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Point of care ultrasound impact in acute heart failure hospitalization: A retrospective cohort study

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ABSTRACT

Background: Acute decompensated heart failure (ADHF) is one of the most frequent causes of emergency department (ED) visits. Point-of-Care Ultrasound (POCUS) is a reliable, easy-to-use, and available tool for an accurate diagnosis of ADHF. We aimed to analyze the impact of introducing POCUS as an additional tool to clinical standard diagnosis in clinical times of hospitalized heart failure patients.
Methods: Retrospective cohort study comparing patients consulting to ED for heart failure acute decompensation previous to the rutinary use of POCUS versus patients who received an ultrasound-guided diagnosis at entrance. Ultrasound evaluation was additional to standard diagnosis (which included natriuretic peptides, images, etc). Cumulative incidence functions were calculated for time to treatment, time to disposition decision, and time to discharge. We used a flexible parametric model for estimate the time ratio (TR) in order to reflect the effect of POCUS.
Results: A total of 149 patients were included. The most frequent comorbid condition was hypertension (71.8%) followed by type 2 diabetes (36.2%). B type natriuretic peptide (BNP) was over 500 ng/ml. Most patients had Stevenson B profile (83.9%) at admission. In the cumulative incidence model (Fig. A), the TR (time ratio) for the outcome time to treatment was 1.539 (CI 95% 0.88 to 2.69). The TR for the outcome time to disposition decision was 0.665 (CI 95% 0.48 to 0.99). The TR for the outcome time to discharge (hospital length of stay) was 0.663 (CI 95% 0.49 to 0.90).
Conclusion: In our study, the introduction of POCUS to ADHF patients decreases time to disposition decision and total length of hospital stay. Conversely, time to treatment augments. There is need for the evaluation of ultrasound as an intervention in clinical trials to confirm these findings.

1. Introduction

Acute Decompensated Heart Failure (ADHF) is a leading cause of Emergency Department (ED) visits and it has been increasing in the last two decades [1] ADHF has become one of the top five admission diagnoses in the United States and Europe and it is not expected to decrease due to the high incidence of risk factors such as type 2 diabetes, hypertension and obesity among others [2].

Point of care ultrasound (POCUS) is a useful tool to diagnose patients in the emergency department. Evidence of high sensitivity and specificity for the diagnosis of ADHF has been published [3]. Systematic reviews have reported better POCUS diagnostic accuracy than chest X-ray and clinical evaluation alone for heart failure [4]. Recently, lung ultrasound has been included in European HF guidelines, highlighting the main role of bedside ultrasonography to obtain a rapid and accurate diagnosis of heart failure in the ED [2].

The impact of POCUS on clinical outcomes has been evaluated in several studies. One study showed dilated inferior vena cava was related to higher mortality [5]. Moreover, a randomized controlled trial using lung ultrasound, demonstrated a decrease in ED visits [6]. Analyzing hospital stay, one study showed no impact in ED length of stay and time to disposition [7]. However, a recent clinical guideline from the American College of Physicians [8] makes a conditional recommendation for the use of POCUS in the acute dyspnea evaluation. This guideline exposes the lack of high-quality evidence on clinical outcomes of ultrasound and urges to evaluate them.

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We set out to determine the impact on hospital stay, time to disposition decision and time to treatment after the introduction of POCUS as an additional diagnostic method in a cohort of patients with dyspnea and a clinical diagnosis of ADHF in the ED.

2. Methods

This is a retrospective cohort study carried-out in a tertiary level university-based institution in Colombia. The Ethics Committee and Institutional Research Board approved the protocol (Act 239 April 29th 2021).

2.1. Study population

Patients presenting to ED from January 2017 to December 2020 with dyspnea were eligible. According to symptoms, past medical history and physical examination, emergency physicians made a clinical suspicion of acute heart failure. Internal Medicine was consulted in every patient with evident congestion to determine disposition: outpatient management or in-hospital treatment.

Diagnosis of ADHF was made using symptoms, natriuretic peptides, and images (chest x-ray, computed tomography) according to guidelines of the moment. Patients were treated according to clinical profile (Stevenson profile) and treating physician criteria.

Individuals diagnosed from January 2017 to December 2018 are referred as “clinical group” because these patients received standard diagnostic methods. Patients evaluated from January 2019 to December 2020 are mentioned as “POCUS group”. This group received standard diagnostic process and Point-of-Care Ultrasound for diagnostic certainty at internal medicine evaluation. Diagnosis of ADHF including ultrasound required clinical suspicion and interstitial syndrome in lung ultrasound, this is more than three B-lines in two exploration chest points bilateral.

Patients over 18 years old, who were diagnosed with ADHF and in-hospital treatment indication were included in the analysis. Heart failure diagnosis was either chronic or de novo. Patients in the POCUS group were required to have an ultrasound evaluation in clinical record. Exclusions were shock and or hypotension, use of inotropes or vasopressors, cardiac arrest or any clinical instability. All information was collected retrospectively from clinical records.

2.2. Point-of-care ultrasound

Sonographic evaluations were performed by a trained internal medicine specialist with 5 years of POCUS experience. This specialist was in charge of the clinical evaluation and treatment of patients at admission. A SonoScape S2 Ultrasound Machine (Sonoscape Corp. Guandong, China. 2016–3) was used with a 2.5MHZ phased array. The evaluation included a three-point lung ultrasound in each hemithorax: anterior, lateral and Postero-Lateral Alveolar-Pleural Syndrome (PLAPS) to determine presence or absence of bilateral B-lines and or pleural effusion. Presence of B-lines was defined as three or more B-lines in two chest exploration points (Fig. 1).

Focused cardiac ultrasound was done to qualitatively evaluate left ventricle function and pericardial effusion using at least two of three main views (subcostal, parasternal and apical). POCUS was performed to guide initial diagnosis and was not intended to guide in-hospital treatment. There were no in-hospital POCUS evaluations.

2.3. Outcomes

Clinical outcomes were time to treatment defined as number of minutes elapsed after internal medicine evaluation until diuretic administration in nurse records; time to disposition decision as minutes elapsed after emergency physician request for internal medicine evaluation until hospital admission is ordered in clinical records; hospital length of stay as total hospitalization days from admission to discharge.

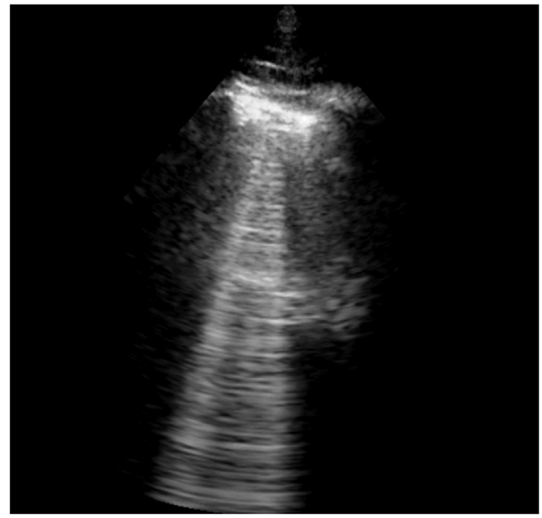

Fig. 1. B-lines in lung ultrasound. B-lines indicating interstitial syndrome, consistent with acute heart failure. The presence was defined as three or more B-lines in two chest exploration points.

2.4. Statistical analysis

Sample was conveniently drawn from patients consulting the ED during shifts where POCUS was available (Monday to Friday daytime). All patients fulfilling criteria were included. Quantitative variables were reported as mean and standard deviation or median and interquartile range; qualitative variables were reported as total and percentage. Cumulative incidence functions were calculated for Time to treatment, time to disposition decision, and time to discharge. We used a flexible parametric model for estimate the time ratio (TR) or sometimes called “acceleration factor” in order to reflect the effect of POCUS on the time to treatment, time to disposition decision, and time to discharge. If a TR was greater than 1, then it was interpreted as an increase (percentage) in the time of the outcome (diuretic treatment, disposition decision, and discharge). We presented the TR adjusted by age, creatine, Stevenson profile), and Left Ventricle Ejection Fraction (LVEF). We evaluated the goodness of fit to different parametric distributions as Generalized Gamma (GG), Weibull (W), Exponential (Ex), and Log normal (LN). Selection model for the best goodness of fit was done using Akaike Information Criteria (AIC); the model with the lowest AIC value was chosen [9]. For time to discharge competing risk analysis was done to estimate the sub-Hazard ratio (sHR) for the time to discharge alive with in-hospital mortality as a competing risk using the Fine & Gray model [10]. All statistical analysis were done with R [11] language R version 4.2.1 (2022-06-23). For flexible parametric models we used the package “flexsurv” [12] and the package “cmprsk” for competing risk analysis [13]. See supplement for more detailed statistical analysis.

3. Results

During the study time 1509 patients had a clinical diagnosis of acute decompensated heart failure and 254 received in-hospital treatment. Regarding hospitalized patients, 105 were admitted during non-available POCUS shifts.

A total of 149 patients fulfilled inclusion criteria and were analyzed. Basal characteristics of all patients and each group are detailed in Table 1. Patients were mostly men of around 73 years old. The most frequent comorbid condition was hypertension (71.8%) followed by type 2 diabetes (36.2%) and chronic renal failure (18.1%). B type natriuretic peptide (BNP) was over 500 ng/ml. Most patients were considered to have a B Stevenson profile (83.9) as clinical presentation at admission.

Table 1
Clinical and demographic characteristics.

Variable	All	Pre-POCUS	POCUS
	n = 149	n = 75	n = 74
Age years	73 (59–82)	75 (62–84)	69 (56–79)
Female	71 (47.7)	42 (56)	29 (39.2)
Coronary artery disease	36 (24.2)	18 (24)	18 (24.3)
Heart failure	48 (32.2)	25 (33)	23 (31.1)
Hypertension	107 (71.8)	61 (81.3)	46 (62.2)
Type 2 Diabetes	54 (36.2)	28 (37.3)	26 (35.1)
Dyslipidemia	3 (2)	0	3 (4.1)
Valvular heart disease	5 (3.4)	4 (5.3)	1 (1.4)
Resinchronization therapy	1 (0.7)	1 (1.3)	0
Implantable defibrillator	2 (1.3)	2 (2.7)	0
Chronic kidney disease	27 (18.1)	11 (14.7)	16 (21.6)
Renal replacement therapy	9 (6)	3 (4)	6 (8.1)
Systolic blood pressure mmhg. Mean (SD)	141 (120–160)	154 (41)	142 (39.9)
Heart rate bpm. Mean (SD)	92 (81–110)	95 (25)	96 (25)
Serum sodium mmol/L	137 (134–139)	137 (134–139)	137 (134–139)
Creatinine mg/dl	1.4 (0.9–2.2)	1.34 (1–2.2)	1.37 (1.07–1.94)
B-type natriuretic peptide pg/ml	829 (502–2377)	642 (303–2557)	959 (535–1819)
Stevenson A Profile	4 (2.7)	3 (4)	1 (1.4)
Stevenson B Profile	125 (83.9)	65 (86.7)	60 (81.1)
Stevenson C Profile	20 (13.4)	7 (9.3)	13 (17.6)
Furosemide	58 (38.9)	36 (48)	22 (29.7)
Thiazides	13 (8.7)	11 (14.7)	2 (2.7)
ACEi / ARA II	76 (51)	41 (54.7)	35 (47.3)
Beta blockers	69 (46.3)	40 (53.3)	29 (39.2)
ARNI	5 (3.4)	3 (4)	2 (2.7)
Mineralocorticoid antagonist	18 (12.1)	6 (8)	12 (16.2)
Digoxine	2 (1.3)	2 (2)	0
Acetil salicilic acid	35 (23.5)	18 (24)	17 (23)
Statins	43 (28.9)	22 (29.3)	21 (28.4)
Left Ventricle Ejection Fraction (%)	35 (23–49)	37 (26–55)	30 (22–40)
B lines	NA	NA	74 (100)
Time to treatment min	78 (25.7–528)	64 (25.2–201.2)	145.5 (31.2–351)
Time to disposition min	311 (169–482)	360 (180–545)	235 (95.5–410)
Hospital lenght of stay days	5 (3—10)	6 (3—11)	3 (2–8)

Note: All categorical variables are expressed in absolute frequencies (#) and percentages (%). Quantitative variables are expressed in median and interquartile range (IQR) unless expressed otherwise. ACEi: Angiotensin-converting enzyme inhibitor. ARAII: Angiotensin II receptor antagonist. ARNI: Angiontenin receptor neprilysin inhibitor.

As shown in Table 1, a greater proportion of patients were not in complete medical treatment.

Comparing the standard-diagnosis group versus POCUS group, we found more hypertensive patients (81.3% vs 62.2%) and lower BNP values (642 ng/ml vs 959 ng/ml) in the standard-diagnosis group; regarding clinical presentation, Stevenson B profile was the most common in both groups (86.7% vs 81.1%) followed by Stevenson C (9.3% vs 17.6%) which was more common in the POCUS-diagnosed group.

According to pharmacological treatment referred at admission, the POCUS group had less proportion of patients (54.7%vs 47.3) with Angiotensin Converter Enzyme inhibitors (ACEi) or Angiotensin II Receptors Blockers (ARB) and Beta Blockers (53.3% vs 39.2). Conversely there were more patients receiving Mineralocorticoid Receptor Antagonist (MRA) in POCUS-diagnosed patients compared to standard-diagnosis group (8% vs 16.2%).

Regarding ultrasound findings, in the standard-diagnosis group we found median LVEF 37% and in the POCUS-diagnosis group a lower median LVEF of 30%.

3.1. Outcomes

The median time to diuretic treatment was 78 min (25–578 min) in global population. In the clinical group compared to POCUS group, median time to disposition decision was 360 min (180–545 min) versus 235 min (95.5–410 min). Median global length of hospital stay was 6 days [3 - 11] in the clinical group compared to 3 days [2 - 8] in the POCUS group.

In the cumulative incidence model (Fig. 2), the TR (time ratio) for the outcome time to treatment was 1.539 (CI 95% 0.88 to 2.69), indicating an increase in the time for the initiation of the diuretic treatment of 53.9%. The TR for the outcome time to disposition decision was 0.665 (CI 95% 0.48 to 0.99) indicating a reduction of 33.5%. The TR for the outcome time to discharge (hospital length of stay) was 0.663 (CI 95% 0.49 to 0.90) indicating a reduction of 33.7%. Calculating HR considering death as a competing risk, the sHR was 1.39 (IC95%: 1.00 to 1.94) indicating the risk of discharge augments 39% in POCUS group.

4. Discussion

In this retrospective cohort study, we found that the introduction of POCUS to the standard diagnostic pathway resulted in a 33.5% reduction of the time to disposition decision and a 33.7% decrease in time to discharge (length of hospital stay). Conversely, the time to treatment (diuretic) increased 53.9%.

To date, point-of-Care ultrasound has become a readily available tool in ED to diagnose and treat patients. Detractors of bedside ultrasound argue the lack of clinical impact, narrowing its benefits to an improved sensitivity and specificity comparing to chest-x-ray and/or clinical examination. There are several studies identifying clinical outcomes derived from the use of POCUS in HF patients. Akhabue et al. [14]

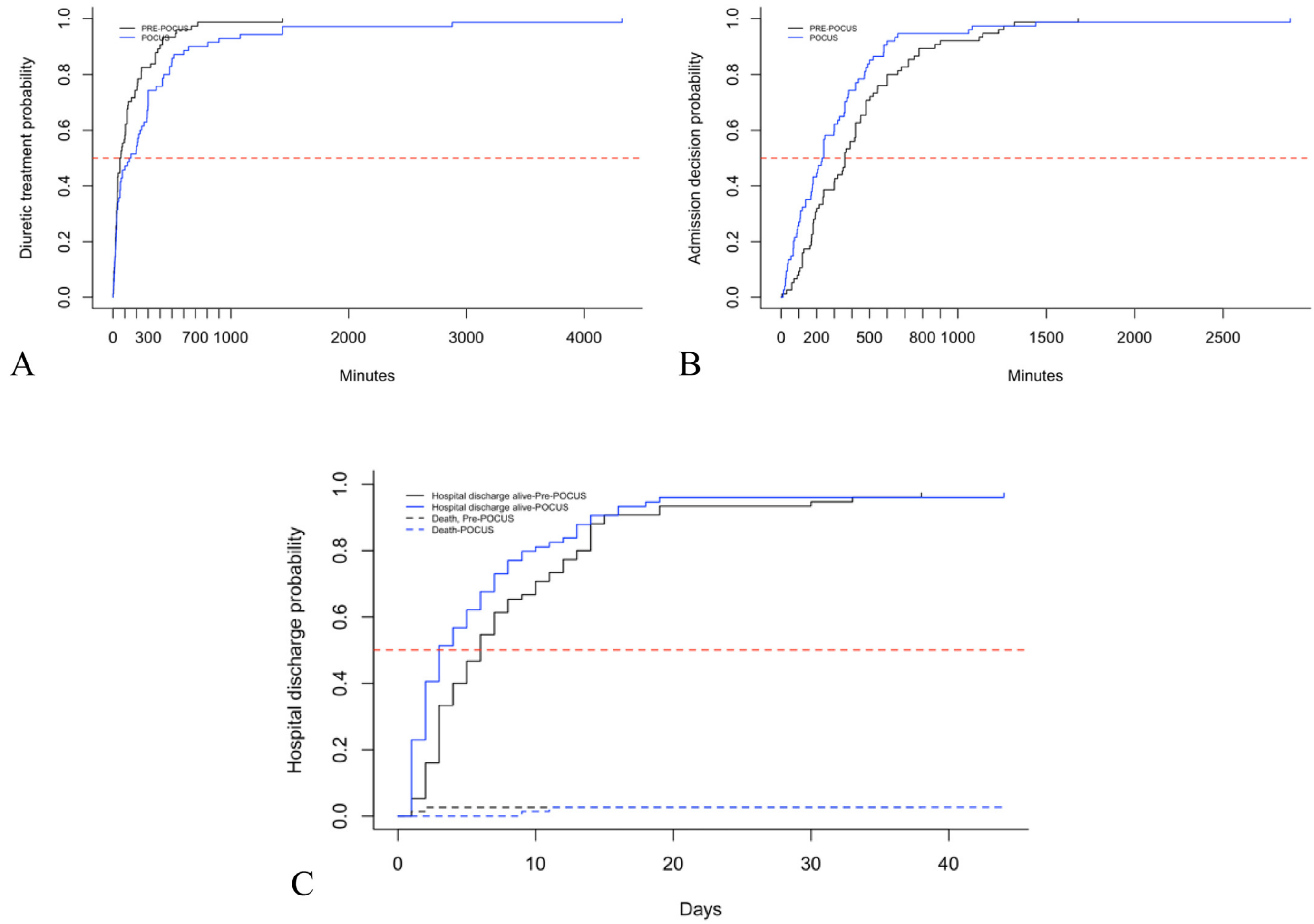

Fig. 2. Cumulative incidence (probability) for time to treatment (panel A), time to disposition decision (Panel B), and time to hospital discharge (Panel C).
After adjusting by age, creatinine, Stevenson profile and LVEF, when POCUS is introduced as a diagnostic tool the relative time to treatment increases 53.9% (time ratio: TR = 1.539: 95%CI 0.88 to 2.69). Regarding the time to disposition decision, POCUS reduces 33.5% the relative time (time ratio: TR = 0.665: 95% CI 0.0.48 to 0.99) to disposition decision. After the introduction of POCUS, the relative time to discharge was reduced in 33.7% (time ratio: TR = 0. 0.663: 95%CI 0.49 to 0.90), and considering death as a competing risk, the sHR was 1.39 (IC95%: 1.00 to 1.94).

reported in a small group of post-hospitalized patients that a dilated IVC resulted in a greater risk of re-hospitalization, independent to B-type natriuretic peptides. This finding, confirmed in a second in-hospital study [15], points to the need of an extended examination alongside with clinical evaluation to ambulatory and hospitalized HF patients to predict adverse outcomes. In 62 patients admitted for HF acute decompensation, Araiza reported a HR 4.38 (CI95% 1.37–13.95) for in-hospital mortality if more than 19 B-lines were visualized at ED entrance [16]. It is known that severity of lung congestion is directly related to the number and coalescence of B-lines in lung ultrasound [17], therefore more pulmonary congestion indicates increased left ventricle preload, elevated cardiac filling pressure and adverse outcomes.

A randomized controlled trial evaluated a lung-ultrasound guided treatment in ambulatory HF patients [6]. Primary outcome was a composite of ED visits, rehospitalization and/or death. LUS-guided therapy resulted in 45% risk reduction of the primary endpoint driven by ED visits. There were no differences in death or rehospitalization rates between groups. This trial demonstrates a meaningful impact in clinical prognosis given a lung ultrasound-guided treatment, considering urgent HF visits an event that carries worse prognosis.

A recent systematic review and metanalysis analyzed the effect of POCUS in HF hospitalization [18]. Three randomized trials were included with 493 patients. Lung ultrasound decreases urgent HF visits (RR 0.32 95% CI 0.18–0.59), but no effect on mortality or acute kidney injury.

One retrospective study from Nakao et al. [7] informed no ED length of stay in heart failure patients diagnosed with POCUS compared to standard clinical diagnosis. This study did show more rapid specific-treatment in emergency department (aHR 1.50 95% CI 1.05–2.15).

Our study evaluated if clinical times in ED and in-hospital treatment are improved by point-of-care ultrasound. To our knowledge, there is no research addressing this specific impact. Patients were intended to be diagnosed faster thus treated faster, and possibly, have a faster clinical improvement. Time to disposition is a critical time in ED considering time-sensitive diagnosis, patient flow at emergency room, healthcare quality perception and patient experience [19]. These items are important to patients and healthcare institutions. Our results suggests that inclusion of POCUS in ADHF patients saves time in ED and improve patient flow. The reduction in length of hospital stay could be attributed to a more determined decongestive treatment during hospitalization.

Considering confounding factors to the clinical times evaluated in our research, we highlight there were no policy changes in the health system or the institution during study time that could affect admission rate, discharge or ED consults. Likewise, the management of ADHF did not change as well as the medical staff responsible for admission and in-hospital treatment.

We demonstrated a more rapid time to decision (hospital admission) and less hospital stay, but time to treatment was increased in more than 50%. A possible explanation could be related to the patient flow in ED and the introduction of newly performed lung ultrasound evaluation.

Before POCUS use, emergency physician would decide at first evaluation to order diuretic treatment. Once POCUS was introduced, emergency physician would wait to internal medicine evaluation alongside with ultrasound images to decide the initiation of diuretic treatment. This situation highlights the need of more widespread POCUS training to all ED personnel so any healthcare provider could identify B-lines and take appropriate decisions. It is unacceptable that bedside ultrasound poses a delay in treatment. This also shows the need of a dedicated process to introduce POCUS in ED. The process of training should include first-contact healthcare providers (nurses, physician assistant, residents, specialists).

This study has several limitations. Small sample makes inference limited. Our POCUS patients were mostly from Monday to Friday ED visits due to bedside ultrasound availability. It was a retrospective analysis of patients with a non-matched historic comparison, thus we intended to control bias using a time to event analysis knowing the nature of our outcomes. We analyzed POCUS as an exposition, but we believe that POCUS should be analyzed as an intervention too, therefore a randomized trial could give more accurate information about the clinical impact of this strategy.

On the other hand, our cohort gives a clear view of a practical and easily reproducible approach of POCUS in the emergency department. We analyze clinical outcomes not evaluated before as time to disposition and shows the impact in patient flow, a mainstay of patient-centered care. Our work compares similar groups with a confirmed diagnosis and evaluates time-sensitive decisions and treatment. We use a well-defined statistical analysis to determine the impact of POCUS in hospitalization of HF patients, which addresses possible biases and confounding of a retrospective cohort study.

Our results show the role of bedside ultrasound, not solely as a more sensitive tool to diagnose, but an instrument to give more rapid and patient-centered attention in ED.

5. Conclusion

In our study, the introduction of Point-of-Care Ultrasound to ADHF patients' attention in the ED decreases time to disposition decision and total length of hospital stay. There is need for evaluation of ultrasound as an intervention in clinical trials to confirm these findings.

Other information

This study had no funding or grants.

CRediT authorship contribution statement

José Atilio Núñez-Ramos: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Daniel Camilo Aguirre-Acevedo:** Formal analysis, Methodology, Writing – review & editing. **María Camila Pana-Toloza:** Conceptualization, Investigation, Methodology, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflict of interest. We have not received any funding.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2023.01.047.

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