REUE | Original article

Use and utility of the 0/1-Hour and 0/2-Hour High-Sensitivity Cardiac Troponin I algorithms in the diagnosis of Acute Myocardial Infarction in the Emergency Department

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OBJECTIVE. The 2023 European Society of Cardiology clinical practice guidelines recommend the use of rapid cardiac troponin algorithms to improve the early diagnosis of non–ST-segment elevation acute coronary syndrome (NSTEACS) in emergency departments (EDs). The aim of this retrospective study was to assess the degree of implementation of validated rapid rule-out/rule-in algorithms for our automated system in patients with suspected acute myocardial infarction (AMI) presenting to the ED of our hospital.

MATERIALS AND METHODS. We reviewed a total of 200 patients for whom cardiac troponin testing was requested in the ED. Adherence to the rapid algorithms was evaluated, as well as their impact on patient classification regarding the occurrence of acute coronary syndrome (ACS), other cardiac conditions, or alternative diagnoses.

RESULTS. Of the 200 patients, 23 (11,5 %) had troponin levels > 120 ng/L and were classified in the "rule-in" group; 20 patients had values < 3 ng/L (10 %) and were classified as "rule-out"; and 157 (78,5 %) patients had troponin values between 3 and 120 ng/L and were assigned to the "observation" group. Only 12 of these 157 patients underwent repeat troponin testing (7,64 %). Two of them developed NSTEACS after discharge from the ED. Overall, 10 (5 %) of the 200 patients included in the study were ultimately diagnosed with AMI.

CONCLUSIONS. The widespread application of rapid troponin algorithms could improve the diagnosis of NSTEACS.

Keywords: Rapid algorithms. Acute myocardial infarction. Non–ST-segment elevation acute coronary syndrome. Troponin.

Uso y utilidad de los algoritmos a 0/1 hora y 0/2 horas de troponina cardiaca I de alta sensibilidad en el diagnóstico de infarto agudo de miocardio en urgencias

OBJETIVO. La guía de la Sociedad Europea de Cardiología de 2023 recomendó el uso de algoritmos rápidos de determinación de troponinas cardiacas para mejorar el diagnóstico temprano del síndrome coronario agudo (SCA) sin elevación del segmento ST en los servicios de urgencias (SU). Nuestro objetivo fue analizar el grado de aplicación de los algoritmos rápidos de descarte/confirmación, en pacientes con sospecha de infarto agudo de miocardio (IAM) en un SU.

MATERIAL Y MÉTODOS. Se revisan 200 pacientes consecutivos a quienes se solicitó determinación de troponinas cardiacas (hs-cTnI). Se evaluó el seguimiento de los algoritmos rápidos y su impacto en la clasificación de pacientes, respecto a la aparición de SCA, de otra patología cardiaca u otro diagnóstico diferente. Para las determinaciones de hs-cTnI se utilizó el analizador Atellica IM Analyzer® (Siemens Healthineers)[7]. Los pacientes se clasificaron en 3 categorias: – Exclusión (hs-cTnI < 3 ng/L y variación temporal dentro de los límites definidos para el algoritmo, Confirmación (hs-cTnI > 120 ng/L o incremento absoluto > 12 ng/L), y Observación (hs-cTnI entre 3 y 120 ng/L, que requerían una nueva determinación a 1 o 2 horas, según el algoritmo utilizado).

RESULTADOS. De los 200 pacientes, 23 (11,5 %) presentaron troponinas > 120 ng/L, incluyéndose en «Confirmación»; 20 pacientes mostraron < 3 ng/L (10 %), clasificándose como «Exclusión», y 157 (78,5 %) pacientes presentaron valores entre 3 y 120 ng/L (grupo «observación»). Sólo a 12 de estos 157 pacientes se les solicitó una nueva determinación (7,64 %). Dos de ellos sufrieron SCA sin elevación del ST tras el alta del SU. De los 200 pacientes, 10 (5 %) fueron diagnosticados finalmente de IAM.

CONCLUSIONES. La aplicación generalizada de los algoritmos rápidos de troponinas, pude mejorar los diagnósticos de SCA sin elevación del ST.

Palabras clave: Algoritmos rápidos. Infarto agudo de miocardio. Síndrome coronario agudo sin elevación del segmento ST. Troponina.

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Article Information: Received: 19-10-2025. Accepted: 21-11-2026. *Online:* 17-2-2026.
Editor in Charge: Guillermo Burillo-Putze.

Introduction

Cardiac troponin (cTn) is the biomarker of choice for the diagnosis of acute myocardial infarction (AMI).[1]

According to the 2023 clinical practice guidelines (CPG) of the European Society of Cardiology (ESC)[2] on the diagnosis and management of non-ST-segment elevation acute coronary syndrome (NSTEACS), AMI is defined as "cardiomyocyte necrosis in a clinical setting consistent with acute myocardial ischemia." The diagnosis of AMI requires a combination of criteria, including the detection of a rise and/or fall in a cardiac biomarker, preferably high-sensitivity cardiac troponin (hs-cTn), with at least one value above the 99th percentile of the upper reference limit.[3]

Early diagnosis of AMI is essential for the timely initiation of therapeutic measures (anti-ischemic therapy, antiplatelet therapy, anticoagulation, and/or coronary revascularization), with the aim of preserving the greatest possible amount of viable myocardium and improving patient prognosis.[4]

In this context, ESC CPG have incorporated so-called rapid algorithms for ruling in or ruling out AMI, based on serial hs-cTn measurements at 0/1 hour and 0/2 hours.[2,3] These algorithms require the availability of an hs-cTn assay specifically validated for this strategy, with defined cut-off values and temporal changes for each analytical method. Several studies have shown that the traditional 0/3-hour algorithm is less efficient and provides lower safety than rapid protocols.[5,6]

Since 2023, the 0/1 h and 0/2 h algorithms for hs-cTnI have been validated in the Atellica IM Analyzer® (Siemens Healthineers),[7] with specific cut-off values for this system. However, validation studies did not comprehensively consider variables such as age, renal function, time since onset of chest pain, or sex,[7,8] highlighting the need to evaluate their applicability in each specific clinical setting.[9]

Numerous conditions other than AMI may be associated with elevated cTn, including arrhythmias, heart failure, hypertensive emergency, shock, sepsis, myocarditis, pulmonary embolism, aortic dissection, pulmonary hypertension, renal dysfunction, or acute neurological events, among others.[10] Therefore, in addition to hs-cTn values, interpretation must always integrate the electrocardiogram and the patient's past medical history.

The aim of this study was to evaluate the clinical application of rapid rule-out/rule-in AMI algorithms (0/1 h and 0/2 h) validated for our automation system, in patients attended in a emergency department (ED) with suspected acute coronary syndrome (ACS) and indication for hs-cTnI measurement.

Material and methods

We conducted an observational, descriptive, retrospective cohort study in the ED of *Hospital Universitario de La Ribera* (Alzira, Valencia, Spain). The hospital has 370 beds and attends an average of 380 patients daily in its ED.

Patients attended in the ED with suspected ACS in whom hs-cTnI measurement was requested in November 2024 (a randomly selected month) were included until completing 200 consecutive cases, as a convenience sample considered sufficient for an initial exploratory approach to the applicability of rapid algorithms in our setting.

Inclusion criteria were age ≥ 18 years, ED attendance with suspected ACS, and request for hs-cTnI measurement at admission. Patients with incomplete medical records regarding final diagnosis or hs-cTnI measurements were excluded.

Serum hs-cTnI concentration was determined using a high-sensitivity troponin I assay on the Atellica IM Analyzer® (Siemens Healthineers). The reference interval for healthy adults was established according to the CLSI EP28-A3c document in the Atellica IM Analyzer:[11]

– Women: 99th percentile (p99) 34 ng/L (90 % CI, 27–66).

– Men: p99 54 ng/L (90 % CI, 39–80).

– Combined: p99 45 ng/L (90 % CI, 33–64).

For patient classification, the cut-off values of the 0/1 h and 0/2 h rapid algorithms validated for this analyzer (Table 1)[7] were used. Patients were classified into three categories:

– "Rule-out": hs-cTnI < 3 ng/L (and temporal variation within algorithm-defined limits).

– "Rule-in": hs-cTnI > 120 ng/L or absolute increase ≥ 12 ng/L.

– "Observation": hs-cTnI values between 3 and 120 ng/L requiring a new measurement at 1 or 2 hours depending on the algorithm used.

The variables collected in the study were:

– Serum hs-cTnI concentration at initial determination and, when applicable, in serial measurements.

– Time elapsed between the first and subsequent blood draws.

– Cardiovascular risk factors (diabetes mellitus, hypertension, dyslipidemia, and active smoking).

– Past medical history of cardiovascular disease (coronary artery disease, prior AMI, coronary revascularization, peripheral arterial disease, heart failure, renal dialysis).

– Renal function (serum creatinine in mg/dL and CKD-EPI eGFR in mL/min/1.73 m^2).

– Diagnosis at ED discharge, obtained from the electronic health record, made by the attending ED physician and not modified by the investigators. Based on this diagnosis and available clinical information, patients were grouped into three categories:

– AMI (including NSTEACS and STEMI), according to the 4th Universal Definition of AMI.[20]

– Non-AMI cardiac disease: including unstable angina, arrhythmias, heart failure, hypertensive emergency, structural Cardiac disease, ischemic syndromes not meeting AMI criteria, pericarditis, or ventricular dysfunction.

– Non-cardiac disease.

To assess the degree of algorithm implementation, the percentage of patients in whom a 0/1 h or 0/2 h algorithm was formally followed (scheduled second measurement within the recommended interval) was calculated and compared with those in whom it was not applied.

The study protocol was evaluated and approved by the Clinical Research Ethics Committee of Departamento de Salud de La Ribera (approval dated February 26th, 2024). Given the retrospective nature of the study and the use of aggregated anonymized data, the committee waived the requirement for individual informed consent.

Statistical analysis

We conducted a descriptive analysis of demographic and clinical variables. Quantitative variables are expressed as mean and 95 % CI, and qualitative variables as absolute frequencies and percentages.

To evaluate the performance of hs-cTnI cut-off values, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for the diagnosis of AMI, for any cardiac disease, and for NSTEACS, according to hs-cTnI ranges for rule-out, rule-in, and observation categories.

Statistical analysis was performed using IBM SPSS Statistics version 22.0.

Results

The cohort had a mean age of 67.8 years (95 %CI, 65.3–70.4), with 53.5 % men. The most frequent risk factors were hypertension (112), dyslipidemia (87), and diabetes (59). Mean creatinine was 1.10 mg/dL (95 %CI, 1.02–1.18), and mean CKD-EPI eGFR was 71.3 mL/min/1.73 m² (95 %CI, 65.0–77.7) (Table 2).

AMI was diagnosed in 10 patients (4 %): 1 in the context of diabetic ketoacidosis, 2 with ST-segment elevation on electrocardiogram, and 7 with NSTEACS (Figure 1).

According to initial hs-cTnI values, 20 patients had values < 3 ng/L (rule-out), 157 were between 3–120 ng/L (observation), and 23 had values > 120 ng/L (rule-in). Among the 23 rule-in patients, 8 were ultimately diagnosed with AMI. The remaining 15 patients were diagnosed with other conditions: pulmonary thromboembolism, atrial fibrillation, congestive heart failure (CHF), etc.

In the observation group (n = 157), repeat hs-cTnI testing within the recommended interval was low: a second measurement was requested in 12 cases (8 %) (2 at 1 hour and 10 at 2 hours). Among these 12 patients, 11 showed no relevant increase and 1 showed an increase in hs-cTnI (from 112 to 256 ng/L), with a final non-coronary diagnosis (cerebrovascular event with epilepsy).

Among observation patients without repeat testing during the index episode, 2 reconsulted later (the following day and after 4 days) with hs-cTnI > 10,000 ng/L and were diagnosed with NSTEACS and admitted to the intensive care unit (ICU). In the index episode, their hs-cTnI values were 35 ng/L and 36 ng/L, respectively, below the reference limit according to CLSI EP28-A3c for the Atellica IM Analyzer.[11]

The diagnostic distribution by hs-cTnI ranges is shown in Table 3: in the < 3 ng/L group, 2 non-AMI cardiac conditions and 18 non-cardiac conditions were recorded; in the 3–120 ng/L group, 33 non-AMI cardiac conditions, 2 NSTEACS, and 122 non-cardiac conditions; and in the > 120 ng/L group, 9 non-AMI cardiac conditions, 3 non–NSTEACS AMI, 5 NSTEACS, and 6 non-cardiac conditions. Diagnostic performance, including sensitivity, specificity, PPV, and NPV of the proposed cut-offs, is also shown in Table 3.

Table 1. 0 h/1 h and 0 h/2 h algorithms validated for Siemens Atellica IM Analyzer®

	Algorithm	Rule-out	Observation	Rule-in
cTnI (pg/mL; ng/L)	0 h/1 h	0 h < 3 ng/L* or 0 h < 6 ng/L y Δ0 h/1 h < 3 ng/L*	Others	0 h > 120 ng/L* or Δ0 h/1 h > 12 ng/L*
cTnI (pg/mL; ng/L)	0 h/2 h	0 h<8 ng/L* or 0 h < 6 ng/L y Δ0 h/2 h < 7 ng/L*	Others	0 h > 120 ng/L* or Δ0 h/2 h > 12 ng/L*

Source: Adapted from Sørensen *et al.* 2021.
*For chest pain onset > 3 hours.
cTn: cardiac troponin; h: hour.

When restricting the analysis to patients with NSTEACS, the role of hs-cTnI as a stratification tool was confirmed. With the low cut-off > 3 ng/L, sensitivity and NPV were 100 % (no false negatives), at the expense of very low specificity (10 %) and a PPV of 4 %, indicating that most elevations in this range did not correspond to NSTEACS. In contrast, the threshold > 120 ng/L showed a better diagnostic balance (sensitivity 71 %, specificity 91 %, PPV 22 %, NPV 99 %), identifying a subgroup with higher probability of ACS, although insufficient as a standalone rule-in criterion and requiring integration with clinical data and, when appropriate, serial measurements. Overall, these results support the potential usefulness of hs-cTnI algorithms for faster and safer initial risk stratification in patients with suspected NSTEACS.

Discussion

According to the Consensus on Non-ST-Segment Elevation Acute Coronary Syndromes of the Argentine Society of Cardiology (2020), most patients presenting with chest pain to EDs ultimately do not have ACS. Between 60 % and 90 % of consultations for precordial pain are not associated with cardiovascular disease, and although approximately half of patients may initially present with a clinical picture suggestive of ACS, only a fraction ultimately confirm the diagnosis. In our case, the percentage of patients with ACS among those with suspected cardiac disease was < 10 %. These results are more consistent with those published by the National Institute for Health and Care Excellence (NICE) in 2020,[13] which estimated that 5 % of emergency hospital admissions for chest pain and suspected AMI occurred in 2017–2018, with AMI occurring in approximately 20 % of those admissions. Even so, estimates of sensitivity, specificity, and predictive values should be interpreted with caution due to the low number of events, which limits the precision and generalizability of these parameters. It is therefore necessary to expand the study in terms of the number of patients, systematically applying the algorithms in the ED to evaluate the diagnostic performance of these rapid algorithms in our setting.

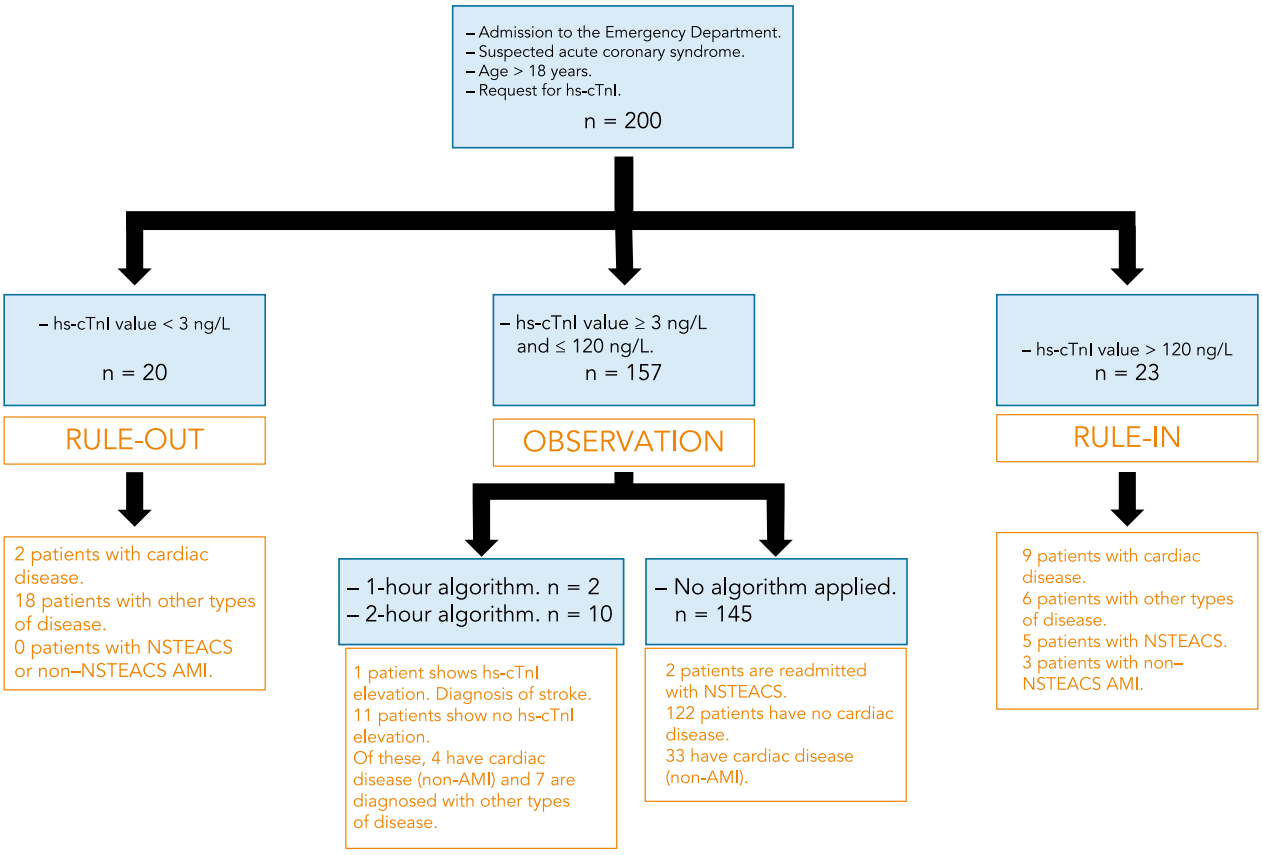

Figure 1. Flow diagram of patient selection and distribution across groups.
AMI: acute myocardial infarction; hs-cTnI: high-sensitivity cardiac troponin; NSTEACS: non-ST-segment elevation acute coronary syndrome; STEACS: ST-segment elevation acute coronary syndrome.

In this study, we observed that rapid algorithms are not routinely applied in daily clinical practice. This may have contributed to the delayed detection of two cases

Table 2. Demographic data of the patient cohort

Patient characteristics	All patients N = 200 n (%)	Patients with AMI N = 10 n (%)	Patients without AMI N = 190 n (%)
Age (95 % CI)	67.8 (70.4-65.3)	67.5 (79.7-55.2)	67.4 (70.0-64.8)
Male sex	107 (53.5)	5 (62.5)	102 (53.10)
Female sex	93 (46.5)	3 (37.5)	90 (46.90)
Risk factors			
Diabetes	59	4	55
Dyslipidemia	87	6	81
Hypertension	112	3	110
Smoker	36	3	33
History of cardiovascular disease	71	2	69
Creatinine, mg/dL	1.10 (1.18-1.02)	1.09 (1.54-0.65)	1.09 (1.18-1.01)
CKD-EPI eGFR (mL/min/1.73 m^2)	71.3 (77.7-65.0)	72.5 (91.6-53.4)	71.3 (75.2-67.5)
eGFR categories			
≥ 90	63 (31.5)	3 (37.5)	59 (30.7)
60–89	69 (34.5)	3 (37.5)	67 (34.9)
45–59	32 (16.0)	1 (37.5)	31 (16.1)
30–44	20 (10.0)	1 (37.5)	19 (9.9)
15–29	13 (6.5)	0	13 (6.8)
< 15	3 (1.5)	0	3 (1.6)

AMI: acute myocardial infarction.

Table 3. Distribution of diagnosed conditions according to hs-cTnI values. Sensitivity, specificity, positive predictive value, and negative predictive value for cardiac pathologies and NSTEACS in the "Rule-out" and "Rule-in" ranges, and for other cardiac conditions in the "Observation" range

	Cardiac disease	STEACS	NSTEACS	Non-cardiac disease
< 3 ng/L	2	0	0	18
3–120 ng/L	33	0	2	122
> 120 ng/L	9	3	5	6
	Sensitivity	**Specificity**	**PPV**	**NPV**
Cardiac diseases (including AMI) with hs-cTnI > 120 ng/L*	0.31	0.96	0.74	0.79
Cardiac diseases (including AMI) with hs-cTnI > 3 ng/L**	0.96	0.12	0.29	0.90
NSTEACS with hs-cTnI > 120 ng/L*	0.71	0.91	0.22	0.99
NSTEACS with hs-cTnI > 3 ng/L**	1.00	0.10	0.04	1

*Negative result defined as hs-TnI < 3 ng/L and positive result as hs-TnI > 120 ng/L.
**Negative result defined as hs-TnI < 3 ng/L and positive result as hs-TnI 3–120 ng/L.
AMI: acute myocardial infarction; NSTEACS: non–ST-segment elevation acute coronary syndrome; hs-cTnI: high-sensitivity cardiac troponin I; STEACS: ST-segment elevation acute coronary syndrome.

with initial hs-cTnI values between 3 and 120 ng/L (candidates for a second measurement), who were readmitted within a few days. These cases required admission to the hospital ICU, with a length of stay of 4 days each.

Although ESC CPG already recommended during the study period the use of rapid hs-cTnI-based algorithms,[2,3] these were not yet explicitly incorporated into the written protocols of the ED at our center, meaning that their application largely depended on the discretion of the emergency physician. This fact, together with analytical turnaround time and workload, may help explain the low rate of systematic algorithm implementation observed.

Furthermore, our study allows us to rule out NSTEACS with hs-cTnI levels < 3 ng/L, which is consistent with findings by Chapman *et al*.[5] Of note, the proportion of patients classified directly as "Rule-out" was considerably lower than in other series, which may be explained by differences in the population, with younger patients and a lower burden of comorbidity than those in our cohort.[18-20] Regarding values > 120 ng/L, the results are also consistent with other studies such as that of Mueller *et al*.,[14] with similar PPV. It is necessary to evaluate these algorithms for each assay, as discrepancies exist among different hs-cTn assays.[15]

Our study has several limitations when evaluating the applicability of rapid algorithms: they were not generally implemented, making it impossible to measure their diagnostic performance; additionally, the number of patients, compared with other studies—particularly multicenter studies[8]—is limited. Despite this, review of the "observation" group suggests that a second measurement could have enabled early detection of two cases (1.3 % of patients eligible for a second measurement) of NSTEACS. A potential verification bias should also be considered, as repeat hs-cTnI measurement was performed in only 12 of 157 patients in the observation category, meaning that confirmation or exclusion of events through serial measurements was not homogeneous across the cohort. Only patients attended in the ED were reviewed, without intervention in triage, initial diagnostic assessment, or final diagnosis. Furthermore, the final diagnosis was determined by the attending emergency physician, which may introduce diagnostic bias. Finally, this is a retrospective single-center analysis limited to a single month, with a convenience sample, reducing external validity and potentially reflecting local organizational patterns that may not be generalizable. Estimates of sensitivity, specificity, and predictive values should therefore be interpreted with caution due to the low number of events, which limits their precision and generalizability. It is therefore necessary to expand the study in terms of patient numbers and to systematically apply the algorithms in the ED to evaluate their diagnostic performance in our setting.

Conclusions

In this study, rapid hs-cTnI algorithms for ACS detection (0/1 h and 0/2 h) were not systematically applied. In particular, most patients with hs-cTnI values in the observation range (3–120 ng/L) were not reassessed with a second determination within the recommended interval. This may have contributed to missed opportunities for early diagnosis during the initial ED visit, thereby delaying the initiation of therapeutic measures. However, these findings do not allow evaluation of the diagnostic performance of the algorithm, but only its level of implementation. We believe that systematic implementation of these algorithms is necessary, along with evaluation of their diagnostic potential.

ARTICLE INFORMATION

Conflict of Interest Disclosures: None reported.

Funding: The authors declare the non-existence of funding in relation to this article.

Ethical Responsibilities: The authors have confirmed the maintenance of confidentiality and respect for the patient rights, agreement of publication, and transfer of rights to Revista Española de Urgencias y Emergencias.

Data availability: Data are available upon request from the corresponding author.

Authors' contributions (CRediT): FDFG: Conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review and editing. EMR: Conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review and editing. SEP: Conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review and editing. EMR: Conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review and editing.

Use of generative artificial intelligence tools: The authors declare that they did not use AI tools in the preparation of this article.

Article not commissioned by the Editorial Board and with external peer review.

Note of the editors: This is a BOWMAN-generated English translation of the officially indexed Spanish-language article, which should be cited as Rev Esp Urg Emerg. 2026;5:99-104. In this translated version, the editors have supervised the process; however, it cannot be ruled out that some errors resulting from the artificial intelligence translation process may have gone unnoticed.

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