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LUNG ULTRASOUND IN THE DIAGNOSIS OF MECONIUM ASPIRATION SYNDROME IN NEONATES: A SYSTEMATIC REVIEW

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ABSTRACT

The aim of the study: Meconium aspiration syndrome (MAS) remains an important cause of neonatal respiratory distress and is traditionally diagnosed using clinical criteria supported by chest X-ray. Lung ultrasound (LUS) is a radiation-free, bedside imaging modality increasingly used in neonatal lung diseases. The objective of this systematic review is to evaluate the diagnostic role of LUS in neonates with MAS.
Materials and methods: A systematic literature search was conducted in PubMed and Google Scholar in accordance with the PRISMA 2020 guidelines. Original studies involving neonates with MAS and reporting MAS-specific LUS data were included. Studies were excluded if they were non-English, animal studies, lacked original data, involved non-MAS populations or focused on therapy guidance rather than diagnosis.
Results: Five studies met the inclusion criteria. Across the included studies, LUS demonstrated high diagnostic performance for MAS, with reported sensitivity ranging from 90% to 100% and specificity 99.3% to 100%. Characteristic LUS findings included lung consolidations with air bronchogram, pleural line abnormalities, disappearance of A-lines and alveolar-interstitial syndrome.
Conclusions: LUS appears to be a reliable diagnostic tool for MAS and offers important advantages including absence of ionizing radiation and bedside applicability. It may be considered a first-line imaging modality in infants with suspected MAS, with chest X-ray reserved for cases of diagnostic uncertainty. Further studies are needed to confirm these findings.

KEYWORDS

Meconium Aspiration Syndrome, Lung Ultrasound, Neonate

CITATION

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Introduction

MAS is a severe condition diagnosed in newborns born through meconium-stained amniotic fluid (MSAF), presenting with respiratory distress and characteristic radiological findings in the absence of other possible etiologies. (Swarnam et al., 2012) MAS typically affects near-term, term or post-term infants since meconium is rare in amniotic fluid prior to 34 weeks gestation. (Lovrenski et al., 2025; Swarnam et al., 2012) With a reported prevalence of 0.1-0.4% of births, MAS is less common than respiratory distress syndrome (RDS) and transient tachypnoea of the newborn (TTN). (Lovrenski et al., 2025) About 10% of all cases of respiratory failure with a 39% death rate are caused by MAS which is still a major issue in developing countries. (Monfredini et al., 2021; Swarnam et al., 2012) The diagnosis of MAS relies on the maternal and perinatal history including a term or post-term pregnancy, evidence of perinatal stress and the presence of MSAF. The characteristic clinical features are meconium painted skin and signs of respiratory distress such as tachypnoea, respiratory retractions, cyanosis, nasal flaring, hyperexpanded and barrel-shaped thorax. It is further supported by chest X-ray showing pulmonary hyperinflation with cottony and patchy infiltrates interspersed with areas of increased radiolucency. (Monfredini et al., 2021) However, in recent years, studies have suggested LUS as a good alternative to chest X-ray for neonatal lung diseases due to absence of ionizing radiation, its portability, ability to provide real-time images and low cost. (Feng & Huang, 2025; Liu et al., 2016; Volpicelli et al., 2012) These advantages are particularly useful in neonatal intensive care units. (Alonso-Ojembarrena et al., 2024; Raimondi et al., 2014) Additionally, the anatomical features of infants, including a small thoracic width, low lung mass and a thin chest wall, make LUS a highly effective diagnostic tool. (Ismail et al., 2023) It has been successfully used in the diagnosis of neonatal respiratory disorders such as RDS, TTN, pneumonia and atelectasis. (Copetti & Cattarossi, 2007; Liu et al., 2016; Pereda et al., 2015) Despite the increasing use of LUS in neonatal respiratory disorders, its diagnostic role in MAS remains incompletely defined. (Liu et al., 2016) This systematic review aims to evaluate the available evidence regarding the role of LUS in the diagnosis of MAS in neonates.

Materials and Methods

The systematic review was conducted in accordance with the PRISMA 2020 guidelines. A literature search was performed in PubMed and Google Scholar to identify studies evaluating the role of LUS in newborns with MAS. The search strategy included the following keywords: „lung ultrasound", „meconium aspiration syndrome", „newborn". The initial PubMed search yielded 68 records. Automated filters for English language and human studies were applied, resulting in 46 records. No duplicate records were identified within the PubMed search results. In addition, the first 100 records from Google Scholar were screened.

All records were screened independently by title and abstract. In the PubMed, 35 records were excluded at the title and abstract screening stage for the following reasons:

- No lung ultrasound assessment (n=22),
- Animal studies (n=1),
- Wrong clinical condition (n=7),
- Wrong study type (case reports, guidelines, recommendations) (n=5).

Eleven records were sought for retrieval. The full texts of 6 articles were not available. The remaining 5 articles were assessed in full text. Of these, 2 studies were excluded due to:

- Wrong study aim (therapy guidance) (n=1),
- Wrong study type (review) (n=1).

Ultimately, 3 studies from PubMed met the inclusion criteria and were included in the synthesis.

From Google Scholar search, 14 duplicate records were removed, leaving 86 records for title and abstract screening. At this stage, 73 records were excluded for the following reasons:

- wrong study type (narrative reviews, guidelines) (n=27),
- wrong study aim (therapy guidance) (n=12),
- wrong clinical condition (n=32),
- animal studies (n=1),
- preprint without peer review (n=1).

The remaining 13 records underwent full-text assessment. The full text was unavailable for 5 studies. Six studies were excluded due to:

- wrong study type (case reports or small case series, review articles) (n=4),
- wrong study aim (therapy guidance) (n=1),
- mixed populations without separate diagnostic data for MAS (n=1).

Two additional studies from Google Scholar fulfilled the eligibility criteria and was included.

In total, 5 studies were included in the final synthesis. Figure 1 presents the complete study selection process.

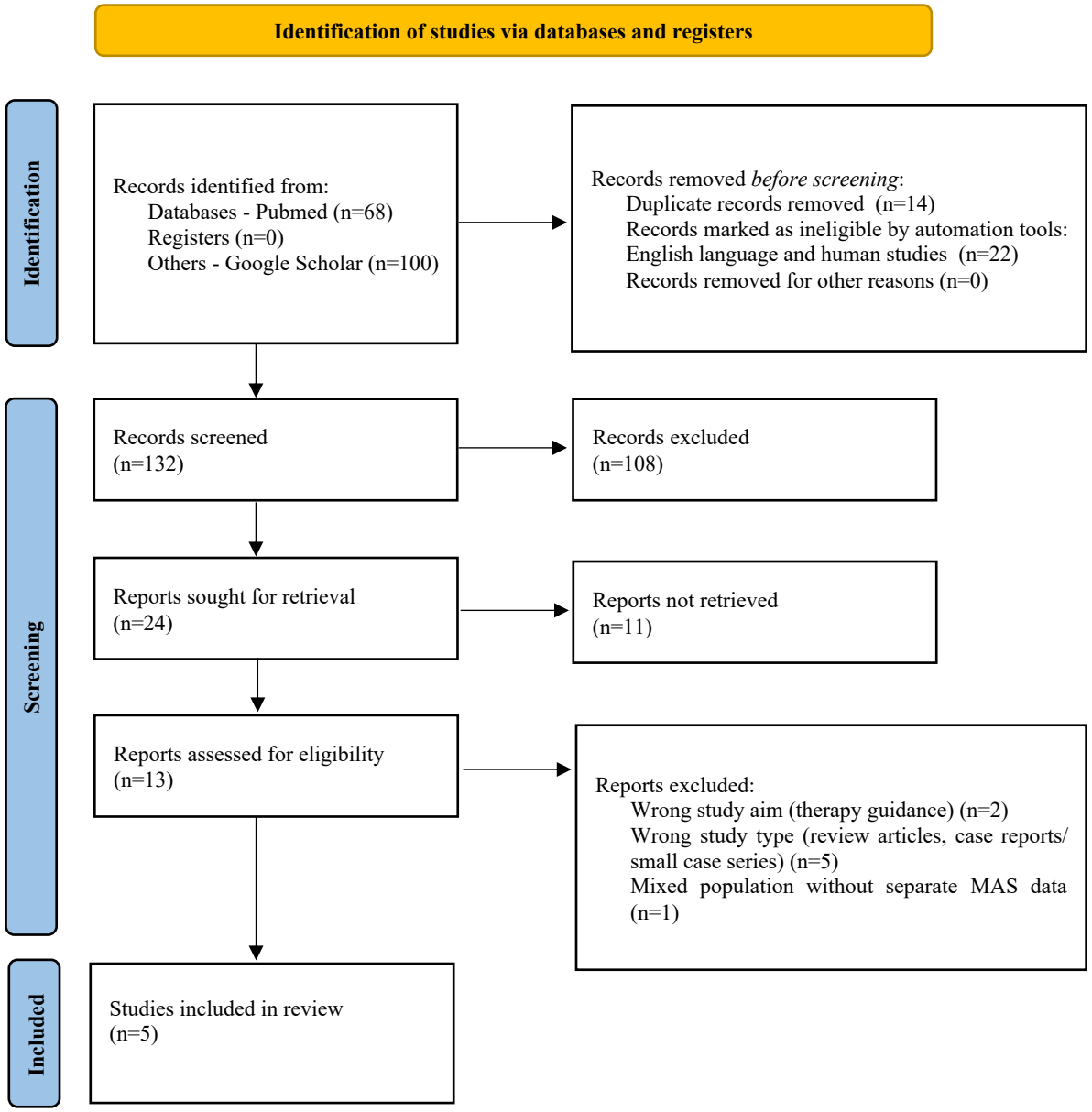

Fig. 1. *PRISMA 2020 flow diagram*

Results

A total of 5 original studies investigating LUS findings in neonates with MAS were included in the review. The included studies were published between 2016 and 2025 and comprised prospective observational or cross-sectional study designs. All studies enrolled neonatal populations and reported LUS findings with a distinct subgroup analysis for MAS. The sample size of infants with MAS varied across studies, ranging from 10 to 227 patients. (Chen et al., 2017; Feng & Huang, 2025; Ismail et al., 2023; Liu et al., 2016; Wu et al., 2024)

All studies that assessed diagnostic accuracy demonstrated high diagnostic performance of LUS for the identification of MAS. Reported sensitivity ranged from 90% to 100% while specificity from 99.3% to 100%. (Ismail et al., 2023; Liu et al., 2016; Wu et al., 2024)

Characteristic LUS findings in MAS included lung consolidations with air bronchogram, pleural line abnormalities, absence of A-lines, alveolar-interstitial syndrome. These features were consistently reported across studies and allowed differentiation of MAS from other causes of neonatal respiratory distress. (Chen et al., 2017; Feng & Huang, 2025; Ismail et al., 2023; Liu et al., 2016; Wu et al., 2024)

In a prospective observational study, Liu et al. included 117 infants with MAS and 100 controls. Key ultrasound features identified in the study comprised lung consolidation with air bronchogram, abnormalities of the pleural line, the absence of A-lines, alveolar-interstitial syndrome or B-lines in the non-consolidation area, all of which were observed in all patients. Atelectasis was present in 16.2% of patients and pleural effusion in 13.7%. The sensitivity and specificity of LUS for the diagnosis of MAS were calculated based on the presence of lung consolidation with irregular margins. This feature achieved 100% sensitivity and 100% specificity for MAS detection, supporting the use of ultrasonography as a reliable and non-invasive alternative to chest X-ray. (Liu et al., 2016)

Ismail et al. conducted a prospective cross-sectional study including 100 newborns with respiratory disorders admitted to the neonatal intensive care unit. In order to diagnose the cause of respiratory distress, the chest X-ray and LUS were performed. All 100 neonates received an initial diagnosis based on clinical examination and chest X-ray. The diagnostic outcomes of chest X-ray and LUS at admission were similar with no statistically significant differences. Although chest X-ray identified slightly more cases of MAS than LUS (13 cases by chest X-ray, 12 cases by LUS), these differences were not significant. LUS demonstrated high diagnostic performance in the evaluation of MAS with a sensitivity of 92.3%, specificity of 100% and overall accuracy of 0.99. A very high level of agreement (99%) between LUS and chest X-ray was observed with a Kappa value of 0.954. Characteristic ultrasonographic features of MAS included lung consolidations and pleural line abnormalities, both present in all affected neonates. The authors stated that LUS may serve as a safe and reliable bedside imaging modality in neonatal patients. (Ismail et al., 2023)

An observational study by Wu et al. enrolled 160 infants with suspected pulmonary diseases. LUS was performed within 24 hours of admission and the final clinical diagnosis was used as the reference standard to diagnostic performance analysis. For patients with MAS, diagnostic criteria included clinical history, respiratory symptoms, physical examination findings and chest X-ray features. Among 142 newborns with confirmed lung disease, 136 cases were correctly identified using LUS, resulting in a positive detection rate of 85%. The method showed high diagnostic performance with a sensitivity of 95.77%, specificity of 77.77%. LUS identified MAS in 9 out of 10 patients, with an overall diagnostic accuracy of 0.988, sensitivity of 90% and specificity of 99.3%. LUS showed a high level of agreement with the final clinical diagnosis with a Kappa value of 0.846. Typical ultrasound findings included disappearance of A-lines, focal consolidations in the subpleural area, alveolar-interstitial syndrome and abnormal pleural line changes, although these findings were nonspecific and could resemble pneumonia. The authors concluded that while LUS is a reliable and dynamic diagnostic tool, it does not fully replace chest X-ray and comprehensive clinical assessment remains essential. (Wu et al., 2024)

Chen et al. presented an observational study which included 3405 neonates (2658 with and 747 without lung disease). In all newborns with MAS (227 cases) the following ultrasound findings were observed: disappearance of A-lines, lung consolidation with air bronchogram and interstitial syndrome. Additional features identified in neonates examined within the first 48 hours (n=155) included: pleural line anomalies (88.4%), pleural effusion (17.4%) and lung pulse (23.9%). MAS shares several imaging features with both RDS and pneumonia which may complicate differential diagnosis. Compared with RDS, MAS more commonly presents with interstitial syndrome and less frequently demonstrates diffuse pulmonary edema or a white lung which are typical of severe RDS. Moreover, lung consolidations in RDS are often lack well-defined boundaries from lung tissue and are accompanied by more exquisite and dense air bronchograms. The authors pointed out that MAS features in LUS are very pneumonia-like. Therefore, reliable differentiation of MAS from RDS and pneumonia requires careful correlation of LUS findings with clinical and laboratory data. (Chen et al., 2017)

Feng and Huang conducted cross-sectional study investigating characteristic LUS features in common pulmonary diseases in neonates. Among 466 newborns, 57 were diagnosed with MAS. The LUS findings in patients with MAS were: lung consolidation (100%), absence of A-lines (100%), beach sign (100%), abnormal pleural line (100%), B-lines (86%), alveolar-interstitial syndrome and/or dense B-lines and/or white lung (19.3%), double lung points (52.6%), pleural effusion (15.8%). The authors indicate that these features are not specific to MAS and may also occur in other conditions. Therefore, they emphasize that LUS findings must always be closely correlated with patient's clinical presentation and other diagnostic data in order to establish an accurate diagnosis. (Feng & Huang, 2025)

Discussion

This systematic review summarizes the current evidence regarding the diagnostic role of LUS in newborns with MAS.

Characteristic lung ultrasound findings in MAS were consistently reported across studies and included pulmonary consolidations with air bronchogram, pleural line abnormalities, disappearance of A-lines and the presence of interstitial syndrome.

In the majority of studies alveolar-interstitial syndrome was observed in nearly all infants with MAS, whereas in a study by Feng and Huang, it was reported in fewer than 20% of cases. This variability may reflect differences in study design, timing of ultrasound examination, disease severity and applied diagnostic definitions. (Chen et al., 2017; Feng & Huang, 2025; Ismail et al., 2023; Liu et al., 2016; Piastra et al., 2014; Wu et al., 2024)

Several authors have highlighted an important limitation that individual LUS signs overlap with those observed in other neonatal respiratory conditions such as pneumonia and RDS. As emphasized in larger observational studies, reliable differentiation of MAS from other causes of neonatal respiratory distress requires careful integration of LUS findings with clinical history, perinatal risk factors, laboratory results and, when necessary, chest X-ray. (Chen et al., 2017; Feng & Huang, 2025; Wu et al., 2024) Therefore, LUS could be considered a first-line diagnostic modality with chest X-ray reserved for cases in which diagnostic uncertainty persists.

Across the included studies, LUS showed high diagnostic performance for MAS with reported sensitivity ranging from 90% to 100% and specificity from 99.3% to 100%. (Ismail et al., 2023; Liu et al., 2016; Wu et al., 2024) These values are comparable to those obtained with chest X-ray imaging. (Ismail et al., 2023) Importantly, a very high level of agreement between LUS and chest X-ray or the final clinical diagnosis was observed, with Kappa values from 0.846 to 0.954. (Ismail et al., 2023; Wu et al., 2024) Despite these findings, it should be acknowledged that the overall evidence base remains limited. Most studies included relatively small sample sizes or mixed population of neonatal respiratory disorders. In addition, differences in study design, reference standards and reported outcomes limit direct comparison between studies. (Chen et al., 2017; Feng & Huang, 2025; Ismail et al., 2023; Liu et al., 2016; Wu et al., 2024) These factors highlight the need for larger, well-designed studies focusing specifically on MAS to further clarify the diagnostic role of LUS and to support its standardized implementation in clinical practice.

The advantages of LUS over chest X-ray are particularly relevant in the neonatal population. LUS is radiation-free, portable, repeatable and allows real-time bedside assessment, making it especially suitable for critically ill neonates. (Alonso-Ojembarrena et al., 2024; Chen et al., 2017; Feng & Huang, 2025; Ismail et al., 2023; Liu et al., 2016; Raimondi et al., 2014; Wu et al., 2024) In addition, the anatomical characteristics of the neonatal chest, including a thin chest wall and limited lung aeration, enhance ultrasound image quality and facilitate the detection of pathological changes. (Ismail et al., 2023) These advantages support the increasing adoption of LUS in neonatal practice.

Additionally, LUS can be used not only for diagnostic purposes but also for therapeutic management in MAS. Qiu et al conducted a study evaluating the therapeutic effectiveness of bronchoalveolar lavage performed under LUS guidance, demonstrating a significant reduction in the need for mechanical ventilation and its duration, mortality rate and the incidence of pulmonary hypertension of the newborn or pneumothorax. (Qiu et al., 2019) Moreover, LUS has been explored as a tool to support surfactant therapy decisions. Popa et al. reported that higher LUS scores correlate with greater severity of respiratory dysfunction and more frequent surfactant administration. Such applications of LUS, both in tracking therapeutic efficacy and in guiding interventions, highlight its value as a bedside, radiation-free modality. (Popa et al., 2024)

Conclusions

LUS appears to be a reliable and accurate imaging modality for the diagnosis of MAS in neonates. The available evidence demonstrates high sensitivity, specificity and strong agreement with chest X-ray while offering important clinical advantages, including the absence of ionizing radiation and the possibility of bedside assessment.

Characteristic ultrasonographic findings of MAS can support early diagnosis when interpreted in conjunction with clinical and perinatal data. Although LUS cannot completely replace chest X-ray in all cases, it represents a valuable first-line diagnostic tool in the evaluation of neonatal respiratory distress. Further well-designed studies are needed to better define the role of LUS in the diagnostic pathway of MAS.

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