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Automatic B-lines: a tool for minimizing time to diuretic administration in pulmonary edema patients in the emergency department of a developing country

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Abstract

Background Effective management of pulmonary edema in the emergency department (ED) is crucial given its significant global impact on health. This study aimed to investigate the hypothesis: "Does the utilization of Automatic B-lines via ultrasonography in patients with pulmonary edema facilitate faster diuretic administration in a developing country?"

Methods This retrospective observational study was conducted at a tertiary academic center in Thailand. Patients with pulmonary edema admitted to the ED between January 2023 and June 2024 were enrolled. Ultrasound documentation and electronic ED medical records were compared to assess the time of diuretic administration between patients who had lung ultrasounds utilizing automatic B-lines and those who had manual B-lines counted by physician eye inspection. Multivariate logistic regression was employed to examine the relationship between the use of automatic B-lines and early diuretic administration.

Results The study included 134 patients with pulmonary edema. The time to diuretic administration was significantly shorter in the automatic B-lines group (median time [Q1-Q3], 55 min; range, 35–110 min) compared to the non-automatic B-lines group (median time, 100 min; range, 75–145 min). In the multivariable logistic regression analysis, early diuretic administration within 60 min of triage was significantly more likely in the automatic B-lines group (adjusted odds ratio, 1.45; 95% confidence interval, 1.10–2.45) than in the non-automatic B-lines group.

Conclusions In a developing country, patients with pulmonary edema who had lung ultrasound evaluation with automated B lines experienced a fastest diuresis compared to those who utilized ultrasonography without automatic B lines. Implementing automatic B-lines as an early screening protocol could enhance clinical practice in the ED.

Keywords Artificial intelligence, Ultrasonography, Lung, Pulmonary edema, Diuretics, Emergency department, Artifacts

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Background

Pulmonary edema is a major public health concern that consumes a significant amount of healthcare resources worldwide. It is a leading cause of hospitalization among patients admitted to the emergency department (ED). Patients with pulmonary edema experience high mortality rates and an elevated incidence of rehospitalization particularly in developing country. As admissions for pulmonary edema increase, effective assessment and management in the ED are critical [1–4].

Lung ultrasound has been widely used as an additional diagnostic method for lung diseases [5–7]. It is a non-invasive tool used to differentiate between various lung pathologies, with diagnostic efficacy comparable to or even higher than that of other methods.

B-lines are one of the ultrasound artifacts that originate at the pleural line, appears as independent laser-like vertical hyperechoic reverberation artifacts that obscures other background lung ultrasound artifacts, which radiate to the bottom of the screen without fading and move continuously with lung sliding [8]. B-lines visible on lung ultrasound correlate with extravascular lung water content, aiding in the diagnosis of pulmonary edema [9–12]. However, ultrasonography is significantly operator-dependent, and differentiating B-lines from other vertical artifacts in lung ultrasonography can be particularly challenging, especially in developing countries where point-of-care ultrasound (POCUS) has not been widely utilized. Artificial intelligence contributes to various functions in healthcare [13–15]. Implementing reliable artificial intelligence real-time automatic tools, including automatic B-lines detection, can reduce testing variation and improve lung ultrasound examination interpretation, eliminating the need for manual assessment or measurements. Reducing reliance on operators' abilities can make the information obtained more reliable and suitable for decision-making [16–19].

Following a diagnosis of pulmonary edema, early decongestion therapy with intravenous diuretics is critical, as it has been linked to better outcomes in pulmonary edema [20–22]. We hypothesized that the use of automatic B-lines detection in lung ultrasound for patients with suspected pulmonary edema would assist emergency physicians in developing immediate management strategies.

This study aimed to determine the relationship between the presence of automatic B-lines during lung ultrasound and the administration time of intravenous diuretics in patients admitted to the ED with pulmonary edema.

Methods

Design and setting

This retrospective observational study investigated the electronic medical records of patients with pulmonary edema who presented to the ED of a tertiary academic teaching hospital in Khon Kaen, Thailand, which serves approximately 60,000–70,000 emergency patients annually.

Patients

The participants in this study were patients who visited our ED between January 2023 and June 2024. Adult patients (age > 18 years) with pulmonary edema, as defined by the ICD-10 International Classification of Diseases, 10th edition, who presented to the ED and received intravenous furosemide were included. The exclusion criteria for our study included: 1) patients without ultrasound documentation, indicating incomplete records; those who did not undergo ultrasound; and individuals unable to interpret results; 2) patients lacking information on the timing of furosemide administration; and 3) patients transferred to another institution.

Data collection

The principal investigator reviewed electronic medical records at Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, Thailand, using the Health Object Program®, an authorized electronic medical records system, for all patients with pulmonary edema who presented to the ED. Eligibility was determined based on the final diagnosis of pulmonary edema, as identified by the ICD-10 International Classification of Diseases, Code J81.0. Data were extracted from various sections of the electronic medical records, with each patient assigned an anonymous identity. The extracted data included demographic information from the patient's profile sheet, medication administration details, nursing notes (including the time of furosemide administration), and ultrasound interpretation.

The ultrasound interpretations were compiled by emergency medicine residents and emergency physicians who routinely evaluate patients suspected of having pulmonary edema using POCUS, which includes ultrasound characteristics of the heart, lungs, and inferior vena cava. However, the decision to perform POCUS was dependent on the attending physician at the time. B-line artifacts in lung ultrasonography could be assessed using either automated B-lines or the physician's visual inspection. The attending physician determined which B-line assessment approach to apply. The ultrasound machine's automatic B-lines function, known as "Smart B-lines," is an artificially intelligent feature that automatically detects and analyzes B-lines (Fig. 1).

This study utilized the Mindray M9 ultrasound machine (Mindray, Shenzhen, China). In terms of lung ultrasound examination, our study was carried out using the BLUE protocol, which included three standardized points: the upper BLUE point, the lower BLUE point, and

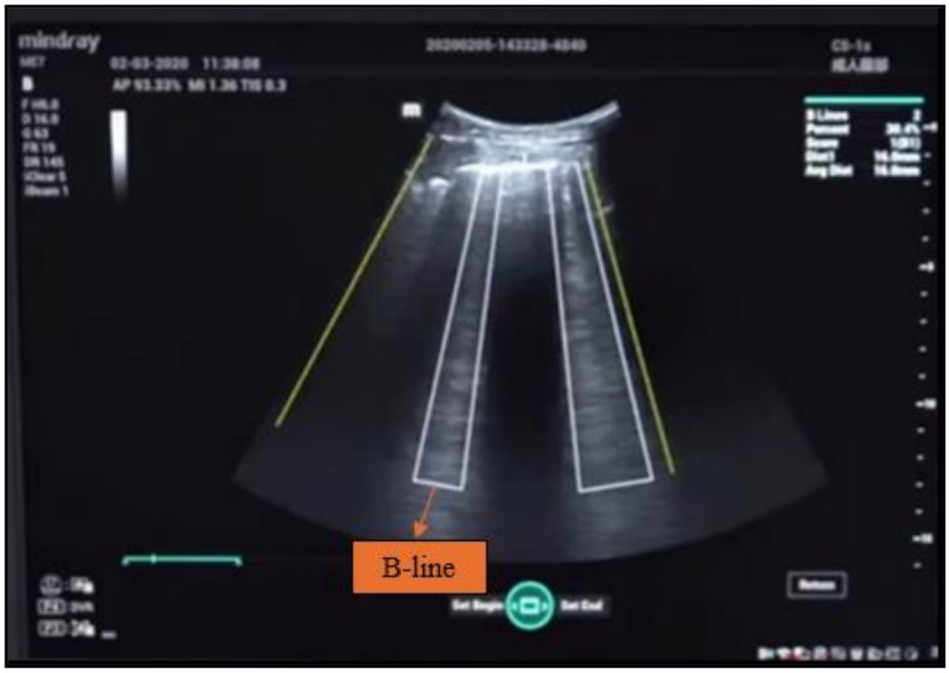

Fig. 1 Coalescent B-lines demonstrated by "Smart B-line"

the PLAPS point. The preset was set as lung preset. The transducer in this study was The Mindray C5-1s Curved Array transducer.

This study included emergency physicians as well as emergency medicine residents (postgraduate years 1–3). All these individuals had to attend a one-hour demonstration of Automatic B-lines. Throughout the academic year, emergency medicine residents completed a one-month ultrasound rotation.

The time to diuretic administration was defined as the interval between the patient's arrival at the ED and the first intravenous administration of furosemide (as recorded in the nursing notes). The arrival time was defined as the time of the patient's first medical contact, typically with a triage nurse (as noted on the profile sheet). In this study, early administration of intravenous diuretics was defined as within 60 min of triage, following the European Society of Cardiology's recommendations for the early management of acute cardiogenic pulmonary edema [23].

Data were gathered and compiled into a research dataset. Two independent investigators then reviewed the data, and any redundant entries were addressed. If discrepancies were found, senior investigators were consulted to ensure the accuracy of the data.

The main objective of this study was to examine the relationship between the use of automatic B-lines during lung ultrasound and the timing of diuretic administration in patients admitted to the ED with pulmonary edema.

Analysis and statistics

A power analysis for a paired sample t-test was conducted to determine the minimum sample size, resulting in 66 patients required for each group [24]. The enrollment ratio was 1.0, with an alpha level of 0.14 and 80% power ($\beta = 0.1$), as estimated from a previous study [25].

Data were entered into Microsoft Excel (Microsoft Windows 10, Khon Kaen University license) and analyzed using IBM SPSS for Windows version 27.0, licensed by Khon Kaen University (SPSS Inc., Chicago, Illinois, USA).

Descriptive statistics included frequencies, means for normally distributed data, and medians (interquartile range [IQR]) for non-normally distributed data. To assess the significance of time to diuretic administration, a t-test or median test, chi-square test, and univariate/multivariate logistic regression models were utilized.

After univariate logistic regression, the principal investigator selects the variables with a p-value less than 0.20, and those variables proceed to multivariate logistic regression.

Results

Baseline characteristics

Between January 2023 and June 2024, 1,110 patients diagnosed with pulmonary edema using the ICD-10 International Classification of Diseases visited the ED. After excluding patients with missing ultrasound documentation ($n = 750$), missing furosemide administration times ($n = 125$), and those transferred to another institution ($n = 101$), 134 patients were included in the final

evaluation. Automatic B-lines detection during lung ultrasound was performed in 67 patients (Fig. 2). Table 1 compares the individual characteristics between the automatic and non-automatic B-lines groups.

Outcome

According to the data presented in Table 2, which analyzed the time of furosemide administration between patients who underwent lung ultrasound using automatic B-lines and those using non-automatic B-lines, the time to diuretic administration was significantly shorter in the automatic B-lines group (median time [Q1-Q3], 55 min; range, 35–110 min) compared to the non-automatic B-lines group (median time, 100 min; range, 75–145 min).

In multiple logistic regression models adjusting for age, sex, mode of arrival, vital signs, medical history, diffuse B-lines in lung ultrasound, and plethoric inferior vena cava, early administration of diuretics within 60 min of triage was significantly more likely in the automatic B-lines group (adjusted odds ratio, 1.45; 95% confidence interval, 1.10–2.45) than in the non-automatic B-lines group.

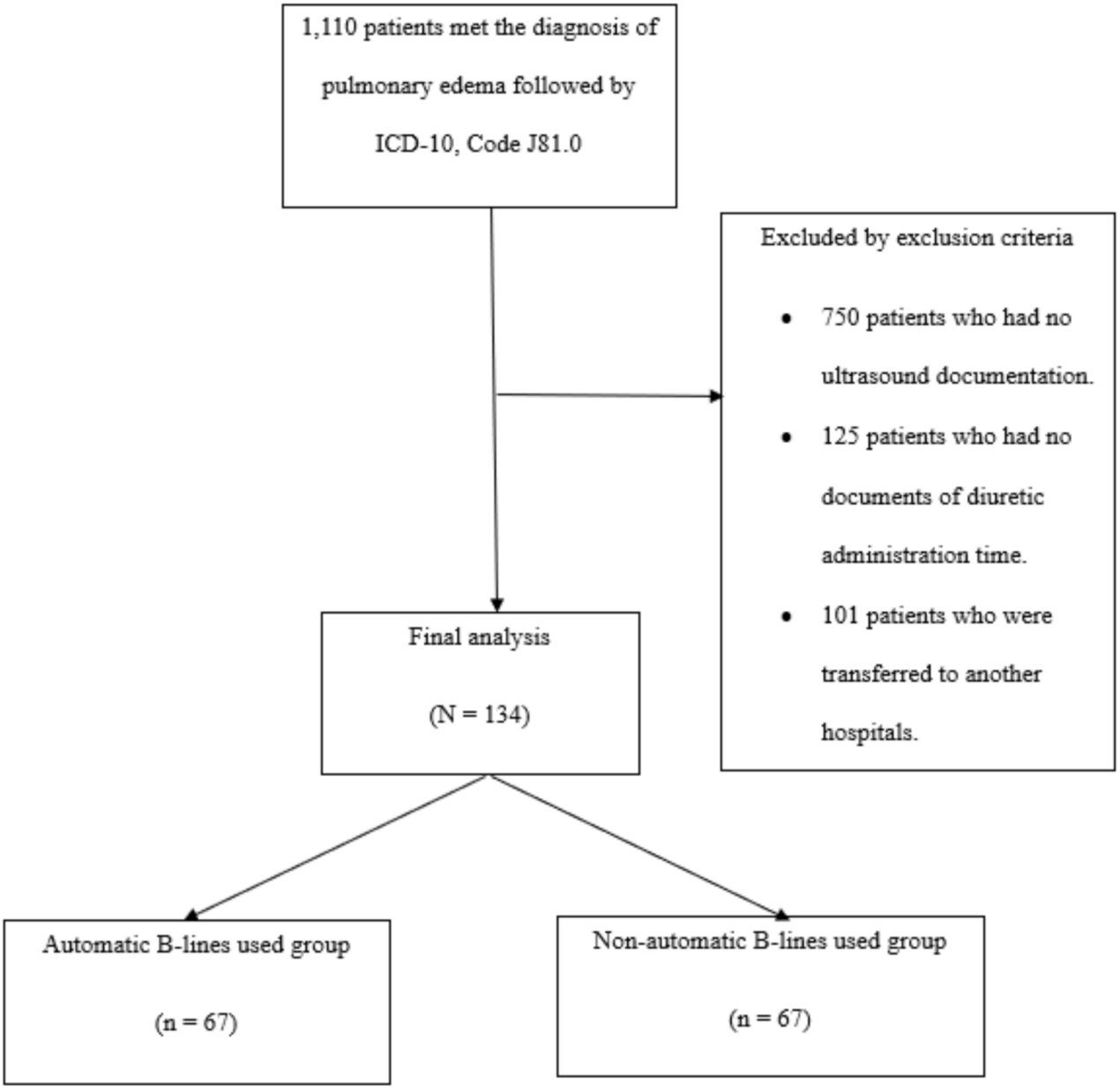

Fig. 2 Patient flow diagram

Table 1 Compares the individual characteristics of Automatic and non-automatic B-lines used

Variables	Automatic B-lines used group (*n* = 67)	Non-automatic B-lines used group (*n* = 67)	*P*-value
Age (year), median (IQR)	64 (50,72)	66 (48,78)	0.185
Male, %	33 (49.25)	31 (46.26)	0.086
Resuscitation patients (1&2 ESI triage level), %	53 (79.10)	50 (74.62)	0.425
Arrived by ambulance, %	21 (31.34)	23 (34.32)	0.075
Vital signs at presentation			
Systolic blood pressure (mmHg), median (IQR)	160 (121,192)	158 (123,193)	0.065
Diastolic blood pressure (mmHg), median (IQR)	85 (58,112)	87 (60,111)	0.067
Heart rate (beats per minute), median (IQR)	82 (54,112)	85 (56,114)	0.071
Respiratory rate (breaths per minute), median (IQR)	22 (18,36)	24 (16,30)	0.068
Oxygen saturation at room air (%), median (IQR)	92 (84,100)	90 (80,100)	0.067
Medical history			
Hypertension, %	48 (71.64)	53 (79.10)	< 0.001
Atrial fibrillation, %	29 (43.28)	25 (37.31)	< 0.001
Diabetes mellitus, %	26 (38.80)	29 (43.28)	< 0.001
Chronic obstructive pulmonary disease, %	15 (22.38)	17 (25.37)	0.075
Coronary artery disease, %	21 (31.34)	20 (29.85)	0.069
Current or ex-smoker, %	27 (40.29)	25 (37.31)	0.072
Ultrasound findings			
B-lines both lung	33 (49.25)	14 (20.89)	< 0.001
Pleural effusion	15 (22.38)	16 (23.88)	0.526
Decrease left ventricle systolic function	26 (38.80)	27 (40.29)	0.645
Plethoric inferior vena cava	28 (41.79)	30 (44.77)	0.089

Abbreviation: IQR = Interquartile range, ESI = emergency severity index

Table 2 Comparison of time interval from triage to administration of diuretic between Automatic and non-automatic B-lines used

	Automatic B-lines used group (*n* = 67)	Non-automatic B-lines used group (*n* = 67)	*P*-value
Time to diuretic (min), median (IQR)	55 (35,110)	100 (75,145)	< 0.001

Abbreviation: IQR = Interquartile range, Min = minutes

Discussion

Pulmonary edema is a serious public health concern that causes significant morbidity, mortality, and economic costs. Recent studies have highlighted the critical role of the ED in managing pulmonary edema. While early diagnosis is essential, the effectiveness of treatment is often time-dependent [3, 26, 27]. Most studies have concluded that B-lines, an ultrasound artifact seen in lung ultrasound, are a valuable bedside tool for diagnosing pulmonary edema, aiding in diagnosis, monitoring, and prognosis. Persistent pulmonary congestion significantly increases the risk of rehospitalization [28–30]. However, in the setting of developing country, untrained sonographers may misdiagnose pathological interstitial syndrome by failing to distinguish B-lines from other vertical ultrasound artifacts [31]. To address this issue, an innovative feature known as the automatic B-lines function, which utilizes artificial intelligence in ultrasound machines, has been developed. This technology can enhance diagnostic efficiency by reducing operator dependency [32]. With the accurate results provided by automatic B-lines in lung ultrasound, emergency physicians can deliver prompt treatment, such as administering intravenous diuretics, which have been shown to reduce pulmonary congestion in cases of pulmonary edema.

This study investigates the relationship between diuretic administration time and the use of automatic B-lines during lung ultrasound in patients presenting with pulmonary edema in the ED. Our findings indicated that among patients with pulmonary edema undergoing ultrasound evaluation, those exhibiting automated B lines received diuresis administration more rapidly than those who utilized ultrasonography without automatic B lines. The median time was 55 min, which is less than half the median time in the non-automatic B-lines group (100 min). These results are consistent with previous research [25], which established that using POCUS, particularly cardiac ultrasound, as a bedside tool reduced the time to furosemide administration compared to the non-focused cardiac ultrasound group. Furthermore, a previous study found that using POCUS in the ED reduced the ED length of stay [33].

The results of the multivariable linear regression analyses indicated that the group using automatic B-lines had significantly higher rates of early diuretic administration within 60 min of triage (adjusted odds ratio, 1.45).

This finding underscores that automatic B-lines during lung ultrasound can reduce the time required to administer intravenous diuretics. This is consistent with a previous study that found early administration of furosemide within 2 h of triage was significantly higher in the focused cardiac ultrasound group (adjusted odds ratio, 1.63). Implementing automatic B-lines in lung ultrasound for patients with pulmonary edema could enhance ED practices in the setting of developing country [25].

Strengths and limitations

One strength of our study is that, to our knowledge, we are the first to use automatic B-lines, a function in an ultrasonography machine that can distinguish B-lines from other lung ultrasound artifacts. Our study focused on using automatic B-lines to enhance acute pulmonary edema management in developing countries' emergency departments. Our study had the following limitations: 1) It was conducted at a single tertiary academic teaching hospital, so the findings may only be representative of similar healthcare settings. 2) Only 134 of the 1,110 patients were included in this study, possibly as a result of the retrospective observational design, which may include biases in patient selection. The majority of the exclusions (750 patients, 67.56%) were related to the lack of ultrasound documentation, insufficient data, and confounding variables that could influence results. 3) The study focused on the immediate effect of automatic B-lines on diuretic administration. Further studies are needed to assess long-term outcomes, such as hospital length of stay and mortality rates. 4) The study utilized a specific ultrasound machine with automatic B-line functionality, so the results may not be generalizable to other ultrasound machines with different capabilities. 5) The study did not demonstrate the diuretic dose administration in patients and the correlation between diuretic dose and the number of B lines assessed. 6) The study did not examine the knowledge and experience levels of POCUS practitioners, which could influence the accuracy of assessing B-lines artifacts. However, the research aims to evaluate the effectiveness of automatic B-lines detection, a feature that could assist both experienced and novice physicians in making decisions about administering diuretics to patients with pulmonary edema.

Conclusion

Patients with pulmonary edema who utilized ultrasonography and exhibited automatic B-lines experienced faster diuresis administration than those who employed ultrasound without automatic B- lines in the setting of developing country. Early diuretic administration within 60 min of triage is significantly more common in the group utilizing automatic B-lines. Our findings suggest that emergency physicians can use automatic B-lines at the bedside to enhance the diagnosis and early management of pulmonary edema.

Abbreviations

ED	Emergency department
POCUS	Point-of-care ultrasound
ICD-10	International classification of disease, 10th edition
IQR	Interquartile range
ESI	Emergency severity index

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Author contributions

KI, KA, LWC, SC participated in planning the study design. KI and KA took part in the data collection. KI and KA analyzed the data and drafted the first version of the manuscript. LWC helped with statistical testing and revised the manuscript. KI, SC, and KA made revised the manuscript. KI completed the final manuscript. All authors agreed on the final version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study and its protocol were authorized by the Khon Kaen University Ethics Committee for Human Research, in accordance with the Declaration of Helsinki and the ICH Good Clinical Practice Guidelines (HE671458). The requirement for informed consent was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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