Anesthesia for Thoracic Surgery in Neonates

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30.1 Introduction

Thoracic anesthesia for noncardiac surgery in neonates and infants is a very specialized and niche area. The neonate presenting for surgery may range from an otherwise healthy, term baby to a very sick neonate with severe cardiopulmonary illness on extracorporeal membrane oxygenation (ECMO) support. Surgical indications may be relatively elective (e.g., pulmonary sequestration) or an emergency, a large lung cyst with airway leak (Table 30.1). Anesthesia for thoracic procedures is challenging for many other reasons. Respiratory physiology is altered in the lateral decubitus position in neonates compared to older children and adults. The small airway size limits the availability of suitable equipment and demands high levels of expertise and skill. With the advent of thoracoscopy options for airway management for VATS are rapidly emerging and changing the anesthetic management scenario. Regardless of the neonates' condition, the anesthesiologist should meticulously plan out airway management with a back-up plan, ensure adequate vascular access, and last but not least, an effective analgesic technique. This chapter will cover the surgery for lung conditions in the neonate. TEF and CDH are discussed separately in other chapters.

Table 30.1 Indications for thoracotomy/VATS for noncardiac surgery in neonates

1.	Tracheoesophageal fistula (TEF)
2.	Congenital diaphragmatic hernia (CDH)
3.	Congenital cyst adenomatous malformation (CCAM)
4.	Congenital lobar emphysema (CLE)
5.	Broncho-biliary fistula (BBF)

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U. Saha (ed.), *Clinical Anesthesia for the Newborn and the Neonate*,
https://doi.org/10.1007/978-981-19-5458-0_30

30.2 Physiological Changes in the Lateral Decubitus Position [1–3]

Surgical neonates tend to have high airway resistance and airflow limitation as a result of poor lung compliance (due to prematurity or soiling), and intraoperative airway manipulation. The tendency toward lung collapse on the dependent side, with high O_2 consumption, sets the stage for respiratory compromise and complications. In the lateral decubitus position, the highly compliant cartilaginous rib cage on the dependent side gets deformed by the pressure of the operating table (Fig. 30.1).

Added to this is the weight of the mediastinum which compresses the dependent lung from above, and abdominal pressure transmitted through the diaphragm. As a result, the dependent lung gets little ventilation and FRC is close to residual volume. The hydrostatic pressure gradient is reduced from the nondependent to dependent lung owing to the small chest size. Thus, a significant amount of lung perfusion continues to stay in the upper, operated lung. When the operated lung is collapsed manually, by surgical sponges and retractors, it results in diversion of ventilation to the dependent lung. The hypoxic pulmonary vasoconstriction in the nondependent lung further diverts some blood to the dependent lung. Despite factors favoring V/Q mismatch and hypoxemia in the lateral decubitus position, majority of neonates tolerate DLV well, barring as in necrotizing pneumonia.

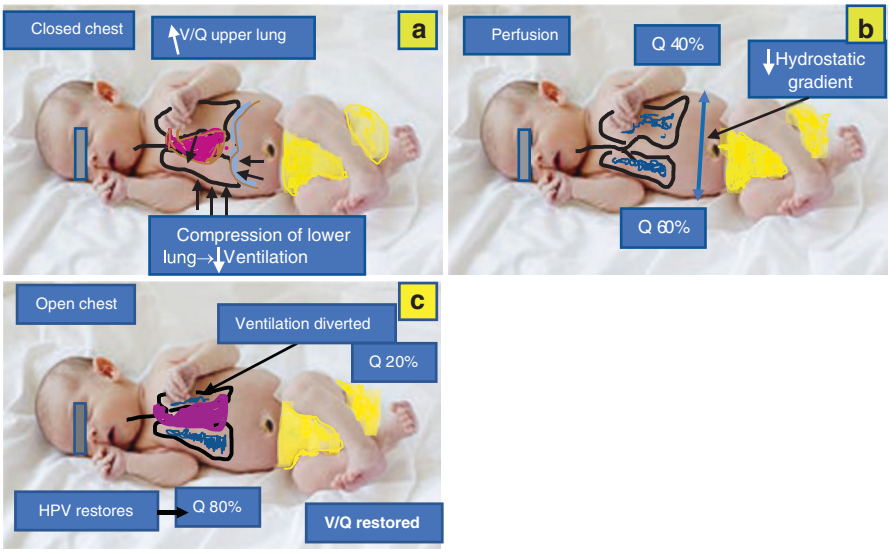

Fig. 30.1 V/Q changes in lateral decubitus position in a neonate: **a** and **b**, closed chest; **c**, open

30.3 Preoperative Evaluation [3, 4]

The goal of preoperative evaluation is (a) to identify potential anesthetic complications related to presence of comorbid conditions (cardiac /airway abnormalities), (b) to determine whether further diagnostic imaging/other laboratory investigations are required, and (c) to plan airway management. Many congenital malformations like TEF and CDH have significant association with congenital heart disease (CHD), with an odds ratio of 3.5 for 30-day mortality in presence of CHD. Conversely, babies with CHD have a high incidence of airway abnormalities. The neonate should be examined for facial features or dysmorphism suggestive of syndromes associated with difficult intubation. Respiratory symptoms (grunting, subcostal/suprasternal recession, alar flaring, sweating, inability to feed without interruption, sleeping in prone position) offer insight into severity of airway involvement and warrant planning of multiple management options. Other areas to be examined are status of hydration and suitability for vascular access.

If pertinent, history of prior airway management, venous access, and extubation should be obtained. Parental informed consent is very important, especially with reference to any additional risk, as in a neonate with anterior mediastinal mass.

Particular emphasis is on 4 aspects of anesthesia preparation:

1. **Induction of anesthesia**: routine, or with special preparations like rigid bronchoscopy?
2. **Airway management**: Does the procedure warrant lung isolation/OLV [equipment, skills]? Is the baby syndromic or having obstructive symptoms [difficult airway, video laryngoscopy]?
3. **Monitoring**: Will arterial blood gases (ABG) be necessary for management [arterial cannula placement]?
4. Is there likelihood of **major blood loss** [large bore vascular access]?
5. What would be the **analgesia plan**?

30.4 Fasting Guidelines and Premedication

Neonates can be breastfed 4 hours prior and administered clear fluids till 2 hours prior to the procedure. Premature babies and newborns within 48 hours of birth are prone to hypoglycemia and should receive 10% dextrose containing IV fluids.

Premedication generally includes airway nebulization /dexamethasone in neonates with hyperreactive airway, atropine/glycopyrrolate to dry secretions and prevent bradycardia (4).

30.4.1 Investigations

A preoperative echocardiogram and ECG should be carried out in all neonates with anomalies necessitating thoracotomy. A pediatric cardiac consultation is beneficial to plan hemodynamic goals in the perioperative period. CHD is associated with significant incidence of airway anomalies like subglottic stenosis and tracheal bronchus (bronchial variation arising from the trachea directed toward the upper lobe, usually arises within 2 cm of the carina, but can arise anywhere below the cricoid cartilage). An enlarged screening X-ray chest ("babygram") should be done and evaluated to confirm/exclude significant airway anomalies.

Hypoglycemia, hyponatremia, hypernatremia, hyperkalemia, hypocalcemia, and hypomagnesemia are all common in premature neonates and should be corrected. Anemic neonates may need preoperative blood transfusion. Low platelets and increased INR need prompt evaluation and correction. Packed RBCs and fresh-frozen plasma (FFP) should be arranged and available.

30.4.2 Blood Products and Vascular Access

In general, thoracic surgery in the neonate is not associated with significant blood loss. However, the proximity to large vascular structures and likelihood of inadvertent injury mandates blood to be crossmatched, as also for large masses with vascular supply. If the neonate does not have vascular access, blood can be drawn for cross-matching while placing the intravenous (IV) cannula after induction. The sites of possible vascular access should be examined. Plan should be made for a central line if venous access is poor or the neonate is likely to require prolonged postoperative fluid therapy and/or inotropes. Cannulation of the umbilical vein in the NICU is useful for perioperative IV fluid management. Vascular access sets should be kept ready.

30.4.3 Operation Room (OR) Preparation

Heat loss is a major concern in thoracotomies. The operation room should be warmed to 27°C before receiving the neonate. All exposed body parts should be covered with waterproof dressing ("cling wrap" or foil) or cotton wool. A warming mattress and forced air warming must be available. IV fluids and inspired gases should be humidified and warmed.

30.4.4 Induction of Anesthesia

In a neonate without hemodynamic instability or respiratory compromise, inhalational (sevoflurane, halothane) or intravenous (IV) induction with thiopentone/propofol can be safely performed. Helium can be added to the

inhaled mixture in babies with obstructive lesions (tracheal stenosis, mediastinal mass), to improve gas flow past the obstruction [4]. After checking for mask ventilation, neuromuscular blockade can be done and airway secured as per plan.

30.5 Airway Management for Thoracotomy

30.5.1 Indications for Lung Isolation and One-Lung Ventilation (OLV)

Airway management for thoracotomy should ensure accurate placement of ETT and provision of lung isolation and OLV if indicated and/or feasible. Lung isolation is not necessary for all thoracotomies. The small size of the neonatal trachea is the main limiting factor, which necessitates specially designed equipment that may be available only in specialized centers.

There are very few absolute indications for lung isolation and OLV in neonates, both to improve the surgical field but also to reduce the risk of lung barotrauma and pneumothorax. The indications are:

1. **Absolute Indications** [1, 5]
   (i) Congenital lobar emphysema,
   (ii) giant unilateral lung cyst, and
   (iii) VATS.
2. **Less Common Indications** [5, 6]
   (i) To protect soiling of healthy dependent lung by secretions, blood, bile,
   (ii) To divert ventilation away from airway leak (bronchopleural fistula), and
   (iii) For lung lavage in pulmonary alveolar proteinosis.

Even for VATS, the highly compliant rib cage allows CO_2 insufflation at the expense of low pressures. Surgical retraction of the lung further improves exposure, and OLV is not "mandatory." However, OLV is instrumental in successful completion of surgery by VATS and reduces the incidence of conversion to thoracotomy.

30.5.2 Techniques of OLV

1. **Single lung ventilation**: Endobronchial intubation of the nonoperated side
   a. Blind or
   b. FOB/fluoroscopy guided.
2. **Extraluminal (parallel) bronchial blocker (BB) placement,** and
3. **Marraro pediatric bilumen tube.**

The techniques, advantages, and disadvantages of all the three will be discussed briefly. Fiber-optic guidance for correct placement is mandatory as margin of error is low. Because of the tendency to desaturaxte in lateral decubitus position, rapid access to both lungs should be available.

30.6 Single Lung Ventilation (SLV) by Endobronchial Intubation

Advantages
- Useful for very small children
- The right bronchus can be intubated blindly
- Useful in emergency situations, such as contralateral pneumothorax

Disadvantages [6]
- Blockade of ETT by blood/secretions,
- Inadequate seal of intubated lung,
- Inadequate collapse of the operated nondependent lung,
- Risk of soiling of healthy lung,
- Inability to provide CPAP and/or suction to operated lung, and
- Blockade of right upper lobe bronchus during right mainstem bronchus intubation.

When choosing SLV, it is preferable to intubate the left mainstem bronchus as the upper lobe bronchus on the right side arises <1 cm from the carina; the take-off of the upper lobe bronchus on the left side is 3 times that of the right upper lobe bronchus, increasing the margin of safety. The diameter of the left main bronchus is smaller than the trachea, and ETT, ½ size smaller must be selected. Uncuffed tubes have a Murphy eye. Intubation of right main bronchus with an appropriately placed Murphy eye may help to ventilate the upper lobe bronchus. The left main bronchus may be intubated "blind" by rotating the level of the ETT 180°, and turning the neonates' head to the right while advancing the tube down (1). Left bronchial intubation can be performed over a fiber-optic bronchoscope (FOB) or using fluoroscopy.

30.6.1 Bronchial Blockers

These are balloon-tipped narrow lumen catheters which have to be placed under fiber-optic guidance. They may be placed alongside the ETT **(parallel placement)** or down the lumen of the ETT **(co-axial placement)**. The issues to be kept in mind are [5]:

(a) During co-axial placement, in order to permit **good ventilation**, the cross-sectional area of the bronchoscope (CSA_B) should be less than 50% of the cross-sectional area of the ETT lumen ($CSA_B/CSA_{ETT} < \mathbf{0.5}$).
(b) For a well-lubricated bronchoscope **to physically fit** inside the lumen of the ETT (and not get stuck due to friction), the outer diameter (OD) of the bronchoscope (OD_B) needs to be <90% of the internal diameter (ID) of the ETT (ID_{ETT}) [$OD_B/ID_{ETT} < \mathbf{0.9}$].

(c) The smallest FOB in general use (2 mm), which if placed inside a 2.5 mm ID tube, may give mobility (2/2.5 = 0.8), but is very unsatisfactory for ventilation.
(d) The blocker is placed in parallel outside the ETT. The combined OD of ETT + OD of blocker should be less than the tracheal diameter. The AP diameter of the neonatal trachea is 4.3 mm, and its lateral diameter 4.7 mm, which can tightly accommodate a 3.5 ID (4.8 mm OD) ETT with a 5 Fr BB (1.7 mm) (Fig. 30.2).
(e) The smallest ETT that can accommodate a 2.2 mm FOB and 5 Fr BB is 4.5 mm ID.

30.6.2 Varieties of Bronchial Blockers (Fig. 30.3)

1. **Vascular Catheters** - low volume, high inflation pressures (>700 cm H_2O with 2 ml air).
   a. Fogarty and
   b. Miller septostomy

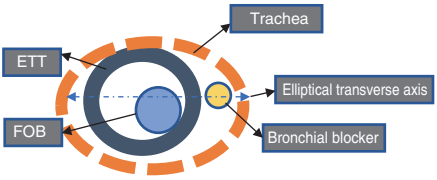

Fig. 30.2 Parallel technique of blocker placement [5]

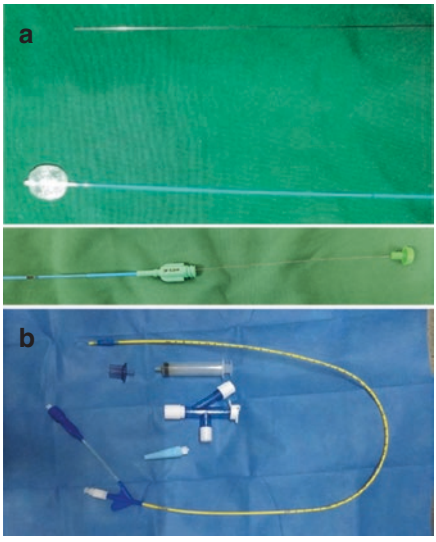

Fig. 30.3 Bronchial blockers: **a**. Fogarty 4 Fr; **b**. Arndt 5 Fr blocker with multiport adaptor

2. **High-Volume Low-Pressure Blocker**—(low pressure of 340–350 cm H_2O with 2 ml air).
   a. Arndt [7] and
   b. Fuji Uniblocker

Advantages
- Can transition from OLV to two-lung ventilation,
- Useful for very small children, and
- Useful in intubated/tracheostomized neonates.

Disadvantages
- High cuff pressure can cause bronchial mucosal damage,
- High chance of displacement with lung manipulation,
- Adequate lung isolation may not be achieved even with good blocker placement, and
- Significant hypercarbia common, even if oxygenation is maintained.

30.6.3 Technique of Placement of BB (Fig. 30.4)

1. Bronchial blockers may be placed extraluminally (parallel) through ETT guided into a mainstem bronchus, ETT removed, and another inserted into the trachea. This is the only available option for BB in children less than 2 years.
2. They may be classically placed using the loop approach as described for the Arndt blocker.
3. Templeton et al. [7] have described the bending of an Arndt blocker by 15°, introducing it into the trachea, then pass an ETT along it (using to advantage the larger transverse tracheal diameter), finally directing the blocker into position by FOB through the ETT.
4. Other innovative workers have done away with the multiport adaptor to give more flexibility to the apparatus [8].

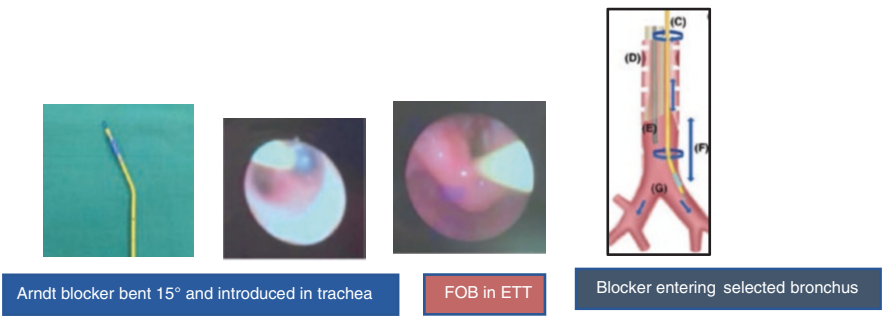

Fig. 30.4 Novel way of extraluminal blocker placement in a 9-day infant [7]

30.6.4 Marraro Bilumen Tube [9] (Fig. 30.5)

This tube was constructed from two uncuffed PVC tubes of different lengths attached laterally, with a radio-opaque line in 1994. The longer tube has a Murphy eye and is bent at 5° before the eye, which is useful for ventilating the right upper lobe when the longer tube is placed in the right main bronchus. Both tubes end in a lip shape facing outwards. There is no carinal hook. They can be connected to a single Y adaptor or to different circuits. Small sizes for newborns and neonates are available (Table 30.2).

It is placed under laryngoscopic view with both lumina antero-posteriorly oriented. After both cross the vocal cords, the tube is rotated 90° to the desired side. Confirmation is by clamping and auscultation or X-ray. The small lumen permits only 1.8 mm FOB.

Fig. 30.5 The Marraro Bilumen Tube [9] with Radio-Opaque Line (from Portex Brochure)

Table 30.2 Suggested sizes of Marraro Bilumen tubes [9]

Age	Caliber (mm)
Premature (1400–2500) g	2+2
Newborn (2500–4000) g	2.5+2 or 2.5+2.5
1 month	2.5+2.5
6 months	3+2.5
12 months	3.5+3

30.7 Pain Management for Thoracotomy

Neonates have immature neural development; pain pathways are poorly understood, and pain is generally unrecognized and untreated. Theoretically, adequate regional analgesia (RA) can avoid exposure to potential neurotoxic effects of general anesthetics and reduce surgical stress response. Inadequately treated pain may impact neurobehavioral impairment, emotional, behavioral, and learning disabilities [10].

Opioids as infusion or boluses (fentanyl 1 μg/kg/hr or 1 μg/kg bolus), or morphine 10 μg/kg/hr or 100 μg/kg bolus) are the mainstay of analgesia in neonates after thoracotomy. In neonates that have been extubated, caution must be exercised as they are at risk of respiratory depression. Paracetamol is an useful adjunct, and its dose should be limited to 7.5 mg/kg 6 hourly.

Epidural, paravertebral, and intercostal nerve blocks have all been used. Both neuraxial or fascial plane blocks (erector spinae plane) provide superior quality analgesia, reduce intraoperative inhalational anesthesia and opioid dose, and reduce or eliminate the need for postoperative ventilatory support [11–14].

30.7.1 Epidural Analgesia

Epidural analgesia in neonates is shown to be safe. It is associated with reduced need for both muscle relaxants and opioids and need for postoperative ventilatory support [11, 14].

Single bolus dose of bupivacaine has been described for neonates undergoing TEF surgery, which provided analgesia up to 8 h postoperatively. However, catheter-based techniques are more popular for providing extended postoperative analgesia.

A short skin-to-epidural space distance, soft ligamentum flavum, and narrow epidural space are characteristics of the neonatal epidural space. A minor leak of drug from the catheter insertion site may occur due to different calibers of the needle and catheter (19 G and 23 G), and the short skin-epidural distance. Higher technical challenge and sporadic reports of spinal cord damage and death warrant high levels of care and skill. Caudally introduced catheters are a better option for the novice anesthesiologist. A caudal block can produce adequate anesthesia up to the mid-thoracic region if an adequate volume and dose is given.

Thoracic catheters can be inserted through the caudal route in neonates owing to the nature of the epidural space. Although thought to be safer, it may be associated with more trauma, malposition and infection. Further, caudally threaded catheter migration occurs commonly in smallest and youngest patients, neonates, and infants, and postoperative imaging is crucial to confirm catheter tip location after its placement [15]. It is strongly recommended to use ultrasound guidance to track the catheter real-time during insertion, as a wide discrepancy between the actual length of catheter inside and the physical distance from the sacral hiatus to the desired vertebral level has been seen [16].

Bolus dosing and infusions have both been described, but risk of accumulation and resultant drug toxicity is higher with infusion, partly due to immature

Table 30.3 Doses of local anesthetics for neonates

Local anesthetic	Recommended dose	Issues
Bupivacaine	1 mg/kg	Commonly used for field blocks and wound infiltration
Ropivacaine	1.5 mg/kg	Less motor block less cardiotoxic Vasoconstrictor effect (avoid digital/penile blocks)
Lidocaine	2.5 mg/kg	Short acting
Prilocaine	Not recommended	Risk of methemoglobinemia
Chloroprocaine	7 mg/kg	No plasma accumulation due to short T 1/2
Eutectic mixture of LA (EMLA)	1g	Equal parts lidocaine and prilocaine Maximum skin contact—1 h Risk of methemoglobinemia

Table 30.4 Adjuncts for neuraxial block [13]

Drug/Route	Dose
Morphine—Caudal/epidural bolus	3–5 μg/kg
Fentanyl—Caudal/epidural bolus Epidural infusion	1.0–1.5 μg/kg 3–5 μg kg^{1} 24 h^{1}
Sufentanil—Epidural bolus Epidural infusion	0.6 μg/kg 2 μg kg^{1} 24 h^{1}
Clonidine—Caudal/epidural bolus Epidural infusion—limited data in < 12 mth age	1–2 μg/kg
Ketamine—Caudal bolus, racemic ketamine Caudal bolus, S (+) ketamine	0.25–0.5 mg/kg 0.5–1.0 mg/kg

metabolism and partly due to a more permeable blood-brain barrier (BBB). Ropivacaine 0.1–0.2% is the local anesthetic (LA) of choice with adjuncts (Tables 30.3 and 30.4). It is advisable not to run continuous epidural infusions of bupivacaine for more than 48 hours as there is a cumulative effect, resulting in local anesthetic systemic toxicity (LAST).

Intrathecal morphine—A dose of 3–5 μg/kg provides analgesia for 12–24 h.

30.7.2 Erector Spinae Plane Block (ESPB) [17, 18]

ESPB is performed under ultrasound guidance and has a good margin of safety because of its more superficial placement and greater distance from important structures (spinal cord, pleura). The catheter is placed congruent to the planned incision. In contrast to paravertebral or neuraxial blocks where coagulopathy is a contraindication, ESPB is safe and has been used in a preterm neonate undergoing TEF repair. The potential risk of a pneumothorax offsets its use for thoracotomy. However, it is effective and safe alternative to epidural and paravertebral catheters in neonates for thoracic procedures.

30.8 Special Surgical Conditions and Concerns

30.8.1 Congenital Cystic Adenomatoid Malformations (CCAM) [17, 19–22]

CCAM is a rare congenital anomaly with an incidence of 1:25,000 to 1:35,000 live births. It is the second most common congenital lung lesion, with a male preponderance, postulated to occur as a result of embryologic insult before the 7th week of gestation, which eventually leads to maldevelopment of the terminal bronchiolar structures. CCAM is also known as Congenital Pulmonary Airway Malformation (CPAM). It is classified (Stocker classification) on the basis of the cyst size (Type I: 2–10 cm; Type II: 0.5–2 cm; Type III: microcystic). In CPAM, an entire lobe of lung is replaced by a cystic abnormal lung tissue, which is nonfunctional.

CCAM can be diagnosed on antenatal ultrasound. In the case of large cysts causing fetal hydrops, serial aspirations or ultrasound-guided placement of thoracic-amniotic shunts can be helpful. Untreated large masses causing airway compression can lead to severe ventilatory compromise at birth, warranting immediate tracheal intubation. For such cases, it would be prudent to plan an ex utero intrapartum (EXIT) procedure so that the airway is secured while the neonate is still on placental support.

Large malformations result in ipsilateral lung compression, pulmonary hypoplasia, and occasional mediastinal shift. At birth, the majority are asymptomatic. About 25% of CPAM may present as respiratory distress, cyanosis, tachypnoea, and intercostal retractions. On examination, hyper-resonance at percussion, diminished vesicular murmur, and an asymmetrical thorax may be found. Associated (renal, intestinal, bony, cardiac) anomalies and malignancies may be present in up to 25% patients which worsen prognosis [19].

Features of severe respiratory distress (tachypnoea, hypoxemia, increased work of breathing) respiratory failure requiring ventilatory support, mediastinal shift and hypotension, are indications for urgent emergency thoracotomy for curative excision of the affected lobe (lobectomy).

Investigations: Chest X-ray and CT scan are mandatory investigations to delineate anatomy and precise location of the cystic lobe. Chest X-ray may show marked hyperlucency if the lesion is aerated and may be mistaken for a pneumothorax. Lesion may also appear as air-filled cysts or a consolidation. Large lesions with mediastinal shift will show depression or inversion of the diaphragm [19] (Fig. 30.6). Apart from confirming radiological, CT may reveal mediastinal shift, downward displacement of the diaphragm, compression atelectasis of surrounding lung tissue, and occasionally herniation of involved lobe across the mediastinum. It may also detect a narrowed bronchus of the affected or collapsed lobe. The left upper lobe is most commonly involved. Bronchoscopy may be indicated to rule out a foreign body or mucus plug. The association of CPAM with CHD is in 15-20% babies, and a 2D echo is indicated in babies presenting with murmur or failure to thrive.

Coagulation parameters and ABG help to guide preoperative optimization.

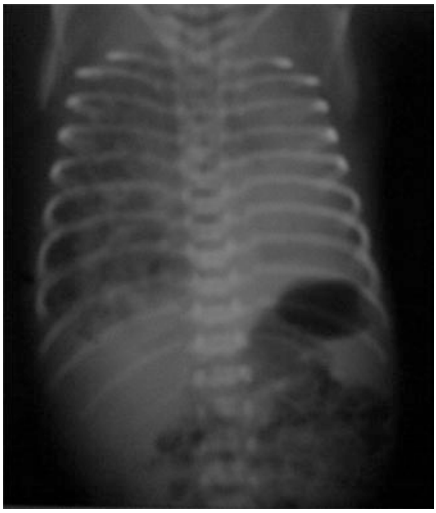

Fig. 30.6 Chest X-ray in CCAM (R)

Inhalational induction is slowed due to lung pathology and intrapulmonary shunting. IV induction with thiopentone, propofol, or ketamine is preferred. In case of large CPAMs and risk of rupture with positive pressure ventilation (PPV), spontaneous ventilation is best preserved with sevoflurane and IV fentanyl till the chest is opened and the malformed lobe allowed to prolapse out of the chest. PPV and PEEP may lead to cyst expansion and rupture, or cause compression of lung and mediastinal shift with possibility of pneumothorax and/or severe hemodynamic compromise and hypotension. Hence, ventilation should be gentle in these patients. Nitrous oxide should be completely avoided.

Provision of OLV has problems due to the small size of the airways. Often surgeons manage with retracting the functional lung. Lung isolation can be done using techniques as described above, such as parallel placement of a 3Fr Fogarty into the left mainstem bronchus for left lung isolation [21], balloon-tipped BB (extraluminal) (Fogarty catheters (3, 4, 5 Fr G), Arndt endobronchial blocker (smallest 5 Fr G)], (7) and Marraro DLT (9). Selective mainstem endobronchial intubation with a single ETT is not preferred because of the inability to suction the operated lung. However, in case of nonaerated lung, OLV is not mandatory.

There is potential for many intraoperative issues:

- Airway problems include hypoxemia due to lateral decubitus position and retraction of functional lung tissue.
- Cardiovascular events include hypotension resulting from aortic/IVC compression/bleeding.
- Trauma to adjoining structures and bleeding.

Thoracic /caudal epidural catheters and ultrasound-guided paravertebral blocks have all been used for analgesia [20–22]. If instituted after induction, these blocks

help limiting the inspired concentration of inhalational anesthetic and opioid dose. ESPB has also been used [17]. Short-acting opioids like fentanyl/remifentanil or paracetamol are used as a part of multimodal analgesia.

Pre- and post-ductal SpO2 monitoring is a must to detect cardiac shunting and desaturation. Invasive arterial monitoring is useful in large CPAM with risk of hemodynamic compromise and also for ABG monitoring. In addition to routine monitoring like temperature, ECG, and EtCO2, a precordial stethoscope is recommended for OLV.

Postoperative nasal CPAP/HFNC helps to maintain FRC and support gas exchange, thus reducing work of breathing. Effective postoperative analgesia is invaluable in facilitating breathing and early extubation [17].

30.8.2 Congenital Lobar Emphysema (CLE) [8, 23–29]

CLE or congenital lobar overinflation (CLO) is a rare condition with incidence of 1:20,000–1:30,000 births. The affected neonates may require lobectomy in early infancy. CLE accounts for 10% of all congenital lung malformations [24, 25] (Fig. 30.7). The association of CHD with CLE is significant (15–20%) [24]. Frequently, hypertensive or dilated pulmonary arteries with VSD or PDA are found in association with CLE. The most frequent site for emphysema is the left upper lobe followed by the right middle lobe. The bronchi of affected lobes are often compressed by dilated pulmonary vessels. Very often the neonate undergoes surgery for correction of the cardiac defect and CLE is discovered either during surgery or due to postoperative respiratory embarrassment. It is therefore important to evaluate the heart and airways thoroughly in the preoperative period, using whichever modality is relevant [contrast-enhanced computed tomography (CECT), MRI, or even cardiac catheterization in selected cases], to plan the operative procedure. CLE may improve with management of CHD, as in neonates who are symptomatic primarily because of enlarged pulmonary vessels, when symptoms of CLE may improve with

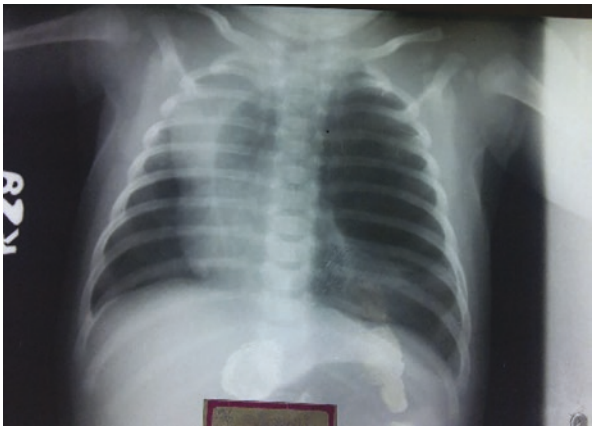

Fig. 30.7 Congenital lobar emphysema (L)

symptom control for CHD. Highly symptomatic neonates will benefit from early lobectomy.

Respiratory distress is the hallmark of CLE. It may have already been diagnosed antenatally. Symptoms worsen as the emphysematous lobe enlarges, with onset of cyanosis. It may be difficult to differentiate bronchopneumonia, cyanotic CHD, and other pulmonary abnormalities from CLE. Often, diagnosis of tension pneumothorax is made, with unfortunate insertion of chest tube, and worsening clinical condition [26].

Anesthetic management is on similar lines to CPAM. Anesthesia is induced with sevoflurane in 100% oxygen. Injudicious PPV during induction may result in expansion of the emphysematous lobe, with potentially disastrous consequences as compression of the surrounding normal lung, mediastinal shift, pneumothorax, and cardiac arrest. Occasional gentle assistance with minimum airway pressures is sometimes used. Nitrous oxide is avoided in all cases.

CLE is one of the few conditions mandating OLV, for preventing expansion of the cyst and consequent rupture and pneumothorax, but also to provide optimal conditions for VATS. OLV is generally established with an end-hole bronchial blocker like the Arndt blocker, to facilitate collapse of the operated lobe. Schmidt et. al. [8] have described co-axial placement of a 5 Fr Arndt blocker through a 4.0 mm ID ETT. Jacob et.al [27]. have described successful left endobronchial intubation with spontaneous ventilation using sevoflurane, passing a Fogarty down the ETT, then removing the ETT and intubating the right bronchus with another ETT.

Caudal epidural catheters have been used for analgesia in neonates with CLE, retaining spontaneous ventilation until thoracotomy to allow the cyst to extrude [24]. Thoracic epidural has been used for postoperative analgesia [28, 29].

30.8.3 Congenital Broncho-Biliary Fistula (CBBF) [30]

CBBF is a rare anomaly, characterized by very high mortality. It occurs consequent to an abnormal fistulous connection between the segmental bronchus (usually the right side) and the biliary tree. These neonates develop choking and respiratory distress with intermittent cyanosis soon after birth. Copious greenish secretions are vomited and also suctioned from the ETT. 3-D CT reveals the fistulous connection originating from the bronchus (usually right) and terminating in the biliary tract. Concomitant findings are air in the intrahepatic biliary tract and lower lobe pneumonia.

As part of preoperative preparation, these neonates are kept fasting, with gastric decompression and IV fluids. Antibiotics are administered as per protocol. Head-elevated position and CPAP reduce respiratory distress and promote secretions to localize in the dependent lobe. Parenteral nutrition and sedation are initiated depending on the duration of preoperative waiting.

Induction can be through inhalational or IV route. Since these fistulae are distal to the carina, there is no danger of distending the stomach, unlike in TEF, and

neuromuscular blockade and mask ventilation can be carried out to facilitate atraumatic intubation.

Intraoperative issues relate mainly to poor lung compliance and hypoxemia. An arterial cannula is helpful to monitor ABG and guide ventilation. The fistula is localized and ligated through thoracoscopy if the infant is able to tolerate the CO_2 insufflation, or by thoracotomy.

As highlighted previously, good analgesia should be provided as described above. Recovery is usually good after a brief period of elective postoperative ventilation.

30.9 Conclusion

Thoracic anesthesia in neonates requires careful preoperative evaluation with reference to additional systemic disorders, airway evaluation and planning, and an effective analgesia plan. With advent of thoracoscopy, more neonates will be subjected to this technique, highlighting the concerns of OLV. All regular pediatric anesthesiologists should train themselves in at least one technique of lung isolation and be well versed with neonatal fiber-optic bronchoscopy. Advances in antenatal care and fetal surgery will also result in survival of more babies, where indicated. Anesthesiologists should be facile with a variety of regional anesthetic techniques which can immensely contribute to a good postoperative outcome.

Declaration I hereby declare that all clinical photographs and X-ray images are my personal ones and not copied from any site.

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