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Review

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Diagnosis and risk stratification of chest pain patients in the emergency department: focus on acute coronary syndromes. A position paper of the Acute Cardiovascular Care Association

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Abstract
This paper provides an update on the European Society of Cardiology task force report on the management of chest pain. Its main purpose is to provide an update on the decision algorithms and diagnostic pathways to be used in the emergency department for the assessment and triage of patients with chest pain symptoms suggestive of acute coronary syndromes.

Keywords
Chest pain, biomarkers, troponin, acute myocardial infarction

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Introduction

This paper provides an update on the European Society of Cardiology (ESC) task force report on the management of chest pain.[1] A consensus statement on the pre-hospital management of patients with chest pain and/or dyspnoea of cardiac origin has previously been published.[2]

Patients presenting with chest pain to the emergency department (ED) constitute a diagnostic and logistic challenge as the majority have symptoms related to non-cardiac and often benign disorders that do not need emergency treatment or hospitalisation. The introduction of high-sensitivity cardiac troponin (hs-cTn) assays allowing the detection and quantification of minute degrees of myocardial injury has led to the development of new decision algorithms that enable a more accurate and rapid rule-in and rule-out of acute coronary syndromes (ACSs).[3] Implementation of these new decision algorithms may speed up the triage of chest pain patients in the ED and prevent the unnecessary hospitalisation of patients with non-critical disorders. The progress of computed tomography angiography (CTA) has made it possible to examine

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non-invasively the coronary arteries in patients with suspected unstable angina, and this imaging method has become the first-line test in patients with suspected acute aortic diseases or high-risk pulmonary embolism (PE).[3]

Since the publication of the latest ESC guidelines on the diagnosis and management of ACSs[4,5] the new decision algorithms for the rapid rule-in and rule-out of ACSs have been further validated. The main purpose of the present paper is therefore to provide an update on the decision algorithms and diagnostic pathways to be used in the ED for the assessment and triage of patients with chest pain symptoms suggestive of ACS.

Definition and epidemiology

Definition

Acute chest pain is the perception of non-traumatic pain or other thoracic discomfort occurring within the preceding 24 hours, localised anteriorly, between the base of the nose and the umbilicus and, posteriorly, between the occiput and the 12th vertebra. Descriptors include a range of features, including stabbing or burning, and also as pressure, tightness or heartburn.

Acute chest pain can be caused by an extensive variety of disorders (Table 1) ranging from life-threatening syndromes such as ACSs, acute aortic diseases and PE to conditions that are relatively harmless.[4–7] It must be emphasised that there are important gender differences in epidemiology, pathophysiology, clinical presentation, response to therapy and clinical outcome of acute chest pain syndromes.[8] ACSs in women are more often caused by microvascular disease, and the Takotsubo syndrome is almost 10 times more frequently observed in women than in men.[9] An underdiagnosed cause of ACSs that predominantly occurs in women is spontaneous coronary artery dissection.[10]

Formulating an accurate differential diagnosis within a very short timeframe and differentiating between an acute chest pain of cardiac or aortic origin and non-cardiac chest pain is a major challenge for all those involved in triage, clinical assessment and treatment of patients presenting with acute chest pain, such as general practitioners, emergency medical services (EMS) personnel, emergency physicians, nurses and cardiologists (Figure 1).

Epidemiology

Acute chest pain is one of the most common reasons to attend the ED, accounting for approximately 10% of non-injury-related visits.[12–17] The incidence of chest pain-related visits to the ED is 8–19 per 1000 person-years,[12,16,17] being higher in urban than in rural hospitals, with a mean age of 52–61 years, and with 49–57% of men.[12,13,15–17] In current practice, about half of the patients presenting with chest pain can be discharged without further hospitalisation from the ED.[15,16] The great majority of these patients (83%) are discharged with a non-cardiac cause of the chest pain (unspecified chest pain in 48% and other non-cardiac causes in 35%).[16] Of the patients who are admitted to hospital, on average only 25% (range 12.2–59.1%) have a final diagnosis of an ACS.[15–17] Another 25% of patients will be discharged with the diagnosis of angina pectoris (3.5–6.6%) or with another non-ischaemic cardiac problem (10–19%). In the remaining half of the admitted patients the final diagnosis will be unspecified chest pain (26%) or a non-cardiac cause (27%).[16] Acute vascular emergencies and PE account only for a very small minority (2–3%) of the patients.[17]

Approximately 2% of chest pain patients with an ACS are erroneously discharged from the ED, which is associated with a twofold increase in 30-day morbidity and mortality.[18] Indeed, the absence of typical chest pain does not exclude an ACS; in patients presenting to the ED without diagnosis-specific symptoms, acute myocardial infarction (MI) was the final diagnosis in 1.6%.[15]

Clinical assessment of acute chest pain

Emergency physicians face a major challenge to identify rapidly and accurately the small group of patients who require hospitalisation for acute management and the larger group with more benign conditions who can be safely discharged from the ED.

If the patients arrive by way of EMS, it is vital that prehospital presentation, findings from the EMS ECG and any treatments provided are formally communicated in a structured handover to ED clinicians.

The triage of chest pain patients in the ED is based on careful history-taking, physical examination, recording and interpretation of a 12-lead ECG within 10 minutes of arrival and measurement of cardiac biomarkers.[5]

The first priority is to identify the patients who need urgent transfer to the catheterisation laboratory. Immediate percutaneous coronary intervention (PCI) (<2 hours) is recommended in ST-segment elevation myocardial infarction (STEMI) patients[4] and in some non-ST elevation ACS (NSTE-ACS) patients with at least one of the very-high-risk criteria (haemodynamic instability or cardiogenic shock, recurrent or ongoing chest pain refractory to medical treatment, life-threatening arrhythmias or cardiac arrest, mechanical complications of MI, acute heart failure with refractory angina or ST deviation, recurrent dynamic ST or T-wave changes, particularly with intermittent ST-elevation).[5] However, in case of a haemodynamically unstable patient, initial haemodynamic stabilization (e.g. cardiogenic shock management, drugs, intubation, mechanical ventilation) may be necessary before the invasive procedure.

Although clinical judgement based on the results of the above-mentioned basic clinical tools allows the identification of a small high-risk group with clinical features

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Table 1. Causes of chest pain.

Primary cardiovascular	Primary non-cardiovascular

Acute coronary syndromes
• ST-segment elevation myocardial infarction (STEMI)
• Non-ST elevation ACS (NSTE-ACS)
  ◦ Non-ST-segment elevation myocardial infarction
  ◦ Unstable angina
Acute pericarditis, pericardial effusion
Acute myocarditis
Severe hypertensive crisis
Stress cardiomyopathy (Takotsubo syndrome)
Tachyarrhytmias
Hypertrophic cardiomyopathy, aortic stenosis
Severe acute heart failure
Acute aortic syndrome (dissection, haematoma)
Pulmonary embolism, pulmonary infarction
Cardiac contusion
	Oesophageal spasm, oesophagitis, gastroesophageal reflux (GER)
	Peptic ulcer disease, cholecystitis, pancreatitis
	Pneumonia, bronchitis, acute asthma
	Pleuritis, pleural effusion, pneumothorax
	Pulmonary embolism, severe pulmonary hypertension
	Thoracic trauma
	Costochondritis, rib fracture
	Cervical/thoracic vertebral or discal damage
	Herpes zoster
	Psychogenic

Reproduced with modifications from the 2018 Acute Cardiovascular Care Association (ACCA) toolkit.[11]

(Table 2) highly suggestive of a NSTE-ACS mandating an early invasive coronary strategy, the findings will remain inconclusive in many low-risk patients. In order to avoid inadvertent early discharge from the ED these patients must be observed and monitored for a prolonged period in which an accelerated diagnostic protocol is performed, comprising serial ECG recordings and cardiac injury biomarker measurements obtained over 1–3 hours to diagnose accurately (rule-in) or exclude (rule-out) an ACS. Most often this is carried out in an observation unit in the

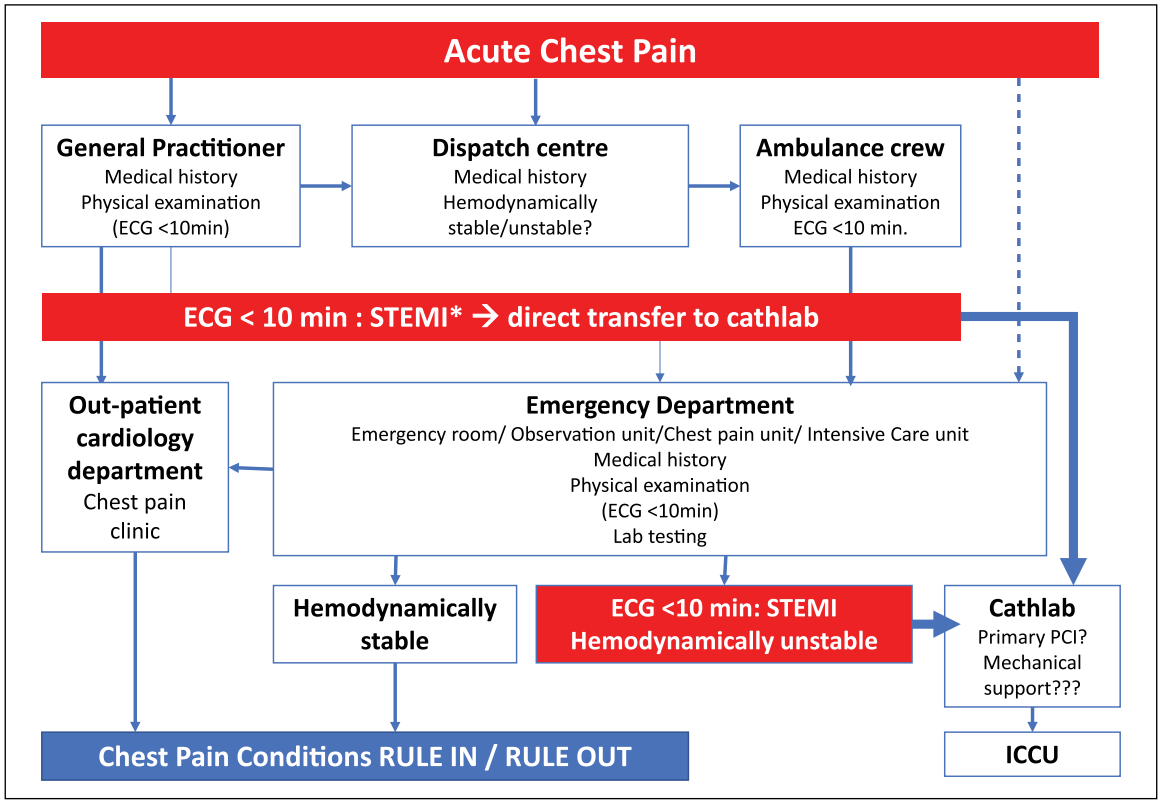

Figure 1. Clinical pathways of acute chest pain.
*If timely (<120 minutes from first medical contact) primary percutaneous coronary intervention (PCI) cannot be performed after ST-segment elevation myocardial infarction (STEMI) diagnosis, fibrinolytic therapy is recommended within 12 hours of symptom onset in patients without contraindications.

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Table 2. High-risk criteria for chest pain suggestive of ACS.

Symptoms	Prolonged ongoing chest pain (≥20 minutes)
History	Prior PCI in the last 6 months
	Prior CABG
Clinical findings	Pulmonary oedema most likely due to ischaemia
	Hypotension
	Tachycardia
	New mitral regurgitation murmur
	Acute heart failure Killip class >I
	New systolic murmur at ERB's point
ECG	Dynamic ST changes >0.5 mm during chest pain
	New or presumably new left or right bundle branch block
	Sustained ventricular tachycardia
	High degree atrioventricular block
Biomarkers	Elevated cardiac troponins
Score	GRACE risk score ≥140
	HEART score ≥7

ACS: acute coronary syndrome; PCI: percutaneous coronary intervention; CABG: coronary artery bypass graft surgery; ECG: electrocardiogram; GRACE: Global Registry of Acute Coronary Events; HEART: History, ECG, Age, Risk factors and Troponin.

ED or in a dedicated chest pain unit (CPU), within or close to the ED.[19] A negative accelerated diagnostic evaluation allows early discharge, whereas patients who are triaged towards rule-in are usually admitted to a monitored unit and require early coronary angiography.

Clinical risk stratification tools may help clinicians to integrate symptoms, ECG findings and biomarkers in the risk stratification of chest pain patients. These tools have been incorporated in accelerated diagnostic pathways that facilitate fast triage and safe early discharge of low-risk chest pain patients.[20,21] The diagnostic pathways based on the ADAPT (2-hour Accelerated Diagnostic protocol to Assess Patients with chest pain symptoms using contemporary Troponins as the only biomarker),[22] EDACS (ED Assessment of Chest Pain Score)[23–25] and HEART[26] scores have the strongest scientific evidence supporting their use. Although these scores perform equally well, this taskforce recommends the use of the HEART score as it most closely follows the clinical reasoning process in the diagnosis of acute chest pain.

The HEART score (Figure 2) was specifically developed for unselected patients with chest pain presenting at the ED.[26] The HEART score differs from other risk stratification tools as it also includes the clinical suspicion by the physician and the presence of multiple coronary risk factors in its calculation. Moreover, as it is mainly based on simple clinical parameters it can be easily calculated at the bedside. The HEART score represents the patients' risk of developing a major adverse cardiac event (MACE) within 6 weeks after initial presentation. The HEART score has been tested and validated in numerous studies performed in Europe,[27–29] the United States[30,31] and Asia Pacific.[26,32] Overall a HEART score of 3 or less allowed us to identify 35–46% low-risk patients with a very high sensitivity and negative predictive value.[33] Patients with a HEART score of 7 or greater are a very high risk subgroup with over 50% of MACE within 6 weeks,[27] who therefore should be immediately admitted to an intensive cardiac care unit. The HEART score was initially validated for use in conjunction with contemporary cardiac troponin (cTn) assays. Use of the HEART score based on the results of hs-cTn assays should therefore be done with caution as the troponin-related points may vary with the assay used. However, in two retrospective cohort studies in which hs-cTn assays were used, application of the HEART score resulted in the identification of 31.6–37.2% of low-risk patients with a sensitivity of 93.7–100% and a negative predictive value of 98.3–100%, results very similar to those observed in earlier validation studies.[28,34]

The utility of clinical risk stratification tools has been reduced since the advent of diagnostic pathways using hs-cTn assays that allow a very accurate and fast diagnosis of acute MI.

The role of nurses

Nurse-led early triage of patients with acute chest pain has been reported to increase timely ECG recording, medicine use in high-risk patients and appropriate admission to the coronary care unit.[35] In rural hospitals, emergency nurse practitioners have been shown to have high adherence to clinical guidelines, a high level of diagnostic accuracy, reduce chest pain patients' waiting times and length of stay without compromising safety.[36] The diagnostic accuracy of ED nurses has been shown in one study to be similar to that of ED physicians, with a nurse-led, accelerated discharge protocol having a 1.1% rate of MACE at 30 days.[37] Although these studies need further confirmation, it appears that the active participation of well-trained nurses can be very helpful in the triage of chest pain patients.

Diagnostic testing

Electrocardiogram

The 12-lead ECG within 10 minutes of EMS arrival or patient presentation (first medical contact defined as the time of first assessment by a healthcare professional who is able to obtain and interpret a 12-lead ECG) is pivotal in the decision-making algorithm for the management of patients presenting with acute chest pain. Only a small number of patients presenting with acute chest pain to the ED show a typical STEMI ECG pattern. The majority have either a completely normal ECG (40–60%) or atypical non-ischaemic ECG changes.[38–42] In a recent study of patients presenting with acute chest pain almost 60% had a normal admission ECG, with a very low (5.0% (3.9–6.3%)) infarction rate.[42]

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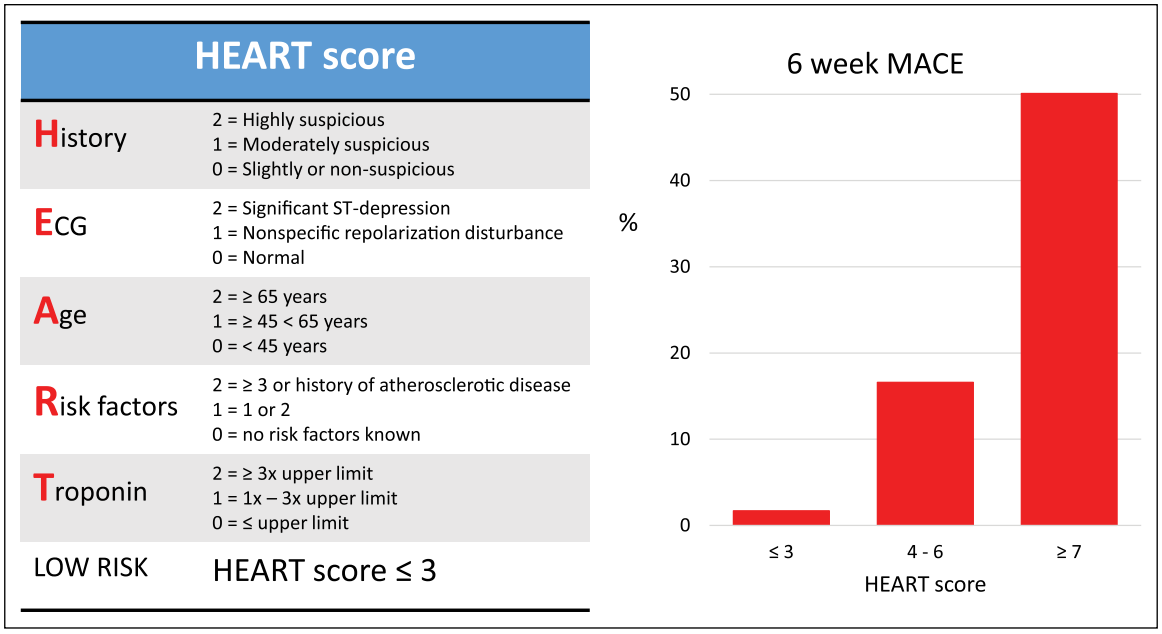

Figure 2. Calculation of the HEART score and incidence of 6-week major adverse cardiac events (MACE) according to the HEART score as tested in a large population of patients presenting with chest pain in the emergency department.[27]

In these patients, although the incidence of acute MI is low, it is not zero, and therefore a normal admission ECG should not be used alone to rule out an ACS. If the ECG is normal or non-diagnostic, the ECG should be repeated after a 10-minute interval, especially if chest pain recurs. A 12-lead ECG is sufficient in most patients. However, patients with an occluded circumflex coronary, acute occlusion of a vein graft, or left main disease, may present without ST-segment elevation.[43] The use of additional posterior chest wall leads (V7–V9) should be considered if there is high clinical suspicion of posterior MI.[4] If the 12-lead ECG shows an acute inferior MI then recording of additional right precordial leads (V3R and V4R) should be considered to identify concomitant right ventricular infarction.[4]

Cardiac troponin testing

Clinical assessment combined with an ECG is not sufficient to diagnose or exclude,[44] additional measurement of cTn T or I with serial measurements is crucial.[5,43,45,46]

CTn T and I are structural proteins unique to the heart. The cTn complex is immobilised on the thin filament of the contractile apparatus and plays a critical role in the regulation of excitation–contraction coupling in the heart. In MI, cTn I and cTn T are released from necrotic myocardium both as intact proteins and degradation products.[47]

hs-cTn assays allow the precise quantification of cardiomyocyte injury around the 99th percentile, substantially increasing the accuracy of MI diagnosis based on the blood sample obtained at presentation.[48–53] Although hs-cTn assays quantify the amount of cardiomyocyte damage, they need to be interpreted as quantitative variables and not in a binary (negative/positive) fashion; the higher the cTn level, the higher is the likelihood of the presence of MI.

The latest ESC non ST-segment elevation ACS guidelines give a IA recommendation for the use of hs-cTn as the standard biomarker for clinical practice, and a IB recommendation for the application of two main novel algorithms with cardiac biomarkers for the management of patients with acute chest pain in the ED.[5] In patients presenting with suspected non ST-segment elevation ACS it is recommended to use the 0/3 hour ESC algorithm (Figure 3). As an alternative, the 0/1 hour ESC algorithm is recommended when hs-cTn assays (hs-cTn T: Elecsys; hs-cTn I: Architect, Centaur) with a validated algorithm are available (Figure 4).

0/3 Hour ESC algorithm. MI is ruled out if the concentrations of hs-cTn remain in the normal range (below the respective 99th percentile) in the blood sample drawn at presentation and 3 hours later, and if the patient fulfils two additional requirements: to be pain-free and to be at low risk of in-hospital mortality, as quantified by a GRACE score[44] below 140.[5] In patients presenting more than 6 hours after the onset of chest pain, in whom chest pain onset can be reliably quantified, one single blood sample at presentation is considered sufficient. Patients are ruled in if they have a clearly elevated hs-cTn blood concentration at presentation, or if the 3-hour sample shows a relevant change. This approach has been recommended by the ESC guidelines since 2011, and is the standard of care in many institutions worldwide (Figure 3). Its use regarding the rule-out of MI seems to be safe for all hs-cTn assays.[54] The

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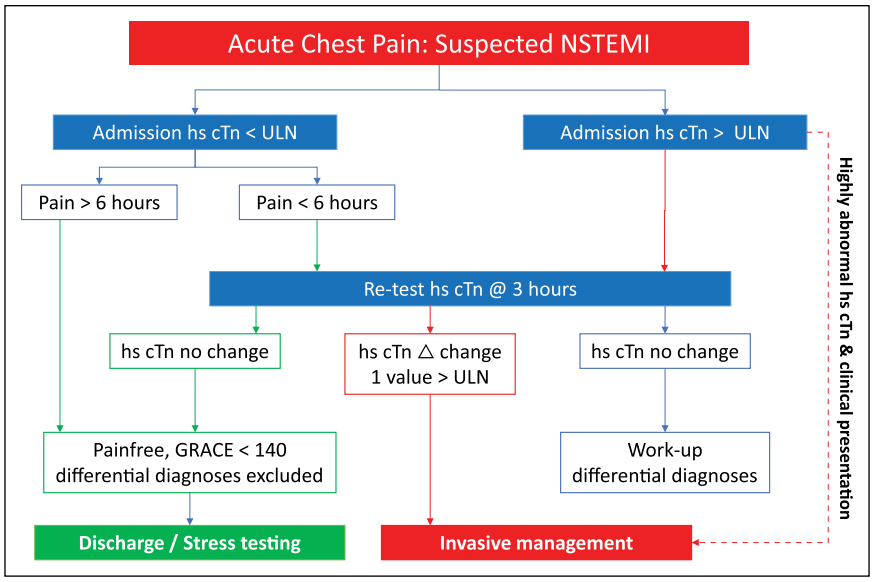

Figure 3. The European Society of Cardiology 0/3 hour rule-out and rule-in algorithm of non-ST-segment elevation acute coronary syndrome using high-sensitivity cardiac troponin (hs-cTn) assays.[5]

exact performance for rule-in cannot be quantified, as no precise definitions of its rule-in cut-off levels are given.

0/1 Hour ESC algorithm. The concept of the 0/1 hour ESC algorithm is based exclusively on information provided by hs-cTn blood concentrations. The decision points derived and validated for each assay are assay-specific (Figure 4).[5,55–60] The 0/1 hour ESC algorithm obviates the need for the formal use of clinical scores and allows the safe rule-out of MI even in patients with mild, non-specific ECG abnormalities.

Undetectable level of hs-cTn. An undetectable level of hs-cTn (below the level of detection of the assay) at presentation in combination with an ECG without ischaemic changes may rule out an acute MI with sufficient sensitivity in patients presenting 1–3 hours after the onset of chest pain.[61–64] Although the use of this criterion may allow us to rule out acute MI in one-third of the patients, it should be applied with caution in patients aged 65 years and less due to an increased risk of a false negative result.[65]

Time of blood sampling, turnaround time and time to decision. The 0/1 hour ESC algorithm refers to the time-points at which blood is sampled. The turnaround time is the time period from sampling to reporting results back to the treating clinician. This is about 1 hour in a well-run hospital using an automated platform in a central laboratory. Adding the local turnaround time to the time of blood sampling determines the earliest timepoint for clinical decision-making based on hs-cTn concentrations. The clinical and economic benefits of the 0/1 hour ESC algorithm versus, for example, the 0/3 hour algorithm are therefore independent of the local turnaround time.

Central laboratory versus point of care. Point-of-care devices usually require 10–20 minutes for the measurement itself, providing results back to clinicians about 40 minutes earlier than the central laboratory. However, they have a number of potential disadvantages:

- To date no hs-cTn assay on a point-of-care device has been appropriately validated to justify routine clinical use. However, several point-of-care hs-cTn I assays are in the late stages of development/validation.[66] Large diagnostic multicentre studies will be required to determine their performance versus the well validated hs-cTn T/I assays run on automated platforms.
- Current point-of-care assays are either conventional or sensitive assays. Therefore, the second sample should be taken at 3–6 hours depending on the assay specifics.
- Point-of-care devices have lower precision (less well standardised), and a higher error rate compared with central laboratory assays.

Other reasons for elevated hs-cTn levels. cTn T and I are organ but not disease-specific markers and thus many factors other than acute myocardial ischaemia may cause hs-cTn elevation. In the absence of myocardial ischaemia, elevated cTn levels are often interpreted as 'false positive' hs-cTn results. However, in the majority of cases this term is incorrect as they mostly reflect

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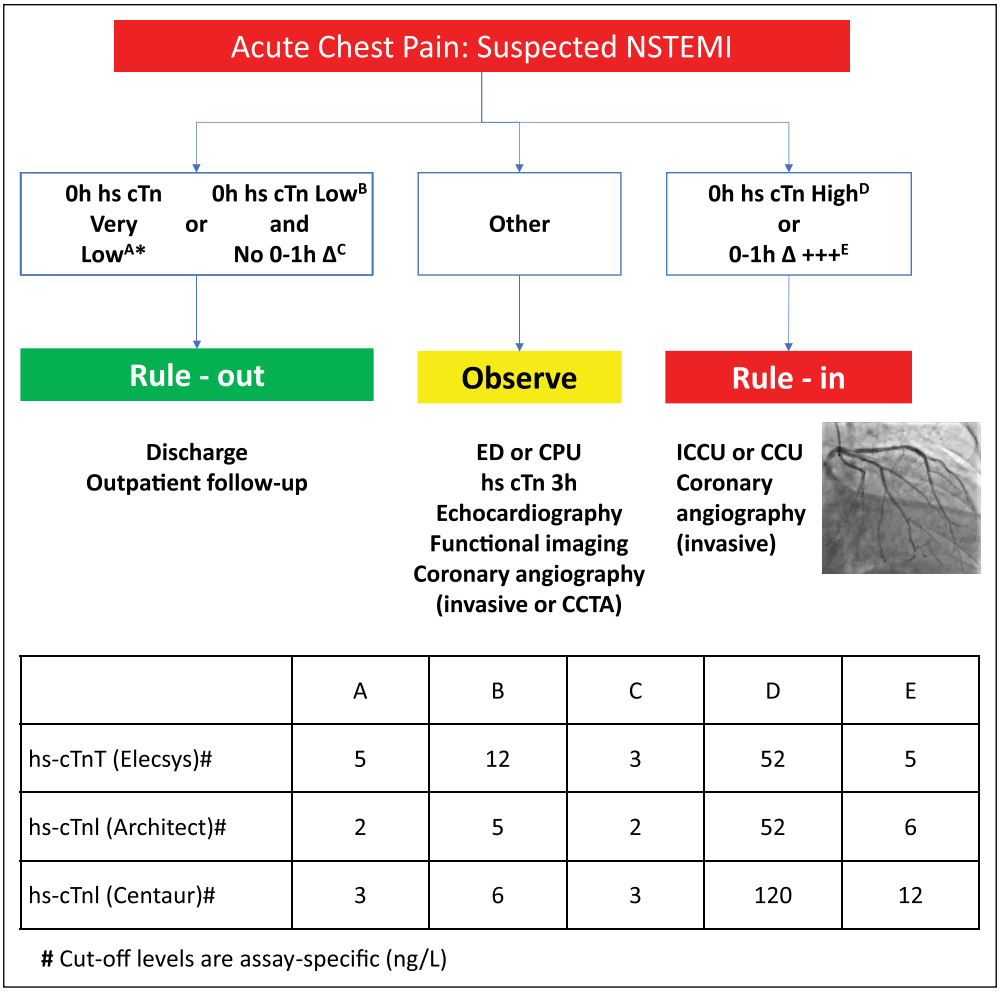

	A	B	C	D	E
hs-cTnT (Elecsys)#	5	12	3	52	5
hs-cTnI (Architect)#	2	5	2	52	6
hs-cTnI (Centaur)#	3	6	3	120	12

Cut-off levels are assay-specific (ng/L)

Figure 4. The European Society of Cardiology 0/1 hour rule-out and rule-in algorithm using high-sensitivity cardiac troponin (hs-cTn) assays in patients presenting with suspected NSTEMI to the emergency department. *If chest pain onset is greater than 3 hours. For three additional hs-cTn I assays a 0/1 hour algorithm has been derived and validated and the respective manuscripts are currently in peer review.

previously undetected or underestimated cardiac disease, including valvular heart disease, heart failure, hypertensive heart disease and chronic coronary artery disease.[67,68] Many cardiac disorders and non-cardiac disorders with cardiac involvement may lead to substantial amounts of cardiomyocyte injury and thereby hs-cTn elevation, even in the absence of macrovascular coronary artery disease. Elevated hs-cTn levels are associated with a worse prognosis. Dynamic changes of hs-cTn during serial sampling help to distinguish ischaemic from non-ischaemic causes of chest pain and minor degrees of troponin elevation (Table 3).

The diagnostic algorithms using hs-cTn assays improve substantially the efficiency of the triage of chest pain patients in the ED. The increased sensitivity of hs-cTn assays abridges the troponin blind period early after the onset of MI and allows marked shortening of the time interval to the second blood sample needed to demonstrate a significant rise of the biomarker. The 0/1 hour ESC algorithm is as effective as the 0/3 hour ESC in ruling in and ruling out acute MI with a very high negative predictive value.[69] Moreover, it allows us to detect – 1 hour earlier – a greater number of patients eligible for early discharge than the previously widely used accelerated diagnostic pathways using contemporary cTn assays (ADAPT-ADP) that included the additional calculation of a clinical low-risk score (Figure 5). Institutional standard operational procedures for the diagnosis of acute chest pain based on the 0/1 hour ESC algorithm will therefore not only increase patients' safety but also markedly shorten the duration of stay in the ED, which may lead to important cost savings. A prospective international multicentre trial recently confirmed the applicability, efficacy and safety of the routine clinical use of the ESC 0/1 hour algorithm for the management of patients presenting with acute chest pain to the ED.[70]

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Table 3. Conditions other than MI associated with cTn elevations.

Tachyarrythmias
Heart failure
Hypertensive emergencies
Critical illness (e.g. shock, sepsis, burns)
Myocarditis
Takotsubocardiomyopathy
Structural heart disease (e.g. aortic stenosis)
Aortic dissection
Pulmonary embolism, pulmonary hypertension
Renal dysfunction and associated cardiac disease
Coronary spasm
Acute neurological event (e.g. stroke or subarachnoid haemorrhage, meningitis)
Cardiac contusion or cardiac procedure (CABG, PCI, ablation, pacing, cardioversion, endomyocardial biopsy)
Hypo and hyperthyroidism
Infiltrative diseases (e.g. amyloidosis, haemochromatosis, sarcoidosis, scleroderma)
Myocardial drug toxicity or poisoning
Extreme endurance efforts
Rhabdomyolysis

MI: myocardial infarction; cTn: cardiac troponin; PCI: percutaneous coronary intervention; CABG: coronary artery bypass graft surgery.

Echocardiography

Echocardiography should be routinely available in the ED or CPU, and performed by a trained staff member.[72] It is not required where a non-cardiac diagnosis is obvious or in whom the probability of an acute cardiovascular cause is considered very low. Transthoracic echocardiography (TTE) is indicated in patients with acute chest pain and: (a) a diagnosis, or a high clinical suspicion of an acute coronary syndrome; (b) haemodynamic instability; (c) acute heart failure; (d) suspicion of acute aortic syndromes, myocarditis, or pericarditis; (e) underlying cardiac disease such as aortic valve stenosis, hypertrophic cardiomyopathy. Although it is reasonable for individual risk stratification during the hospital stay, echocardiography is not recommended in haemodynamically stable, normotensive patients with suspected PE.[6] Transoesophageal echocardiography (TOE) may be indicated when TTE is non-diagnostic. In the case of suspected aortic dissection TOE is more sensitive than TTE.[7] Echocardiographic signs suggestive of myocardial ischaemia or necrosis include: (a) segmental wall motion abnormalities; (b) impaired myocardial perfusion detected by contrast echocardiography; (c) reduced regional function using strain and strain rate imaging.[72]

Chest X-ray

The chest X-ray is often performed in the evaluation of patients attending the ED. In one large study a quarter of such patients showed significant findings: cardiomegaly, pneumonia and pulmonary oedema.[73] When there is a high clinical suspicion of acute life-threatening conditions other than ACS (pericardial effusion, acute aortic dissection, PE, pneumothorax or pneumonia) chest X-ray is indicated and should be available, preferably within 30 minutes.

Computed tomography

Coronary computed tomography angiography (CCTA) has been proposed as a rapid and accurate diagnostic technique to rule out obstructive coronary artery disease given its very high negative predictive value.[74,75] Three multicentre studies have evaluated the feasibility, safety and diagnostic accuracy of early CCTA compared to usual care in the triage of chest pain patients in the ED.[76–78] A meta-analysis showed that a diagnostic strategy using early CCTA is as safe as usual care of chest pain patients in the ED and results in a significant reduction of cost and length of hospital stay.[79]

However, in a recent multicentre study that compared early CCTA with standard optimal care diagnostic protocols based on the use of hs-cTn assays, early CCTA failed to identify more patients with significant coronary artery disease requiring coronary revascularisation, shorten hospital stay, or allow for more direct discharge from the ED.[80] A selective use of CCTA may be considered in the 20% of chest pain patients in whom the diagnosis of NSTE-ACS cannot be reliably ruled out or ruled in by the ECG and hs-cTn diagnostic algorithms.[5,81]

CTA of the aorta plays a central role in the diagnosis, risk stratification and management of acute aortic syndromes. In most patients with suspected acute aortic dissection, CTA is the preferred initial imaging modality.[7]

Pulmonary CTA allows the detection of PE and adequate visualisation of the pulmonary arteries down to at least the segmental level. Pulmonary CTA is the

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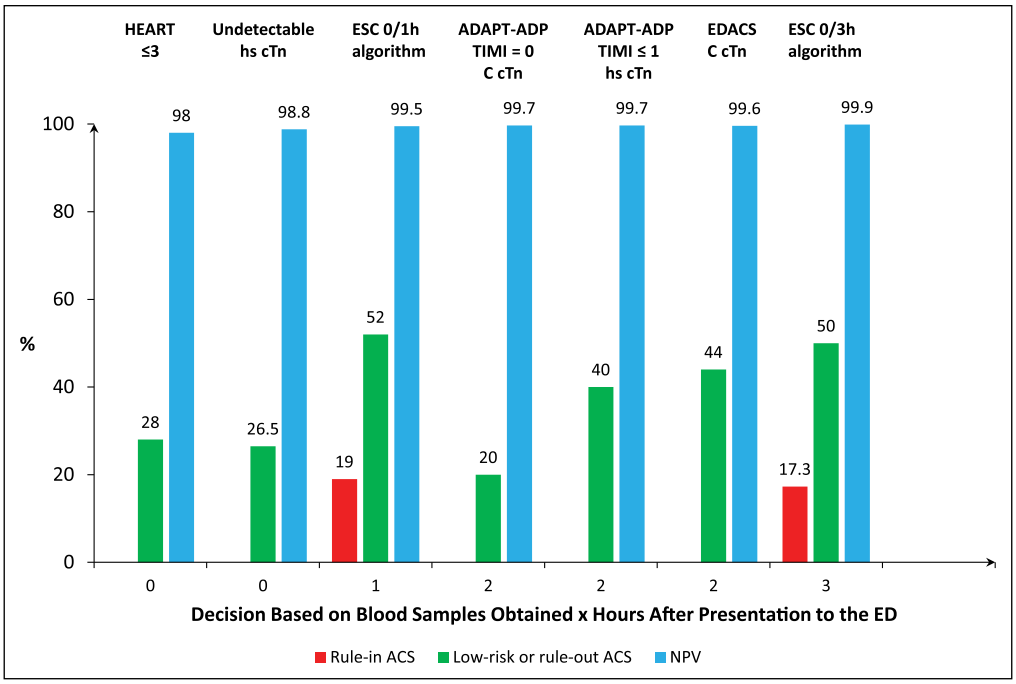

Figure 5. Comparison of the performance in ruling in and ruling out acute myocardial infarction (MI) or identifying low-risk chest pain patients of various risk stratification scores and/or diagnostic pathways either using contemporary (C-cTn) or high sensitivity cardiac troponin assays (hs-cTn).[20,71] The 0/1 hour European Society of Cardiology algorithm is very effective in ruling in and ruling out acute MI with a very high negative predictive value.

second-line test in patients with suspected non-high-risk PE and an elevated D-dimer level, whereas it is the first-line test in patients with suspected high-risk PE, i.e. presenting with shock or hypotension or patients with a high clinical probability of PE.

The high accuracy of CTA in the diagnosis of PE and acute aortic dissection and the utility of CCTA in excluding coronary artery disease have led to the development of a triple rule-out scan protocol allowing the simultaneous assessment of all three causes of acute chest pain with a single scan.[82] Even with modern scanners, which offer a wider coverage and a greater temporal resolution, this necessitates a longer scanning time and an increased contrast volume. In a recent registry a triple rule-out protocol was associated with a slightly higher yield of PE and acute aortic dissection than CCTA, specifically in patients presenting in the ED.[83]

Ultrasonography (other than echocardiography)

Ultrasonography can help in the management of acute chest pain, in particular when evaluating possible non-cardiac causes. Lung ultrasonography is useful to detect pleural effusion or pneumothorax. The chest X-ray may miss the diagnosis when the volume of fluid or air is small, while ultrasonography has a higher sensitivity and specificity (>90%). Typical findings in pleural effusion are the 'quad and sinusoid signs', while the 'seashore sign' (lung sliding) and 'stratosphere (barcode) sign' suggest pneumothorax.[84] Lung ultrasound is also important to detect B-lines or 'comets', which indicate the amount of extravascular lung water and correlate with acute heart failure that can be associated with acute ischaemic chest pain. When gastrointestinal causes of chest pain are suspected (e.g. cholecystitis, biliary colic, pancreatitis) abdominal ultrasonography is appropriate.

Further predischarge testing

Exercise ECG or non-invasive stress testing has been recommended in low-risk patients as the final confirmatory test before safe discharge from the ED.[85,86] Routine use of pre-discharge ischaemia testing may, however, lead to a longer length of stay in the ED or observation units, more downstream invasive angiography and revascularisation procedures, more radiation exposure and greater costs without any improvement in clinical outcome.[87–90] Use of the HEART score may aid in identifying the patients in whom predischarge testing should be considered.[30,31] In the HEART pathway implementation trial, patients with a HEART score of 3 or less in whom an ACS was excluded by serial troponin testing could be safely discharged without further testing.[91] Based on these studies it is proposed to limit pre-discharge exercise testing and cardiac imaging to patients with a HEART score greater than 3 (Figure 6).

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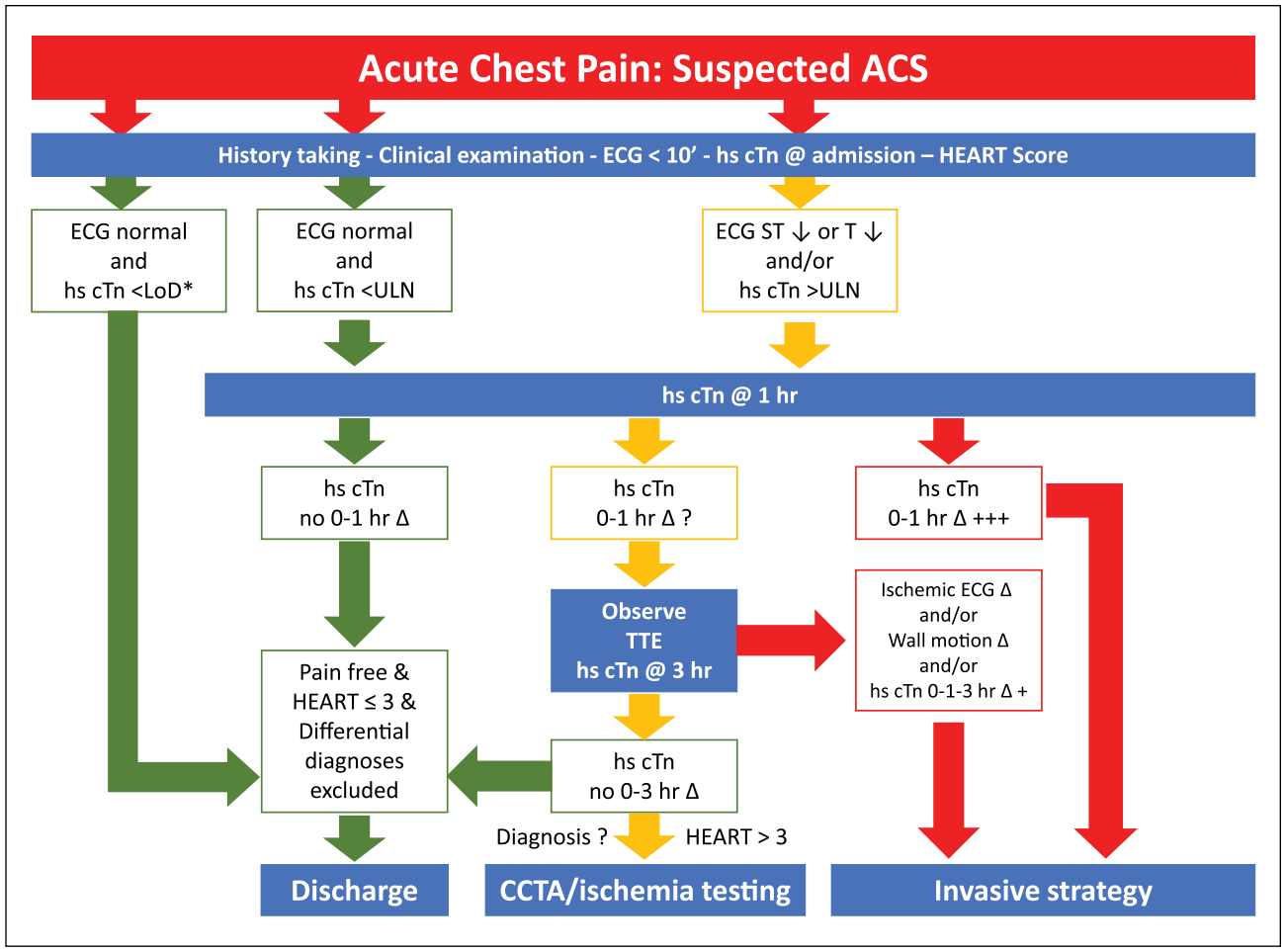

Figure 6. Management of chest pain within the emergency department. TTE: transthoracic echocardiography.
*If chest pain onset is more than 3 hours.

Conclusion

The diagnosis and management of patients presenting with chest pain to the ED can be considerably improved by the implementation of new diagnostic clinical algorithms based on the use of hs-cTn assays in conjunction with meticulous assessment of clinical symptoms and signs, the ECG and other bedside examination techniques. The new diagnostic algorithms allow a more effective and rapid triage of chest pain patients, as an acute MI can be diagnosed (rule-in) or excluded (rule-out) in three of four patients based on the measurement of hs-cTn on admission and one hour later. Up to halve of the patients are eligible for early discharge if differential diagnoses are excluded. Although the new hs-cTn-based diagnostic algorithms obviate the use of clinical risk stratification scores, it is proposed to add a HEART score of 3 or less as an additional criterion for the decision on early discharge as this score predicts a very low MACE risk during early follow-up. The small group of patients in whom the diagnosis is unclear should remain in the ED, CPU or observation units until further ECG monitoring, repeated hs-cTn measurement, bedside echocardiography and additional CCTA or ischaemia testing allows us to clarify the diagnosis (Figure 6).

The new hs-cTn-based diagnostic algorithms allow a more effective and rapid triage of chest pain patients allowing early discharge and preventing ED crowding. It is time to implement them universally!

Consensus statements

A careful evaluation of symptoms and a prognostic risk stratification should be made in all patients presenting with chest pain, in order to initiate specific therapy when indicated and reduce avoidable admissions and inappropriate discharges.

- At the first medical contact, the clinician should look for signs of haemodynamic instability and manifestations of life-threatening conditions.
- 12-Lead ECG recording and interpretation is indicated as soon as possible within 10 minutes after the first medical contact.

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- Additional 12-lead ECG recordings should be performed in the case of recurrent symptoms or diagnostic uncertainty.
- Additional ECG leads (V3R, V4R, V7–V9) are recommended if ongoing ischaemia is suspected when standard leads are inconclusive.
- A normal admission ECG should not be used as a single test to exclude ACS.
- Routine blood sampling for serum markers is indicated as soon as possible after admission to the ED.
- It is recommended to measure cardiac troponins, preferably with high-sensitivity assays and obtain the results within 60 minutes.

A rapid rule-out and rule-in protocol at 0 hours and 1 hour is recommended if a hs-cTn test with a validated 0/1 hour algorithm is available. Additional testing after 3–6 hours is indicated if the first two troponin measurements are not conclusive and the clinical condition is still suggestive of ACS.

The HEART score should be used to risk stratify patients with chest pain in the ED.

TTE is indicated in patients with acute chest pain and:

- increased cardiac necrosis biomarkers and non-diagnostic ECG
- haemodynamic instability
- acute heart failure
- suspicion of acute aortic syndromes, myocarditis, or pericarditis
- underlying cardiac disease (aortic valve stenosis, hypertrophic cardiomyopathy. . .)

In acute chest pain patients with inconclusive results after an accelerated diagnostic chest pain protocol using hs-cTn assays CCTA should be considered to exclude the presence of coronary artery disease.

In suspected acute aortic dissection, CTA is the preferred initial imaging modality.

CCTA is the second-line test in patients with suspected non-high-risk PE and an elevated D-dimer level, and the first-line test in patients with suspected high-risk PE presenting with shock or hypotension or patients with a high clinical probability of PE.

Lung ultrasound is useful to detect pleural effusion or pneumothorax. It can also detect B-lines that indicate lung congestion in ACS complicated by acute heart failure.

Patients in whom ACS is ruled out, with a HEART score of 3 or less and in whom other diagnoses of chest pain are excluded may safely be discharged without further in-hospital testing.

Conflict of interest

The authors declare that there is no conflict of interest.

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