Chapter 1

Basic Concepts

Content and Objectives

Objectives:

1. Identify precautions needed to minimize side effects of x-ray exposure.
2. List three areas to address when determining the quality of neonatal chest x-rays.
3. Discuss the evaluation of neonatal lung fields on x-ray.
4. Describe the steps taken to assess the infant's inspiratory effort on an x-ray.

Chapter 1

Basic Concepts

Editor

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Systematic Approach, History, and Measurement

The nurse often initiates the request for a neonatal x-ray examination. She may also be the first to see the film. The nurse's ability to interpret new findings, abnormal tube or line placements, the presence of major complications, or the overall progression of a disease process can mean prompt intervention and treatment. Information from x-ray findings also allows the caregiver to evaluate the effectiveness of nursing and medical interventions and change care to meet the patient's needs.

When evaluating an x-ray film, nurses should know the patient, the indication for the x-ray examination, and the normal anatomy of the structures being evaluated. X-ray films are only one piece of a diagnostic pattern and are best viewed with a thorough knowledge of the patient. Accurate interpretation of radiographic changes or abnormalities seen on x-ray is optimized by correlating them with findings from the physical examination. Knowledge of the infant's history, physical assessment, recent changes in clinical status, and prior films will provide the necessary background information to view the film in context. Those who have attended rounds with radiologists in the radiology department are familiar with their frequent requests for a clinical summary or case presentation prior to giving an interpretation.

Different disease processes may produce similar x-ray findings. Probably the best example of this may be found in the frequently indistinguishable, early x-ray findings of infants with respiratory distress syndrome and those with Group B beta-hemolytic streptococcal pneumonia. Knowledge of history and clinical findings allows for an interpretation consistent with one diagnosis or the other.

Look at the chest x-ray in Figure 1-1, for example. In this case, the neonate is 36 weeks gestational age, has a mature lung profile, presented with tachypnea and shock at two hours of age, and has an abnormal complete blood count (CBC) and differential. These findings are more consistent with pneumonia than respiratory distress syndrome.

Focusing on one aspect of the film or on one obvious pathologic process can lead to neglect of less obvious but important pathology or other abnormalities. The evaluator of the film in Figure 1-2, for example, immediately recognized atelectasis in the right lung field and an elevated right diaphragm in a neonate with tachypnea and decreased breath sounds on the right, but overlooked the broken clavicle and broken seventh rib. Someone concentrating on the lung fields in the chest film in Figure 1-3 could miss the abnormal position of the umbilical artery catheter and the high position of the endotracheal tube.

FIGURE 1-1 ■ Chest x-ray film of a neonate with Group B ß-hemolytic streptococcal pneumonia.

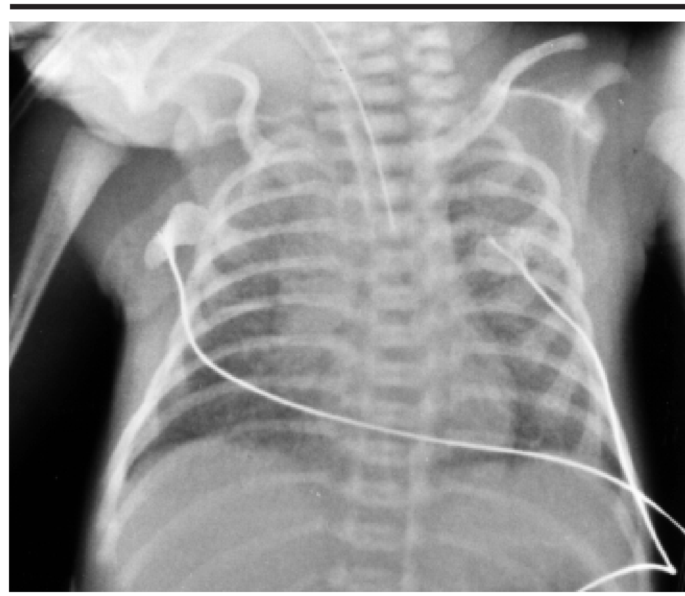


FIGURE 1-2 ■ Chest x-ray film of a neonate with tachypnea and decreased breath sounds on the right.

Note the fractured clavicle and fractured seventh rib.

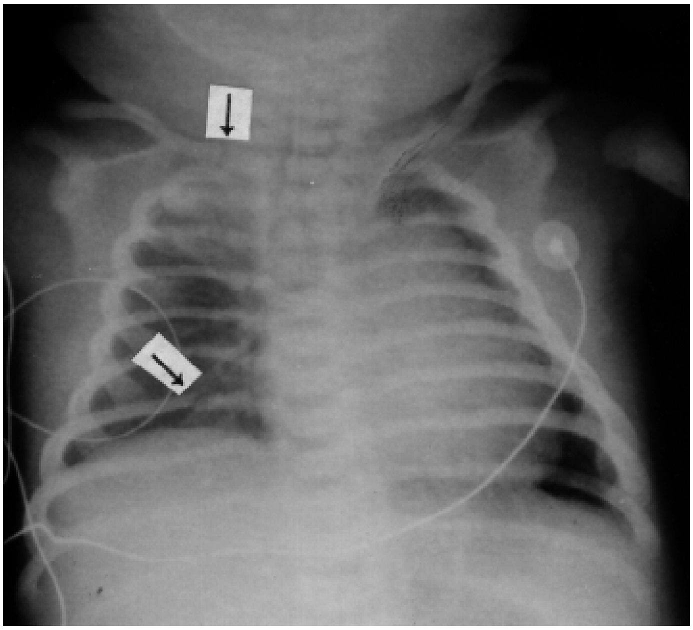
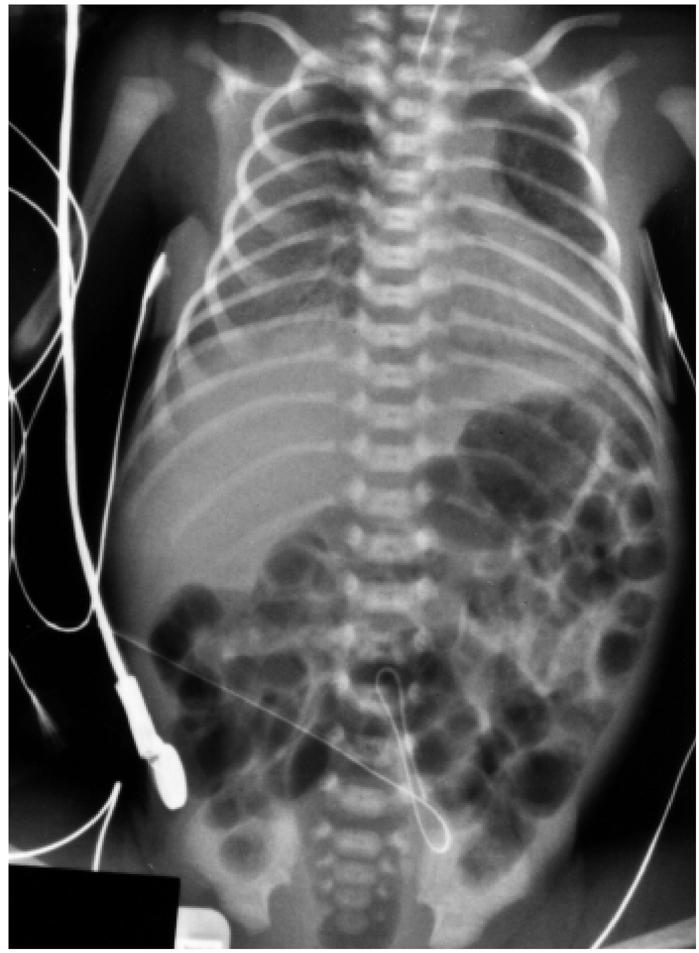


FIGURE 1-3 ■ X-ray film of a neonate showing abnormal position of umbilical artery catheter and endotracheal tube.



To prevent such "tunnel vision," it is helpful to employ a systematic approach when reviewing x-ray films. Begin your review by confirming the patient's name, date and time the film was taken, and type (view) of film (anterior-posterior [AP], posterior-anterior [PA], lateral, or lateral decubitus). Then move from one aspect of the film to another, as in the following example, until you have made a comprehensive examination.

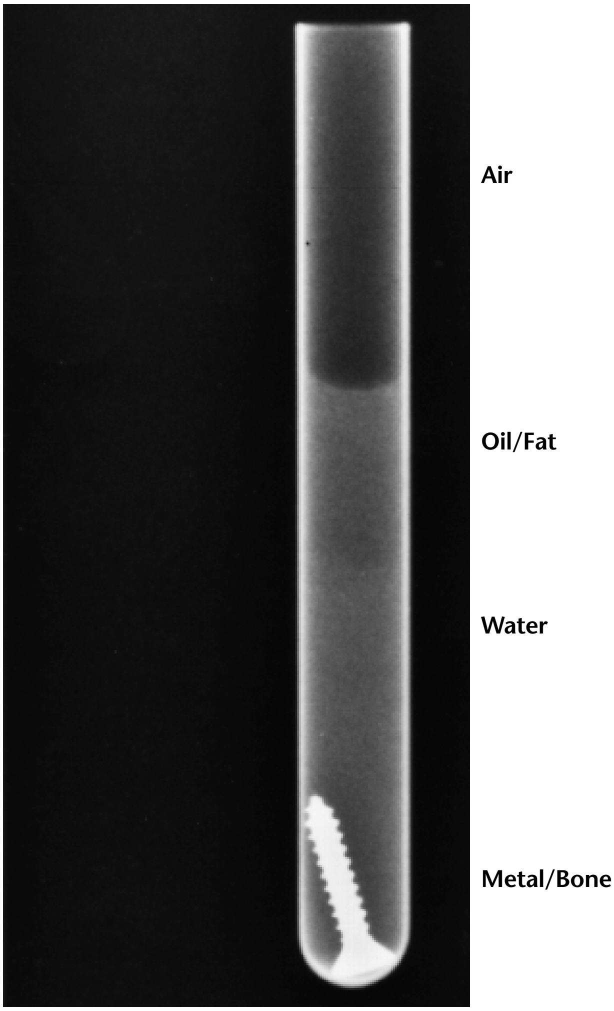
1. Compare this film to recent films and evaluate the quality of the film.
2. Look at the soft tissues for edema or subcutaneous emphysema.
3. Review the bony framework for equality, size, and configuration of clavicles; number and intactness of ribs; and integrity of visible bones: vertebrae; humeri; cervical, thoracic, and lumbar spine; and sacrum, if visible. In serial films of premature infants, look for changes in bone density.
4. Check the trachea for air column and deviation.
5. Examine the hilum for evidence of increased or decreased pulmonary blood flow.
6. Evaluate the mediastinum and mediastinal structures, including the thymus, great vessels, and heart. Evaluate the heart for size and shape, location, and the presence of abnormalities.
7. Look at the diaphragm for contour and thoracic vertebral level.
8. Check the pleura and costophrenic angle for sharpness.
9. Identify the gastric bubble (if visible) and liver size.
10. Evaluate lung fields for general aeration, width of intercostal spaces, and areas of density and lucency.
11. Examine tubes and lines for normal placement.

Accurate assessment and interpretation of newborn x-ray films are skills that are acquired over time. Although practices vary, many neonatal intensive care units have films available for review so that interested nurses can gain skills in assessment. This series is meant to provide the reader with the necessary background information essential for interpreting x-rays and to provide examples of common problems encountered in the neonate.

HISTORY

X-rays are a form of short-wavelength radiant energy and as such are part of the electromagnetic spectrum that includes gamma rays, x-rays, ultraviolet rays, and radio waves. X-ray films or pictures are produced when an electronic beam is directed through an object to a photosensitive surface such

FIGURE 1-4 ■ Test tube containing examples of the four basic tissue densities.



as film in a cassette. The amount of energy reaching the film determines the degree of exposure.

The image produced on the film is determined by the density of the object through which the beam passes.[1] A very dense structure will block most of the beam and prevent it from reaching the film, resulting in the creation of an opaque or gray image on the film. If the structure is not very dense (air, air-filled alveoli, free air in the chest, or air in the stomach), the beam easily penetrates, and the image created is more lucent (dark gray or black).[2]

Wilhelm Konrad Röntgen discovered x-rays in Germany in 1895. Röntgen had been experimenting with an apparatus that (unknown to him) caused the emission of x-rays as a by-product. In his darkened laboratory he observed that "whenever the apparatus was working, a chemical-coated piece of cardboard lying on the table glowed with a pale green light" (p. 1).[3] We now know that fluorescence, or the emission of visible light, can be produced in a variety of ways by complex nuclear energy exchanges.

Röntgen recognized initially that he had unintentionally produced a previously unknown form of radiant energy that was invisible, could cause fluorescence, and passed through objects opaque to light. When he placed his hand between the beam and the lighted cardboard, he could see the bones inside his fingers within the shadow of his hand. He realized that the rays had a penetration power dependent on the density of the material and recognized the potential medical use of these rays.[3]

DENSITY

Radiology is the science of interpreting relative densities. Radiologists recognize four basic tissue densities: air, fat, water, and metal or bone (in order of increasing density). Air or gas does not absorb much x-ray beam and results in a black or dark gray image on the x-ray film. Fat is not quite as dense as water. It is contained in subcutaneous tissue and some muscle and produces a gray image. Water is denser than fat and blocks a significant amount of energy, producing a lighter gray image. Bone or metal is the most dense substance and produces the whitest shadows on x-ray film (Figure 1-4).[2,4]

Anatomic structures are recognized on x-ray film by their differences in density. The heart, aorta, blood, liver, spleen, and most muscles are water density. When density in the lung is changed by disease processes (producing atelectasis, for example), the x-ray film will reflect the loss of air in the alveoli and become more opaque. This occurs because the lung takes on a density similar to water. Neonatal lung pathology such as pneumonia, pulmonary edema, pulmonary hemorrhage, and disorders associated with atelectasis all result in an increased density and therefore make the lung more opaque on x-ray.

Two substances side by side in the same plane and of the same density cannot be differentiated from each other on an x-ray film. We see this in the x-ray films of infants with respiratory distress syndrome associated with widespread atelectasis. The lung becomes water density, and the heart borders, which are normally water density, cannot be seen. This is sometimes referred to as "loss of heart borders" or the "silhouette sign." It occurs when the heart, aorta, or diaphragm is obliterated.[2]

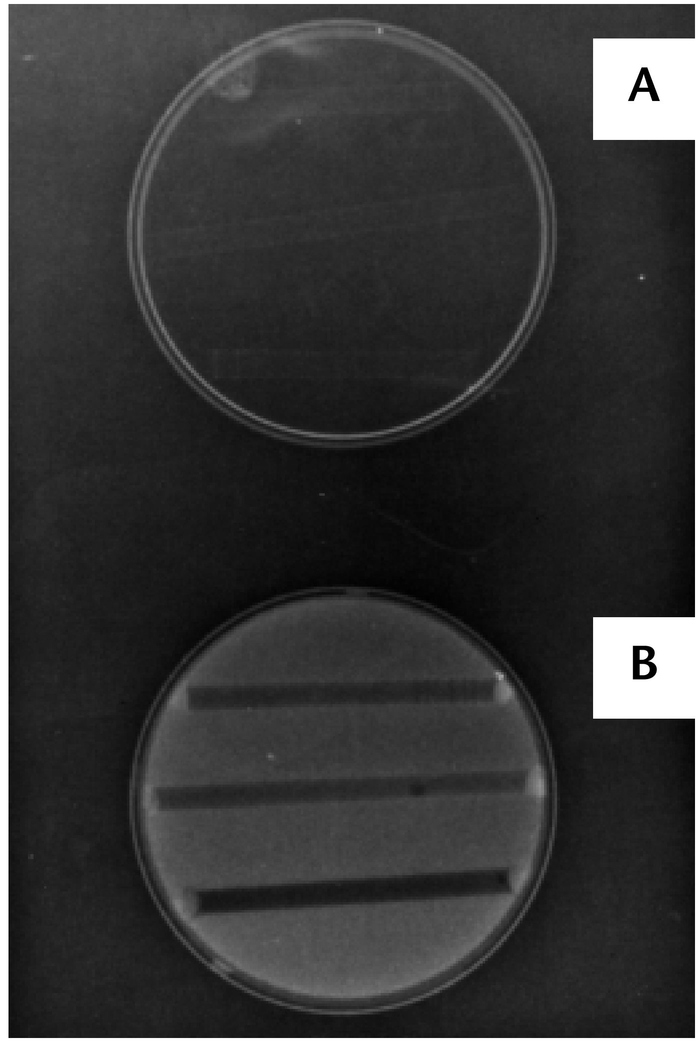
Water density not in contact with the heart, aorta, or diaphragm will not obliterate the border. So a right upper lobe atelectasis may obliterate the right superior heart border (Figure 1-5), but atelectasis in a right lower lobe that is not directly adjacent to the heart will not cause a loss of the heart border.

Another finding that illustrates differences in density in the lung is the air bronchogram sign.[2,3] If the lung becomes water density because of airless alveoli, fluid, or exudate, the air-filled bronchi may be seen outlined over the lung. Air bronchograms are normally seen over the heart, which is of water density, but are not seen over normal lung fields because the normal lung should be of air density, and the bronchi contain air.

FIGURE 1-5 ■ **X-ray film of an infant with right upper lobe atelectasis, which obliterates the right superior heart border.**

FIGURE 1-6 ■ **Illustration of the air bronchogram sign.**

(A) Petri dish containing air-filled straws (representing bronchi) against an air-filled background. (B) Petri dish containing air-filled straws in water simulating the air bronchogram sign.



In Figure 1-6, Petri dishes are visible. The top dish (A) contains air-filled straws (bronchi) against an air-filled background. You can barely see the outline of the straws. Contrast this to the second dish (B), in which lucent air-filled straws are now visible against a more opaque background of water: The air bronchogram sign is present.

Figure 1-7 is the x-ray film of a neonate with severe respiratory distress syndrome. It demonstrates both the air bronchogram sign and the silhouette sign.

MEASUREMENTS AND RADIATION PRECAUTIONS

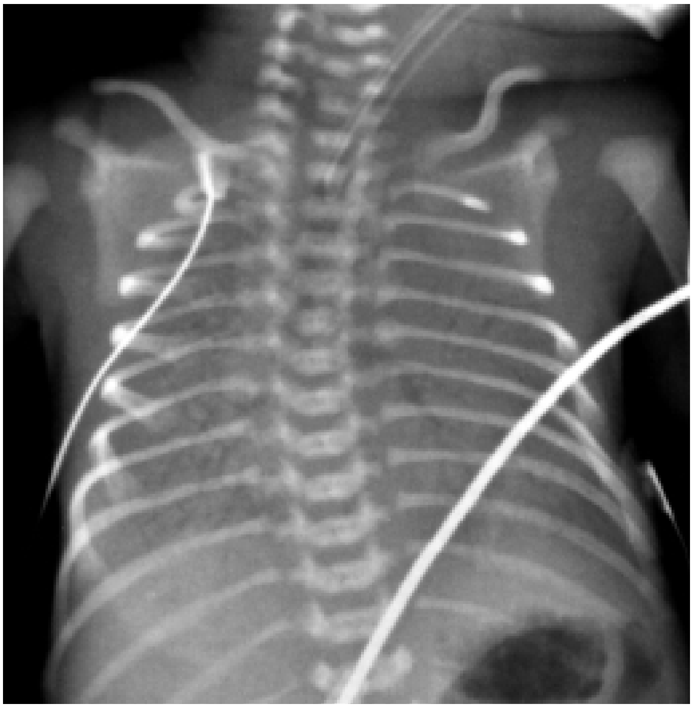
In the early days of radiology, the only measure of radiation was called the "erythema dose"; this was the amount of radiation required to turn skin red. In 1938, "roentgen" or "R" was adapted as the standard measurement of ionization in air; and in 1956, another unit, the "rad," was established to measure the amount of radiation absorbed in a medium.[5,6]

There are now several different units of measure to express different characteristics of radiation. The roentgen continues to be the conventional unit for expressing exposure and is sometimes expressed in milliroentgens (mR). "Rad" stands for *radiation absorbed dose,* which is the quantity of ionizing radiation by any material per unit of mass. The International System of Units, universally abbreviated SI (from the French *Le Système International d'Unités*), uses Coulomb/kilogram (C/kg) in place of roentgen, gray (Gy) instead of rad, and Sievert (Sv) for **r**oentgen **e**quivalent in **m**an (rem) (Table 1-1).[5,6]

Uncertainties remain regarding the effects of radiation at low dose rates. The most reliably estimated risks are those associated with doses of 1 Gy (100 rad) or more.[5] It had been estimated that the average x-ray taken in children exposes them to less than 5 millirads and that 50 x-ray examinations would result in a dose of less than 0.15 rad.[7]

Knowledge of the effects of radiation has been gained from animal irradiation studies and by ongoing study of the survivors of Hiroshima and Nagasaki. The results from the latter study were published in 1988 by the United Nations.

FIGURE 1-7 ■ **X-ray film of a neonate with severe respiratory distress syndrome demonstrating both the air bronchogram sign and the silhouette sign.**



These data showed a higher risk than was previously thought to exist for the development of cancer in children and young people. The risk is most marked for children less than ten years of age at the time of exposure. An increased incidence of breast cancer was seen in girls and leukemia in both boys and girls.[8]

Arroe used this data to measure and calculate the radiation dose of one chest x-ray examination of the lungs to neonates. He found that, together, an AP and a lateral chest x-ray produced radiation between 25 and 60 microsieverts (microSv). He estimated that a neonate could have 75 such films taken without exceeding the amount of natural background radiation that we are exposed to in one year (3 millisieverts [milliSv]).[8]

TABLE 1-1 ■ **Radiation Measurement Equivalents**

Quantity	Traditional Unit	SI Unit
Exposure	Roentgen (R)	Coulomb/kg (C/kg) 1 R = 2.58×10^{-4} C/kg
Absorbed dose	Radiation absorbed dose (Rad)	Gray (Gy) 1 rad = 0.01 Gy
Dose equivalent	roentgen equivalent in man (Rem)	Sievert (Sv) 1 rem = 0.01 Sv

Using the data from the United Nations study, which showed increased risk rates for cancer following radiation exposure, Arroe calculated the risk of cancer mortality for neonates receiving 25 AP and lateral chest x-rays. These calculations resulted in higher risk rates than previously estimated. The risk rate for the development of breast cancer in girls was 6×10^5, for leukemia in girls 2.4×10^5, and for other malignancies in girls 2.6×10^5. The increased risk for leukemia and other malignancies in boys was the same except for the risk of breast cancer in boys, which was 0.[8]

Arroe suggests that the average radiation dose is lowered when lateral films are obtained only when necessary and that additional lowering of breast cancer risk could be attained by lowering the dose to the breast tissue. This could be achieved by obtaining posterior-anterior rather than anterior-posterior projections. Radiation dosage to the bone marrow can be reduced by placing the arms outside the radiation field.[8]

Radiation precautions to protect the neonate should include gonad shielding when the gonads are less than 5 cm from the primary beam. It has been demonstrated that a 95 percent exposure reduction to male testes and a 50 percent reduction to the female ovaries can be achieved by shielding the gonads. Examinations that give a high exposure dose to the gonads are hip, upper female lumbar spine, lumbar sacral spine, sacrum, barium enemas, and urography studies.[5]

The National Council on Radiation Protection and Measurement has developed maximal permissible dose equivalents for annual public exposure of 1 milliSv or 0.1 rem with frequent exposure and 5 milliSv or 0.5 rem for infrequent exposure, with a maximum of 50 microSv limits for the lens of the eye, skin, and extremities.[6] Annual occupational exposure limits are higher: 50 milliSv or 5 rems. The pregnant woman is limited to a total dose during pregnancy of 5 milliSv (0.5 rem) at 0.5 milliSv in a month.[6]

The usual films obtained in the NICU by portable methods have low radiation risks for the staff and neonate. Risk is increased if lateral films are taken with personnel or patients in the direct path of the x-ray beam. Guidelines for personnel when mobile x-ray equipment is used are as follows:[6]

1. Remain six feet from the patient, x-ray tube, and beam.
2. Wear a lead apron and gloves if you are holding the patient or when it is necessary to remain closer than six feet from the beam.
3. Hold patients only when necessary and then infrequently.
4. If pregnant, do not hold patients.

FLUOROSCOPY

Fluoroscopy procedures have high radiation levels (levels of 10 R/minute have been measured at the patient's skin).[6,7] There is also high potential for scattered radiation. Fluoroscopy studies are performed in the radiology department and with maximal precautions. Exposed personnel should always wear a lead apron and gloves.

Nuclear medicine studies involve a dose of radionuclide, and exposure rates to personnel around the patient depend upon the particular radionuclide used, its half-life, and rate of excretion. Technetium 99, a frequently used substance, has a half-life of six hours, but monitoring of nurses caring for these patients has not detected any measurable doses delivered to the nurses. Fluoroscopy procedures are performed when it is necessary to study a dynamic abnormality, and the dose to the patient depends on length of time of the exposure.

SUMMARY

With basic knowledge of the principles of relative density, nurses can begin to evaluate the differential densities on the x-ray films they encounter in the NICU. Although risks of radiation exposure in the NICU are low, it is important to maintain an awareness of the necessary protection for patients and staff in order to avoid unnecessary exposure.

Revised and updated from: Carey BE and Trotter C. 1992. Introduction to the neonatal radiology column. *Neonatal Network* 11(5): 71–72. Used with permission of Springer Publishing Company, LLC, www.springerpub.com/nn.

Assessment of the Quality of the Neonatal Chest X-Ray Film

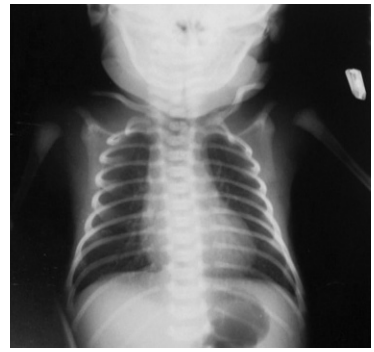
The roentgenogram is still one of the simplest, least expensive, and most valuable diagnostic tools the practicing clinician has. It is only valuable, however, if it provides the clinician with needed information, and its ability to do so depends on the technical quality of the film. An x-ray film that is not rotated, overexposed, underexposed, or riddled with artifacts may mean the difference between an accurate diagnosis and a completely overlooked one. The quality of the film is essential for proper evaluation.

The normal appearance of the high-quality newborn chest film differs from that of older children (Figure 1-8). The newborn chest is characterized by a horizontal orientation of the ribs, with the usual level of the diaphragm at the eighth anterior rib. The normal cardiothoracic ratio can be as large as 60 percent because both the heart and thymus gland make up the cardiac shadow on the frontal view.[9]

The size of the thymus is highly variable and occupies the supra-anterior mediastinum. Because of this location, many of the great vessels, along with other structures, may be obscured on the chest film. The lobes of the thymus may be asymmetric with a large, usually right-sided, thymic lobe. The thymus can involute rapidly in association with prenatal or postnatal stress or following the administration of exogenous steroids.

FIGURE 1-8 ■ A normal neonatal chest x-ray film.

The chest is well expanded to the 9th anterior rib bilaterally. The lung fields are clear with normal perihilar vascularity for a newborn infant. There is no visible thymus and the cardio-thoracic ratio is slightly less than 50 percent.



The lung fields of the neonate normally have a uniform radiolucent appearance on a roentgenogram, with the exception of the hilar and perihilar regions (the area at the root of the lungs at the level of the fourth and fifth dorsal vertebrae). The perihilar and hilar regions may appear more dense (more hazy) because of the bronchi and the vascular structures in this area.

In the extremely small, premature infant, normal lungs may appear hyperlucent. The reason is that the soft tissues, pulmonary vessels, and hilar lymph nodes are small and thin and there is a high ratio of air-filled lung to soft tissues. Air filled structures appear more lucent than solid structures. At times, this hyperlucent appearance is so pronounced that some abnormality of aeration is suspected.

Figures 1-8 and 1-9 illustrate the difference between a good and a poor quality chest film. There are several factors to be considered when evaluating the quality of an x-ray film. These are position and rotation, degree of penetration, and presence of artifacts. Each is addressed below.

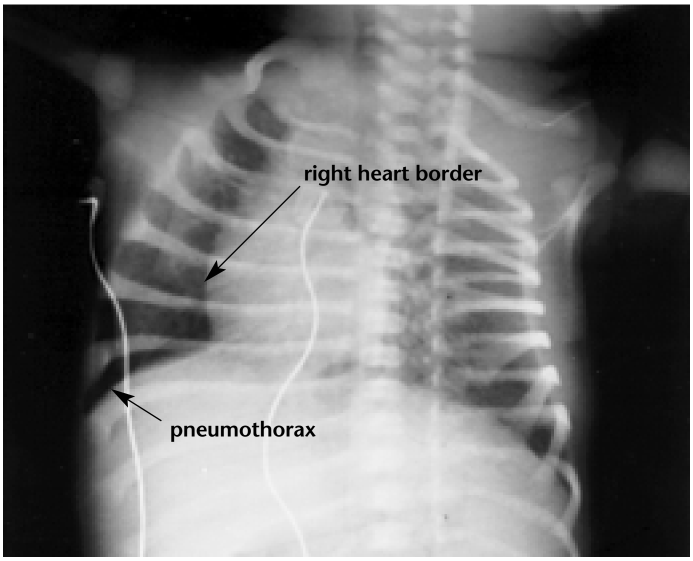
POSITION AND ROTATION

The infant's position and rotation contribute significantly to the quality of the x-ray film. The infant's position on the film cassette dictates whether the image will be rotated on the film. Rotation of the infant's shoulders, chest, or body to one side will cause the features on the image to become distorted.

Accurate evaluation of a film depends on the ability to make relative comparisons. There should be symmetry between the hemithoraces. The spine should lie in the middle of the chest, bisecting the lung fields. Symmetry, and therefore rotation, can be evaluated by comparing one lung field to the other, the length of the ribs bilaterally, the elevation of the diaphragm, and the heart size and shape as it relates to the midline.

FIGURE 1-9 ■ A poor quality neonatal chest x-ray film.

This infant was poorly positioned and consequently has a rather large degree of rotation. The vertebral column is deviated to the left, and the ribs are distorted on both sides. As a result, the heart appears to be on the right side of the chest. Although the numerous lead wires do not technically obscure the view of the lung fields, they are distracting. Note that this is an expiratory film, which is indicated by the dome-shaped diaphragm.



Lordotic positioning must also be considered when evaluating the quality of a film. The normal chest film of an infant may appear somewhat lordotic by virtue of the infant's anatomy. The chest cavity of an infant less than one year of age is more conical in shape than that of an older child or adult. If the infant's back is parallel to and against the cassette, the front of the chest is tipped upwards, and a large part of the posterior lung fields disappear behind the diaphragm. This means that posterior, lower lung pathology can go undetected.[10]

Lordotic positioning of the infant can be greatly exaggerated, tipping the chest further upwards when the infant pulls away from the cold, hard film cassette. This produces an abnormal anterior convexity of the spine and is manifest by a more horizontal attitude of the posterior ribs. The anterior ribs may appear higher than the posterior ribs or more elevated in position, but the clavicles remain horizontal.

Lordotic positioning produces a tetralogy-like appearance of the heart. The cardiac apex may be thrown into such prominence that the right ventricle may appear hypertrophic. It also accentuates the vascular markings, especially in the upper lobes.

Nurses may help to reduce lordotic positioning by warming the cassette or placing it under a soft blanket and by raising the head of the bed slightly (approximately five to ten degrees). For a similar result, the x-ray tube may be tilted five to ten degrees caudally.[10]

Rotation may also be the cause of a condition called pseudopneumomediastinum.[10] Occasionally in some infants, on a lateral projection, one may see a hyperlucent triangular area in the lower retrosternal space. Although it is much less common, on some films a similar configuration is seen behind the upper sternum. These configurations may not appear as radiolucent as true free air and should not be misinterpreted as representing a pneumomediastinum or anterior pneumothorax. The presence of pseudopneumomediastinum is felt to be due to rotation and deep inspiration and can be prevented primarily by appropriate positioning of the infant.

Pseudohyperlucent lung is another chest x-ray finding that is due to rotation of the chest to one side or the other. The hyperlucent side usually corresponds to the side that is rotated away from the cassette.[11] This finding should not be misinterpreted as hyperlucency due to some pathologic problem.

Infants who are intubated seem to be at a higher risk to have a rotated chest film. When the intubated infant is placed on a film cassette, his head is usually positioned to one side along with the ventilator tubing. Even with careful placement of the ventilator tubing, the weight and tension may cause the opposite shoulder to elevate so that rotation of the chest occurs. To reduce rotation in the intubated infant, the infant's head should be kept from lying completely flat, thus helping to alleviate the opposite shoulder elevation. Midline positioning is ideal.

Warming the cassette and using a soft blanket to position the infant may also help alleviate rotation, as well as lordosis mentioned previously. The cassette should never be placed under a warming or cooling pad as this will distort the film. Placing the infant on the cassette and allowing the infant a short time to adjust before taking the film may help the infant quiet and lessen the chance for rotation.

DEGREE OF X-RAY PENETRATION

The degree of x-ray penetration affects the quality of the neonatal chest film. Many important findings may be overlooked if the film has been overexposed or underexposed. The overpenetrated film is extremely dark. There is not the contrast usually seen between the background of the film, which is always dark, and the lung fields, which should be lighter in contrast. The entire film has a "burned out" (black) appearance, and few lung markings can be seen.

The underpenetrated film has a very light gray appearance overall and again lacks contrast. The lung fields are light and may appear hazy with no details. In both the overpenetrated and underpenetrated film, air leaks such as a pneumothorax may be difficult to detect.

The most effective way to obtain the proper exposure and contrast is to have the x-ray exposure and magnification determined according to the infant's weight. Once these parameters are determined, they should be used consistently with that particular infant to ensure the best results. Consistency in technique is also highly important when comparing an

FIGURE 1-10 ■ **Neonatal chest x-ray film demonstrating overpenetration.**

The details of the lung fields are difficult to distinguish, and the bones of the ribs and vertebral bodies are very distinct. The soft tissue is not as apparent when compared to Figure 1-11.

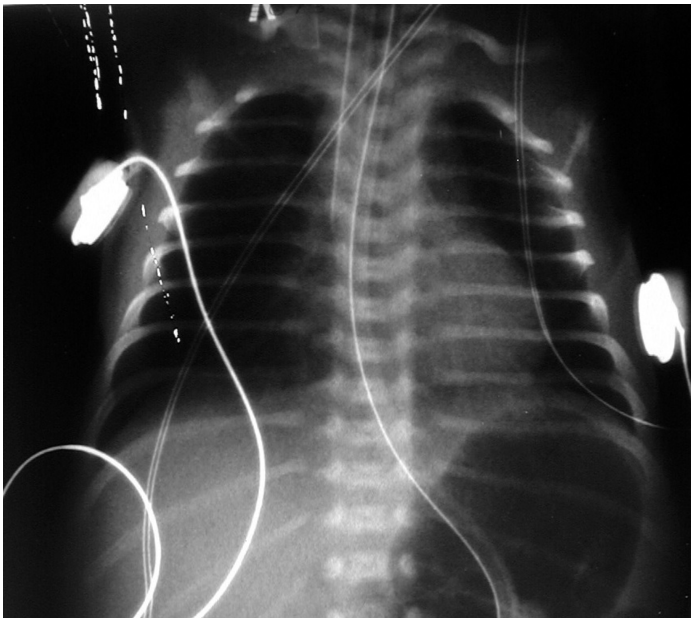


FIGURE 1-11 ■ **Neonatal chest x-ray film demonstrating underpenetration.**

The overall appearance is very white compared to Figure 1-10. The details of the lung fields are readily apparent and possibly exaggerated due to the exposure. The vertebral bodies are not as clearly defined as in Figure 1-10. The soft tissues of the chest and arms are very apparent.

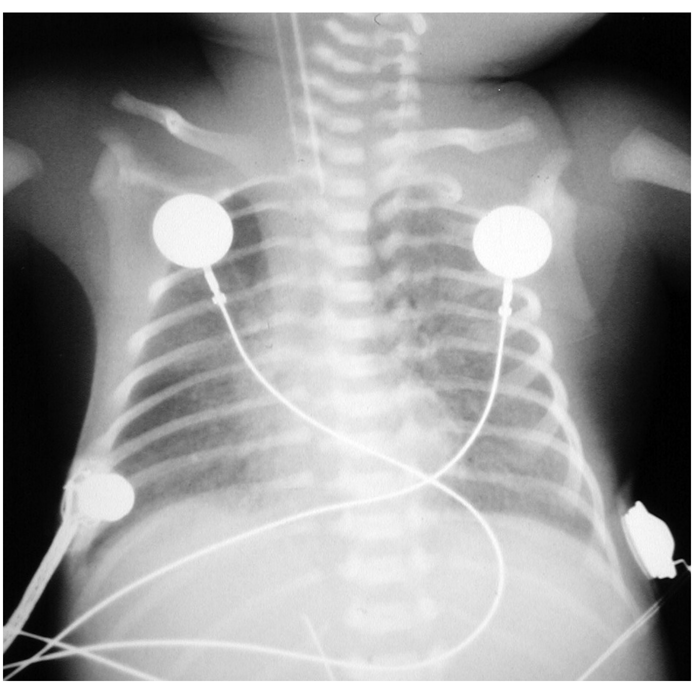
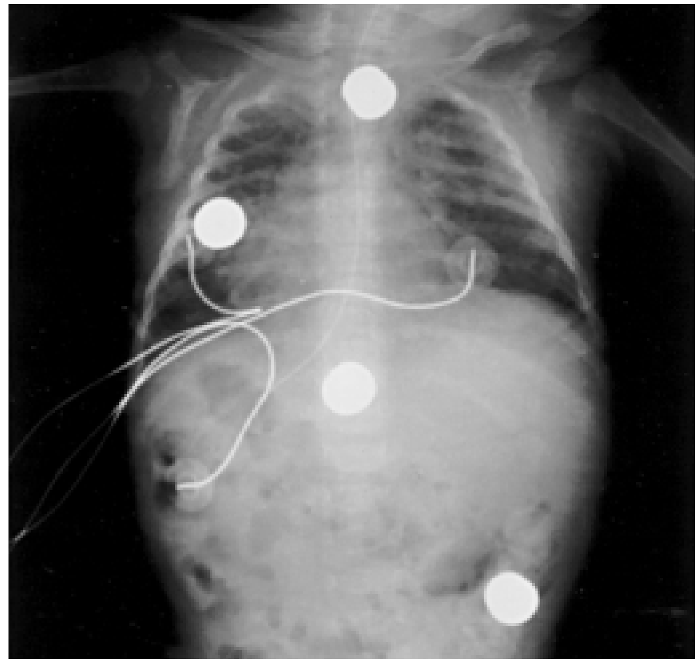


FIGURE 1-12 ■ **An x-ray film demonstrating round white artifacts.**

These artifacts are the snaps on the infant's sleeper.



infant's current film with his previous films. The intensity of the x-ray beam is determined by weight, and this provides a consistency in technique. Figures 1-10 and 1-11 highlight exposure differences in chest x-rays for two different infants.

PRESENCE OF ARTIFACTS

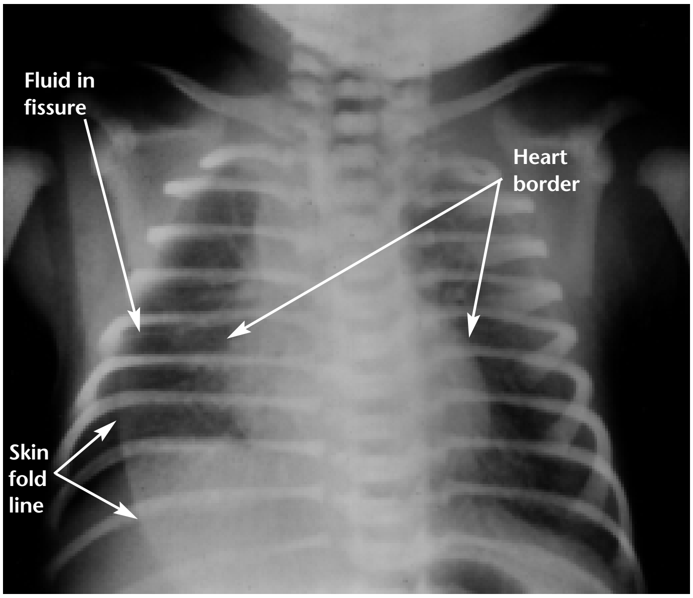
The presence of artifacts may reduce the quality of the film. Artifacts need to be recognized so that they are not mistaken for pathology (Figure 1-12). The skin of neonates, particularly premature infants, can be redundant and very mobile because of the lack of subcutaneous fat, such that a long vertical skin fold may simulate a pneumothorax (Figure 1-13). Awareness of the possibility of a skin fold, careful evaluation of pulmonary vascular markings, and, if necessary, decubitus radiographs will assist in accurate interpretation of a skin fold marking.

Another difficulty in the infant with respiratory distress and suprasternal retraction is that air collecting in the suprasternal fossa may mimic the appearance of the dilated upper esophageal pouch associated with esophageal atresia on the AP chest film. A lateral chest film or a direct examination of the infant by passing a nasogastric tube will allow the clinician to evaluate more accurately for this anomaly. A similar situation may occur when deep retraction of the lower sternum produces a central radiolucency that simulates a pneumomediastinum.

A number of artifacts on an infant's chest film are caused by the numerous monitoring leads. This is an especially difficult problem when evaluating the chest x-ray of the very small

FIGURE 1-13 ■ Neonatal chest x-ray film. Note skin fold over the right lung field.

This is a linear artifact that may be distinguished by the fact that the line extends out of the lung fields over the diaphragm and the lung densities are similar on both sides of the line. Note fluid in the right horizontal fissure.



infant because the monitoring leads may cover relatively large portions of the infant's chest. When possible, leads, monitor sensors, and probes should be placed on the infant's abdomen or on the sides of the infant's chest, under the axillae.

SUMMARY

Radiographs of the newborn chest must be of a high quality for accurate interpretation. The clinician evaluating the newborn chest film must be able to evaluate rotation, the presence of artifacts, and the technique used to be able to make an accurate diagnosis.

Revised and updated from: Grossglauser L. 1993. Assessment of the quality of the neonatal chest x-ray film. *Neonatal Network* 11(7): 69–72. Used with permission of Springer Publishing Company, LLC, www.springerpub.com/nn.

How to Evaluate Lung Fields on the Neonatal Chest X-Ray Film

Along with clinical knowledge of the patient, the first step in determining a differential diagnosis is to understand the types of lung density patterns observed on x-ray films and to correlate these observations with various disease states. The essential components in this process are addressed here.

ASSESS THE OVERALL QUALITY OF THE FILM

- **Assess the degree of x-ray penetration.** Radiology is the science of interpreting relative densities. Air or gas does not absorb much of the x-ray beam and results in a black or dark gray image on the radiograph. Water blocks a significant amount of the x-ray beam, producing a light gray image. Generally, with appropriate x-ray technique, a darker or more lucent x-ray film suggests the presence of air, and a more gray appearing film suggests more dense underlying lung parenchyma. Normal lungs will appear dark or lucent because the alveoli and airways are air filled; diseased lungs will have varying degrees of gray throughout the lung fields. The distribution of the gray or hazy appearance will depend on the underlying pathology. Gray or hazy areas

FIGURE 1-14 ■ Neonatal chest x-ray film showing a right upper lobe collapse with a slight shift of the mediastinal structures to the right.

The carina is just to the right of the spine at approximately the fourth to fifth thoracic vertebrae (T4–T5).

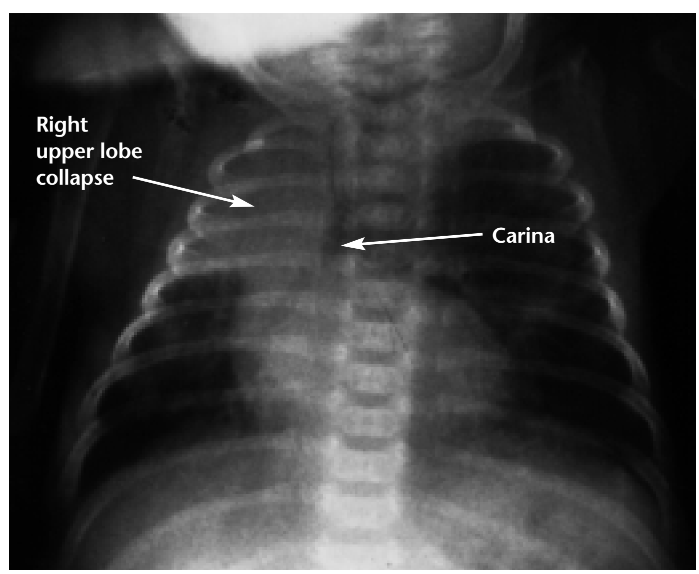


FIGURE 1-15 ■ **Radiographic image showing sail sign.**

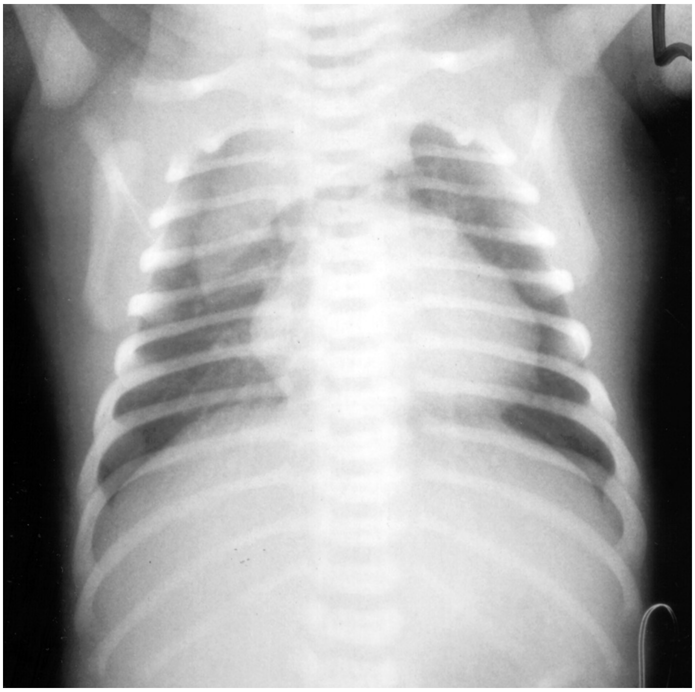
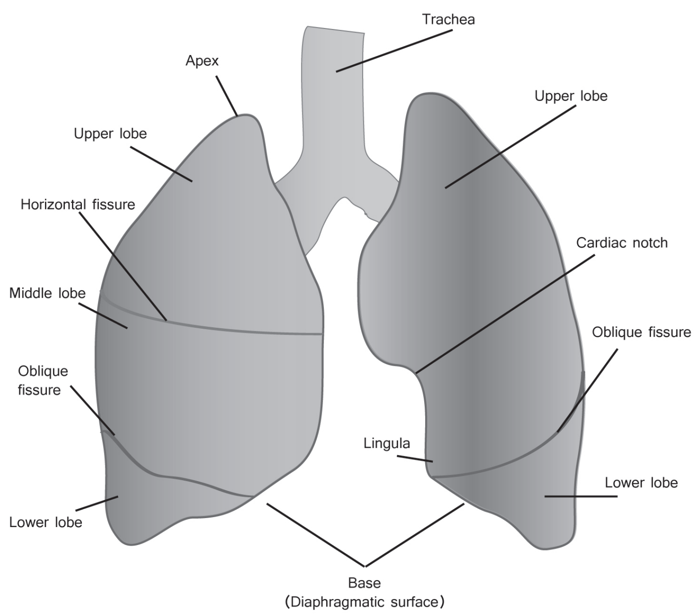


FIGURE 1-16 ■ **Anatomical diagram of the anterior view of the lungs.**



within the lung fields generally represent either infiltrates (lung parenchyma filled with blood, pus, or fluid) or atelectactic areas (collapsed alveoli).

- **Determine adequacy of inspiratory effort.** If the film is underexposed or taken on expiration, the lung fields will appear more hazy and may be interpreted as worsening lung disease.
- **Check for rotational artifact.** See "Assessment of the Quality of the Neonatal Chest X-ray Film."

IDENTIFY HILAR VESSELS AND CARINA

The area to the right and left of the heart borders may appear denser than the rest of the lung fields. This area is referred to as the hilum; the area adjacent to the hilum is referred to as the parihilar area. This corresponds to the area where the major bronchi and pulmonary vessels intersect each lung.

On radiograph, the hilum is primarily composed of vascular markings that appear as small water density (white) lines on either side of the mediastinum. If each lung were divided into three equal segments on the vertical plane, vessels would normally be seen in the segment closest to the mediastinum and occasionally in the middle third of the lung. The presence of vessels in the outer third of the lung is abnormal and usually indicates increased pulmonary blood flow. Lack of vessels in the portion of the lung closest to the heart and mediastinum may indicate cardiac disorders of decreased pulmonary blood flow or pulmonary hypertension.

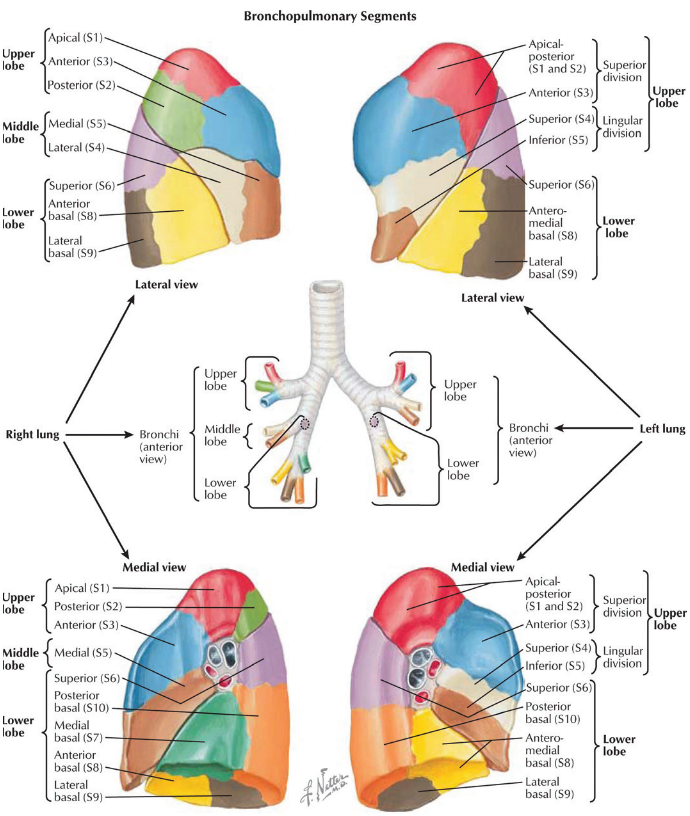
The carina—the point at which the trachea divides into the two mainstem bronchi—is an important anatomical landmark to use in identifying proper placement of the endotracheal tube. The carina generally lies over the fourth thoracic vertebrae on the radiograph. (The carina is depicted in Figure 1-14.)

IDENTIFY THE THYMUS

The normal thymus can be visualized on AP chest radiographs of infants and young children. A normal thymic shadow can be distinguished from an abnormal mediastinal mass by the absence of signs of tracheal compression or deviation.[12] Radiographically, the thymus has been described as "a bi-lobed, pyramidal structure occupying the anterosuperior mediastinum. On the lateral chest radiograph it can be seen filling the anterior retrosternal air space" (p. 399).[12]

On neonatal chest x-rays, the thymus frequently obscures the upper heart border, making evaluation of cardiac size and mediastinal structures difficult. The term *sail sign* refers to the triangular opacity (the thymus) that projects from the right (most commonly) or the left side of the superior mediastinum. The sail sign (Figure 1-15) may be more prominent if air is present in the mediastinum (pneumomediastinum) and may be referred to in this case as the *wave sign*.[7] As Chapman aptly describes the radiographic findings of the thymus gland in children, "fat healthy children have big thymuses and sickly children have small thymuses" (p. 399).[12] Investigators have found a correlation between the size of the thymus and

FIGURE 1-17 ■ Anatomical diagram of the bronchopulmonary segments of each lung lobe.



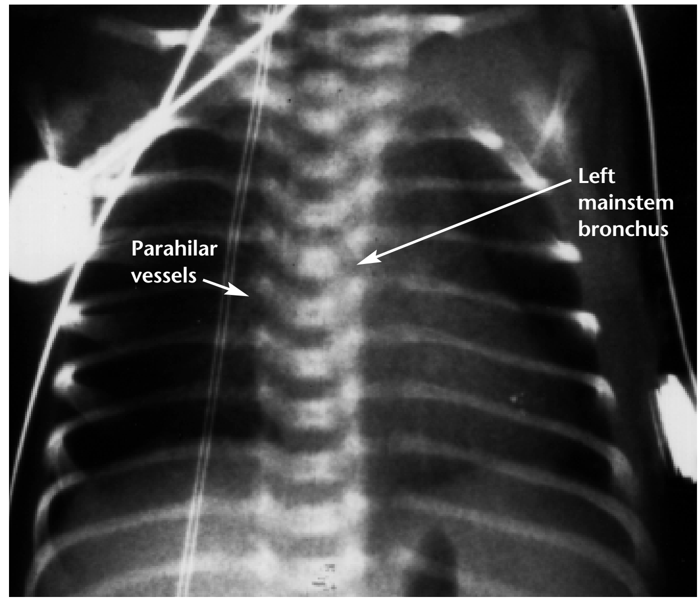
increasing gestational age as well as between thymus size and birth weight.[14] This confirms Chapman's descriptions.

EVALUATE THE OVERALL SYMMETRY/ ASYMMETRY OF THE RIGHT AND LEFT AND UPPER AND LOWER LUNG FIELDS

Before discussing the identification of asymmetric lung patterns, it is essential to ensure understanding of basic lung anatomy. Figure 1-16 identifies the anatomy of the lung lobes as they would be seen on an AP chest film. All lung lobes are divided into bronchopulmonary segments (Figure 1-17). Diseases that cause airway plugging, such as chronic lung disease or meconium aspiration syndrome, may affect the lung lobes differently. Thus, what is observed on the chest x-ray will relate to the underlying structure affected as well as the pathology involved.

A particular pattern throughout all lung fields is referred to as a "diffuse, homogenous, or symmetrical" pattern. Lung fields that are distinctly different are referred to as "nonhomogenous or asymmetrical." Figure 1-18 depicts the normal, well-aerated, preterm neonatal chest film. Note the symmetrical dark, lucent, lung fields. Compare this to Figure 1-19, which depicts a symmetrical or homogenous pattern of diffuse, light gray lung fields. This pattern is consistent with disease states causing diffuse atelectasis or fluid-filled alveoli.

FIGURE 1-18 ■ Normal chest x-ray film of a preterm neonate.



While the practitioner is evaluating symmetry of lung fields, she or he may observe linear demarcations along lung lobe margins. Because the fetal lung is full of fluid prior to delivery, fluid may sequester between the lung lobes. This fluid may not be cleared for hours after delivery and appears as a linear infiltrate or effusion on the x-ray film. Figures 1-13 and 1-20 depict fluid in the fissure between the right upper and middle lobes. Another type of linear marking observed on some films, particularly those of larger infants with redundant skin, is a skin fold line. Figure 1-14 shows a skin fold line over the right lung field.

CONSIDER AREAS OF DENSITY

Figure 1-14 shows a significant, right upper lobe focal density. This density represents a right upper lobe collapse that resulted from mucus plugging of the right upper lobe bronchioles. This is an asymmetrical pattern of lung infiltration.

Obstruction, compression, and contraction are mechanisms that can cause lobar or segmental collapse in the lung. A decrease in volume occurs in the affected area as it loses aeration, and it appears opaque on the x-ray film. An indirect sign of collapse is hilar displacement in the direction of the collapse. In marked collapse of one or more lobes, the heart and mediastinum shift toward the side of collapse.

This is in contrast to lung densities caused by free pleural fluid such as lymph, blood, exudate, or transudate. When free

FIGURE 1-19 ■ **Chest x-ray film of a preterm neonate with moderate hyaline membrane disease.**

Note the symmetrically distributed hazy pattern in both lungs. The parahilar vessels are adjacent to the right mediastinal area.

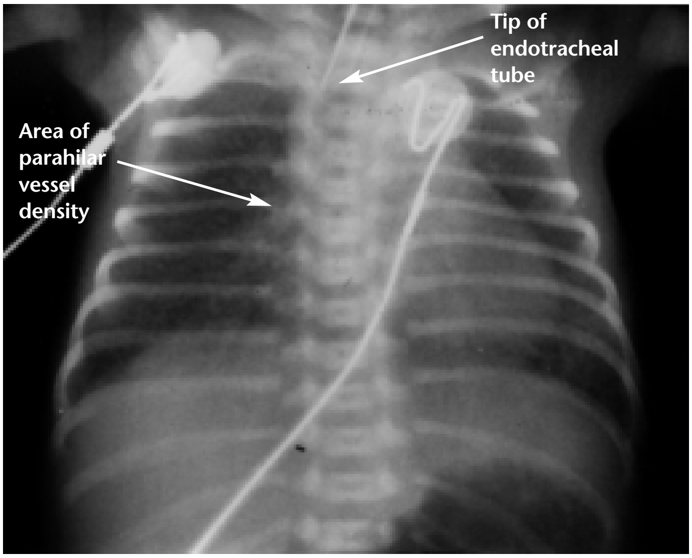


FIGURE 1-20 ■ **Neonatal chest x-ray film.**

Note the linear marking showing fluid in the horizontal fissure between the right upper lobe and right middle lobe.

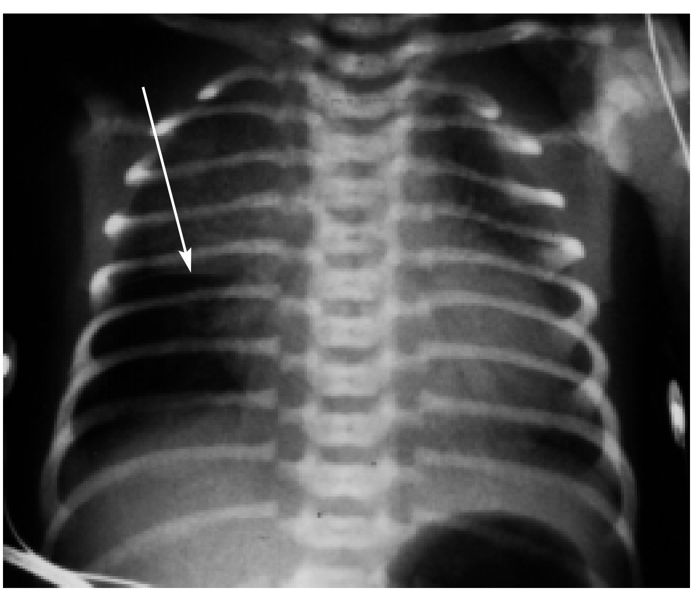


FIGURE 1-21 ■ **Chest x-ray film of a 36-week gestational age infant with an ill-defined right middle lobe infiltrate.**

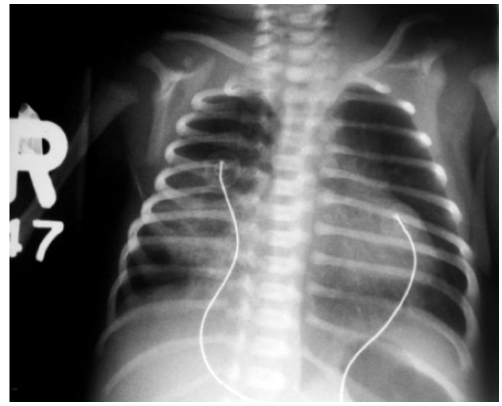
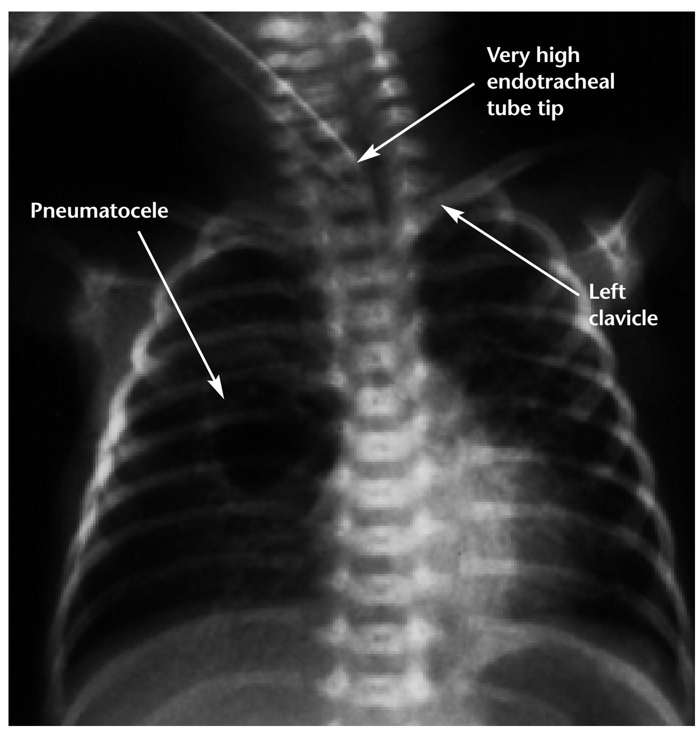


FIGURE 1-22 ■ **Chest x-ray film of a ventilated infant showing pneumatocele over the right middle lobe.**

Note that the endotracheal tube is well above the clavicles, just at the level of the thoracic inlet.



pleural fluid is present in large amounts, the heart and mediastinal structures shift toward the opposite thorax. Additionally, free pleural fluid will gravitate to the dependent side of the pleural cavity while densities due to collapse remain the same.

Figure 1-21 depicts another pattern of asymmetrical lung infiltration: an ill-defined, right middle lobe infiltrate with a relatively clear left lung and right upper and lower lobe. This chest film was obtained on a 36-week gestational age, 36-hour-old infant who had just been weaned to room air. The infant demonstrated increasing tachypnea after being placed in room air, so this film was obtained. A diagnosis of right middle lobe pneumonia was established, and the infant was started on antibiotics. Mucus plugging of the right middle lobe and aspiration may present a similar x-ray appearance.

ADDRESS AREAS OF LUCENCY

Areas of lucency may be symmetrical or asymmetrical as well. Determine whether the lucent areas are inside or outside of the lung parenchyma, as, for instance, in the pleural, mediastinal, or pericardial spaces. Air within the lung parenchyma may have a symmetrical appearance (as it does in patients with diffuse pulmonary interstitial emphysema) or an asymmetrical pattern.

Figure 1-22 depicts an air-filled structure noted in the right middle lobe. This is a pneumatocele, which is a sharply defined, lucent, air-filled bleb resulting from ruptured alveoli that coalesce to form a larger pocket of air. Pneumatoceles can be large and under tension or small and localized, such as the one in Figure 1-22. They most commonly result from lung injury associated with mechanical ventilation or with pneumonia.

SUMMARY

The general principles of evaluating lung fields have been presented. Just as in newborn assessment, the technique for interpretation of the neonatal radiograph is best performed with components in the same order each time. Begin each interpretation with an assessment of the quality of the film by addressing degree of x-ray penetration, adequacy of inspiration, and observation for possible rotation of the infant. Identify landmarks such as hilar vessels and the carina. Continue through assessment of symmetry, density, and lucency of organ areas to determine the diagnosis. These interpretive concepts will be applied as disease entities are discussed in the next sections.

Revised and updated from: Trotter C. 1993. How to evaluate lung fields on the neonatal chest x-ray film. *Neonatal Network* 12(2): 63–66. Thymus information excerpted from: Askin D, and Young S. 2001. The thymus gland. *Neonatal Network* 20(8): 7–13. Used with permission of Springer Publishing Company, LLC, www.springerpub.com/nn.

Assessment of Inspiratory Effort

Assessment of adequacy of inspiratory effort is essential in the evaluation of a chest roentgenogram. Underinflation of the chest may suggest serious cardiac or pulmonary disease or worsening of the existing condition.[11] Therefore, it is essential that adequacy of inspiration is provided for when chest x-ray films are taken. There are several methods used by practitioners to assess the degree of inspiration, although most agree that with experience one develops an overall feeling or prototype for the well-aerated chest.[11]

NUMBER OF RIBS ABOVE THE DIAPHRAGM

Counting the number of ribs above the diaphragm is a frequently employed method. Adequate inspiration is suggested by a diaphragm at or below the eighth rib. Compare Figure 1-23, which depicts a well-inflated normal chest with lung expansion to eight or eight and one-half ribs, to Figure 1-24, which depicts lung expansion to the sixth or seventh ribs. Some authors feel that this method is of little value in the newborn, but may be helpful in the older child and adult.[11]

CONTOUR OF THE DIAPHRAGM

Assessment of the contour of the diaphragm is a second method for determining adequacy of inspiration. When stimulated to contract during inspiration, each diaphragmatic leaf moves down, causing gas to flow into the lungs.[15] Therefore, diaphragms should be low and slightly rounded on inspiration. Overly flattened diaphragms suggest overinflation of the lung fields (Figure 1-25). During expiration, the diaphragm relaxes and domes upward into the chest cavity.[15] Therefore, diaphragms that appear very rounded and as though they are bulging into the lung fields suggest underinflation (see Figure 1-24).

RIB CONFIGURATION AND CHEST VOLUME

The configuration of the ribs and chest volume should also be considered in assessing the degree of lung inflation. A well-expanded chest will provide for a more bell-shaped or full, rounded chest versus a tented chest appearance. Ribs should extend relatively straight out from the spine to the periphery of the chest with a wide angle as the rib turns posteriorly. Ribs that angle down in a caudal direction or angle off sharply to the posterior suggest an expiratory film. Overall, the upper chest should be almost as well expanded as the lower chest. Compare the underinflated chest in Figures 1-24 and 1-26 with the well-inflated chest in Figure 1-23.

POSITION OF THE STOMACH BUBBLE

The position of the stomach air bubble (if it is present) may help in assessing inspiratory effort. The stomach air bubble should be located below the edge of the left diaphragm. If the

FIGURE 1-23 ■ Well-inflated chest of a 2-week-old, 30-week gestational age infant.

By counting the ribs, you will note that the diaphragms are at or below the eighth rib. Note the distance between the ribs when compared to Figure 1-24.

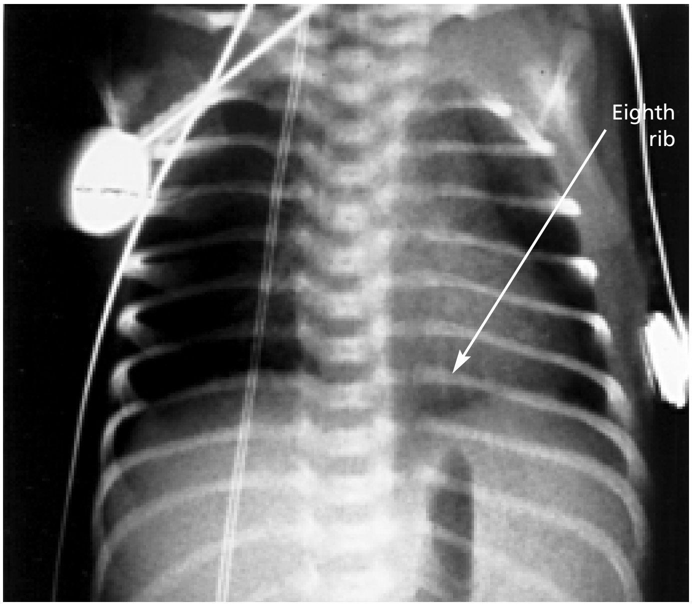


FIGURE 1-25 ■ Overinflated chest of an infant with chronic lung disease.

Note the low and flattened diaphragms at the level of the tenth rib and the healing rib fractures on the right.

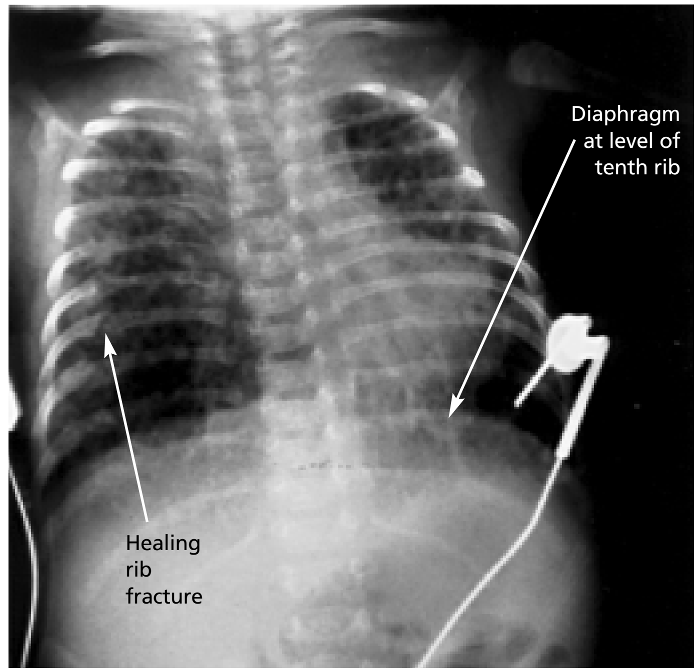
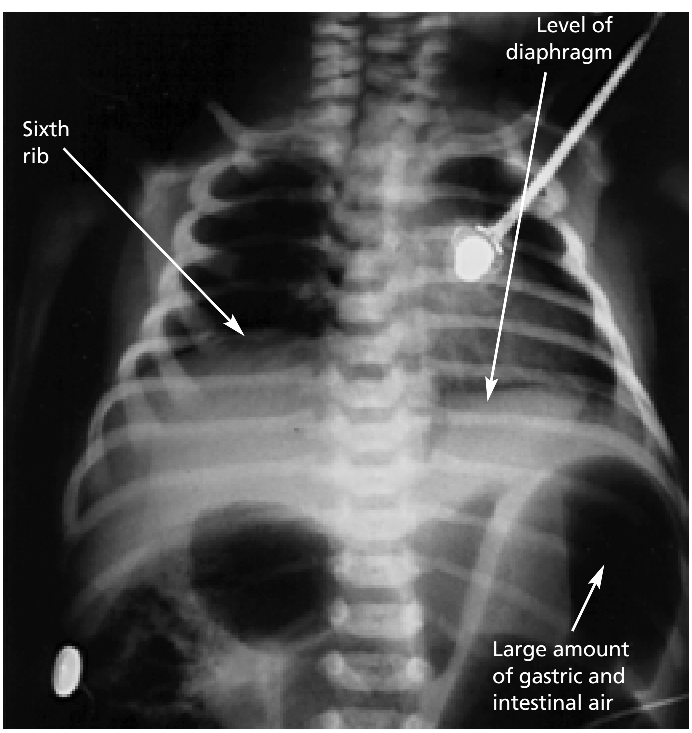


FIGURE 1-24 ■ Underinflated chest with elevated diaphragms.

This most likely resulted from the severe abdominal distention.



stomach air bubble appears to be bulging into or overlaying the lower left lung border, this suggests an expiratory film (Figure 1-27).

HAZINESS

If the x-ray film shows increasing haziness in the face of a stable clinical status, one must consider the possibility of shallow inspiratory effort or a radiograph taken on expiration. Worsening lung disease will generally be substantiated by the clinical course of the infant.

CASE PRESENTATION

Figures 1-27 and 1-28 depict x-ray films taken on the same infant five hours apart. This 28-day-old, 25-week gestational age preterm male with hyaline membrane disease, Group B ß-hemolytic streptococcal sepsis, and bronchopulmonary dysplasia has been mechanically ventilated since birth. The x-ray film shown in Figure 1-28 was taken in the morning as a daily surveillance film. The overall low lung volume in this film may be explained by the high position of the endotracheal tube, which is well above the clavicles. This position is just at the thoracic inlet. The abdominal distention most likely resulted from the high endotracheal tube placement and high position of the gastric tube with the tip in the lower

FIGURE 1-26 ■ Expiratory film of a five-day-old, 33-week gestational age male.

The aerated areas in the right lower lobe represent trapped air from pulmonary interstitial emphysema that persists on expiration. Note the narrowed shape of the chest and the caudal angle of the ribs.

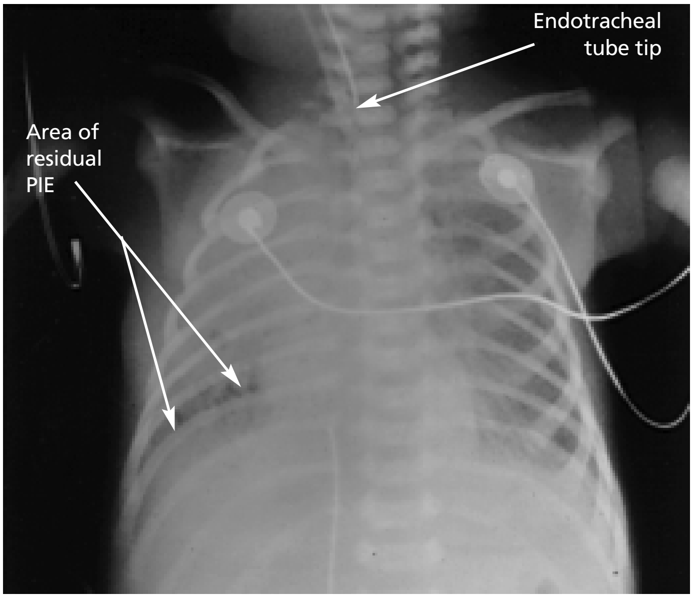
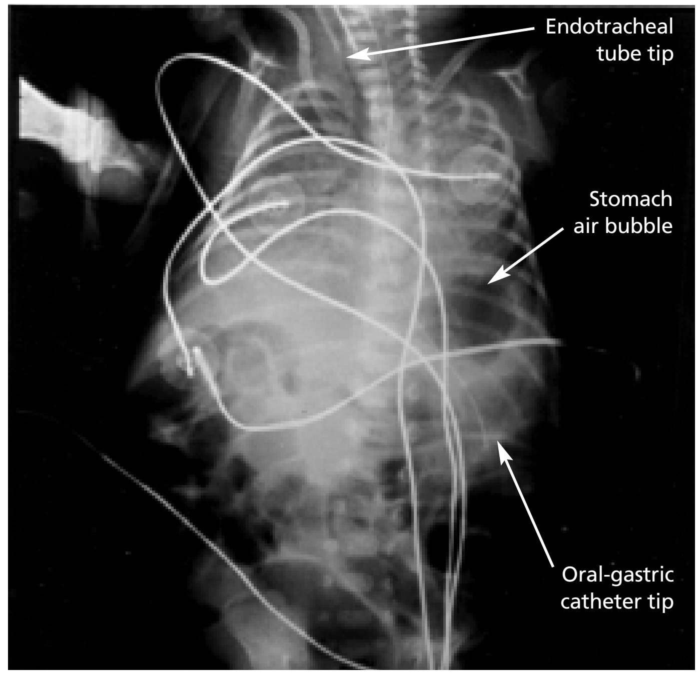


FIGURE 1-27 ■ Expiratory film of a 28-day-old, 25-week gestational age preterm male.

Note the diffuse and homogenous pattern of haziness, high stomach air bubble, and rib position.



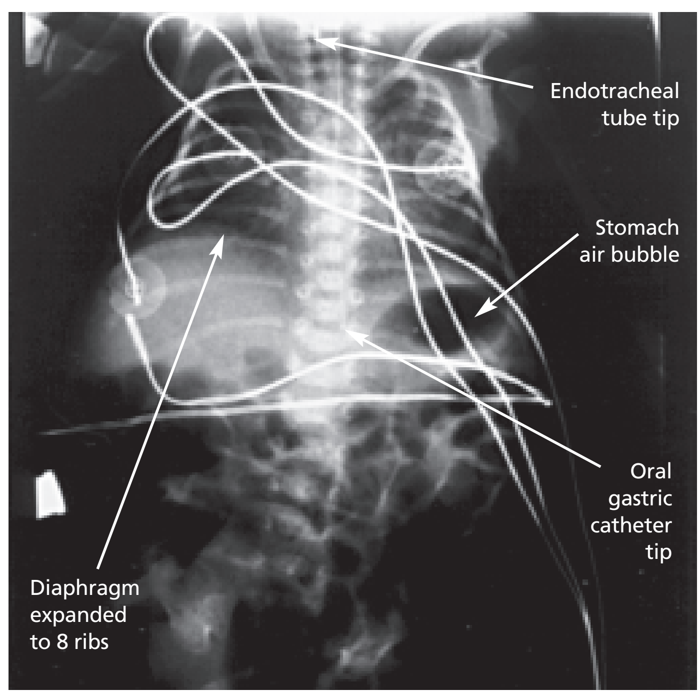
esophagus. The neonate would have better expanded lungs had both the endotracheal tube and the nasogastric tube been in correct position.

By applying the previously outlined criteria to Figure 1-28, you will note that the overall chest configuration is bell shaped with fairly well expanded ribs. The left lung is inflated to the eighth rib. The diaphragms are rounded but not so much as to appear to be bulging up into the chest. The stomach bubble is high, but is below the left diaphragm. And finally, the overall quality of the lung fields is clear rather than hazy. This, therefore, appears to be an adequately inflated film.

When evaluating the film in Figure 1-27, which was taken five hours later on the same day as Figure 1-28, notice that the lung fields look much more hazy. This is a diffuse and homogeneous pattern of haziness. Clinically, the infant was stable and had not changed between the time the two x-ray films were taken. It is important to note that the endotracheal tube remains very high and that the abdominal distention has improved slightly. When compared to the film in Figure 1-28, the ribs are closer together. The angling of the ribs on the right side is most likely due to rotation of the infant to that side, which may have resulted in a higher displacement of the endotracheal tube. The diaphragms are difficult to assess because of the overall haziness of the lung fields, but they do not appear to be lower than the seventh rib. Furthermore, the right diaphragm appears to bulge into the right lung. The stomach bubble also appears higher on this film. Initial evaluation of Figure 1-27 may lead to an interpretation of

FIGURE 1-28 ■ Inspiratory film of a 28-day-old, 25-week gestational age preterm male.

Note the improvement in aeration of the lung fields when compared to Figure 1-27. Note the rib expansion and rib configuration as well as the lower stomach air bubble compared to Figure 1-27.



worsening lung disease. However, considering the infant's stable clinical picture and using the methods of assessment outlined previously, the practitioner can correctly interpret this film as representing poor inspiratory effort.

SUMMARY

Inspiratory effort is one parameter that must be evaluated when interpreting the neonatal chest radiograph. Whether the x-ray was taken on inspiration or expiration must be ascertained. Over time, by using a systematic approach to interpretation, the practitioner will realize the well-aerated chest easily.

Revised and updated from: Trotter C, and Carey BE. 1992. Assessment of inspiratory effort. *Neonatal Network* 19(2): 61–63. Used with permission of Springer Publishing Company, LLC, www.springerpub.com/nn.

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