essential at the appropriate level of care. The OUT-ACS strategy, utilising the ESC hs-cTnT 0/1-hour algorithm for assessing low-risk patients with chest pain, previously shown to be safe, has also been demonstrated to be effective and applicable when implemented in an emergency primary care setting without laboratory expertise.

Abbreviations

ECG	electrocardiogram
ED	emergency department
ESC	European Society of Cardiology
GP	general practitioner
Hs-cTnT	high-sensitivity cardiac troponin T
ICD-10	International Statistical Classification of Diseases and Related Health Problems 10th Revision
ICPC-2	International Classification of Primary Care 2nd version
IQR	interquartile range
LOS	length of stay
MI	myocardial infarction
NSTE-ACS	non-ST-segment elevation acute coronary syndrome
OAEOS	Oslo Accident and Emergency Outpatient Clinic

OUT-ACS	One-hoUr Troponin in a low-prevalence population of Acute Coronary Syndrome
POC	point-of-care
URL	upper reference limit

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Author contributions
The study was conceived and designed by TRJ with support from all the co-authors. TRJ, OMV, BN, SER, and ACKL were engaged in implementing the algorithm at the clinic. TRJ collected and analysed the data with inputs from OMV, DA, SH, and ACKL. TRJ wrote the manuscript in close collaboration with all the co-authors, reviewing, revising and finally approving the final version for submission.

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Data availability
The dataset analysed in this current study is not publicly available as it was generated from the electronic patient record without patient consent. The dataset may still be available from the corresponding author upon reasonable request.

Declarations

Ethical approval and consent to participate
The project was a quality improvement study commissioned by the director of the Department of Emergency General Practice at the OAEOC, under the Norwegian Health Personnel Act § 26. Accordingly, as per the Norwegian ethics committee regulations for quality improvement studies, the requirement was waived for ethics committee approval and obtaining informed patient consent. The project was approved by the Information Security and Privacy Office of the City of Oslo Health Agency. Data were registered anonymously from electronic medical records.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
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Author details
[1]Department of General Practice, University of Oslo, Oslo, Norway
[2]Oslo Accident and Emergency Outpatient Clinic, City of Oslo Health Agency, Oslo, Norway
[3]Department of Medical Biochemistry, Oslo University Hospital, Oslo, Norway
[4]Institute of Clinical Medicine, University of Oslo, Oslo, Norway
[5]Department of Cardiology, Oslo University Hospital, Ullevaal, Oslo, Norway

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