Lung ultrasound in acute myocardial infarction. Updating Killip & Kimball

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ABSTRACT

Background: Heart failure complicating acute myocardial infarction marks an ominous prognosis. Killip and Kimball’s classification of heart failure remains a useful tool in these patients. Lung ultrasound can detect pulmonary congestion but its usefulness in this scenario is unknown.

Objective: To investigate the diagnostic accuracy of lung ultrasound to predict heart failure in patients with acute myocardial infarction.

Methods: Patients admitted with acute myocardial infarction and without heart failure were evaluated with a lung ultrasound. The presence of B-lines was recorded and counted. The presence of new heart failure (Killip Class B, C, or D) during hospitalization was evaluated by a cardiologist blinded to the results of lung ultrasound. A ROC curve analysis was done to evaluate the diagnostic accuracy of B-lines to predict heart failure.

Results: 200 patients were included. Three patients were diagnosed with cardiogenic shock, 5 with acute pulmonary edema, and 17 with mild heart failure. Patients who develop heart failure had a median of 14 B-lines, however, patients who remained in Killip class A had a median of 2 (p = 0.0001). The area under the ROC curve of the sum of B-lines to predict any form of heart failure was 0.91 (CI95% 0.86–0.97). The best cut-off value was 5 B-lines, with a sensitivity of 88% (IC95% 0.68,8–0.97,5) and specificity of 81% (IC95% 0.73.8–0.86.2).

Conclusion: Lung ultrasound done at admission can help to predict heart failure in patients with acute myocardial infarction. © 2020 Cardiological Society of India. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Background

Heart failure complicating acute myocardial infarction is a powerful predictor of fatal and non-fatal events.1 Since its original description by Killip in 19672 this classification has remained a cornerstone in the clinical armamentarium to evaluate a patient suffering an acute myocardial infarction.

Patients with an acute myocardial infarction are categorized as Killip class A if they have no clinical signs of heart failure, class B as the presence of rales, third heart sound, and jugular venous distention, class C with acute pulmonary edema, and class D as cardiogenic shock. Even more recent, large, and well-designed registries as GRACE had confirmed its value in a changed scenario of modern strategies of primary percutaneous revascularization, stents, and antiplatelet therapy. Although cardiogenic shock marks the worst prognosis, even lesser grades of heart failure are associated with higher mortality. In the GRACE risk score model, a Killip class B had a twofold increase of risk of death as compared with no evidence of heart failure.3 Cardiogenic shock and acute pulmonary edema generally are distinctive syndromes, however, to detect signs of mild heart failure can be more challenging in certain patients.

Abbreviations: ROC, Receiver Operating Characteristic; GRACE, Global Registry of Acute Coronary Events; STARD, Standards for Reporting of Diagnostic Accuracy Studies; POC, Point of care; BSA, body surface area; BMI, body mass index; STEMI, ST-segment elevation myocardial infarction; LBBB, left bundle branch block; RBBB, right bundle branch block; OR, odds ratio.

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Lung ultrasound is a simple tool that can be used to detect pulmonary congestion and was validated in several studies and meta-analysis.\(^4\)\(^{−}\)\(^9\) Briefly, abnormal accumulation of lung water can be detected as “comet tails” artifacts using ultrasound in a bedside examination. These artifacts are called B-lines and the presence of more than 3 bilaterally are considered abnormal.

2. Objective

To investigate the diagnostic accuracy of lung ultrasound to predict heart failure in patients with acute myocardial infarction.

3. Methods

We studied patients admitted to the Emergency Department of our hospital with a diagnosis of suspected acute myocardial infarction (with or without ST-segment elevation).

Inclusion criteria were:

- Male and female patients aged 18 years or more.
- Suspected acute myocardial infarction, based on the presence of typical symptoms associated with ischemic abnormalities in the electrocardiogram.
- Less than 24 h of symptoms onset.

Patients were excluded if they presented at admission with any form of heart failure.

The trial was approved by the local Investigation Committee. All patients gave informed consent to participate in the study.

The medical history, physical examination, and electrocardiogram were obtained and evaluated by a cardiologist. Myocardial infarction was suspected in the presence of typical symptoms and ischemic changes in the electrocardiogram.

A lung ultrasound examination was done according to a scanning protocol\(^10\) by cardiologists with the training of at least 10 studies under the direct supervision of an expert and a 1-h lecture about the method.

Anatomic zones to be scanned were defined by vertical lines through the sternum, anterior and posterior axillary lines, and by horizontal lines through the clavicle, third intercostal space, and the diaphragm. With this approach 8 thoracic lung zones were obtained, 4 anterior and 4 lateral. The examination was done bedside with the patient reclined at 45°. The study typically was completed in less than 5 min and did not generate any delay in the normal management of patients.

A commercially available portable ultrasound machine (Sonosite Titan, USA) with a curvilinear probe was used. The depth was set at 15 cm.

The presence of pleural and A-lines was considered a normal pattern. B-Lines were defined as hyperechogenic vertical lines arising from the pleural line and extending to the border of the screen. These “comet tail” artifacts move with the respiratory cycle.

Fig. 1. Typical patterns of lines A (a) and line B (b) in lung ultrasound scan.

3.1. Statistical analysis

The total number of B-lines were compared between the group of patients with and without incident heart failure. We used a non-parametric test (Mann–Whitney U test). A \(p\)-value of less than 0.05 was considered statistically significant.

We also evaluated the sensitivity, specificity, and the best cut-off value (estimated by the Youden index) of B-lines using ROC curve analysis. Assuming a heart failure rate of 10%, with a type I error level of 0.05 and statistical power of 80% a sample size of 198 was calculated to detect an area under the curve of at least 0.7.

A logistic regression model was constructed to evaluate if the presence of B-lines was an independent predictor of heart failure. Statistical analysis was performed using STATA 14 version software (StataCorp, College Station, TX).

We have tried to apply the STARD guidelines for reporting diagnostic accuracy studies.\(^12\)

4. Results

From March 11, 2019, through November 27, 2019, we included 200 consecutive patients. Baseline characteristics are shown in Table 1. The mean age was 62 (SD11), 75.5% were male. Less than 5% of patients had a diagnosis of chronic pulmonary disease, and 85 were obese (BMI more than 30).

Seventy-six percent of patients received a primary coronary angioplasty. Typical medical treatment was administered including intravenous nitroglycerin in 50% of patients as anti-ischemic.
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Three patients were diagnosed with cardiogenic shock, 5 with acute pulmonary edema, and 17 with mild heart failure after admission to the coronary care unit. All of them were treated with intravenous furosemide. The findings of lung ultrasound were not available to the attending physician; therefore, doses of the diuretic were chosen according to clinical criteria.

Five patients (2.5%) died during hospitalization. The median length of stay was 4 (IQR 3–6) days. The events of heart failure were detected at a median of 1 day after admission.

Patients who develop any form of heart failure during hospitalization had a median of 14 B-lines, however, patients who remained in Killip class A had a median of 2 (p = 0.0001). Fig. 2.

A comprehensive Doppler echocardiography was done in 192 patients at a median of 1 day after admission. Patients who develop heart failure had a lower ejection fraction (47 vs. 58%) p = 0.0001, larger left atrial volume index (35 vs. 29 ml/m²) p = 0.008, higher E/e’ ratio (16 vs. 11) p = 0.001, tricuspid regurgitation velocity (291 vs. 235 cm/s) p = 0.003, estimated central venous pressure (7.6 vs. 3.8 mmHg) p = 0.001 and left ventricular mass index (139 vs. 119 gr/m²) p = 0.001.

Patients with heart failure had a higher value of cardiac troponin T (6303 vs. 2622 ng/L) p = 0.001. A comparison of other variables is shown in Table 2.

The area under the ROC curve of the sum of B-lines to predict any form of heart failure was 0.91 (CI95% 86–97). The best cut-off value was 5 B-lines, with a sensitivity of 88% (CI95% 68.8–97.5) and specificity of 81% (CI95% 73.9–86.2). Fig. 3.

Univariate analysis identified left bundle branch block, ST-segment elevation myocardial infarction, and systolic blood pressure at admission as variables associated with heart failure.

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Univariate analysis identified left bundle branch block, ST-segment elevation myocardial infarction, and systolic blood pressure at admission as variables associated with heart failure.

We constructed a logistic regression model to predict heart failure with these variables and the sum of B-lines as co-variables. The presence of B-lines remained statistically significant (p = 0.001) with OR 1.3 (IC95% 1.18—1.45). Table 3.

5. Discussion

In a recent article,13 the authors suggest adding a fifth pillar to the classic physical examination, e.g. insonation. The selective use of bedside ultrasound as a point of care (POC) tool has gained broad impulse in the last years. Ultrasound is safe, inexpensive, rapidly available, repeatable, and reproducible.14 Lung ultrasound, particularly, was extensively studied as a marker of lung congestion. Its usefulness was confirmed in different clinical scenarios. Helping in the diagnosis of heart failure in patients with acute dyspnea in the emergency department, monitoring treatment response in acute pulmonary edema,15–17 evaluating decompensation in patients with chronic heart failure in ambulatory care.18 Lung ultrasound also had shown value as a prognostic tool.19,20

In acute myocardial infarction, the detection of subtle or early phases of heart failure can be challenging. Several factors may be involved: elderly patients, obesity, chronic obstructive pulmonary disease makes detection of signs of mild heart failure difficult. Also, some evidence suggests that currently, the physical examination is used less and with worst proficiency.21

Recently, a “lung water cascade in heart failure”22 has been described. In these sequence of events, B-lines precedes rales and dyspnea. Therefore, this clinically silent interstitial pulmonary edema can be interpreted as an early stage in the path of heart failure complicating acute myocardial infarction. B-lines can be considered a biomarker of congestion allowing the physician to anticipate a worsening of Killip class.

In our study, half of the incident cases of heart failure (including cardiogenic shock) occurred within 24 h of admission. Lindholm et al23 published similar data, 59% of cases of cardiogenic shock developed within 48 h, 11% during days 3 and 4, and only 30% later than 4 days. The late shock was associated with a higher proportion of female sex, less use of revascularization, and a worse prognosis.

Our results show that lung ultrasound detecting B-lines can predict heart failure complicating acute myocardial infarction. Identifying patients at risk of heart failure offer an opportunity to tailor treatment, therefore the early use of revascularization in non-ST segment elevation myocardial infarction, angiotensin-converting enzyme inhibitors, mineralocorticoid receptor

### Table 1

Baseline characteristics of patients, including demographics, clinical, electrocardiographic and angiographic data. Numerical variables are expressed as mean and ± standard deviation.

| Patient characteristics | N = 200 |
|-------------------------|---------|
| Female                  | 49 (24.5%) |
| Age (years)             | 62 (±12) |
| BMI (kg/m²)             | 1.93 (±0.02) |
| Systolic blood pressure (mmHg) | 148 (±27) |
| Diastolic blood pressure (mmHg) | 83 (±14) |
| Pulse rate              | 77 (±14) |
| Hypertension            | 148 (74%) |
| Diabetes                | 62 (31%) |
| Hyperlipidemia          | 73 (36.5%) |
| Smoking                 | 46 (23%) |
| STEMI                   | 134 (67%) |
| Localization            |         |
| Anterior                | 70 (35%) |
| Inferior                | 60 (30%) |
| Undetermined            | 70 (35%) |
| LBBB                    | 18 (9%)  |
| RBBB                    | 18 (9%)  |
| Number of vessels       |         |
| 0                       | 18 (9%)  |
| 1                       | 116 (58%)|
| 2                       | 36 (18%) |
| 3                       | 29 (14.5%)|
| Primary angioplasty     | 152 (76%)|

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* BMI: body mass index.
* BSA: body surface area.
* LBBB: left bundle branch block.
* RBBB: right bundle branch block.
* STEMI: ST-segment elevation myocardial infarction.
Numerical variables are expressed as mean and ± standard deviation.

### Table 2
Comparison between patients with and without heart failure. Comparison of clinical and key echocardiographic variables between patients without (Killip A) and with heart failure (Killip B, C or D) developed during hospitalization.

| Variable                        | Killip A (n = 175) | Killip B, C or D (n = 25) | P value |
|---------------------------------|--------------------|---------------------------|---------|
| Age (years)                     | 62 (±12)           | 65 (±11)                  | 0,1     |
| STEMI (count)                   | 111 (83%)          | 23 (17%)                  | 0,004   |
| Non STEMI (count)               | 64 (97%)           | 2 (3%)                    |         |
| Onset of symptoms (hours)       | 6.2 (±10)          | 5.2 (±7)                  | 0,0001  |
| Cardiac troponin T (ng/l)       | 2623 (±4763)       | 6303 (±2753)              | 0,001   |
| Systolic blood pressure (mmHg) | 84 (±14)           | 134 (±28)                 | 0,01    |
| Diastolic blood pressure (mmHg) | 142 (±1.7)         | 138 (±1.9)                | 0,05    |
| Hemoglobin (g/dl)               | 10.353 (±3796)     | 11837 (±3356)             | 0,01    |
| Blood glucose (mg%)             | 163 (±83)          | 201 (±110)                | 0,1     |
| Creatinine (mg%)                | 0.97 (±0.3)        | 1.15 (±0.7)               | 0.3     |
| Clearance (mL/min/1.73 m²)      | 85.8 (±27)         | 81 (±36)                  | 0.5     |
| Left ventricular mass index (gr/m²) | 118.7 (±34)     | 139 (±28)                 | 0.01    |
| Ejection fraction (%)           | 58 (±8)            | 47 (±9)                   | 0.001   |
| Left atrial volume index (ml/m²) | 29.3 (±9)        | 35 (±10)                  | 0.008   |
| E/e' ratio                      | 10.8 (±3.8)        | 15.9 (±7.6)               | 0.001   |
| Tricuspid regurgitation velocity (cm/s) | 235 (±25)   | 291 (±62)                 | 0.003   |

### Table 3
Multivariate analysis. Logistic regression model: variables statistically significant in univariate analysis of heart failure complicating acute myocardial infarction where included as co-variates. Dependent variable is heart failure (Killip B, C or D). Associated OR and p-values are shown.

| Variable                        | OR (95% CI) | P value |
|---------------------------------|-------------|---------|
| B-lines (number)                | 1.3 (1.18–1.45) | 0.0001  |
| LBBB (yes/no)                   | 11.2 (2.1–59.4) | 0.004   |
| STEMI (yes/no)                  | 3.1 (0.4–22.8) | 0.2     |
| Systolic blood pressure (mmHg)  | 0.97 (0.94–0.99) | 0.027   |

5.1. Limitations

Patients included in our study showed baseline characteristics similar to those reported in other published registries and studies. However, the generalization of our results must be done cautiously in different clinical scenarios.

The specificity of lung ultrasound is affected by several causes. Acute and chronic lung diseases (infectious and not infectious) can produce B-lines not associated with heart failure. The correct classification of these patients warrants further investigations.

In our study, 42% of patients were obese. The sensitivity of lung ultrasound may be lower in these patients.

Killip classification is subjective, however, its value remained unaltered since its original description.

Some investigators had used N-terminal brain natriuretic peptide (NT-pro BNP) to identify patients at higher risk of adverse events after an acute myocardial infarction, specially infarct size and function. We did not include this biomarker in our investigation. However, our goal was to provide a point of care (POC) tool at patient admission. Obtain the NT-pro BNP results usually requires several minutes to hours to be available.

### 6. Conclusions

Lung ultrasound done at admission can help to predict heart failure in patients with acute myocardial infarction.

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Declaration of competing interest

The authors declare that there is no conflict of interest.

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