Precordial Heart Image Disappearance: An Uncommon New Specific Ultrasound Sign for Diagnosing Neonatal Pneumothorax and its Thoracentesis Treatment at the Precardiac Area- an Pilot Study Reports from Two Centers

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Research

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Abstract

Background: Use of lung ultrasonography (LUS) to diagnose neonatal pneumothorax (PTX) has been well documented. This study aimed to emphasize the value of precordial heart image (PHI) disappearance as an ultrasound sign to diagnose neonatal PTX and to perform thoracentesis at the precardiac area in patients with PTX.

Methods: From March 2017 to May 2021, a total of 288 infants were included in this retrospective study, including 48 patients with PTX, 48 patients with respiratory distress syndrome, 48 patients with transient tachypnea, 48 patients with meconium aspiration syndrome, 48 patients with pneumonia, and 48 patients with normal lung tissue. LUS was performed routinely, and thoracentesis was performed under LUS guidance.

Results: Eight of 48 patients with PTX (16.7%) presented with PHI disappearance on LUS, which exhibited a sensitivity of 16.7% and a specificity of 100% for diagnosing neonatal PTX. Needle aspiration was performed on 42 patients with PTX (87.5%), 8 of whom underwent puncture at the precardiac area. Satisfying results were obtained in 40 patients (95.2%) without any complications.

Conclusion: PHI disappearance is an uncommon ultrasound sign on LUS that can be used to diagnose neonatal PTX. Selection of the precardiac area as the puncture site is safe for the treatment of neonatal PTX in patients with PHI disappearance.

Introduction

Pneumothorax (PTX) occurs when gas accumulates in the pleural space. PTX is one of the common complications of neonatal pulmonary disease, and it leads to a significant increase in neonatal mortality. A retrospective survey from Canada on 71,237 newborn infants indicated that the neonatal population incidence rate of PTX was 4.0% in early preterm (gestational age [GA] < 32 weeks), 2.6% in moderate-late preterm (GA 32–36 weeks), and 6.7% in term (GA ≥ 37 weeks) neonates [1]. Another investigation from the US showed that in 13,811 newborn infants, the prevalence of PTX was 0.27% in infants with a birth weight of < 2500 g and 2.5% in infants with a birth weight of ≥ 2500 g [2]. PTX is not only associated with a 30% increase in mortality with an odds ratio of 5.27 (95% confidence interval 1.96–14.17) [3, 4], but it is also associated with a high rate of bronchopulmonary dysplasia, severe intraventricular hemorrhage, and a prolonged neonatal intensive care unit (NICU) length of stay, especially in early preterm neonates [1–4]. Therefore, early and accurate diagnosis followed by correct treatment is imperative to improve the prognosis of patients with PTX.

PTX is traditionally diagnosed by chest X-ray or computed tomography (CT), both in adults and children [5–7]. However, there is a certain missed diagnosis rate in radiological diagnosis, especially for occult PTX [8]. Moreover, there is inevitable radiation damage associated with CT. Radiation damage is particularly severe for growing newborns and premature babies. Recently, lung ultrasonography (LUS) has been successfully used to diagnose PTX. Clinical studies and literatures have proved that the sensitivity and

specificity of LUS in the diagnosis of PTX, both in adults and children, are superior to X-ray [9–11]. Relevant guidelines have been published to promote the application of LUS in the diagnosis and treatment of neonatal lung diseases and PTX [12–15].

Generally, LUS is used to diagnose PTX based on the following ultrasound characteristics [13, 14]: (1) disappearance of lung sliding; (2) absence of B lines; (3) presence of pleural lines and A lines; (4) sandy beach signs replaced by stratosphere signs on M-mode imaging; (5) presence of lung point in mild-to-moderate PTX.

Recently, we identified a new LUS sign that could be used to diagnose neonatal PTX; that is, precordial heart image (PHI) disappearance. To promote PTX diagnosis using LUS, this new sign is introduced in this paper.

Materials And Methods

Study setting

The study was conducted at the NICUs of two tertiary hospitals.

Ethics statement

The study protocol was approved by the ethics committees of Beijing Chaoyang District Maternal and Child Healthcare Hospital and Henan Zhumadian City Center Hospital. All methods were performed in accordance with the relevant guidelines and regulations. Written informed consent was obtained from participants' parents.

Instruments and examination methods

A Voluson S10 or Voluson E 10 (GE Healthcare, USA) ultrasound system with a linear array probe (frequency > 10 MHz) was used for LUS examination. All examinations were strictly performed in accordance with published guidelines and specifications [11, 12]. PTX was diagnosed according to criteria for LUS diagnosis of PTX [13, 14].

Participants

From March 2017 to May 2021, a total of 48 patients with PTX were diagnosed at the NICUs of Beijing Chaoyang District Maternal and Child Healthcare Hospital and Henan Zhumadian City Center Hospital. In a ratio of 1:1, 48 neonates with no lung disease, 48 patients with respiratory distress syndrome (RDS), 48 patients with transient tachypnea (TTN), 48 patients with meconium aspiration syndrome (MAS), and 48 patients with pneumonia were randomly selected as controls. Therefore, a total of 288 infants were included in this retrospective study. All LUS examinations were performed by well-trained neonatologists. Clinical data were collected by different doctors, and the LUS operator was blinded to the clinical conditions of neonates.

Observation indices

PHI was the key observation. Traditional signs, such as pleural lines, A lines, B lines, lung consolidation, lung sliding, lung point, and the stratosphere sign, were also examined [12–14].

Thoracentesis at the precardiac area

In PTX patients with a PHI, thoracentesis was performed according to internal guidelines [13]. In PTX patients with PHI disappearance, thoracentesis was performed at the precardiac area under LUS monitoring.

Statistical analysis

SPSS 21.0 software was used to conduct the statistical analysis. Fisher's exact test was used to compare the rate of positive neonatal LUS findings between groups. The specificity and sensitivity of PHI disappearance for diagnosing PTX were calculated based on Fisher's exact test. A p value of < 0.05 was considered statistically significant.

Results

Clinical and demographic data

The GA of this study population ranged from 27 ± 3 weeks to 41 ± 1 week. The study population consisted of 99 preterm infants and 189 full-term infants. The birth weight ranged from 880–4210 g. There were 156 males and 132 females. A total of 176 infants were delivered by vaginal delivery, while 112 infants were delivered by cesarean section.

The study subjects included 48 patients with PTX and 240 controls. The control subjects included 48 infants with healthy lungs, and 192 infants with different types of lung disease (48 cases of RDS, 48 cases of TTN, 48 cases of MAS, and 48 cases of pneumonia). There were no significant differences in GA and birth weight among the subgroups.

Normal LUS manifestations

Healthy neonatal lung demonstrates a bamboo sign on B-mode LUS (Fig. 1A) and a seashore sign (Fig. 1B) on M-mode LUS. Lung sliding is clearly evident on real-time LUS (Video 1) [12, 13]. In addition, the heart image in the left precardiac area is visible in healthy newborns. Moreover, heart movement should be visible on real-time LUS (Video 2).

Ultrasound manifestations of PTX

The major LUS manifestations of PTX are summarized in Table 1. These include (1) disappearance of lung sliding on real-time LUS (in this study, disappearance of lung sliding was observed in all patients with

PTX);(2) absence of B lines (all patients lacked B lines at PTX sites);(3) presence of pleural and A lines (all patients demonstrated pleural and A lines at PTX sites);(4) lung point (which was observed in 30 cases [62.5%] of mild and moderate PTX);(5) spared areas (which were observed in 12 patients with PTX [35%]);(6) the stratosphere sign (which was seen in all patients with PTX at the PTX site);and (7) PHI disappearance (8 patients with PTX [16.7%] demonstrated PHI disappearance).

Sensitivity and specificity of PHI disappearance in PTX diagnosis

Many LUS signs,such as presence of pleural and A lines,absence of B lines,lung sliding disappearance, lung point in mild-to-moderate PTX,spared areas in patients with mild PTX,and the stratosphere sign on M-mode LUS,are used to diagnose PTX [10–14, 16, 17].However,PHI disappearance has not been described previously.Thus,we investigated the value of PHI disappearance for the diagnosis of neonatal PTX using LUS in this study. Specifically,PHI disappearance was used as a parameter to calculate the sensitivity and specificity of LUS to diagnose neonatal PTX.The results indicate that PHI disappearance exhibits a sensitivity of 16.7% and a specificity of 100% for diagnosing neonatal PTX (Table 2).

Effectiveness of thoracentesis

Among the 48 patients with PTX,needle aspiration was performed in 42 patients (87.5%) with significant clinical symptoms under LUS monitoring.Satisfying results were obtained in 40 patients (95.2%),and gas was completely removed after puncture.The remaining 2 cases underwent closed thoracic drainage for 1–3 days.The drainage gas volume was 55–520 mL.

The puncture site was at the second intercostal space of the left or right midclavicular line (the traditional puncture site) in 14 cases;at the fifth to sixth intercostal space of the left or right midaxillary line in 12 cases;at the seventh to eighth intercostal space of the left or right subscapular line in 8 cases;and at the precardiac area in 8 cases,including 5 cases at the sixth intercostal space of the left midclavicular line and 3 cases 1 cm medial to the fifth intercostal space of the left midclavicular line.

Typical case presentation

To aid understanding of the results,we herein present a typical case.An infant with a GA of 32 ± 1 week,who was delivered by caesarean section with a birth weight of 1980 g,was admitted to the NICU because of severe dyspnea 3 hours after birth.LUS confirmed RDS in the right lung.Pleural lines and A lines were observed in the regions of L1–L2, L3–L4, and L5–L6, but no heart image or heart movement was observed (Video 3).Lung sliding also disappeared (Videos 4 & 5).

When 75 mL of gas was removed by pleural puncture from the sixth intercostal space at the left midclavicular line (Fig. 2),dyspnea was relieved,and heart rate decreased from more than 180 ~ 200 beats/min to approximately 140 beats/min.LUS showed that the heart image and heart movement emerged in the left precardiac region (L1–L2) (Video 6) after thoracic puncture.Therefore,it was confirmed that PHI disappearance was caused by left-sided PTX.

Discussion

Use of LUS to diagnose neonatal PTX has been documented, and this approach has a higher sensitivity than traditional chest X-ray [11–14, 16–20]. The major LUS signs of PTX are disappearance of lung sliding, absence of B lines, presence of pleural and A lines, and/or presence of lung point [11–14, 16–20]. This study is the first to report that PHI image disappearance is an unusual but specific LUS sign that can be used to diagnose neonatal PTX.

In the present study, PHI disappearance was only observed in 16.7% of patients with PTX, while it was not observed in patients with TTN, RDS, MAS, pneumonia, or healthy lungs. Thus, we believe that PHI disappearance is an uncommon, yet specific, LUS sign of neonatal PTX. The sensitivity and specificity of PHI disappearance were 16.7% and 100%, respectively.

Previously, the most commonly selected puncture site for the treatment of PTX based on chest X-ray diagnosis was the second intercostal space in the midclavicular line. However, thoracic puncture under LUS completely changed this opinion. According to our experience and international expert recommendations, suitable puncture sites are generally as follows [13]: (1) the intercostal space where pleural and A lines exist in B-mode; (2) the intercostal space where lung sliding disappears on real-time LUS; and (3) the intercostal space that presents with a stratosphere sign in M-mode. However, according to the results of this study, for patients with PHI disappearance, we can also select the precardiac area as the puncture site. Eight patients underwent puncture at this area, including 5 cases at the sixth intercostal space of the left midclavicular line and 3 cases 1 cm medial to the fifth intercostal space of the left midclavicular line. To our knowledge, this is the first report to use the precardiac area as the puncture site for the treatment of neonatal PTX. Performing pleural puncture in this area to treat PTX would not have been possible before LUS was developed.

Limitations

This study has some limitations that should be noted. First, LUS examinations were performed by well-trained doctors; thus, the results may not apply in the hands of less experienced examiners. Second, we did not measure inter-observer or intra-observer variability. Any physician who wishes to perform LUS should be properly trained [21, 22]. Third, the sample size of this study was small, so there may be some deviation in the results. Therefore, further expansion of the sample size and prospective multi-center studies are needed to verify the observations.

Conclusion

In conclusion, the present study performed an in-depth investigation of the LUS characteristics of neonatal PTX and its treatment under LUS monitoring. It was confirmed that PHI disappearance is an uncommon and specific sign that could be used to diagnose neonatal PTX. Moreover, use of the

precordial area as the puncture site was safe for the treatment of neonatal PTX in patients with PHI disappearance in this study.

Abbreviations

PTX

Pneumothorax; RDS = Respiratory distress syndrome; LUS = Lung ultrasound; NICU = Neonatal intensive care unit; TTN = Transient tachypnea of the newborn; MAS = Meconium aspiration syndrome; PHI = Precordial heart image; GA = Gestational age.

Declarations

Ethical Approval and Consent to participate

The study protocol was approved by the ethics committees of Beijing Chaoyang District Maternal and Child Healthcare Hospital and Henan Zhumadian City Center Hospital. All methods were performed in accordance with the relevant guidelines and regulations. Written informed consent was obtained from participants' parents.

Authors' contributions

JL contributed to the study conception, ultrasound examination, and data analysis, and wrote and approved the manuscript. **WY** contributed to clinical data analysis, manuscript preparation, and approval of the final manuscript. **JWY** contributed to clinical data analysis, manuscript preparation, and approval of the final manuscript. **GG** contributed to clinical data collection, manuscript revision, and approval of the final manuscript. **RXQ** contributed to data collection, manuscript revision, and approval of the final manuscript.

Availability of supporting data

The data set used and analyzed are available from the corresponding author on reasonable request.

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Conflict of Interest Statement: No

Consent for publication

Not applicable.

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Tables

Due to technical limitations, table 1 and 2 is only available as a download in the Supplemental Files section.

Figures

Figure 1

Healthy lung ultrasound manifestations. The healthy lung presents a bamboo sign on B-mode ultrasound (A) and a seashore sign (B) on M-mode ultrasound, as well as lung sliding (Video 1). The heart image can be seen in the left precardiac area (Video 2) on real-time ultrasound.

Figure 2

Pleural puncture. Thoracentesis was performed at the site of the sixth intercostal space at the left midclavicular line. Dyspnea was relieved, and heart rate decreased from more than 180~200 beats/min to approximately 140 beats/min after 75 mL of gas was removed.

Supplementary Files

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