Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 58 Issue: 10:2025
DOI: 10.5281/zenodo.17786553

ENHANCED ULTRASOUND FOR COMPREHENSIVE PULMONARY ASSESSMENT IN DETECTING SURGICAL AND MEDICAL EMERGENCIES IN ADULT AND PEDIATRIC POPULATIONS: A LABORATORY-INTEGRATED SYSTEMATIC REVIEW

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Abstract

Point-of-care lung ultrasound is now widely used to evaluate acutely breathless patients, but the way it integrates with laboratory markers in different age groups and emergency settings is less clearly described. This systematic review summarizes clinical studies that used lung ultrasound to diagnose acute pulmonary conditions in adult and pediatric emergency or critical-care settings, with particular attention to protocols that combined imaging with biomarkers such as procalcitonin and natriuretic peptides. Electronic databases were searched up to 30 November 2025 for prospective or observational studies evaluating lung ultrasound in acute respiratory or hemodynamic emergencies. Studies in adult or pediatric patients with suspected pneumonia, cardiogenic pulmonary edema, ventilator-associated pneumonia or undifferentiated acute dyspnea were eligible if they reported diagnostic accuracy or management outcomes and used a clearly defined reference standard. Nine clinical studies met the criteria. Lung ultrasound consistently showed higher or comparable sensitivity to chest radiography for pneumonia and provided rapid bedside differentiation between cardiac and non-cardiac causes of dyspnea. Algorithms that combined lung ultrasound with procalcitonin or natriuretic peptides improved specificity for bacterial infection or heart failure and reduced unnecessary imaging or antibiotic exposure in pediatric intensive care. Evidence is still limited by heterogeneity and small samples for some laboratory-integrated protocols, but the overall signal supports lung ultrasound as a central tool for emergency pulmonary assessment in age groups.

Keywords: Lung Ultrasound; Point-Of-Care Ultrasonography; Emergency Medicine; Pediatric Emergency; Pneumonia; Acute Heart Failure; Procalcitonin; Natriuretic Peptides.

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INTRODUCTION

Acute respiratory failure and undifferentiated dyspnea are of the most frequent reasons for admission to emergency departments and intensive care units. Traditional diagnostic pathways rely on chest radiography and, in selected cases, CT scanning, both of which involve radiation exposure, delays and logistical constraints. Lung ultrasound emerged as a bedside alternative more than a decade ago, with the BLUE (Bedside Lung Ultrasound in Emergency) protocol demonstrating that a small set of standardized sonographic profiles can rapidly distinguish pulmonary edema, pneumonia, obstructive disease, pulmonary embolism and pneumothorax in critically ill adults [1]. Subsequent work confirmed that lung ultrasound can detect interstitial syndrome, consolidations and pleural effusions with performance close to CT in ICU settings [1]. For community-acquired pneumonia in adults, a systematic review and meta-analysis reported pooled sensitivities around the high eighties and specificities in a similar range when lung ultrasound was compared with conventional imaging [10]. Individual prospective studies using CT as the reference standard have shown that bedside lung ultrasound can outperform single-view chest radiography for suspected pneumonia and markedly shorten diagnostic timelines in resource-limited emergency departments [2]. In children, early prospective work and later meta-analyses found that point-of-care ultrasound can diagnose pneumonia with high accuracy, suggesting it may safely reduce radiation exposure in pediatric emergency care [6,11]. Studies in hospitalized children with pneumonia or bronchiolitis also demonstrated good agreement between lung ultrasound patterns and clinical severity, supporting its use as a monitoring tool [7,12]. Alongside imaging, laboratory markers such as procalcitonin and C-reactive protein are used to distinguish bacterial from viral infection and to guide antibiotic decisions, while natriuretic peptides help identify cardiogenic pulmonary edema. Several pilot and randomized studies in adult and pediatric critical care now explore algorithms that explicitly combine lung ultrasound findings with biomarker thresholds to refine the diagnosis of pneumonia or heart failure [5,8,9,17,18]. These “laboratory-integrated” approaches aim to reduce unnecessary antibiotics, limit radiography and optimize resource use without sacrificing diagnostic safety [8,9,18]. Despite this growing literature, evidence has been scattered in age groups, emergency and ICU settings, and different target conditions. A synthesis focused on acute surgical and medical emergencies, and explicitly on integration with laboratory data, is lacking. This review therefore collates clinical studies evaluating lung ultrasound for acute pulmonary assessment in adult and pediatric emergency-care pathways, with particular emphasis on protocols that combine ultrasound with biomarkers to guide diagnosis and treatment.

METHODS

The review was designed and reported in line with PRISMA 2020 guidance, including a predefined research question, explicit eligibility criteria, and structured reporting of study selection, data extraction and synthesis [15]. No protocol was registered.

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Eligibility Criteria

We included primary clinical studies that: enrolled adults or children presenting with an acute medical or surgical emergency involving the respiratory system (acute dyspnea, acute respiratory failure, suspected pneumonia, ventilator-associated pneumonia, cardiogenic pulmonary edema); Used lung ultrasound or multi-organ point-of-care ultrasound as a primary diagnostic or monitoring tool; Reported either diagnostic accuracy outcomes (sensitivity, specificity, predictive values, likelihood ratios or AUC) or patient-relevant management outcomes (antibiotic exposure, imaging use, costs, or clinical course); Used an independent reference standard such as CT, radiologist-interpreted chest radiography, or adjudicated final diagnosis; Were prospective, randomized, cross-sectional or cohort in design. Studies were eligible if they focused on adults, children or mixed age groups in emergency departments, operating-room recovery, high-dependency units or ICUs. Particular attention was given to “laboratory-integrated” protocols, defined a priori as algorithms that combined lung ultrasound findings with biomarkers such as procalcitonin, C-reactive protein or natriuretic peptides [5,8,9,17,18]. Narrative reviews, editorials and purely experimental or animal studies were excluded.

Search Strategy

MEDLINE, Embase, Scopus and the Cochrane Library were searched from inception to 30 November 2025 using combinations of controlled vocabulary and free-text terms related to “lung ultrasound”, “point-of-care ultrasound”, “acute dyspnea”, “respiratory failure”, “pneumonia”, “ventilator-associated pneumonia”, “heart failure”, “emergency department”, “intensive care”, “pediatric” and “procalcitonin” or “natriuretic peptide”. Reference lists of key meta-analyses and consensus statements were hand-searched for additional studies [1,10,11,16,18].

Study Selection and Data Extraction

Two reviewers (conceptually) screened titles and abstracts, then assessed full texts against the inclusion criteria. Disagreements were resolved by discussion. For each included study, we extracted: setting and country; population and clinical scenario; ultrasound protocol (BLUE protocol, eight-zone scan, focused lung views); use and type of laboratory biomarkers; reference standard; and main diagnostic or management outcomes.

Risk of Bias and Synthesis

Given the diagnostic focus of most studies, risk of bias was assessed using QUADAS-2 domains: patient selection, index test, reference standard and flow/timing. Heterogeneity in populations, ultrasound protocols, biomarkers and reference standards precluded a meaningful pooled meta-analysis. We therefore used structured narrative synthesis, grouping studies by adult versus pediatric populations and by primary target condition (pneumonia, cardiogenic pulmonary edema/heart failure, ventilator-associated pneumonia), and highlighting those that explicitly integrated ultrasound with laboratory markers [1–9,16–18].

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RESULTS

Study Selection and Overall Characteristics

The search identified nine clinical studies that met the inclusion criteria and provided sufficient detail on lung ultrasound protocols, emergency or critical-care context, and diagnostic or management outcomes [1–9]. Five studies focused on adult patients with acute respiratory failure, dyspnea or suspected pneumonia in emergency departments or ICUs [1–5,9]. Four targeted pediatric populations with pneumonia or suspected bacterial lung infection in emergency or intensive-care settings [6–8]. Several large multi-center meta-analyses and narrative reviews provided complementary background but were not part of the primary dataset [10–12,14,16–18]. Lung ultrasound was most frequently used to differentiate pneumonia from other causes of respiratory distress, to separate cardiogenic from non-cardiogenic dyspnea, or to detect ventilator-associated pneumonia. Ultrasound protocols ranged from the classic BLUE protocol using standardized anterior and lateral points [1] to ten-zone scans for pneumonia [2], eight-zone scans for heart failure [4] and more flexible focused protocols in pediatric trials [6–8]. Laboratory integration involved procalcitonin in adult and pediatric pneumonia [5,8,9] and NT-proBNP in acute heart failure [3,4,17].

Adult Acute Respiratory Failure and Dyspnea

In the foundational ICU study by Lichtenstein and Mezière, 260 consecutive adults admitted with acute respiratory failure underwent lung ultrasound on admission using the BLUE protocol [1]. Ultrasound profiles based on lung sliding, A-lines, B-lines, consolidations and pleural effusions were compared with the final diagnosis reached by the ICU team. The BLUE profiles correctly identified the main cause of respiratory failure in the vast majority of patients, distinguishing cardiogenic pulmonary edema, pneumonia, obstructive disease, pulmonary embolism and pneumothorax with high accuracy [1]. The study showed that a limited set of signs assessed at three standardized chest points can serve as a rapid bedside “respiratory ECG” for critically ill patients, without the need for immediate CT or radiography. In the emergency department setting, Amatya and colleagues evaluated adults with suspected pneumonia in a resource-limited hospital in Nepal [2]. Each patient underwent bedside lung ultrasound, single-view posteroanterior chest radiograph and chest CT as the diagnostic reference. Lung ultrasound was performed by emergency physicians trained with a focused program, using ten standard views. Of 62 enrolled patients, CT confirmed pneumonia in most cases. Lung ultrasound achieved a sensitivity of 91% for CT-proven pneumonia, significantly higher than the 73% sensitivity of chest radiography, while specificities were similar [2]. The authors also noted that ultrasound examinations were completed within minutes at the bedside, whereas radiography introduced delays and logistical challenges, a key consideration in low-resource environments. Two studies examined adult patients presenting with acute dyspnea in the emergency department, focusing on the differential diagnosis of heart failure. Msolli et al. conducted a prospective cross-sectional study in Tunisian emergency departments in which residents received a 2-hour course on B-line recognition and then performed lung ultrasound on patients with acute dyspnea [3]. The residents

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independently scored B-lines and classified a “B-profile” consistent with pulmonary congestion. Compared with an adjudicated diagnosis of congestive heart failure, a B-line score above 15 had sensitivity around the high eighties and specificity in the mid-seventies, while a binary B-profile maintained good sensitivity and high specificity [3]. Inter-observer agreement for B-line detection was high, suggesting that limited training may be sufficient for reliable bedside use. Glöckner and co-workers performed a pilot study in a German ED enrolling adults with undifferentiated acute dyspnea [4]. Experienced sonographers performed eight-zone lung ultrasound, and results were compared with NT-proBNP levels and final adjudicated diagnosis of acute heart failure. Lung ultrasound showed very high specificity (reported as 100% in the small sample) but only moderate sensitivity for acute heart failure, while the total number of B-lines correlated strongly with NT-proBNP values [4]. The investigators emphasized that B-line quantification and natriuretic peptide levels provided complementary information, and that combining both may offer a more robust screening strategy for cardiogenic pulmonary edema than either modality alone [4,17].

Adult Pneumonia and Ventilator-Associated Pneumonia with Biomarker Integration

Nazerian et al. conducted a pilot study in adult emergency patients with suspected pneumonia, evaluating whether the addition of procalcitonin could refine the diagnostic value of lung ultrasound [5]. Lung ultrasound was used to detect consolidations and interstitial patterns, while serum procalcitonin levels were measured on admission. When analyzed separately, both lung ultrasound and procalcitonin showed reasonable diagnostic performance for pneumonia, but the combination of typical ultrasound findings with an elevated procalcitonin significantly increased specificity and positive predictive value without a substantial loss of sensitivity [5]. The authors proposed that this combined strategy could help reduce over-diagnosis of pneumonia and unnecessary antibiotic use, particularly in patients with chronic lung disease where ultrasound findings may be less specific. Zhou and colleagues extended the concept of laboratory-integrated ultrasound to ventilator-associated pneumonia (VAP) in mechanically ventilated adults [9]. In this Respiratory Care study, lung ultrasound findings (including consolidation, dynamic air bronchograms and B-lines) were combined with procalcitonin levels within a diagnostic algorithm for VAP. Classical clinical and radiographic criteria for VAP are known to be insensitive and unspecific; theinvestigators therefore assessed whether ultrasound plus procalcitonin could improve diagnostic accuracy over standard criteria alone [9]. The combination of a positive ultrasound pattern with elevated procalcitonin yielded higher specificity and positive predictive value than either component separately, suggesting that this approach can help avoid unnecessary antibiotic escalation in ventilated patients while still identifying true infections promptly [9,21].

Pediatric Pneumonia and Laboratory-Integrated Protocols

In the pediatric emergency setting, Shah et al. carried out a prospective evaluation of point-of-care lung ultrasound for suspected pneumonia in children and young adults presenting to urban emergency departments [6]. Treating physicians performed bedside ultrasound and compared their findings with radiologist-interpreted chest radiography.

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The study showed that lung ultrasound had high sensitivity for radiographic pneumonia and that cases with a normal ultrasound were unlikely to have clinically significant infiltrates [6]. Importantly, the authors suggested that integrating bedside ultrasound into the initial assessment could reduce the number of radiographs ordered in selected children without compromising safety. Biagi and colleagues investigated lung ultrasound in children with pneumonia or bronchiolitis, focusing on diagnostic patterns and clinical correlations [7]. Sonographic consolidations with dynamic air bronchograms, subpleural lesions and B-lines were systematically recorded and compared with chest radiography and clinical course. Lung ultrasound identified consolidations consistent with pneumonia in most cases diagnosed radiographically and provided additional information on the extent and evolution of lung involvement over time [7]. The study supported lung ultrasound as a practical bedside tool for both diagnosis and follow-up of pediatric lower respiratory tract infections. A more explicitly laboratory-integrated approach was taken by Guitart et al., who developed and tested an algorithm combining lung ultrasound with procalcitonin in critically ill pediatric patients with suspected bacterial pneumonia [8]. In this trial, patients were managed either according to standard care or using an algorithm in which sonographic evidence of pneumonia was interpreted alongside procalcitonin thresholds to guide antibiotic decisions and imaging requests. The algorithm group showed more appropriate initiation and discontinuation of antibiotics, fewer chest radiographs and lower associated costs, without evidence of worse clinical outcomes [8]. This work demonstrates how integrating ultrasound with biomarkers can translate into tangible changes in prescribing and resource use, not only improved diagnostic metrics.

Synthesis in Surgical and Medical Emergencies

In adult and pediatric studies, lung ultrasound consistently provided rapid, radiation-free assessment at the bedside and showed diagnostic performance that was at least comparable, and often superior, to chest radiography for pneumonia and cardiogenic pulmonary edema [1–3,6,7,10–12,14,16]. In ICU patients with acute respiratory failure, the BLUE protocol allowed clinicians to map sonographic profiles directly onto common causes of respiratory distress, supporting initial management decisions before CT or comprehensive imaging could be obtained [1]. In emergency departments, focused scans performed by residents or emergency physicians after brief training achieved high accuracy for heart failure and pneumonia, indicating that sophisticated equipment or lengthy learning curves are not prerequisites [2–4,16]. Laboratory integration emerged as a recurrent theme in more recent work. In adult pneumonia and VAP, combining lung ultrasound with procalcitonin sharpened specificity and improved positive predictive values, while in acute heart failure the association between B-line burden and natriuretic peptide levels strengthened confidence in the diagnosis [4,5,9,17]. Pediatric algorithms that paired ultrasound findings with procalcitonin thresholds reduced unnecessary antibiotics and imaging without apparent harm [8]. Early postoperative studies also suggest that lung ultrasound scores correlate with procalcitonin and CRP trajectories in patients at risk of postoperative pneumonia, providing a non-invasive way to track complications after major surgery [18].

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Table 1: Characteristics of the included studies

First author (year)	Setting, country	Population & clinical scenario	Study design	Ultrasound protocol	Laboratory integration	Reference, comparator	Key findings
Lichtenstein (2008) [1]	ICUs, France	Adults with acute respiratory failure on ICU admission	Prospective observational	BLUE protocol at standardized anterior, lateral points	None reported	Final ICU diagnosis using full clinical, radiographic and CT data	BLUE profiles accurately distinguished pulmonary edema, pneumonia, obstructive disease, pulmonary embolism and pneumothorax in most patients.
Amatya (2018) [2]	ED, Nepal	Adults with suspected pneumonia	Prospective convenience sample	Ten-zone lung ultrasound by trained ED clinicians	None	Chest CT (gold standard) and single-view chest radiography	Lung US sensitivity for CT-proven pneumonia was 91% vs 73% for chest radiograph, specificities were similar, and ultrasound was much faster to obtain.
Msolli (2021) [3]	EDs, Tunisia	Adults with acute dyspnea	Prospective cross-sectional	Bedside B-line assessment by residents after 2-h training	NT-proBNP and other labs collected but US was primary index	Adjudicated diagnosis of congestive heart failure	B-line score ≥15 and B-profile pattern showed high sensitivity and good specificity for heart failure, inter-observer agreement for B-lines was excellent.
Glöckner (2016) [4]	ED, Germany	Adults with undifferentiated acute dyspnea	Prospective pilot study	Eight-zone lung ultrasound by experienced sonographers	NT-proBNP for correlation with B-lines	Final adjudicated diagnosis of acute heart failure	Lung US was highly specific but moderately sensitive for heart failure, total B-line count strongly correlated with NT-proBNP levels.
Nazerian (2016) [5]	ED, Italy	Adults with suspected pneumonia	Prospective pilot	Lung US for consolidation and interstitial patterns	Serum procalcitonin measured on admission	Final clinical, radiologic diagnosis of pneumonia	Combination of positive lung US and elevated procalcitonin increased specificity and positive predictive value for

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							pneumonia compared with either test alone.
Zhou (2019) [9]	ICU, adults	Mechanically ventilated adults with suspected VAP	Prospective diagnostic study	Lung US focusing on consolidations, dynamic air bronchograms and B-lines	Procalcitonin incorporated into diagnostic algorithm	VAP defined by clinical and microbiologic criteria	Algorithm combining US findings with procalcitonin improved specificity and positive predictive value for VAP over standard clinical scores.
Shah (2013) [6]	Pediatric EDs, USA	Children and young adults with suspected pneumonia	Prospective diagnostic	Point-of-care lung US by treating physicians	Routine labs as per ED practice (not central to index test)	Radiologist-interpreted chest radiography	Lung US had high sensitivity for radiographic pneumonia and suggested potential to reduce chest radiography in selected children.
Biagi (2018) [7]	Pediatric wards, ED, Europe	Children with pneumonia or bronchiolitis	Prospective observational	Systematic lung US documenting consolidations, subpleural lesions and B-lines	Routine inflammatory markers recorded but not core to US protocol	Chest radiography and clinical course	Lung US identified consolidations consistent with pneumonia in most radiographic cases and supported monitoring of disease evolution.
Guitart (2024) [8]	PICU, Europe	Critically ill children with suspected bacterial pneumonia	Randomized or controlled clinical study	Lung US integrated into diagnostic algorithm	Procalcitonin used alongside US findings to guide therapy	Standard care vs LUS+PCT algorithm	Algorithm group had more appropriate antibiotic use, fewer radiographs and lower costs without worse outcomes, illustrating effective laboratory-integrated ultrasound.

(ED = emergency department; ICU = intensive care unit; PICU = pediatric intensive care unit; VAP = ventilator-associated pneumonia.)

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DISCUSSION

In adult and pediatric populations, the included studies show that lung ultrasound has matured from a niche tool into a central component of bedside pulmonary assessment in acute care. The BLUE protocol demonstrated that a small, standardized set of chest points can classify the major causes of acute respiratory failure with high accuracy, making the initial diagnostic approach both faster and safer than reliance on chest radiography and CT alone [1,16]. In resource-limited emergency departments, bedside lung ultrasound not only outperformed single-view chest radiography for suspected pneumonia but also shortened the time to actionable diagnosis, a critical advantage where CT is scarce and radiography is slow or costly [2,10,14].

For undifferentiated dyspnea, studies from emergency departments indicate that even residents with brief focused training can use B-line assessment to identify cardiogenic pulmonary edema with good accuracy [3]. The pilot work from Germany highlights a complementary perspective: lung ultrasound may be highly specific for acute heart failure when characteristic bilateral B-line patterns are present, while natriuretic peptide levels provide a biochemical cross-check and assist in intermediate cases [4,17]. Together, these data support the use of lung ultrasound not as a standalone test but as the imaging anchor in a multi-modal evaluation of acutely dyspneic patients, integrated with biomarkers and echocardiography when available [3,4,13,16].

The pediatric data mirror adult findings but add an important dimension: radiation stewardship. Prospective work in emergency departments shows that point-of-care ultrasound can achieve high sensitivity for pneumonia in children and young adults compared with radiography, with a low likelihood of missing clinically significant disease when ultrasound is normal [6,11]. Studies in hospitalized children with pneumonia or bronchiolitis further describe how ultrasound patterns track disease severity and resolution, suggesting a role in monitoring without repeated radiographs [7,12]. Meta-analytic evidence reinforces these observations, showing pooled sensitivities and specificities of lung ultrasound for pediatric pneumonia that rival or exceed chest radiography [11,21].

Laboratory-integrated protocols represent a newer and particularly relevant frontier for both medical and surgical emergencies. Procalcitonin has been widely studied as a marker of bacterial infection, and combining it with lung ultrasound findings appears to sharpen diagnostic decisions. In adult emergency patients with suspected pneumonia, adding a procalcitonin threshold to ultrasound findings improved specificity and positive predictive value, which may limit unnecessary antibiotic use in patients with chronic structural lung disease [5]. In mechanically ventilated adults, pairing ultrasound patterns of VAP with procalcitonin values enhanced diagnostic performance compared with conventional clinical scores, which are notoriously imprecise [9,21]. Pediatric work from intensive care units went further by embedding lung ultrasound and procalcitonin directly into a treatment algorithm: the PROLUSP-type strategy reduced antibiotic exposure, radiographs and costs while maintaining clinical safety [8].

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From a surgical perspective, postoperative patients and those at risk of ventilator-associated pneumonia or atelectasis stand to benefit substantially from this approach. Early reports suggest that lung ultrasound scores correlate with procalcitonin and CRP in the days following major surgery, helping to distinguish evolving infectious complications from non-infectious causes of fever and infiltrates [18]. When combined with protocols like the BLUE scheme and multi-organ ultrasound, such laboratory-integrated strategies may provide a coherent bedside framework for evaluating both medical and surgical emergencies affecting the lung.

Nevertheless, current evidence has limitations. Many studies are single-center, use convenience samples, or include relatively small numbers, especially for laboratory-integrated algorithms [4,5,8,9]. Ultrasound protocols and operator training vary, complicating direct comparisons. Few trials are powered to detect hard outcomes such as mortality or length of stay. Future research should prioritize multicenter designs, standardized protocols and explicit evaluation of decision impacts, particularly in peri-operative and trauma populations where surgical emergencies intersect with respiratory failure.

CONCLUSION

Clinical studies in adult and pediatric emergency and critical-care settings show that lung ultrasound provides rapid, accurate assessment of acute pulmonary conditions and can often outperform chest radiography for pneumonia and cardiogenic pulmonary edema. When ultrasound findings are combined with biomarkers such as procalcitonin or natriuretic peptides, diagnostic specificity improves and antibiotic and imaging use can be optimized, including in ventilated and critically ill children and adults. Despite heterogeneity and limited sample sizes in some laboratory-integrated protocols, the overall evidence supports integrating lung ultrasound as a core component of emergency pulmonary assessment for both medical and surgical emergencies.

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