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ORIGINAL RESEARCH

Lung Ultrasound in the Acute Phase of ST-Segment–Elevation Acute Myocardial Infarction: 1-Year Prognosis and Improvement in Risk Prediction

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BACKGROUND: Lung ultrasound (LUS) has emerged as a useful tool in the acute phase of patients admitted for ST-segment–elevation myocardial infarction. However, its long-term significance remains uncertain, and risk scores do not include LUS findings as a predictor. This study aims to assess the 1-year prognostic value of LUS and its ability to enhance existing risk scores.

METHODS AND RESULTS: This is a multicenter prospective cohort study involving 373 patients with ST-segment–elevation myocardial infarction. LUS was performed during the first 24 hours after angiography. LUS results were assessed both as a categorical (wet/dry lung) and continuous variable (LUS score). The primary end point comprised the following major adverse cardiovascular events: all-cause mortality or hospitalization for heart failure, acute coronary syndrome, or stroke within 1 year. We also evaluated whether LUS could enhance the predictive value of the GRACE (Global Registry of Acute Coronary Events) score. Major adverse cardiovascular events occurred in 51 (13.7%) patients over a median follow-up of 368 days. After multivariate analysis, the LUS score was an independent predictor (hazard ratio [HR], 1.06 [95% CI, 1.01–1.10]; P=0.009] for each additional B-line), whereas the categorical classification was an independent predictor in patients with ST-segment–elevation myocardial infarction Killip I (HR, 3.12 [95% CI, 1.34–7.31]; P=0.009). Incorporating LUS into GRACE resulted in a net reclassification index of 31.6% and a significant increase in the area under the curve; GRACE alone scored 0.705 compared with GRACE+LUS 0.791 (P=0.002).

CONCLUSIONS: Detecting B-lines on LUS at the acute phase predicts major adverse cardiovascular events at 1 year in patients with ST-segment–elevation myocardial infarction and enhances the predictive value of the GRACE score.

REGISTRATION: URL: https://www.clinicaltrials.gov; Unique identifier: NCT04526535.

Key Words: B-lines ■ GRACE score ■ lung ultrasound ■ STEMI

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CLINICAL PERSPECTIVE

What Is New?

- Few studies have evaluated the prognostic value of lung ultrasound in ST-segment–elevation myocardial infarction. These studies are focused on the short-term prognosis, and the longer-term prognostic value of lung ultrasound in patients with ST-segment–elevation myocardial infarction is unknown.
- Most of the risk scores used in acute coronary syndromes rely solely on clinical variables.

What Are the Clinical Implications?

- Lung ultrasound may be a useful prognostic tool that independently predicts adverse outcomes during the first year after admission for ST-segment–elevation myocardial infarction.
- Given the growing prominence of imaging techniques in cardiology and their increasing availability, we contend that future risk scores incorporating lung ultrasound findings may improve risk stratification compared with current approaches.

Nonstandard Abbreviations and Acronyms

LUS	lung ultrasound
MACE	major adverse cardiovascular event

Lung ultrasound (LUS) has emerged as an inexpensive, rapid, and easily learned technique with established validity as a diagnostic and prognostic tool in patients with heart failure (HF).[1–8] Recent studies have shown its effectiveness in stratifying risk among patients with ST-segment–elevation myocardial infarction (STEMI).[9–13] These studies consistently indicate that the degree of pulmonary congestion, assessed by the number of B-lines on LUS, is significantly associated with a worse prognosis during hospitalization and short-term (30-day) follow-up. However, this prognostic value has mainly been evaluated during hospital admission or a few days after discharge. In contrast, the longer-term prognostic value of LUS in patients with STEMI is unknown.

STEMI risk scores were developed before the widespread use of LUS, and thus, LUS findings have not been integrated into any existing risk stratification scales for STEMI. In those scores, the degree of HF relies on the Killip scale at admission.[14–17] Considering the previously mentioned prognostic role of LUS, its rapid learning curve, and quick performance, the incorporation of this variable into the GRACE (Global Registry of Acute Coronary Events) score[15,18] could enhance its prognostic capability.

This study aimed to assess the 1-year prognostic value of LUS performed in patients with STEMI at admission and evaluate its ability to improve risk classification on top of the widely used GRACE score.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Design and Research Ethics

LUS-AMI (Lung Ultrasound in Acute Myocardial Infarction) is a multicenter, prospective cohort study conducted at 3 tertiary hospitals. All 3 centers are part of the STEMI regional network,[19] which ensures 24/7 access to emergent primary angioplasty therapy for patients with STEMI across the Spanish region of Catalonia. LUS-AMI participants were enrolled between June 2020 and December 2021. The study design is in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines[20] and an expert consensus document on LUS studies.[21] The LUS-AMI study protocol received approval from the ethics committee of each participating center (promotor center identification IIBSP-ECO-2019-105, CEIm HSCSP, CEIm PSMAR, CEIm HUVH). All study procedures adhere to the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants. The study was registered at ClinicalTrials.gov (NCT04526535).

Study Participants

Patient recruitment started in June 2020 at 2 of the study sites, and in June 2021 at the third site, ultimately concluding in December 2021. The inclusion criteria were patients ≥18 years of age, admitted to the hospital with a diagnosis of STEMI based on symptoms indicative of myocardial ischemia, ECG evidence of ST-segment elevation, or equivalent abnormalities.[22] Exclusion criteria were the absence of culprit lesions on coronary angiography, severe lung disease (such as severe obstructive pulmonary disease, lung fibrosis, pleural disease, lobectomy, or pneumonectomy), chronic hemodialysis therapy, adult distress respiratory syndrome or pneumonia at the time of inclusion, cardiac arrest at presentation, and life expectancy of <6 months before admission. Potential participants were also excluded if no independent operator was available to conduct the LUS examination within the initial 24 hours following coronary revascularization.

The comparison of baseline characteristics between the included and nonincluded patients is summarized in Table S1. The data for the nonincluded patients were obtained from the STEMI regional database.

LUS Protocol

LUS was conducted within the initial 24 hours following coronary revascularization using a pocket-size, portable device (VScan; GE Healthcare, Chicago, IL) at 2 sites, and a portable device (Vivid iq, GE Healthcare) at the third site. All examinations were performed using a cardiac probe by experienced operators. To avoid any potential bias in management decisions, the operators were independent of the clinical team, and the clinical team remained blinded to the LUS results. Clips were recorded, and the counting of B-lines was performed offline, also blinded to clinical data. The patient was in a semirecumbent position, and the probe was placed perpendicular to the ribs, following an 8-field protocol (including anterior midclavicular superior and inferior, midaxillary superior and inferior points in each hemithorax). Each clip was acquired for 4 seconds, at a depth of 14 cm, and saved for subsequent offline analysis. A lung field was considered interpretable if it showed the bat sign (pleural line and rib shadows), A-lines, B-lines, or lung sliding.

The exploration was considered interpretable if there were at least 2 valid fields in each hemithorax. B-lines were identified as hyperechogenic comet-tail artifacts extending from the pleural line to the bottom of the screen without fading, moving synchronously with lung sliding.[23,24] Four investigators, all of them blinded to the study clinical information and trained in LUS, analyzed the clips offline.

For the analyses, the LUS results were modeled in 2 clinically relevant ways: (1) categorical (wet/dry lung): following previously published definitions in STEMI,[10,13] a wet lung was defined as the presence of at least 1 field ≥3 B-lines, whereas all others were classified as a dry lung; and (2) continuous (LUS score),[21] which comprised the total sum of B-lines in all lung fields, ranging from 0 to 24 (0–3 for each field).

Clinical Outcomes and Study Follow-Up

The primary study end point was time to present a major adverse cardiovascular event (MACE): all-cause mortality or readmission for acute HF, acute coronary syndrome, or stroke. Readmission was defined as hospitalization or >24 hours of stay in the emergency department. Patients were followed up from their initial admission due to STEMI until 1 year after hospital discharge through the review of reports, clinical records, and phone calls to the participants or their relatives. Because LUS was performed on the first day of the index admission, mortality encompassed both in-hospital deaths and postdischarge deaths up to 1 year of follow-up. The analysis of incident events was conducted by investigators who were blinded to the results of the LUS. A secondary analysis of 30-day survivors was performed to evaluate the prognostic value of LUS beyond the acute phase.

GRACE Score

To ascertain whether LUS could enhance the predictive capacity of current risk scales, the GRACE score[15,18] was calculated for all patients. Patients were divided into low/medium versus high-risk categories (>140 points) according to GRACE,[22] and into wet versus dry lung categories according to LUS, thus treating both GRACE and LUS variables as binary.

Statistical Analysis

Continuous variables were summarized as mean±SD or median and interquartile range (IQR), as appropriate. Categorical variables are shown as number and percentage. Descriptive analysis and comparison of baseline characteristics between the dry and wet lung groups were performed using the *t* test or Wilcoxon rank sum test as appropriate for continuous variables and χ^2 or Fisher exact test for categorical variables.

Time-to-event analyses comparing the study groups were performed using Cox proportional hazards models. The results were expressed using hazard ratio (HR) with 95% CIs. The proportional hazards assumption was verified by testing the interactions between the time variable and the covariates. LUS was analyzed as both a categorical and a continuous

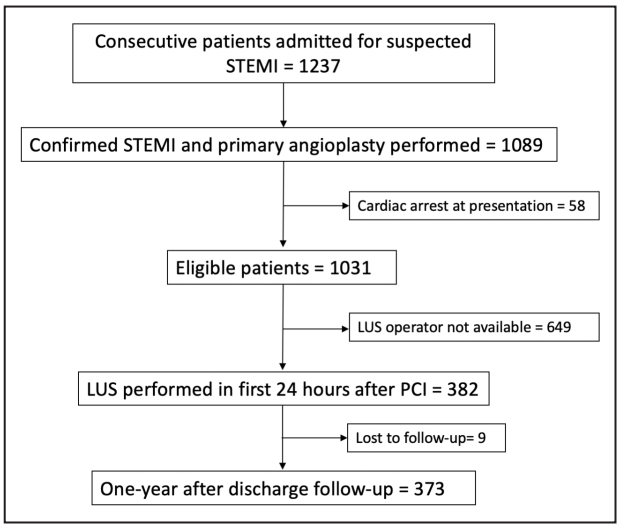

Figure 1. Study flowchart.
LUS indicates lung ultrasound; PCI, percutaneous coronary intervention; and STEMI, ST-segment–elevation myocardial infarction.

variable. A stepwise regression method, with an inclusion criterion of $P<0.05$ and an exclusion criterion of $P>0.10$, was used to identify independent predictors related to the composite outcome. This included all variables with biological plausibility that were significantly related to the event ($P<0.2$) after univariate screening.

To assess whether LUS improves the predictive ability of current scores, the absolute net reclassification index[25] of the categorical variables GRACE low-medium/high risk and LUS (wet/dry lung) was estimated. Also, predicted risk comparisons were performed using receiver operating characteristic curve analysis and the DeLong test for predicted risks of the GRACE variable and the combination of GRACE+LUS, also defined as categorical variables.

Finally, to evaluate interobserver variability between the LUS operators and the off-line analysis, Cohen's κ index was estimated for the categorical classification and individuals intraclass correlation coefficients

Table 1. Baseline Characteristics of Patients With Wet Lung and Dry Lung on Lung Ultrasound

Baseline characteristics	Overall, N=373	Wet lung, N=79	Dry lung, N=294	*P* value
Age, y, mean±SD	62.6±13.8	68.4±14.6	61.1±13.1	<0.001*
Men, n (%)	292 (78.3)	52 (65.8)	240 (81.6)	0.003*
Body mass index, kg/m^2, mean±SD	27.3±4.5	26.9±4.4	27.4±4.6	0.352
Hypertension, n (%)	211 (56.6)	45 (57.0)	166 (56.5)	0.937
Dyslipidemia, n (%)	241 (64.8)	52 (65.8)	189 (64.5)	0.828
Diabetes, n (%)	90 (24.2)	21 (26.9)	69 (23.5)	0.527
Smoker/former smoker, n (%)	244 (65.4)	47 (59.5)	197 (67.0)	0.213
COPD, n (%)	22 (5.9)	6 (7.6)	16 (5.4)	0.471
Chronic kidney disease stage ≥3, n (%)	43 (11.5)	15 (19.0)	28 (9.5)	0.019*
Previous atrial fibrillation/flutter, n (%)	11 (3.0)	8 (10.1)	3 (1.0)	<0.001*,†
Previous coronary revascularization, n (%)	39 (10.5)	8 (10.1)	31 (10.5)	0.914
Previous heart failure, n (%)	9 (2.4)	3 (3.9)	6 (2.1)	0.404†
Clinical variables at admission				
Killip class				
I	306 (82.0)	45 (56.9)	261 (88.9)	<0.001*
II	34 (9.1)	16 (20.3)	18 (6.1)	
III	13 (3.5)	8 (10.1)	5 (1.7)	
IV	20 (5.4)	10 (12.7)	10 (3.4)	
Symptom onset to wire cross time, min, median (IQR)	210 (133–270)	210 (120–467)	210 (135–360)	0.562
SBP, mm Hg, mean±SD	128.0±27.1	121.1±24.2	129.8±27.5	0.011*
Heart rate, mean±SD	77.6±15.8	82.3±18.1	76.3±14.9	0.003*
SpO_2, %, mean±SD	97.4±3.4	96.6±3.4	97.7±3.4	0.017*
Multivessel coronary disease, n (%)	146 (39.1)	35 (44.3)	111 (37.8)	0.290
TIMI flow grade post-PCI <3, n (%)	18 (4.8)	9 (11.4)	9 (3.1)	0.002*
NT-proBNP, pg/mL, median (IQR)	455 (121–1454)	1656 (419–4776)	337 (109–975)	<0.001*
Anterior STEMI, n (%)	147 (39.4)	41 (51.9)	106 (36.1)	0.011*
LVEF, %, mean±SD	48.0±10.5	40.3±10.4	50.0±9.5	<0.001*
LUS score, median (IQR)	0 (0–3)	9 (6–12)	0 (0–1)	<0.001*

LUS score: total number of B-lines. COPD indicates chronic obstructive pulmonary disease; IQR, interquartile range; LUS, lung ultrasound; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; PCI, percutaneous coronary intervention; SBP, systolic blood pressure; SpO_2, peripheral capillary oxygen saturation; STEMI, ST-segment–elevation myocardial infarction; and TIMI, Thrombolysis In Myocardial Infarction.

*Significant values.

†Fisher's exact test.

in a 2-way mixed-effects model for the continuous LUS score.

The threshold for statistical significance was set at a 2-sided $P \leq 0.05$. All statistical analyses were performed using Stata SE version 15.0.

RESULTS

Study Population

During the recruitment period, a total of 1089 patients with STEMI were admitted in the 3 study sites. Of these, LUS was performed in 382 patients. Only 9 participants (2.4%) were lost due to transfer to non-participant centers during index hospitalization, resulting in a final study population of 373 patients for the present analysis (Figure 1). Significant differences were found only in left ventricular ejection fraction between the patients included and those not included, although this difference was not considered clinically relevant (48.0±10.5 for the included group and 46.3±10.1 for the non-included group, $P<0.001$) (Table S1).

Baseline Characteristics

One hundred ninety-three patients (51.7%) showed 0 B-lines on LUS. As a result, the median LUS score was 0 (IQR, 0–3). Out of the 373 patients, 79 (21.2%) displayed a wet lung on LUS. The baseline characteristics and clinical variables at admission in wet and dry lung patients are presented in Table 1. Wet lung patients were older and predominantly women. They had a higher prevalence of previous history of atrial fibrillation/flutter or chronic kidney disease, whereas no statistically significant differences were observed in terms of previous history of HF or coronary revascularization. Patients classified as Killip I at admission were more frequently observed in the dry lung group.

Outcomes During Follow-Up

Fifty-one (13.7%) of the 373 patients presented the composite outcome during a median follow-up time of 368 days. Events occurred more frequently in the wet lung group: 27 (34.2%) versus 24 (8.2%), $P<0.001$. Twenty-eight (7.5%) patients died, whereas 15 (4.2%) were readmitted for acute HF, 13 (3.5%) for acute coronary syndrome, and 7 (1.9%) for stroke. All individual components separately were more frequent in the wet lung group (Table 2). Twelve patients experienced >1 type of event during the follow-up period.

Prognostic Significance of LUS at 1 Year of Follow-Up

The incidence of MACE was higher in patients with wet lung (Figure 2 [II A]) and increased with the number of B-lines (Figure 2 [II B]), as did all the individual components of the composite outcome separately (Table 2). The results of the Cox regression models for the categorical (wet/dry lung) and continuous (LUS score) exposures and their associations with the composite outcome are presented in Table 3. In the univariate analysis, the presence of a wet lung implied an HR of 4.86 (95% CI, 2.80–8.43; $P<0.001$), whereas each additional B-line on the LUS score indicated an increase in the HR of 1.14 (95% CI, 1.10–1.18; $P<0.001$). In the multivariate analysis, the LUS score remained an independent predictor (HR, 1.06 [95% CI, 1.01–1.11]; $P=0.009$), whereas the categorical classification of LUS did not (HR, 1.39 [95% CI, 0.73–2.66]; $P=0.319$). Given the rarity of dry lungs in patients with a high Killip class, we conducted a multivariate analysis in patients admitted in Killip class I. In this subgroup, having a wet lung remained an independent predictor (HR, 3.12 [95% CI, 1.34–7.31]; $P=0.009$). There was a linear relationship between the number of B-lines and the predicted risk of an event (Spearman rank correlation coefficient=0.73; $P<0.001$, Figure 3). LUS maintained its prognostic value beyond the acute phase in the analysis of the 30-day survivors for both the categorical (log-rank $P=0.005$) and the continuous (log-rank $P=0.014$) classifications (Figures S1 and S2).

Table 2. Study Events at 1 Year of Follow-Up and Differences Between Wet and Dry Lung Groups

Event	Overall N=373	Wet lung N=79	Dry lung N=294	*P* value
MACE	51 (13.7)	27 (34.2)	24 (8.2)	<0.001*
Individual components				
All-cause mortality	28 (7.5)	16 (20.3)	12 (4.1)	<0.001*
Acute HF	15 (4.2)	8 (11.3)	7 (2.4)	0.003*,†
ACS	13 (3.5)	6 (7.6)	7 (2.4)	0.036*,†
Stroke	7 (1.9)	4 (5.1)	3 (1.0)	0.039*,†

Results are presented as absolute number of events and percent incidence. ACS indicates acute coronary syndrome; HF, heart failure; and MACE, major adverse cardiovascular events.

*Significant values.

†Fisher's exact test.

Mortality Risk Reclassification Beyond the GRACE Score

The GRACE score was calculated in all patients. Of these, 155 (41.6%) had a low or medium risk (GRACE ≤140) and 218 (58.4%) had a high risk (GRACE >140) at admission. Because the GRACE score was designed to predict mortality, we conducted a reclassification of this score considering 1-year mortality. The reclassification analysis of the GRACE score with the categorical classification of LUS demonstrated relevant reclassification of the GRACE results, resulting in an

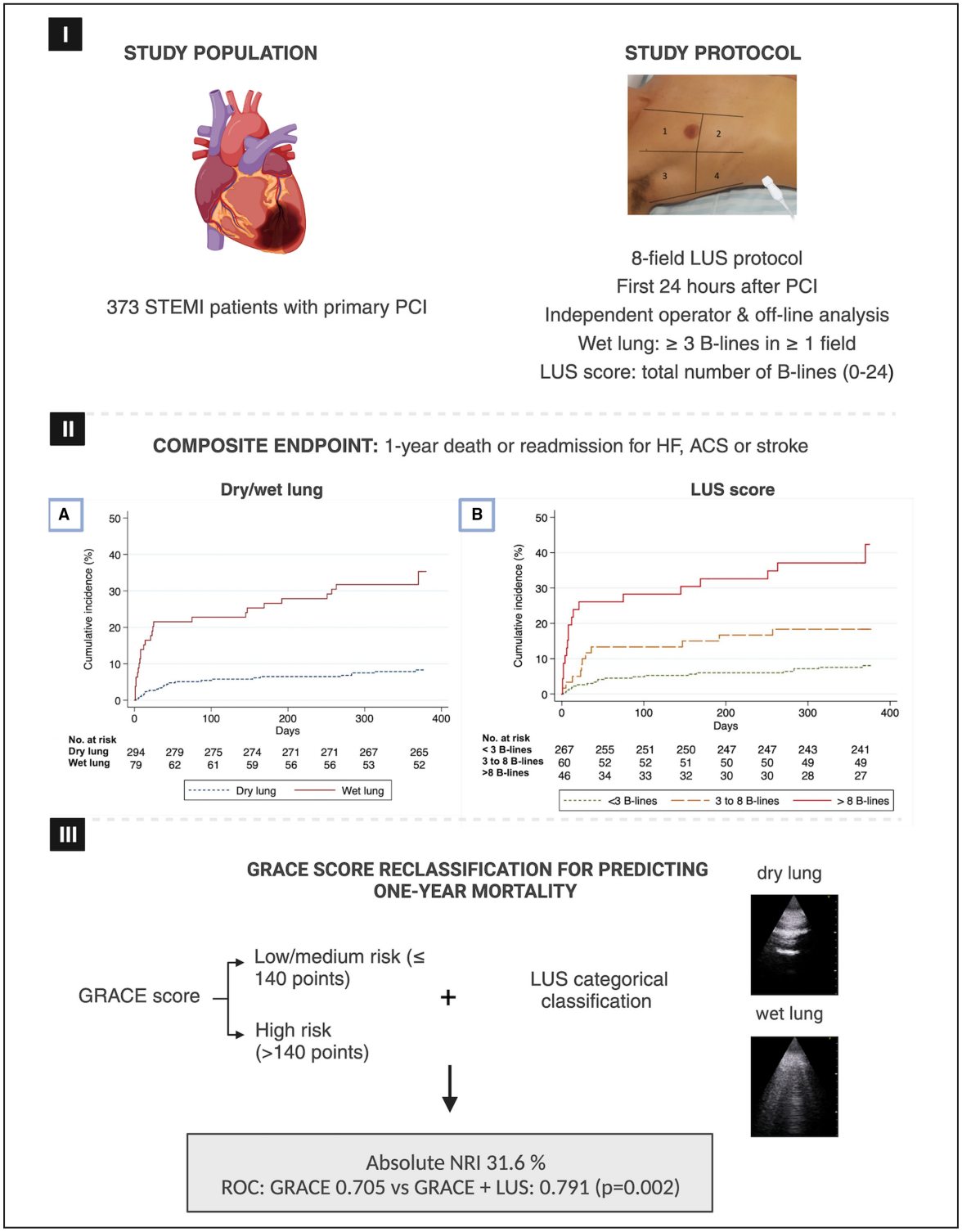

Figure 2. Study methods and results.
I, Study population and LUS protocol. **II**, MACE cumulative incidence and Kaplan-Meier curves of the categorical (**A**) and continuous (**B**) classification. In (**B**), 3 groups were defined in relation using the 75th and 90th percentiles of the LUS score as cutoff points (<3 B-lines, 3 to 8 B-lines, and >8 B-lines, respectively). **III**, On the left, GRACE score categorical distinction into low/medium or high risk. On the right, examples of dry and wet lungs in LUS images. The gray square highlights reclassification results. Created with BioRender.com. ACS indicatees acute coronary syndrome; GRACE, Global Registry of Acute Coronary Events; HF, heart failure; LUS, lung ultrasound; MACE, major adverse cardiovascular events; NRI, net reclassification index; PCI, percutaneous coronary intervention; ROC, receiver operating characteristic; and STEMI, ST-segment–elevation myocardial infarction.

absolute net reclassification index of 31.6%. Finally, the area under the receiver operating characteristic curve comparison of models composed of GRACE and GRACE+LUS revealed that the addition of LUS enhanced the accuracy of predicted risk (0.705 [95% CI, 0.661–0.748] versus 0.791 [95% CI, 0.721–0.862], *P*=0.002).

LUS Feasibility and Interobserver Variability

LUS was considered interpretable in all scans performed, both by the independent operator and by investigators analyzing the clips offline. The median time between admission and LUS performance was 9.0 hours (IQR, 2.0–17.3), with no significant differences between the wet and dry lung groups (7.3 versus 9.0, respectively; *P*=0.132). We did not observe a relationship between time to LUS and total number of B-lines (*r*=−0.07). Pleural effusion was detected on LUS in 13 patients (3.5%), being more frequent in the wet lung group (12.7% versus 1.0%, *P*<0.001). Interobserver variability was low between the bedside analysis by the LUS operator and offline analysis by investigators for both categorical and continuous classifications, with a κ index of 0.87 (95% CI, 0.81–0.93) and an intraclass correlation coefficient of 0.90 (95% CI, 0.86–0.93), respectively.

DISCUSSION

In this multicenter prospective cohort study, we evaluated the 1-year prognostic value of systematic LUS assessment in patients admitted with STEMI. After conducting a multivariable analysis, the LUS score was identified as an independent predictor. Additionally, having wet lungs was established as an independent predictor in patients admitted in Killip I class. Furthermore, the inclusion of LUS to the GRACE score enhanced its prognostic capacity for 1-year mortality.

LUS has gained increasing prominence as a clinically useful tool in patients with HF. It can play a role in diagnostics, prognostic stratification, and guiding diuretic treatment for these patients.[2–7] Therefore, guidelines recommend its use at the diagnostic workup of HF.[26] LUS has also been recently studied in patients with acute coronary syndrome.[9–13] The published studies concur on the prognostic usefulness of LUS performed during hospitalization and in terms of predicting short-term outcomes. Araujo et al conducted an analysis of reclassification of the Killip scale adding LUS results and obtained a positive reclassification of patients in terms of in-hospital mortality.[10] In a previous subanalysis of this cohort restricted to patients classified as Killip I, those with subclinical congestion at admission (defined as a wet lung in patients without other signs of HF at admission) exhibited a worse prognosis during hospitalization and within a 30-day follow-up.[13] Similar to our approach in the present study, the reclassification of patients based on LUS results improved the prognostic accuracy of the Zwolle score,[27] a short-term risk score.

Table 3. Univariate and Multivariate Predictors of the End Point

Characteristic	Hazard ratio	95% CI	*P* value
Univariate analysis			
Age	1.06	1.04–1.09	<0.001
Men	0.79	0.42–1.49	0.473
Diabetes	1.69	0.95–3.02	0.072
Hypertension	1.94	1.06–3.55	0.031
COPD	4.15	2.01–8.54	<0.001
Chronic kidney disease stage ≥3	4.80	2.70–8.54	<0.001
Previous atrial fibrillation/flutter	6.55	3.05–14.04	<0.001
Killip class	2.06	1.66–2.56	<0.001
SBP, per each mm Hg	0.99	0.98–0.99	0.047
Total ischemic time, h	1.02	1.01–1.04	0.006
Multivessel coronary disease	2.28	1.19–4.35	0.013
TIMI flow grade post-PCI <3	5.78	2.80–11.94	<0.001
Anterior MI	2.80	1.59–4.95	<0.001
LVEF	0.91	0.89–0.94	<0.001
LUS score	1.14	1.10–1.18	<0.001
LUS wet/dry	4.86	2.80–8.43	<0.001
Multivariate analysis with LUS score			
Age	1.05	1.02–1.07	0.016
TIMI flow grade post-PCI <3	3.62	1.56–8.41	0.003
LVEF	0.94	0.90–0.96	<0.001
Chronic kidney disease stage ≥3	2.15	1.09–4.24	0.027
LUS score	1.06	1.01–1.11	0.009
Multivariate analysis with LUS wet/dry			
Age	1.05	1.02–1.07	<0.001
TIMI flow grade post-PCI <3	2.93	1.31–6.51	0.008
LVEF	0.95	0.92–0.99	0.014
Chronic kidney disease stage ≥3	2.06	1.03–4.13	0.041
Anterior MI	2.05	1.12–3.77	0.030
Killip class	2.00	1.07–3.74	0.006
LUS wet/dry	1.39	0.73–2.66	0.319
Multivariate analysis with LUS wet/dry in Killip class I			
Age	1.04	1.00–1.08	0.038
TIMI flow grade post-PCI <3	6.26	1.75–22.39	0.005
Chronic kidney disease stage ≥3	3.76	1.42–9.92	0.008
Anterior MI	2.83	1.18–6.77	0.020
LUS wet/dry	3.12	1.34–7.31	0.009

Results are presented as hazard ratios from Cox regression models with 95% CIs. Multivariate analysis tables include variables that yield a significant result (*P*<0.05) after stepwise regression. COPD indicates chronic obstructive pulmonary disease; LUS, lung ultrasound; LVEF, left ventricular ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; SBP, systolic blood pressure; and TIMI, Thrombolysis In Myocardial Infarction.

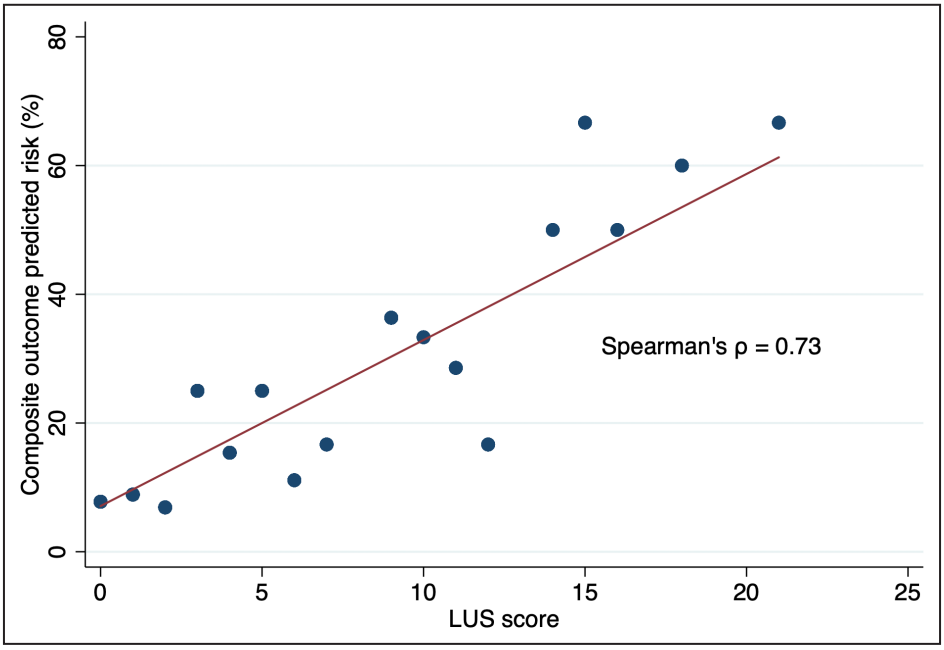

Figure 3. Correlation of LUS score–outcome risk.
Correlation between LUS score (total number of B-lines) and composite outcome risk (blue dots). The red line represents the fitted values. LUS indicates lung ultrasound.

The role of LUS in predicting long-term events in patients with STEMI has only been assessed in 1 previous small study, which enrolled participants with an anterior-wall STEMI (N=96). In this specific cohort, patients with ≥18 B-lines showed a higher incidence of readmission due to HF or mortality than patients with <18 B-lines, at a median time of 25 months follow-up.[9] In contrast, in our cohort we chose a low cutoff (≥3 B-lines in at least 1 field) for categorizing LUS results. This approach offers a practical means of rapidly stratifying a patient's risk upon admission, especially in patients in Killip I class.

In our study, the presence of B-lines was associated with a higher risk of adverse events during the subsequent 12 months. These events extend beyond mortality or HF. As described in previous studies,[28–30] patients with higher Killip classes also have a greater incidence of acute coronary syndrome or stroke, and these events are included in most definitions of MACE.[31] The risk increased proportionally with the total number of B-lines, constituting the LUS score. On the other hand, the categorical classification of LUS resulted in being an independent predictor only in the subgroup of patients in Killip class I. Having a dry lung (no lung field with ≥3 B-lines) is rare in established high Killip classes, rendering this classification potentially useless in such situations. This finding suggests that using this categorical classification of LUS solely among patients in Killip class I may offer greater sensitivity in detecting patients with a higher risk within a group presumed to have a good prognosis. These results have important clinical implications.

Because LUS can be performed with a cardiac probe and has a fast learning curve,[24] it would be expected to be relatively easy to incorporate this assessment into the routine echocardiograms performed on patients admitted for STEMI. This additional information may provide useful insight into the prognosis of these patients. Ideally, LUS should be performed either immediately upon admission or during the first 24 hours, because during this timeframe it can provide high prognostic value. As described in previous studies,[10] an 8-zone LUS does not take >3 minutes to perform. In this way, even if the LUS assessment was performed before coronary angiography, it should not result in significant delays in door-to-balloon time.

To the best of our knowledge, this is the first study to evaluate the ability of LUS to improve a current risk score in STEMI. Thus, our study provides a novel and comprehensive evaluation of the midterm value of LUS in STEMI care. Moreover, none of the previous studies conducted an offline counting of B-lines, the omission of which may introduce bias. Lastly, our study maximized external validity through a multicenter design and recruited a relatively large patient cohort, larger than that enrolled in the other relevant study in this field.

Study Limitations

Despite the aforementioned strengths, our study has some limitations. First, the inclusion rate was nearly 40% with respect to the total number of eligible patients with STEMI. This was primarily due to the low

availability of independent LUS operators at the study sites. Nonetheless, our analyses showed that baseline characteristics did not significantly differ between included and nonincluded patients (see Table S1).

A composite end point (MACE) was used. Although this approach has some limitations compared with assessing each end point separately, the components included in our composite end point are all deemed highly relevant from a clinical standpoint and are similar to those included in the Food and Drug Administration-endorsed MACE definitions used in landmark clinical trials in this space. Also, all of them showed significant differences in their incidences between the study groups (Table 2). Finally, another reason not to perform regression analyses for each of those components separately was the low number of events.

Finally, the GRACE score was designed to predict in-hospital and 6-month mortality after discharge.[15] In our study, we assessed its ability to predict mortality up to 1 year from admission. Subsequent studies by the GRACE investigators have evaluated its ability with a unique end point from admission.[18] Other studies by different groups show that GRACE has a comparable capacity to predict events in a 1-year follow-up.[32,33]

Although this study yields relevant conclusions, the evidence of LUS in acute myocardial infarction is limited, and larger studies are needed to support its routine use in these patients.

CONCLUSIONS

The presence of B-lines on LUS within the first 24 hours after revascularization in patients with STEMI is associated with MACE during the first year of follow-up. The addition of LUS findings to the GRACE score seems to improve its prognostic capacity. Although replication in larger cohorts is necessary, our study, along with previous reports, suggests that LUS assessment could be a valuable tool in the care of patients with STEMI.

ARTICLE INFORMATION

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Disclosures

None.

Supplemental Material

Table S1
Figures S1–S2

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