Interpretation of the neonatal chest X-ray

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Most neonatal X-rays are seen initially by a paediatrician without formal training in interpretation of chest X-rays. This article aims to help improve the information obtained from these X-rays which are often complex. Many factors affect accurate interpretation of the neonatal chest X-ray, including good quality radiographs, appropriate viewing conditions and thorough education.

The interpretation of a neonatal chest X-ray to produce a report is the end product of a process involving many stages. The report on the radiograph will only be as good as the radiograph itself and the technique involved to produce this requires considerable attention to detail. The interpretation of the radiograph will only be appropriate if ideal viewing conditions are observed and the final report will depend on the clinical information provided to the person viewing the film and the level of training and experience of neonatal chest X-rays that the person concerned has.

TECHNIQUE

Table 1 shows suggested parameters for a good quality neonatal radiograph. Most radiographs are obtained anteroposteriorly, i.e. with the baby lying on its back with the film behind it.

The chest X-ray should be taken in full inspiration, which is easily judged in most neonates on a ventilator but more difficult in those breathing spontaneously. As many overlying tubes and wires should be cleared from the field as is feasible. Coning of the radiograph to the chest area is mandatory to improve the quality of the film as well as to address radiation protection issues. Very short exposure times, which can often only be obtained from high output mobile machines, are ideal to reduce movement blurring especially respiratory. This ideal cannot always be achieved with small mobile X-ray machines available on many special care baby units (SCBU).

VIEWING CONDITIONS

Holding the film up to the fluorescent lights on the ceiling or to the daylight through the window is often used for interpretation of the grossest abnormalities but, as many abnormalities in seriously ill neonates are more subtle this should be discouraged. A conventional light viewing box in the neonatal nursery should be the minimum requirement. Full formal reporting of neonatal chest X-rays requires reduced ambient lighting and a means whereby the area of the light from the viewing box can be reduced to the area of the film. If possible this should be undertaken by a radiologist with a specific interest in the problems of neonatal radiology.

THE NORMAL CHEST X-RAY

There is considerable variation in the shape of the heart and mediastinal shadow. The heart size is normally 55% or less of the maximum internal thoracic diameter. The mediastinal shadow in the neonate is very variable. There are two main factors contributing to this, the first being the con-

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TABLE 1.
Parameters for a good neonatal chest X-ray

Parameter	Comment
Rotation	The neonate should be parallel to the film so that artefacts of unequal magnification are not produced. This can be judged by the equal distance of the medial ends of the clavicles to the vertebrae at this level
Exposure	The correct amount of radiation is used to produce the best exposure of the X-ray film. Neonatal chest X-rays tend to be overexposed, resulting in loss of lung detail. The lung behind the heart should just be visible on a correctly exposed film
Coning	The X-ray beam is limited in size so that only the required areas are visible on the film. The field should be restricted as close to the chest wall as possible
Movement	The chest X-ray should be taken in inspiration. Any rapid movement of the chest will blur the X-ray. In practice, movement is minimized as a result of the short exposure times used
Removal of obscuring objects	There should be as few objects as possible obscuring detail on the X-ray

siderable variation seen in the size and shape of the thymus from patient to patient and the second being the tendency for neonatal films to be taken in a lordotic posture. This is not a result of poor technique but the fact that the neonatal thoracic spine lacks the normal kyphosis seen in older children.

The normal thymus can fill the entire upper part of the chest or extend just to the right or the left side. Its outer margin tends to have an ill-defined border and is frequently confused with upper lobe consolidation (*Figure 1*). On the right the lower border of thymus is usually well defined (*Figure 2*). Its lateral margin may well be defined. This margin has a slightly lobulated appearance corresponding to an impression caused by the anterior rib ends (Mulvey, 1963).

The lung fields normally have the same density on each side and are uniform throughout. The lung vessels are often difficult to demonstrate in the first few days of life, the hilar shadows often being obscured by the mediastinal shadow. The diaphragm, chest wall and mediastinal shadows should have a clearly defined outline in comparison to the lung. The diaphragm normally lies at a level between the 4th and 5th anterior rib ends but again this is increased if the film is a lordotic one. The trachea and main bronchi can be identified, as can the first division bronchi, particularly on the left. Minor kinking of the trachea is common if the head is rotated.

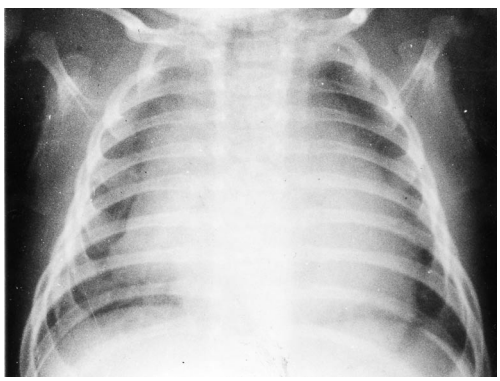

Figure 1. Normal neonatal chest X-ray with large thymus. Note the ill defined border of the thymus particularly in the right upper zone.

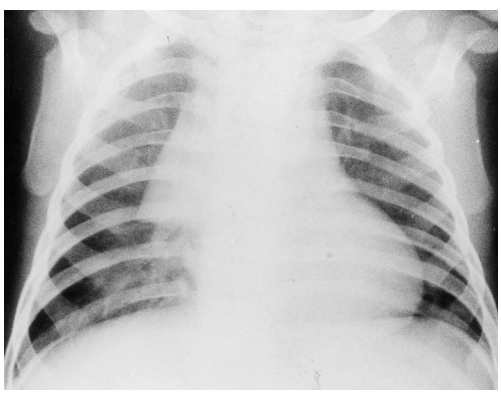

Figure 2. Normal neonatal chest with typical well defined thymic shadow on the right. Note slightly 'wavy' lateral border corresponding to anterior rib ends.

LINES AND TUBES

If an endotracheal tube is in place its tip should lie between the level of C7 and the carina. An umbilical arterial line is seen dipping down from the umbilicus to enter either the right or left internal iliac artery before moving up the iliac artery into the aorta (*Figure 3*). Its tip should lie somewhere in the mid-thoracic aorta, ideally from about T4 to T9. A position between T12 and L2 makes the major arterial branches of the aorta particularly vulnerable to thrombosis.

An alternative position for an umbilical arterial line is between L3 and L5 which is below the position of the major arterial branches. An umbilical venous line takes an upward course from the umbilicus with a small kink where the catheter passes through the ductus venosus into the inferior vena cava (*Figure 4*). The position ideally should be in the inferior vena cava or low in the right atrium.

Venous lines entering from the limbs should ideally lie in the superior vena cava if entering

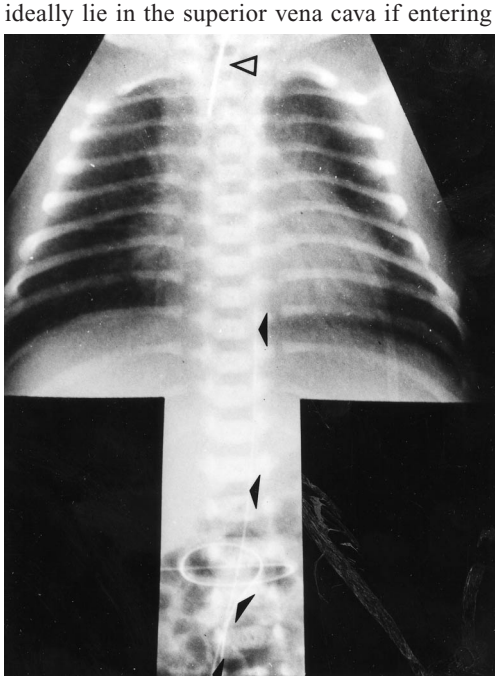

Figure 3. Normal neonatal chest X-ray showing endotracheal tube (open arrow) and well positioned umbilical arterial line (closed arrows). Note the course of the catheter from the umbilicus to the internal iliac arteries and then to the aorta.

from the upper limb or inferior vena cava if entering from the lower limb. As many of the lines used in neonates are only faintly radiopaque it is sometimes necessary to opacify the lines with intravenous contrast media. A small volume (0.5 ml) of non-ionic contrast medium such as Niopam 300 is usually sufficient to opacify the line and show the tip.

INFORMATION REQUIRED TO INTERPRET A NEONATAL CHEST X-RAY

When interpreting an X-ray it is important to have full clinical information as outlined in *Table 2*. A knowledge of the antenatal history is important, for example certain abnormalities are associated with oligohydramnios, particularly pulmonary hypoplasia, and polyhydramnios, such as oesophageal atresia. The chest X-ray changes vary with gestation and while a rough assessment of the gestational age can be obtained from the size of the patient, the problems encountered by growth-retarded babies differ to some extent from the appropriately grown baby of the same size. The current age of the patient is important as certain abnormalities only happen in the first few hours or days of life.

Knowledge of clinical events surrounding delivery such as meconium aspiration or prolonged hypoxia will influence the conclusions of the report. The ventilatory status is also important even though the position of the endotracheal tube will give some hint as to the patient's situation. Knowledge of the recent clinical events such as pneumothorax or recent collapse are also important as many X-rays are taken after an acute event has passed, and the signs can be confusing if detailed up-to-date information is not available.

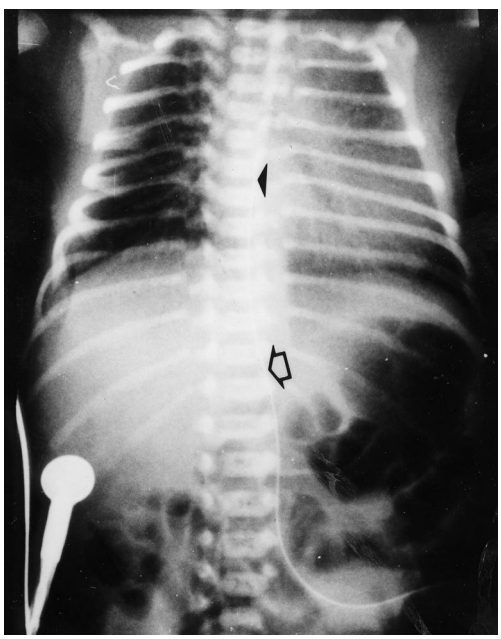

Figure 4. Normal neonatal chest and abdominal X-ray. Note the course of the umbilical venous catheter with typical 'kink' at the level of the ductus venosus.

THE ABNORMAL CHEST X-RAY

When assessing a chest X-ray a systematic approach is essential. There are many such schemes but essential features of all include assessment of the position of the patient and film exposure. If the film is deemed technically adequate then a logical scheme of assessment of all areas of the film including the heart and mediastinum, lungs chest wall, diaphragm and upper abdomen is undertaken. *Figure 5* gives a suggested scheme.

HEART AND MEDIASTINUM

Heart size in the neonate is varied for both clinical and technical reasons. The relatively higher position of the diaphragm tends to exaggerate the heart size and relatively little reliance is placed on the plain X-ray appearances of the heart. The lordotic position tends to make the heart 'boot' shaped and suggest an abnormality which is not present.

Generalized cardiac enlargement has many causes, including pericardial effusion, cardiomyopathy, and major shunts, stenoses and atresias. The plain X-ray is not good at assessing individual chamber enlargements and there is little to be gained by in-depth analysis of the cardiac contour in the neonate. Echocardiography is the definitive means of assessing this further. Enlargement of the lung vessels (pulmonary plethora) is less often a feature of cardiac disease in the neonate

TABLE 2.
Clinical information required

Antenatal history
Antenatal ultrasound: oligo/polyhydramnios
Gestation
Current age of patient
Resuscitation history: meconium aspiration
Ventilation: current/previous, length of time
Respiratory state in oxygen
Infection state
Acute events: recent collapse, pneumothorax

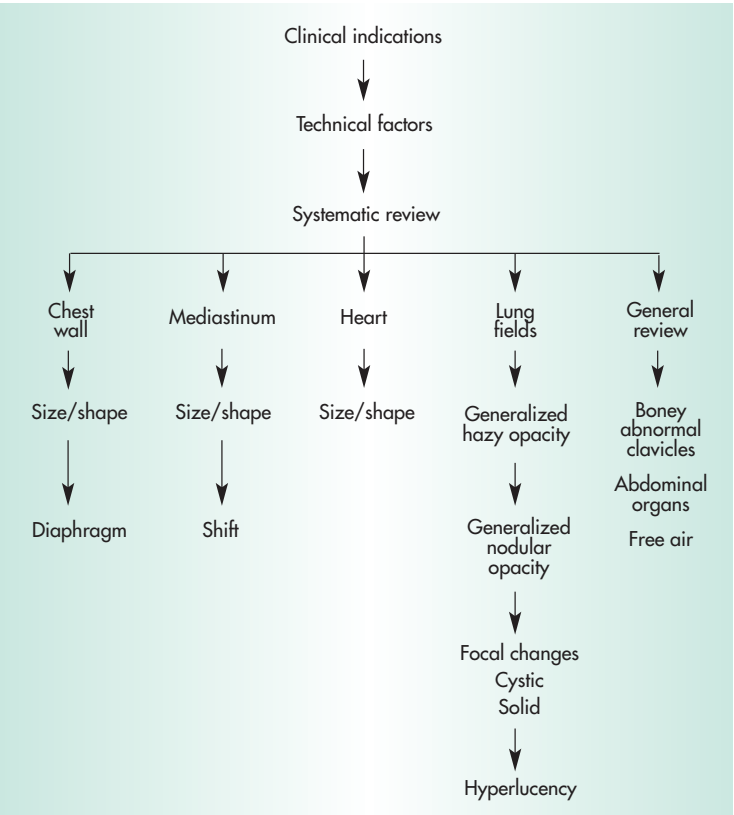

Figure 5. Systematic review of chest X-ray.

and indeed is rarely visible before 48 hours of life, even if very obvious later in the neonatal period.

One of the most difficult areas of interpretation of the neonatal chest is the thymus as described above. However, thymic abnormalities in the neonate are rare.

Air in the mediastinum or pericardium as a complication of ventilation and with or without a pneumothorax is a not uncommon finding. Differentiating this from a small pneumothorax adjacent to the mediastinum can be very difficult if not impossible (*Figure 6*).

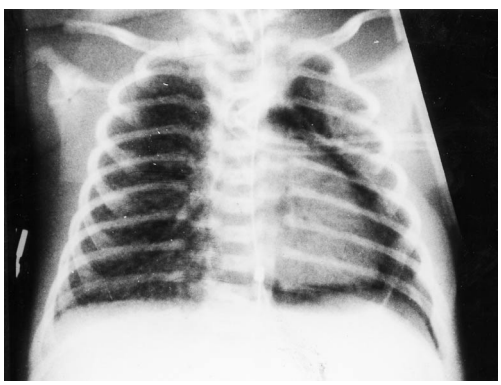

Figure 6. Pneumopericardium. Note air shadow around the heart.

THE LUNGS

Generalized hazy shadowing

First day of life: The commonest cause of generalized hazy shadowing, particularly with an air bronchogram appearance, is surfactant deficiency or hyaline membrane disease (*Figures 7* and *8*). This is particularly common in the preterm infant but other risk factors include caesarean section and maternal diabetes. The radiological appearances have been substantially modified with the advent of treatment with artificial lung expanding compound (ALEC), a synthetic surfactant. Transient tachypnoea of the new born or 'wet lung' can present in a similar way (*Figure 9*).

Radiologically the signs overlap with surfactant deficiency disease, but usually the lung volume is normal in wet lung whereas it is reduced in surfactant deficiency. The changes in wet lung resolve in 48 hours and are often rather more streaky than those seen with surfactant deficiency.

Later in the first week of life: In the slightly older neonate, both gestationally older and beyond the first few days of postnatal life, generalized hazy shadowing can be caused by pulmonary oedema. There are many causes of

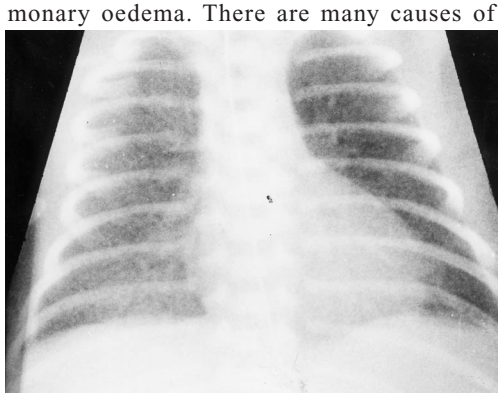

Figure 7. Moderate surfactant deficiency disease. Note generalized hazy shadowing and relatively small volume lungs.

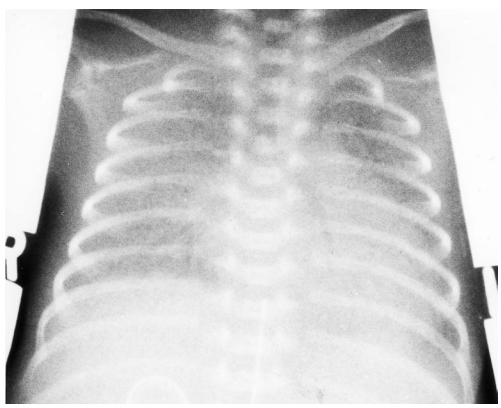

Figure 8. Surfactant deficiency disease. Note air bronchogram appearance at the left base.

pulmonary oedema in the pre-term infant but the commoner ones include a patent ductus arteriosus, generalized sepsis and much less commonly pulmonary venous hypertension, particularly secondary to total anomalous pulmonary venous drainage. Pulmonary oedema is also a common feature of hydrops of any cause. In addition infection should always be considered, especially if there are no risk factors for surfactant deficiency disease. In extremely low birth weight babies pulmonary oedema can occur as a result of both prematurity and hypoxia, the so-called 'leaky lung syndrome', and cause generally hazy lungs (Swischuk and John, 1996).

Because films are usually taken supine pleural effusions can manifest as a generalized hazy shadowing. Often the lungs are seen separated from the chest wall by fluid tracking around the lung which helps to confirm this diagnosis (*Figure 10*).

Generalized coarse shadowing

Generalized coarse reticular and nodular shadowing is seen in a number of conditions. Most typically it is seen after meconium aspiration (*Figure 11*), with alveolar shadowing secondary to pulmonary oedema caused by the irritation of the inhaled meconium with interspersed areas of overinflation (Gooding and Gregory, 1971). The appearances can also less commonly be seen in pulmonary infection. Longstanding large nodules with interspersed overinflation are seen in chronic lung disease, a well recognized outcome of a number of neonatal respiratory conditions but especially surfactant deficiency disease (Swischuk, 1977). Repeated ventilation for infection particularly where high pressure or long-term ventilation has been required can lead to chronic lung disease (*Figure 12*).

Focal lung changes

Lobar or segmental lung consolidation is quite common. Most often this is related to sticky bronchial secretions with or without infection causing loss of aeration, and is a transient phenomenon (*Figure 13*). The position of the endotracheal tube in particular should be clearly identified. Lobar or total lung collapse caused by malposition of the endotracheal tube is a very common finding.

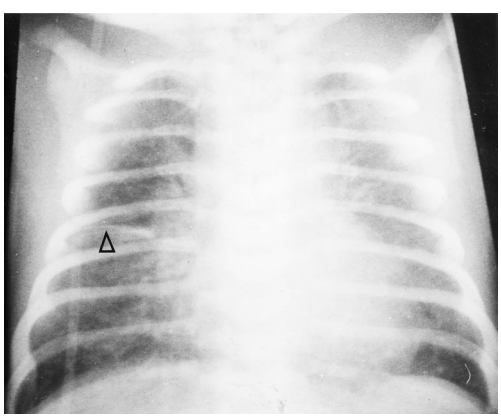

Figure 9. Transient tachypnoea of new born ('wet lung'). Note fluid in horizontal fissure (arrow) and generalized streaky shadowing.

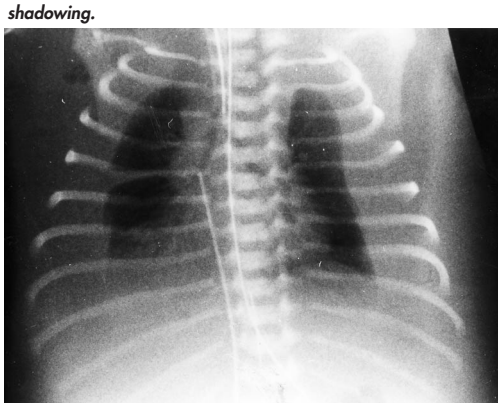

Figure 10. Large pleural effusion. Note separation from chest wall, and also soft tissue oedema.

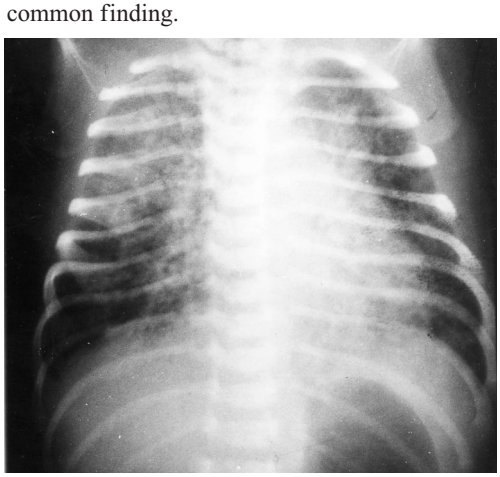

Figure 11. Normal volume lungs with patchy alveolar shadowing typical of meconium aspiration.

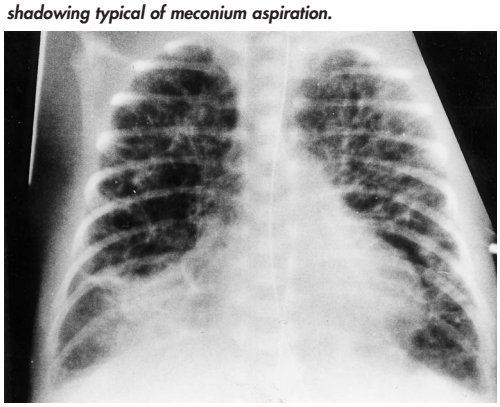

Figure 12. Typical Type 2 chronic lung disease with overinflation and intervening large nodules.

Aspiration of gastric content or pulmonary haemorrhage (*Figure 14*) can also cause focal consolidation and in the case of aspiration can lead to chronic lung disease (Bomsell et al, 1975). 'Surgical' causes of localized lung abnormalities are uncommon. A mixed solid and cystic appearance can be seen with a congenital cystic adenomatoid malformation or pulmonary sequestration. If an abnormality is basal and especially of mixed density a diaphragmatic hernia should always be considered.

Chest hyperlucency: The commonest cause of unilateral hyperlucency of the chest is a pneumothorax (*Figure 15*). In the neonate it is most usual for the lung edge not to be visible and the pneumothorax to be anteriorly situated, identified only by the increased hyperlucency of the chest and the 'etched heart border' sign. This is an appearance where the heart border adjacent to the pneumothorax is more clearly defined than would be expected as there is free air adjacent to the heart rather than aerated lung (*Figure 16*). The fact that most films in neonates are taken supine probably accounts for this appearance with neonatal pneumothorax, a sign not often seen in older children or adults.

Focal hyperlucency: In the early days of life focal areas of hyperlucency throughout the lungs produce a streaky appearance. This is caused by interstitial air alongside the bronchi (pulmonary interstitial emphysema; PIE). Its linear appearance is characteristic and is easily differentiated from the patchy consolidation seen with infection or chronic lung disease which has a coarser appearance with large nodules (Swischuk, 1977). Larger focal areas of hyperlucency can be caused by lung cysts, usually acquired following high pressure ventilation. These can cause considerable difficulty by compression of the adjacent lung and shift of the mediastinum. If the cysts are multiple in nature, and particularly when seen in the lower part of the chest, differentiation from diaphrag-

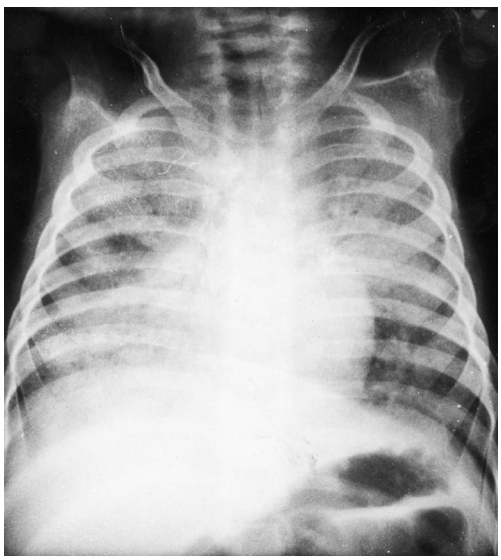

Figure 13. Widespread pulmonary consolidation as a result of infection.

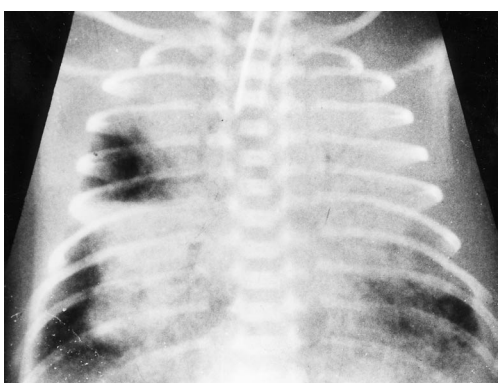

Figure 14. Widespread pulmonary consolidation as a result of pulmonary haemorrhage.

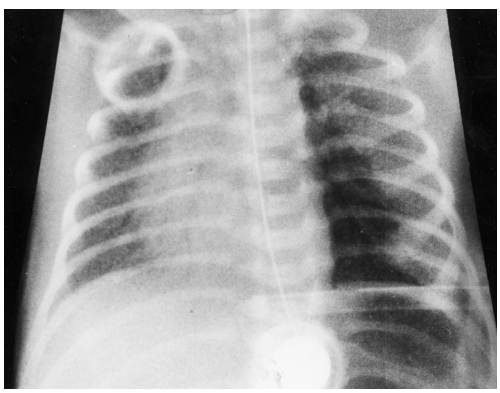

Figure 15. Chest hyperlucency in the left as a result of anterior pneumothorax. The drain is posteriorly situated. Note that no lung edge can be seen laterally.

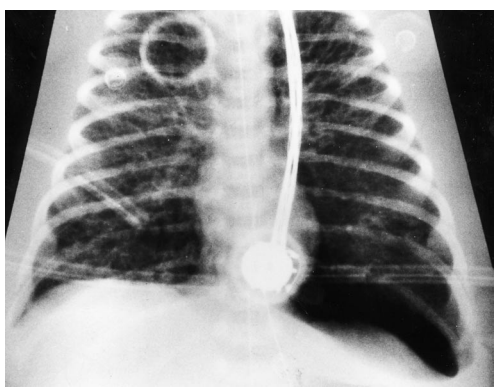

Figure 16. 'Etched heart border' sign on the left. Note the clearer definition of the left heart border than the right as a result of adjacent free air. Sub-pulmonary pneumothorax is also seen. Note pulmonary interstitial emphysema particularly in the left upper lobe.

matic hernia and congenital cystic adenomatoid malformation is necessary. If the focal areas of overinflation are in the right middle or left upper lobes, congenital lobar emphysema should also be considered.

Diaphragmatic level: If one or other diaphragm is elevated a phrenic nerve paresis should be considered. This can be the result of birth trauma or occasionally iatrogenic as a result of damage by chest drain. Depression in the level of the diaphragm is often seen with either overinflation of the lung or a tension pneumothorax.

Chest shape: The chest shape is modified by disease. In the presence of pulmonary hypoplasia (commonly preceded by maternal oligohydraminos) the chest is bell-shaped. This can also be seen transiently with hyaline membrane disease, but is more persistent with pulmonary hypoplasia if the infant survives. A bell-shaped chest is also a feature of a number of rare skeletal dysplasias with rib abnormalities. The chest can become barrel shaped in chronic lung disease as a result of pulmonary overinflation.

Chest wall: Rib fractures are uncommon in neonates but are occasionally seen after birth trauma and in some extremely low birth weight infants as a result of metabolic bone disease of prematurity, although this is now much less common nowadays than it was in the early 1980s. Osteogenesis imperfecta is a rare cause of rib fractures in the neonate and is usually accompanied by other fractures. Chest wall oedema (*Figure 10*) is a common finding either resulting from fetal hydrops, or developing in the neonatal period either secondary to administration of pancuronium to paralyse the baby for ventilation or as a manifestation of generalized cell damage, particularly related to septicaemia and severe metabolic abnormalities.

GENERAL REVIEW OF THE RADIOGRAPH

Occasional abnormalities can be diagnosed by reviewing the areas outside the immediate area of the chest. Bony abnormalities, either congenital or traumatic, are uncommon but clavicular fractures are one possible exception to this. Free subdiaphragmatic air from a pneumoperitoneum can be identified as an ill-defined increase in radiolucency over the liver and may be the first sign of intra-abdominal pathology on X-ray. Pneumoperitoneum caused by tracking of air down from the chest in a ventilated neonate with air leak is uncommon but must be considered if there are no clinical signs of abdominal abnormality.

ADDITIONAL VIEWS

It is very seldom that additional views are required. A lateral chest radiograph is very occasionally of value. Often it will not solve the difficulty of differentiation between an over inflated lung and a pneumothorax. However, it can sometimes be helpful in determining the position of a chest drain with certainty, particularly if a pneumothorax is not draining well and the drain is thought to be posterior with a pneumothorax lying anteriorly.

CONCLUSIONS

Full assessment of the neonatal chest X-ray can be very challenging. The range of pathology is relatively restricted but accurate diagnosis can only be assured with a high quality radiograph, full clinical information, a thorough knowledge of the normal appearances and a systematic approach to the review of the entire chest X-ray, both within and without the thoracic cavity. A comparison of a sequence of films extending over a period of days will often help to establish the final diagnosis if this is not clear on the initial film.

As management of neonatal emergencies requires a 24 hour a day service, it is essential in the UK that all involved in neonatal intensive care are able to assess the chest radiograph with a high degree of skill. This should allow prompt management decisions to be made as a specialist radiological opinion will probably not be available out of hours. HM

Bomsell F, Couchard M, Larroche JC et al (1975) Radiologic diagnosis of massive pulmonary haemorrhage in newborn. *Ann Radiol* **18:** 419–30

Gooding CA, Gregory GA (1971) Roentgenographic analysis of meconium aspiration in newborn. *Radiology* **100:** 131–5

Mulvey RB (1963) The thymic 'wave sign'. *Radiology* **81:** 834–8

Swischuk LE (1977) Bubbles in hyaline membrane disease. Differentiation of three types. *Radiology* **122:** 417–26

Swischuk LE, John SD (1996) Immature lung problems: can our nomenclature be more specific? *Am J Roentgenol* **166:** 917–8

KEY POINTS

- In interpretation of neonatal chest X-rays appropriate X-ray equipment and film/screen combinations are important, as are the ideal film viewing conditions.
- All paediatricians who view neonatal X-rays should be given proper training in the interpretation of chest X-rays.
- Full clinical information with regard to antenatal and postnatal events should be available.
- Extensive experience of neonatal work is preferable if all the available information on a radiograph is to be utilized effectively.