9 Pneumothorax of the Newborn

Jing Liu, Hai-Ying Cao, and Erich Sorantin

9.1 Pneumothorax

The pleural cavity consists of the parietal pleura and the visceral layer, and it is a gas-free potential enclosed lacuna. After pleural rupture for any reason, the formation of pneumatosis in the thoracic cavity after the air enters the pleura is called pneumothorax, which is a common and critical neonatal illness in clinics and a common cause of death among newborns and preterm infants [1, 2].

9.1.1 Etiology and Pathophysiology

High-risk factors of neonatal pneumothorax include the following:

1. Lung diseases: lung leakage is a common complication of neonatal lung diseases; 27% of lung leakage occurs in infants with hyaline membrane disease, 41% in infants with meconium aspiration syndrome, and 10% in infants with wet lung, pulmonary infection, pulmonary hypoplasia, diaphragmatic hernia, etc.
2. Latrogenic: improper resuscitation, lung iatrogenic fracture, and rib fractures caused by chest compressions.
3. Improper application of ventilator: inspiratory pressure that is too high, end expiratory pressure that is too high, incoordination of respiration, endotracheal intubation position, and suction inducing pulmonary rupture.
4. Spontaneous pneumothorax: for unknown reasons.

The formation of pneumothorax is induced by the following causes: lung tissue bronchi rupture, and air escapes into the pleural cavity; or chest injuries puncture the pleura, the pleural cavity is connected with the outside world, and the outside air enters the pleura. Pneumothorax is the most common form of neonatal pulmonary air leak (including pneumothorax, pneumomediastinum, emphysema, pneumopericardium, and pneumoperitoneum). The heterogeneous alveolar aeration induced by any cause can lead to alveolar rupture, and the gas enters into the pulmonary interstitia to form interstitial emphysema. Interstitial emphysema can directly break into the chest cavity to form pneumothorax, and it can also reach the mediastina to form mediastinal

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-94-024-1549-0_9) contains supplementary material, which is available to authorized users.

J. Liu (✉)
Department of Neonatology and NICU, Beijing Chaoyang District Maternal and Child Health Care Hospital, Beijing, China

H.-Y. Cao
Department of Ultrasound, GE Healthcare, Beijing, China

E. Sorantin
Division of Pediatric Radiology, Department of Radiology, Medical University Graz, Graz, Austria

J. Liu et al. (eds.), *Neonatal Lung Ultrasonography*, https://doi.org/10.1007/978-94-024-1549-0_9

emphysema along the blood vessels, lymphatic vessels, or peribronchial regions. Mediastinal gas can enter the thoracic cavity to form pneumothorax. If the gas enters into the pericardium along large vessels, pneumopericardium is formed; if it enters into the subcutaneous tissues, subcutaneous emphysema is formed; and if it enters into the abdominal cavity, a gas film is formed. It is occasionally seen that the air breaks into the blood capillaries or lymphatic vessels to form aeroembolism. Since the negative pressure in the pleural cavity is neutralized, the wounds and edema site become collapsed. In case of small pneumothorax, in those with lung collapse of less than 30%, the influence on the respiratory and circulatory functions is relatively small, with many obvious clinical symptoms. In case of large pneumothorax, infants can experience dyspnea and cyanosis, the trachea shifts to the healthy side, the percussion of wounded chest presents tympani, and the auscultation indicates that the breath sounds decrease or disappear. Chest X-ray examination might show different degrees of lung collapse and aerothorax sometimes accompanied by a small amount of fluid. After the formation of pneumothorax, the pressure in the pleural cavity increases, and the negative pressures turn into positive pressure, compressing the lungs and blocking the venous blood; therefore, different degrees of pulmonary and heart dysfunctions are produced and are classified into closed pneumothorax, open pneumothorax, and tension pneumothorax.

9.1.1.1 Closed Pneumothorax

Closed pneumothorx, is also known as spontaneous pneumothorax, which is mostly a complication of rib fracture. After the formation of pneumothorax, pneumatosis and compression are seen in the pleural cavity. Visceral pleura rupture is closed so that there is no longer air that continues to be leaked into the pleural cavity.

9.1.1.2 Open Pneumothorax

Open pneumothorax, is also known as communicating pneumothorax, as the chest wall injuries make the outside air go in and out of the pleural cavity freely with respiration, the pressure in the affected pleural cavity is approximately 0. After air exhaust, it is observed that the pressure in the pleural cavity does not decrease. The pathophysiology of open pneumothorax is as follows:

(a) The negative pressure of the pleural cavity disappears; the lungs are compressed to collapse; the pressures at the bilateral pleural cavities are equal, making the bilateral mediastinal shift; and the pulmonary dilation at the healthy side is then limited.
(b) Upon inspiration, the negative pressure at the healthy side of the pleural cavity increases, and the difference with the pressure at the wounded side increases, causing the mediastina to further shift; upon expiration, the difference in the pressures on the bilateral sides of the pleural cavity decreases, the mediastina then shifts back to the wounded side, and this abnormal movement is called mediastinal flutter. Mediastinal flutter can affect venous return, resulting in severe circulatory disorder.
(c) Upon inspiration, the healthy side becomes dilated and inhales the outside air, and the gas with a low oxygen content discharges from the wounded side; upon expiration, some of the gas expired from the healthy side enters the wounded side, and some is discharged through the upper respiratory tract; because the gas with a low oxygen content is exchanged at the two lungs, the anoxia and dyspnea become aggravated.

9.1.1.3 Tension Pneumothorax

Tension pneumothorax, is also known as pressure pneumothorax, the most common reasons is alveolar lacerated wound or bronchial rupture, a flap obstruction is formed at the pleural cleft. Upon inspiration, the open air enters the pleural cavity from the cleft; in respiration, the flap is opened, and the cleft in the pleural cavity returns and is discharged from the respiratory tract. The increasing accumulation of gas in the pleural cavity and the constantly rising pressure form high pressure in the pleural cavity, so the collapse of the injured side of the lung becomes aggravated, the mediastina are pushed to the healthy side under the gradually increased pressure, and the healthy side of the lung is squeezed, resulting in severe respiratory and circulatory disorder. Sometimes, the high-pressure air of the pleural cavity is pushed in the mediastina, spreads to the subcutaneous tissues, and forms subcutaneous emphysema in the neck, face, chest, etc. Air discharge is needed to relieve the symptoms. If gas is sucked until negative pressure is achieved, the positive pressure is not restored quickly, and pleural cavity air discharge equipment should be installed.

9.1.2 Clinical Manifestations

In cases of small pneumothorax, in those with lung collapse of less than 30%, the influence on the respiratory and circulatory functions is relatively small with many obvious clinical symptoms.

In cases of large pneumothorax, the main reasons include the following: the conditions suddenly deteriorate, dyspnea and cyanosis become suddenly worsened, the patient feels listless and inert with low reactions, bilateral breasts are asymmetric, the affected side of the thorax is bulging and full, the respiratory movement becomes weakened with tympani, auscultation indicates that the respiratory sound becomes diminished or disappears, the trachea shifts, the heart rhythm becomes slow, the heart sound is low and distant, and there might be sudden cardiac arrest, decreased blood pressure, and even shock. Obvious collapse and pneumatosis of the pleural cavity are seen on chest X-ray examination, and no markings are visible outside of the pneumothorax line. Mediastinal organs such as the trachea and heart shift to the healthy side of the lungs with the manifestations of decreased diaphragmatic muscle and compression of the healthy side of lungs, and sometimes, a small amount of pleural effusion could be heard. The appearance of a photic zone beside the mediastina suggests mediastinal emphysema. Blood gas analysis shows decreased PaO_2 and increased $PaCO_2$. X-ray examination can identify congenital pulmonary cysts, hernia, and other lung diseases.

9.1.3 Auxiliary Examination

Chest X-ray diagnosis is the most common diagnostic tool for pneumothorax, but its sensitivity and accuracy are not high. It has been reported that pneumothorax in nearly 55% of patients with chest injuries cannot be diagnosed by chest X-ray. CT examination is the gold standard for diagnosis of pneumothorax, but there are some flaws, such as severe radiation injury, the need to transport critically ill patients, and relatively high costs.

9.1.4 Treatment of Pneumothorax

The principle for pneumothorax treatment is to discharge gas properly according to the different types of pneumothorax for the purpose of relieving the respiratory and circulatory disturbances resulting from the aerothorax so that the lung recruitment functions can be recovered as soon as possible and to meanwhile provide active therapies for complications and primary diseases.

1. Gas discharging method: An evaluation is made regarding whether it is necessary to perform gas discharging treatment and what gas discharging method is selected according to the symptoms, signs, X-ray images, and other factors for the judgment of pneumothorax.
2. Closed pneumothorax: For those with small pneumothorax and lung collapse of less than 20–30%, the effect on pulmonary respiration and circulation is not great, and the gas can be self-absorbed in 1–2 weeks without the need for pumping, and dynamic observation is performed. The gas volume is relatively high, gas is pumped once every day or every other day until most of the pulmonary recruitment functions are recovered, and the remaining pneumatosis is absorbed.
3. *Tension pneumothorax*
   (a) Simple approach for air exhaustion: A scalp needle for intravenous infusion is used for puncture and degassing and is connected to a 20–50 ml syringe; the needle is inserted at the second intercostal of the midclavicular line or the fourth to fifth intercostal of the anterior axillary line along the upper margin of ribs, and gas discharge can be seen after the thoracic cavity is entered. Hemostatic forceps are

closely attached to the skin to fix the needle tip until no gas can be discharged. After the needle is pulled out, X-ray radiography is performed to visualize the recruitment. After the needle is pulled out, re-disinfection is performed at the posterior region, which is covered by sterile gauze attached with adhesive tape.

(b) Thoracic cavity closed drainage: (1) The patient is lying in the supine position. (2) The second intercostal at the midclavicular line or the fourth to fifth intercostal at the anterior axillary line serves as the puncture site. (3) Antiseptic facemasks and gloves should be worn to disinfect the skin according to routine procedures. (4) A small incision is made at the upper margin of the ribs at the puncture site after local anesthesia. Cut the skin and subcutaneous tissues, perform blunt dissection of muscles, clamp the transparent catheter with the style with a Venturi forceps (or 8Fr or 10Fr latex catheters), insert the catheter along the incision at the site 1.5–2.0 cm away from the top (45° to the plane), pull out the needles after the pleural cavity is entered (clamp the catheter when it is halfway pulled), and then pull all of them out to prevent the entry of air. Then, propel the needle into the thoracic cavity by 2–3 cm. (5) Perform purse string suture at the incision, fix the catheter, perform disinfection, cover it with sterile gauze, and fix with sticky cloth. Chest X-ray is used to examine the catheter position. (6) Connect the catheter and pneumothorax drainage equipment. (7) After the symptoms disappear, there is no gas suction in the thoracic cavity catheter. Chest X-ray indicates that pneumothorax disappears over 24–48 h. End negative pressure aspiration and clamp the catheter. In cases of no signs of air leakage after 0–12 h, the catheter can be pulled. (8) After pulling out the catheter, suture the incisions, re-disinfect the wound, and cover it with sterile gauze for fixation. (9) If the drainage using this water-sealed bottle cannot heal the pleural crevasse, fluoroscopy indicates that the lungs cannot be recruited persistently, and negative-pressure enclosed drainage equipment is added at the end of the previous drainage. As the aspirator can form injuries induced by excessive negative pressure, the pressure-adjusting bottle can be used to ensure that the negative pressure does not exceed −0.8 to 1.2 kpa (−8 to 12 cmH_2O); if this negative pressure is exceeded, the internal air will enter the pressure-adjusting bottle through the pressure-adjusting catheter; therefore, the aspiration negative pressure imposed on the patient's thoracic cavity is over −8 to 12 cmH_2O. In cases using the closed negative pressure aspiration, it is proper to continuously perform aspiration. If the lungs still cannot recover recruitment function for more than 12 h, the cause should be found. (10) Change the disinfection water-sealed bottles and tubes every day.

4. Pneumothorax occurs with the application of an artificial ventilator during treatment; in cases of mediastinal emphysema, the parameter-adjusting principles are as follows: use a higher frequency such as increased oxygen concentration and a shorter inspiratory time, lower the blood pressure through inspiration and PEEP, and maintain normal blood gas (the water-sealed bottle is connected to the negative-pressure inspiration equipment).
5. Subcutaneous emphysema and concentration of oxygen inside the mediastina facilitate the dissipation of emphysema. Most neonate mediastinal edemas are at the anterior mediastina, which is a potential space between the chest bone and pericardium without important vascular nerves, and the gap becomes widened after pneumatosis and is filled with gas. The puncture is safe and effective, the lateral margins of the chest bones are chosen for puncture and decompression, and good efficacy can be achieved.
6. Emergency treatment of open pneumothorax: first use sterile dressings such as petrolatum gauze cotton pads to seal the wounds, then use

tape or bandages for bandaging and fixation so that the open pneumothorax and closed pneumothorax are connected, and finally, puncture the pleural cavity and suck air for compression and to temporarily relieve dyspnea. Then, perform further treatment.

9.2 Ultrasound Diagnosis of Pneumothorax

9.2.1 Ultrasound Manifestations of Pneumothorax

In recent years, ultrasound has been successfully used to diagnose lung pneumothorax, and ultrasound examination can be used conveniently, more quickly, and more reliably to diagnose pneumothorax. Lung ultrasound is superior to traditional X-ray examination in diagnosing pneumothorax or ruling out pneumothorax [3–6]. Recently, a systemic review and meta-analysis involving 864 cases of adult pneumothorax by Alrajhi et al. [7] showed that the sensitivity and specificity of pneumothorax diagnosis using ultrasound reached 91% and 98.2%, respectively [8]. In examination, priority is given to microconvex transducers, and other transducers such as line array, phase array, or convex array transducers can also be selected. In application of ultrasound for diagnosing pneumothorax, the patient can be in the sitting or supine positions. When in the supine position, pay attention to the anterior chest wall and lateral chest wall, and perform scanning on each intercostal space at the clavicular midline, anterior axillary line, and middle axillary line. During scanning, the transducer might be perpendicular to the ribs and can also be parallel to the intercostal space, and each intercostal space should be scanned for 4–5 breathing cycles. When the patient is in the sitting position, pay attention to scanning the apex of the lungs; in cases of detection of suspicious regions, perform a scan on key regions. The main ultrasound imaging feature of pneumothorax (the sensitivity of the lung point upon diagnosis of pneumothorax is 66%, and the specificity is 100%) includes a clear presence of a lung point, and a lung point is a highly specific sign for diagnosing pneumothorax; M-ultrasound can provide more clear identification of lung points. Disappearance of pneumothorax (the negative predictive value of using lung sliding for pneumothorax is 99.2–100%), disappearance of pleural liens, and no comet tail sign or B-lines, such as the presence of enhanced images, can rule out pneumothorax (the negative predictive value of using comet tail sign or B-lines for pneumothorax is 99.2–100%) and are formed by multiple reflections induced by gas. When the A-lines of pneumothorax patients are present, if lung sliding disappears but the A-line exists, the sensitivity and specificity for the diagnosis of recessive pneumothorax are 95% and 94%. Therefore, in the first examination, first observe the presence of lung sliding; in the case of lung sliding, the presence of pneumothorax is ruled out; if lung sliding is not found, then observe the existence of the comet tail sign; in case of the presence of the comet tail sign, pneumothorax can also be ruled out. If lung sliding and the comet tail sign are not found, we need to consider the possibility of pneumothorax. Further observe whether there might be lung points; if lung points are found, the diagnosis of pneumothorax can be made; if these three signs cannot be observed, the diagnosis of pneumothorax cannot be confirmed. The sensitivity of ultrasound is superior to that of chest X-ray examination, especially in the diagnosis of occult pneumothorax. Lichtenstein et al. carried out retrospective studies on 200 cases of ICU patients, and the ICU physician performed ultrasound scanning with CT as the criterion. When only the disappearance of signs of lung sliding was used as the basis for the diagnosis of pneumothorax, the sensitivity was 100% and the specificity was 78%; when the disappearance of lung sliding and only the detection of A-lines were used as the diagnostic criteria, the sensitivity was 95% and the specificity was 94%. If the signs of lung sliding disappear, the detection of A-lines and the detection of lung points were used, and the sensitivity and specificity were 79% and 100%, respectively.

It can be seen that the use of lung ultrasound to diagnose pneumothorax is mainly based on the following four signs [9, 10]: (1) the presence of lung points, (2) the disappearance of lung sliding, (3) the disappearance of B-lines, and (4) the exist of pleural line and A-lines. The procedures for diagnosing pneumothorax are shown in Fig. 9.1.

9.2.2 Precaution when Using Lung Ultrasound Examination for Diagnosing Pneumothorax

When applying ultrasound for diagnosing pneumothorax, the patient can be in the sitting and supine positions. When the patient is in the supine position, pay attention to check the anterior chest wall and lateral chest wall, and perform scanning on each intercostal space at the clavicular midline, anterior axillary line, and middle axillary line. The transducer can be vertical or parallel to the ribs. When the ultrasound transducer is perpendicular to the ribs for scanning, the acoustic shadows of the ribs to assess signs such as the pleural line and each intercostal space should be scanned for four to five respiratory cycles. When the patient is in the sitting position, pay attention to scanning the apex of the lungs; in cases of detection of suspicious regions, perform scanning on key regions. In the examination, the patient's medical history and physical signs are combined for comprehensive consideration. First, observe the presence of lung sliding. In cases of lung sliding, the presence of pneumothorax is ruled out; if lung sliding is not found, then observe the existence of the comet tail sign. In cases of the presence of the comet tail sign, pneumothorax can also be ruled out. If lung sliding and the comet tail sign are not found, we need to consider the possibility of pneumothorax. Further observe whether there might be lung points; if lung points are found, the diagnosis of pneumothorax can be made. If these three signs cannot be observed, the diagnosis of pneumothorax cannot be confirmed.

9.2.3 Experience from Our Team

According to our experience in this field, the main sonographic signs of neonatal pneumothorax include the disappearance of lung sliding via real-time ultrasound, no B-lines or lung consolidation, and the existence of the pleural line and A-line; in addition, mild-moderate patients also present lung points [7]. Regarding these signs, several key points emerge [7]. (1) In our population, the disappearance of lung sliding under real-time ultrasound is the most valuable ultrasonic sign. If lung sliding disappears and B-line or lung consolidation is not observed, the presence of pneumothorax is essentially confirmed. (2) Patients with pneumothoraxes do not present lung sliding, B-line, or lung consolidation. If any one of these signs is present, pneumothorax can be excluded. However, because the majority of normal neonates do not have the B-line, its absence does not necessarily indicate pneumothorax. Therefore, this finding should be combined with other signs. In addition, lung sliding also disappears during severe lung consolidation (such as large areas of atelectasis) [11]. Therefore, for neonatal patients with disappearance of lung sliding to be considered to have pneumothorax, lung consolidation should be excluded. Nonetheless, the presence of lung sliding can definitely exclude pneumothorax [12]. (3) All of the patients with pneumothoraces had existing pleural lines and A-lines. The sensitivity and specificity of the diagnosis of pneumothorax using the disappearance of lung sliding and the presence of the pleural line and A-line were both 100%. (4) The lung point is not the most sensitive sign for pneumothorax diagnosis. Particularly in severe pneumothorax, the areas below the probe are all air; therefore, the lung point is not present. However, this feature is the most specific sign for pneumothorax diagnosis. If this sign is discovered, the specificity of diagnosis of mild-moderate pneumothorax is 100%, and the presence of (mild-moderate) pneumothorax can be confirmed [13]. Because neonates have faster respiratory rates under normal conditions, the respiratory rates of pediatric patients will significantly increase after the development of pneumothorax. Because their respiratory rates are very fast, the cutoff point, i.e., the lung point, between normal and abnormal cannot be clearly displayed in a shorter time under the probe. Therefore, when pneumothorax is suspected, lung sliding should first be evaluated under real-time ultrasound. If a lack of lung sliding and lung point is identified, then pneumothorax can be diagnosed. Therefore, the disappearance of lung sliding under real-time ultrasound is the most important ultrasonic feature and is the key for the diagnosis of pneumothorax using ultrasound.

Our study also found that both the positive and negative predictive values of the disappearance of lung sliding and the existence of pleural lines and A-lines in diagnosing pneumothorax by ultrasound were 100% [7]. The presence of the lung points indicates a mild to moderate pneumothorax; otherwise, the pneumothorax would be severe. Therefore, these three signs, the disappearance of lung sliding, existence of the pleural line and A-line, and the lung point, are the decisive factors for the diagnosis of or exclusion of pneumothorax.

M-mode ultrasound is also usually used for pneumothorax diagnosis. Under M-type ultrasound, the “seashore” sign of normal lung tissues is replaced by the “parallel sign” formed by intrathoracic gas [13]. Then, the lung point or parallel sign t found by M-mode ultrasound would further confirm the existence of pneumothorax. The disappearance of lung sliding under B-type ultrasound is the first and most important step in the diagnosis of pneumothorax using ultrasound [7].

Although the diagnosis of lung diseases using ultrasound is simple overall, the diagnosis of neonatal pneumothorax using ultrasound is relatively difficult; skill in this technique is also the most difficult to achieve and is significantly different in neonates compared to adults. The main reason for the difficulty is that after the development of pneumothorax, the neonates’ difficulty breathing further significantly increased on the basis of their original lung diseases; therefore, the lung point is difficult to identify when the respiratory rate is very fast. Therefore, when using ultrasound for the diagnosis of neonatal pneumothorax, proper training and certain levels of experience are required [14]. Based on our experiences and observations, for neonatal patients with suspected pneumothorax in the clinic, the presence of lung sliding is the first sign observed via real-time ultrasound (Fig. 9.1). (1) If lung sliding is present, then pneumothorax is essentially excluded. (2) If lung sliding disappears, (a) the lung point and pleural line and A-line are searched—if they are present, pneumothorax can be diagnosed; (b) the B-line and atelectasis should be checked. If no B-line is detected, the presence of pneumothorax can be essentially confirmed. If a B-line is present, pneumothorax can be excluded. (3) If necessary, the M-mode ultrasound can also be used to find the lung point or parallel sign, which confirms the pneumothorax (Figs. 9.2, 9.3, 9.4, 9.5, 9.6, and 9.8).

We stated that all the pictures or ultrasound images included in the chapter were taken from

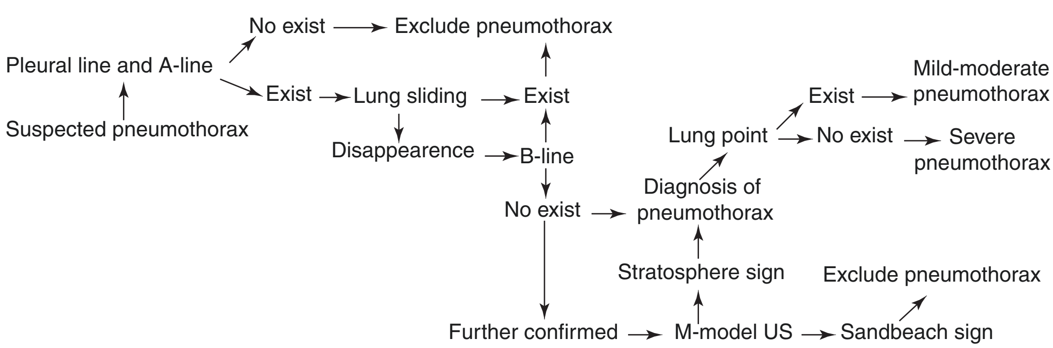

Fig. 9.1 The flowchart for neonatal pneumothorax

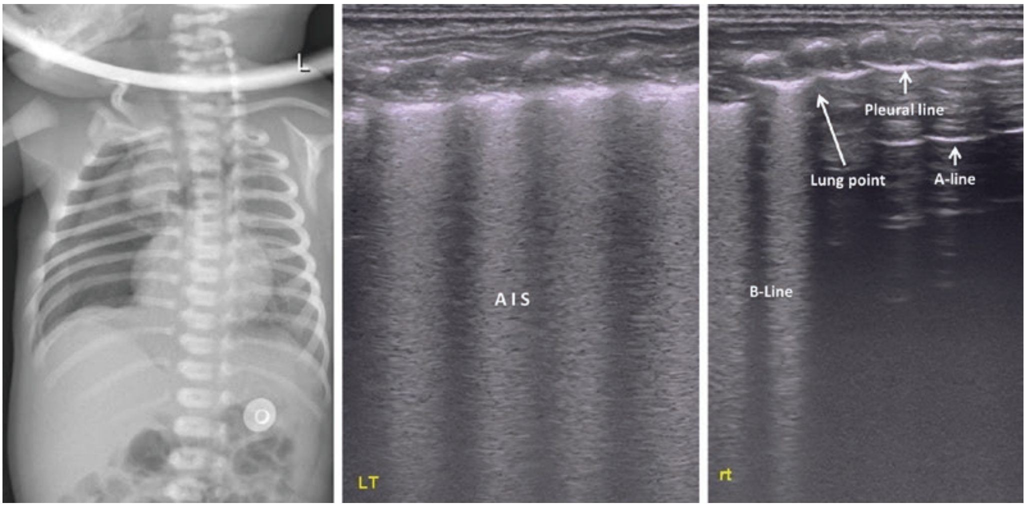

Fig. 9.2 Ultrasonic manifestation of mild-moderate pneumothorax in a transient tachypnea of the newborn (TTN) patient. The gestational age (GA) and birth weight of this baby, who was admitted to our NICU because of breathing difficulties for 4 h with a diagnosis of TTN, were 38 weeks and 2550 g, respectively. The lung ultrasound showed an abnormal pleural line, adenocarcinoma in situ (AIS), and disappearing A-lines in the left lung, whereas the right lung shows the lung point, that is, the transition from the B-line area (*left side*) to a hypoechoic area with horizontal reverberations of the parietal pleura in the right side. Under real-time ultrasound, the lung sliding was occurring in the B-line area, while it was disappearing in the A-line area (also see Video 9.1)

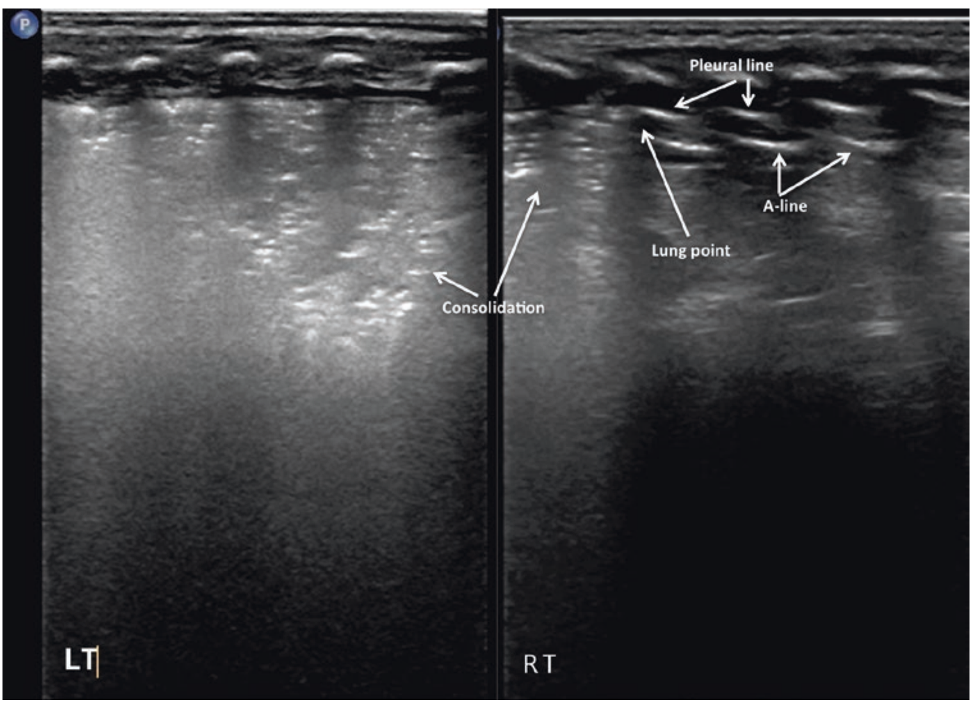

Fig. 9.3 Ultrasonic manifestation of mild-moderate pneumothorax in a respiratory distress (RDS) patient. The infant had a GA of 37^{+6} weeks and was delivered by cesarean section with a birth weight of 2850 g. The infant was admitted to our NICU because of severe dyspnea for 32 h. The lung ultrasound showed a large area of lung consolidation with significant air bronchograms in the left lung and a small area of lung consolidation with air bronchograms in the left side of the right lung; there were clear pleural lines and A-lines on the right side of the right lung. Under real-time ultrasound, lung sliding was occurring in the consolidation area, while it was disappearing in the A-line area (also see Video 9.2)

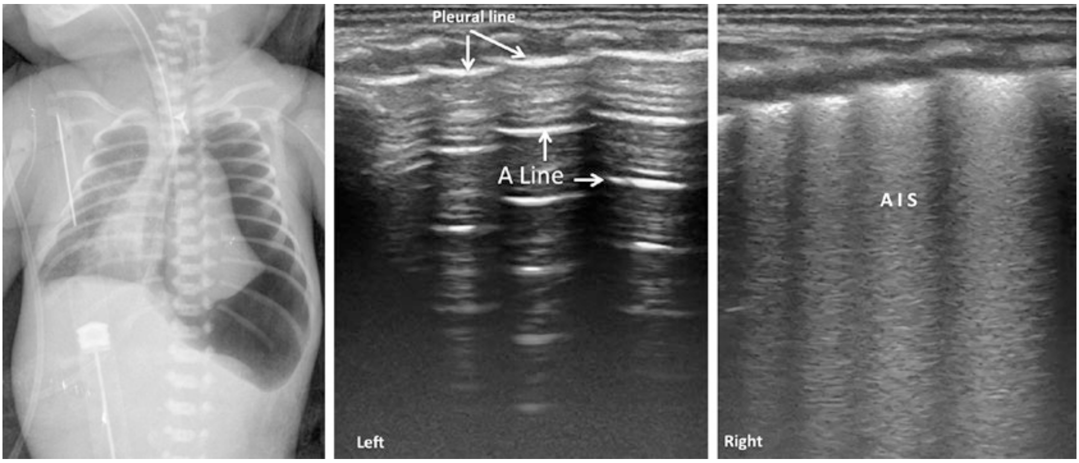

Fig. 9.4 Ultrasonic manifestation of severe pneumothorax in a TTN patient. The GA of the infant was 32 weeks, and the birth weight was 2400 g; the infant was admitted to our NICU due to breathing difficulties for 4 h. The chest X-ray showed severe pneumothorax in the left lung. The lung ultrasound showed AIS in the right lung and pleural line as well as A-lines in the left lung, whereas no lung point was found in the left lung. Under real-time ultrasound, the lung sliding was disappearing in the whole right lung field, while it was appearing in the left lung (also see Videos 9.3 and 9.4)

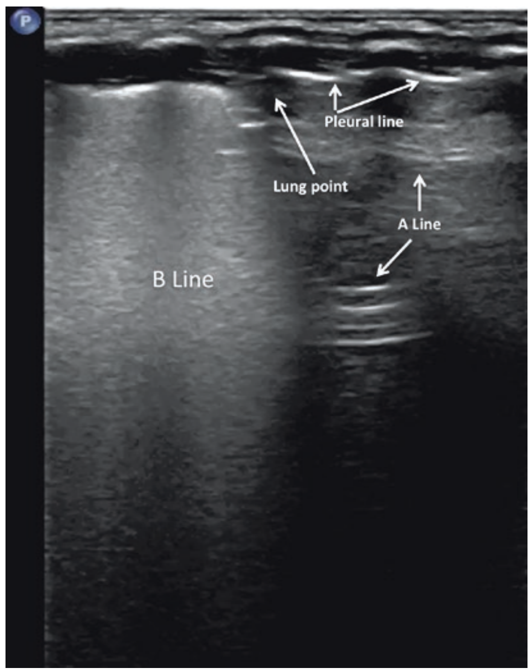

Fig. 9.5 Ultrasonic manifestation of pneumothorax. Ultrasound lung scan in B mode showing the lung point, that is, the transition from the B-line area (*left side*) to a hypoechoic area (*right side*). Under real-time ultrasound, lung sliding is occurring in the B-line area, while it is disappearing on the right side of the same picture; the point of demarcation between the consolidation and the right side of the same picture was the lung point (Video 9.5)

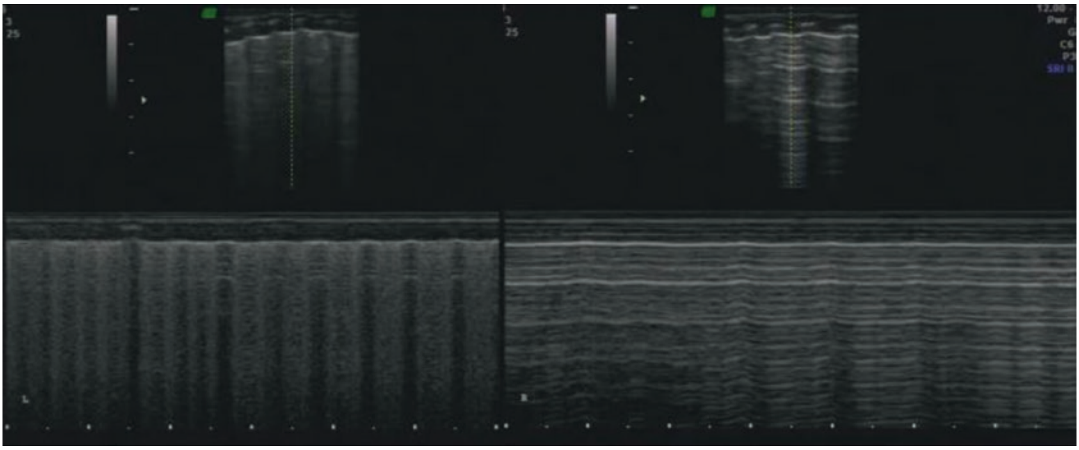

Fig. 9.6 Severe pneumothorax under M-model ultrasound. Under M-model ultrasound, the left lung showed the beach sign, while the right lung presented the stratosphere sign (also known as barcode sign), which confirmed the severe pneumothorax in the right thorax

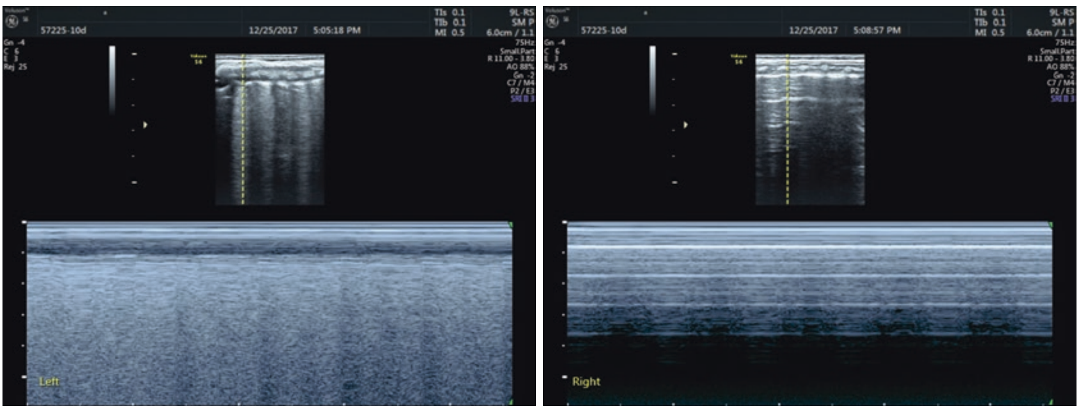

Fig. 9.7 Severe pneumothorax. Severe pneumothorax in the right thorax. M-model ultrasound showed that beach sign in the left lung, while the stratosphere sign in the right lung

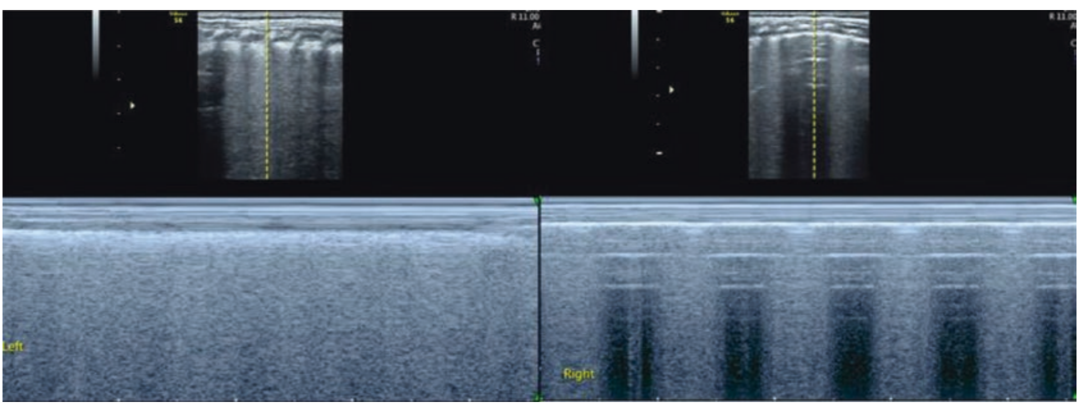

Fig. 9.8 Mild pneumothorax under M-model ultrasound. Under M-model ultrasound, the left lung showed beach signs, while the right lung presented the lung point (the point that appears opposite of the beach sign and the stratosphere sign), which confirmed the mild pneumothorax in the right thorax

the Army General Hospital of the Chinese PLA and Beijing Chaoyang District Maternal and Child Healthcare Hospital; the related studies were approved by both the committee of the Army General Hospital and Chaoyang District Maternal and Child Healthcare Hospital.

9.2.4 Limitations of Using Ultrasound to Diagnose Pneumothorax

There are some limitations of using ultrasound to diagnose pneumothorax. The results of ultrasound examination are greatly subject to the skill level of the examinees, and the judgment on the ultrasound images directly affects the accuracy of the results. For example, under normal conditions and in the case of pneumothorax, vertical hyperechoic strips that stem from the pleural lines can be seen. What is different from B-lines is that these echo strips will become attenuated and disappear (cannot reach the edge of screen) after a certain distance, cannot cover A-lines, cannot move with respiration, and need to be differentiated with comet tail signs. In cases of emphysema of the periphery of the lungs, the high echo strips perpendicularly originate from the superficial surface tissues and reach the edge of screen. At this time, the shadows of the pleural lines and ribs are invisible and need to be differentiated with B-lines. A-lines can be seen in normal lungs, some diseases, and pneumothorax. When ultrasound examination is applied, it is necessary to reasonably select the imaging criteria, and further studies are needed for the more accurate and reliable ultrasound signs. The dressings for bandaging the chest wall skin injuries and local wounds will limit the use of ultrasound examination, and subcutaneous emphysema might affect the examination results.

References

1. Duong HH, Mirea L, Shah PS, et al. Pneumothorax in neonates: trends, predictors and outcomes. J Neonatal Perinatal Med. 2014;7:29–38.
2. Bhatia R, Davis PG, Doyle LW, et al. Identification of pneumothorax in very preterm infants. J Pediatr. 2011;159:115–20.
3. Volpicelli G. Sonographic diagnosis of pneumothorax. Intensive Care Med. 2011;37:224–32.
4. Alrajab S, Youssef AM, Akkus NI, Caldito G. Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of the literature and meta-analysis. Crit Care. 2013;17:R208.
5. Raimondi F, Fanjul JR, Aversa S, et al. Lung ultrasound for diagnosing pneumothorax in the critically ill neonate. J Pediatr. 2016;175(8):74–78.e1.
6. Alrajhi K, Woo MY, Vaillancourt C. Test characteristics of ultrasonography for the detection of pneumothorax: a systematic review and meta-analysis. Chest. 2012;141:703–8.
7. Liu J, Chi JH, Ren XL, et al. Lung ultrasonography to diagnose pneumothorax of the newborn. Am J Emerg Med. 2017;35(9):1298–302.
8. Berlet T, Fehr T, Merz TM. Current practice of lung ultrasonography (LUS) in the diagnosis of pneumothorax: a survey of physician monographers in Germany. Crit Ultrasound J. 2014;6:16.
9. Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012;38(4):577–91.
10. Liu J, Feng X, Hu CB, et al. Guideline on lung ultrasound to diagnose pulmonary diseases in newborn infants. Chin J Appl Clin Pediatr. 2018;33(14):1057–64.
11. Liu J, Chen SW, Liu F, et al. The diagnosis of neonatal pulmonary atelectasis using lung ultrasonography. Chest. 2015;147(4):1013–9.
12. Lichtenstein DA, Menu YA. Bedside ultrasound sign ruling out pneumothorax in the critically ill: lung sliding. Chest. 1995;108(5):1345–8.
13. Lichtenstein D, Mezie're G, Biderman P, et al. The 'lung point': an ultrasound sign specific to pneumothorax. Intensive Care Med. 2000;26(11):1434–40.
14. Krishnan S, Kuhl T, Ahmed W, Togashi K, Ueda K. Efficacy of an online education program for ultrasound diagnosis of pneumothorax. Anesthesiology. 2013;118:715–21.