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Diagnostic Accuracy of Point of Care Ultrasound (POCUS) for Diagnosing Neonatal Pneumothorax Keeping Chest X-ray as Reference Standard

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ABSTRACT

Neonatal pneumothorax needs immediate medical assessment because it poses a danger to life. Neonates face radiation risks from chest X-ray (CXR), which physicians frequently use, but it creates treatment delays. Point-of-care ultrasound (POCUS) offers a rapid, bedside, radiation-free alternative. **Objective:** To assess how accurately POCUS detects neonatal pneumothorax compared to CXR, which serves as the standard reference. **Methods:** The descriptive, cross-sectional study took place in the Combined Military Hospital's Neonatal Intensive Care Unit from October to December 2025 after researchers obtained permission through ethical approval (Ref No. 576/2024). The study enrolled one hundred neonates who were 28 days old or younger and showed clinical signs of pneumothorax. A trained radiologist performed bedside POCUS using a high-frequency linear probe. A radiologist who remained blinded to the study read the CXR results. Researchers computed sensitivity, specificity, PPV, NPV, and overall accuracy together with ROC-AUC values. **Results:** CXR confirmed pneumothorax in 35 neonates. POCUS showed sensitivity 91.6%, specificity 93.75%, PPV 89.18%, NPV 95.2%, and overall diagnostic accuracy 93%. The AUC measurement reached 0.93 while the 95% confidence interval ranged from 0.87 to 0.97. **Conclusion:** POCUS provides high diagnostic accuracy which makes it an effective NICU screening tool for detecting neonatal pneumothorax.

INTRODUCTION

Neonatal pneumothorax (NP) is a critical condition that can lead to the death of the newborn and it has a global incidence of 0.05-2% in newborns and up to 9% in preemies that are extremely immature [1, 2]. The occurrence of NP in neonatal intensive care units (NICUs) is about 1-2%, but it is higher in babies on mechanical ventilation and having respiratory distress syndrome (RDS) [3]. In Pakistan and the neighboring countries, the rate of NP among NICU-admitted patients is approx. 0.8-1.02%, mostly seen in preterm boys with low Apgar scores [4, 5]. The standard radiological procedure, that is, chest X-ray (CXR), is the most sensitive and specific method for NP diagnosis, but it also has the disadvantage of exposing babies to ionizing radiation and delaying diagnosis in places where resources are limited. POCUS, i.e., point-of-care ultrasound, at the bedside presents a way of detecting NP that is free from radiation and is at the same time superior in sensitivity (98%) and specificity (99%) to CXR (82% and 96%) in neonates. Meta-analyses have indicated POCUS pooled sensitivity of 74-98% and specificity exceeding 93% against CXR, while faster performance fits well with NICUs [6, 7]. This is a descriptive cross-sectional study that plans on evaluating the accuracy of POCUS by taking CXR as the reference in Pakistani neonates.

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Nevertheless, there are not enough local data available about its effectiveness in the neonatal population in Pakistan, where resource scarcity and delayed imaging are the norm. The study hypothesized that point-of-care ultrasound technology would achieve the same level of diagnostic accuracy as chest X-ray for detecting neonatal pneumothorax. The device can function as an effective first evaluation tool for NICU patients. Thus, this study aims to evaluate the diagnostic accuracy of POCUS in comparison with chest X-ray, with the intention of supporting the evidence-based utilization of POCUS for the early and efficient diagnosis in neonatal intensive care units.

METHODS

This descriptive, cross-sectional study was conducted in the Combined Military Hospital Neonatal Intensive Care Unit, Lahore, Pakistan, from October 2025 to December 2025, following ethical approval, No 576/2024. The sample size was calculated using the diagnostic accuracy formula for sensitivity estimation: $n = (Z^2 \times Se\,(1 - Se)) / (d^2 \times P)$. Where: Z = 1.96 (95% confidence level). Expected sensitivity (Se) = 0.90 (based on previous neonatal ultrasound studies). Absolute precision (d) = 0.08. Estimated prevalence (P) of neonatal pneumothorax in NICU = 0.35 (35%, based on anticipated suspected cases). The calculated minimum sample size was 94 neonates. After adjusting for possible incomplete data, a total of 100 neonates were enrolled [8]. The sample size was then rounded up to cover possible data loss and incomplete evaluations; finally, a total of 100 neonates with suspected pneumothorax were included in the study. Non-probability consecutive sampling was the technique chosen because neonatal pneumothorax is a critical but not very common emergency that needs to be evaluated without delay. Through this method, all the newborns who were eligible and showed signs of having a pneumothorax were admitted during the study period, which helped in quick recruitment without postponing treatment. Neonates aged ≤ 28 days with clinical signs suggestive of pneumothorax (e.g., respiratory distress, decreased breath sounds, chest asymmetry) were considered eligible after parental consent was obtained. Neonates with contraindications to ultrasound (e.g., severe skin conditions), a history of pneumothorax requiring surgical intervention, or severe comorbidities affecting the accuracy of ultrasound or chest X-ray (CXR) were excluded. Eligible neonates were enrolled after informed consent was obtained from parents or legal guardians. Privacy and confidentiality were ensured. POCUS was performed by trained radiologists using a GE LOGIQ P9 ultrasound system fitted with a 7–12 MHz high-frequency linear transducer. The chest was scanned in anterior, lateral, and subcostal views. Pneumothorax was assessed by the presence of a lung point or by the combined absence of lung sliding and B-lines. Findings were documented on a predesigned proforma. Standard anteroposterior (AP) and lateral CXR images were obtained, and pneumothorax was diagnosed by visualization of the visceral pleural line along with absence of peripheral lung markings. All radiographs were interpreted by a radiologist blinded to POCUS findings. Pneumothorax diagnosis was confirmed by an expert consultant radiologist with at least 10 years of experience. Operator's knowledge, device's standard, and clinical stability of newborns were taken into account. A highly skilled consultant radiologist carried out all ultrasound examinations using machines produced in the last five years. Only those newborns whose condition was stable in hemodynamic terms underwent scans. All ultrasound tests were conducted by superior radiologists with recognized postgraduate diplomas in radiology and at least five years of practice in the area of neonatal and pediatric imaging. The readers of the radiological images had the benefit of prior training in point-of-care lung ultrasound, were accustomed to the standard diagnostic criteria for neonatal pneumothorax, and were unaware of each other's findings in order to maintain objectivity and reproducibility in the results. The data were gathered through a structured proforma that was used to record the demographic data, clinical signs, and POCUS and CXR findings. The patients' confidentiality was secured. Two different radiologists of the consultant level were hired: one to perform all POCUS and the other to interpret all CXRs. They were not aware of each other's results.

The accuracy of POCUS diagnosis was computed through SPSS version 23.0. The analyses carried out resulted in a combination of descriptive, comparative, and diagnostic accuracy analyses. The analysis of variables involved demographic variables (age in days, gender), perinatal variables (gestational age in weeks, birth weight in kilograms), and clinical variables (respiratory distress, decreased breath sounds, chest asymmetry), among others. The variables related to imaging included POCUS findings (loss of lung sliding, absence of B-lines, lung point) and chest X-ray features (visceral pleural line, absence of peripheral lung markings). The comparative analysis was performed using independent sample t-tests and chi-square tests. The variables for diagnostic accuracy consisted of sensitivity, specificity, PPV, NPV, and overall accuracy. ROC curve analysis was used to assess the diagnostic performance of POCUS. The area under the curve (AUC) with 95% confidence intervals was calculated using SPSS version 23.0. The optimal cutoff point was determined using the Youden index (sensitivity + specificity – 1).

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RESULTS

Out of the total of 100 neonates that were selected for the study, 35 had pneumothorax, and 65 did not. The average ages of both groups were practically the same, with pneumothorax (14.33 ± 6.64 days) and without pneumothorax (14.36 ± 6.06 days; p=0.710). The male/female ratio was also found to be similar in both groups (22/13 vs. 36/29 male/female; p = 0.680). The researchers did not find any significant difference in the mean gestational age (35.74 ± 2.41 vs. 36.9 ± 3.17 weeks; p=0.420) or in the birth weight (2.50 ± 0.52 vs. 2.48 ± 0.67 kg; p=0.530). Respiratory distress was a common condition in both groups (100% vs. 93.8%; p=0.130). Decreased breath sounds (85.7% vs. 15.4%; p<0.001) and chest symmetry (42.8% vs. 6.2%; p<0.001) were two symptoms that occurred much more frequently among the neonates suffering from pneumothorax (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics of Neonates with and without Pneumothorax (n=100)

Variables	Pneumothorax Present, (n=35)	Pneumothorax Absent, (n=65)	p-value
Days	14.33 ± 6.64	14.36 ± 6.06	0.710
Gender			
Male	22	36	0.680
Female	13	29	
Others			
Gestational Age (weeks)	35.74 ± 2.41	36.9 ± 3.17	0.420
Birth Weight (kg)	2.50 ± 0.52	2.48 ± 0.67	0.530
Respiratory Distress			
Yes	35 (100%)	61 (93.8%)	0.130
No	0 (0%)	5 (6.2%)	
Decreased Breath Sounds			
Yes	30 (85.7%)	10 (15.4%)	<0.001*
No	5 (14.3%)	55 (84.6%)	
Chest Asymmetry			
Yes	15 (42.8%)	4 (6.2%)	<0.001*
No	20 (57.2%)	61 (93.8%)	

Independent sample tests for continuous and chi-square tests for categorical variables *Statistically significant at p ≤ 0.05*

In neonates diagnosed with pneumothorax through POCUS, the most common finding was the loss of lung sliding, which was seen in 30 cases (90.9%), and then the absence of B-lines in 28 cases (84.8%). The lung point, the most specific sonographic sign, was seen in 24 neonates (72.7%). The most common radiographic feature in chest X-ray was the visualization of visceral pleural line in 26 cases (74.2%), whereas peripheral lung markings were absent in 22 neonates (62.8%) (Table 2).

Table 2: Distribution of Point-of-Care Ultrasound (POCUS) and Chest X-Ray Features Among Neonates Diagnosed with Pneumothorax

POCUS Features	n (%)	Chest X-ray	n (%)
Loss of Lung Sliding	30 (90.9%)	Visceral Pleural Line	26 (74.2%)
Absence of B Lines	28 (84.8%)	Absence of Peripheral Lung Markings	22 (62.8%)
Lung Point Visualized	24 (72.7%)	–	–

POCUS was able to correctly identify 33 true-positive cases of neonatal pneumothorax, alongside giving 4 false positives and 3 false negatives, while also correctly categorizing 60 cases as true negatives. From these results, it could be said that POCUS had a sensitivity of 91.6% and a specificity of 93.75%. The positive predictive value was calculated to be 89.18%, while the negative predictive value was remarkable at 95.2%. In general, POCUS was found to have a diagnostic accuracy of 93% when assessed against chest X-ray as the reference gold standard. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the overall discriminatory performance of point-of-care ultrasound (POCUS) for detecting neonatal pneumothorax, using chest X-ray as the reference standard. The area under the ROC curve (AUC) for POCUS was 0.93 (95% CI: 0.87–0.97), indicating excellent diagnostic performance. An optimal operating point was identified based on the maximum Youden index, corresponding to a sensitivity of 91.6% and specificity of 93.75% (Table 3).

Table 3: Diagnostic Accuracy Parameters of Point-of-Care Ultrasound (POCUS) Compared with Chest X-Ray for Detection of Neonatal Pneumothorax

Diagnostic Parameter	Value	95% Confidence Interval
True Positives (TP)	33 (33.0%)	–
False Positives (FP)	4 (4.0%)	–
True Negatives (TN)	60 (60.0%)	–
False Negatives (FN)	3 (3.0%)	–
Sensitivity	91.6%	78.2% – 97.1%
Specificity	93.75%	85.0% – 97.5%
Positive Predictive Value (PPV)	89.18%	75.3% – 95.7%
Negative Predictive Value (NPV)	95.2%	86.9% – 98.4%
Overall Accuracy	93.0%	86.3% – 97.0%

DISCUSSION

The study sensitivity (91.6%) is slightly lower when compared to meta-analyses, which reported 98-99% for lung ultrasound (LUS) in diagnosing neonatal pneumothorax. For example, the 2021 systematic review by Fei *et al.* encompassing eight prospective studies with a total of 529 neonates, reported a pooled sensitivity of LUS at 98%, specificity at 99%, and a diagnostic odds ratio (DOR) of 920 that was much higher than CXR's 82% sensitivity and 96% specificity [9]. One possible reason for

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this difference could be related to our having a larger number of false-positive results (4 cases), which might be attributed to the operator's experience or to subtle artifacts mimicking absent lung sliding, a finding that was noted in 90.9% of our true positives. On the other hand, our specificity (93.75%) is in line with Ruoss *et al.* review (96.7-100%), where LUS consistently diagnosed pneumothorax in NICU environments [10]. The PPV (89.18%) and NPV (95.2%) obtained in our study are better than those reported in some adult-focused POCUS but are still inferior to neonatal-specific ones; a study reported a pooled sensitivity of 74.3% and a specificity of 93.6% with a total of 3,840 subjects from different age groups and attributed the variance to non-standardized protocols [11]. This study's detection of lung point (72.7%) resembles that of Wang *et al.* who declared a specificity of this sign (100% in their cohort) to be 94.28% [12]. Some CXR characteristics, like visceral pleural line (74.2% here), showed common ground, yet the immediacy of POCUS at the bedside serves to address the delays in CXR that were the subject of criticism in Liu *et al.* where LUS specificity was found to be 98% [13]. The POCUS signs that we observed in our group—absent lung sliding (90.9%), absent B-lines (84.8%), lung point (72.7%)—are consistent with recent validations; Dong *et al.* confirmed the so-called lung point's specificity in neonatal respiratory distress [14]. Nazir *et al.* made a similar comparison between ultrasonography and CT in the case of pneumothorax detection, noting that pleural line visualization was as high as our 74.2% CXR rate [15]. It should be emphasized that our false negatives (3 cases) were presumably due to tiny pneumothoraxes not detected during the initial POCUS, a difficulty that has been pointed out in preterm-heavy cohorts like ours (mean GA 36.3 weeks), whereas term neonates show a higher detection rate as reported by Liu [13]. There were no baseline differences (age, sex, GA, birth weight, respiratory distress) that could confound our results; thus, they are in agreement with the similar populations in the studies conducted post-2020. The assessment of reduced breath sounds (85.7% vs 15.4%, p<0.001) was a strong indicator of POCUS positives, giving further justification to the integrated clinical-ultrasound protocols in ESPNIC guidelines (as implied in recent POCUS endorsements) [16]. In Pakistan, where resources are scarce, our POCUS-first protocols were backed by 93% accuracy. The reduction in CXR radiation (0.01-0.1 mSv per view) is significant, especially considering the high respiratory distress burden. Our practical metrics (e.g., 91.6% sensitivity) confirm that the application of the technology is justified, even though there are minor discrepancies from the ideal pooled estimates [17, 18]. Compared to the 2021 meta-analyses, this study's results show that the integration of symptoms allows for more precise diagnostics and therefore necessitates training according to the recent consensus [12, 19]. Among the strengths were the potential pairing of POCUS-CXR in 100 neonates, corresponding to the actual NICU workflows, and the high NPV allowing safe rule-out, which was reported by Indian cohorts with the 93.22% sensitivity [19-21]. Operator blinding reduced bias to a minimum, contrary to some reviews in which there was a lot of variability.

On the other hand, limitations included a small sample (n=100), a single-center design that limited generalizability, and CXR as an imperfect gold standard that is susceptible to inter-observer variability (up to 20% in neonates). The lack of serial imaging missed the evolution of dynamic pneumothorax, and the preterm predominance (implied by GA) might have been responsible for the false positives from the atelectasis mimics being inflated. The absence of volume quantification restricts severity correlation as well as emerging air-fluid points. Operator dependency still exists, but our metrics are getting closer to expert benchmarks. The study demonstrates that POCUS technology provides exceptional diagnostic performance because it achieved a high AUC score of 0.93, which shows that it can identify different medical conditions.

CONCLUSIONS

The research showed that POCUS tests achieve both high sensitivity and high specificity and demonstrate total diagnostic accuracy when used to identify neonatal pneumothorax through comparison with chest X-ray results. The test shows a high negative predictive value, which establishes its function as an accurate bedside tool for ruling out medical conditions. The study results cannot be applied to other situations because the research used a small number of participants and was conducted in one medical facility. The existing requirement for primary confirmation in neonatal intensive care units should remain until larger multicenter research studies are finished.

Authors' Contribution

Conceptualization: SK
Methodology: SK, SA, AMA, HA
Formal analysis: SK, SA, SFAN
Writing and Drafting: SK, SA, SAHK
Review and Editing: SK, SA, AMA, HA, SFAN, SAHK

All authors approved the final manuscript and take responsibility for the integrity of the work.

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Conflicts of Interest

All the authors declare no conflict of interest.

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