Physical Therapy for Neonates with Respiratory Dysfunction

LINDA CRANE, MMS

Chest physical therapy for neonates with pulmonary dysfunction is a growing specialty of physical therapy practice. The purpose of this article is to provide physical therapists current information regarding chest physical therapy for the newborn infant. The neonatal diagnoses for which chest physical therapy is useful or has good rationale are discussed. Common complications are reviewed that affect physical therapy and medical treatment for infants with respiratory diseases and prematurity. Specific indications, contraindications, and precautions for physical therapy techniques are listed. Chest physical therapy evaluation and treatment are described and rationale for the application of various techniques is provided. Literature is reviewed dealing with the effects of chest physical therapy on neonates with pulmonary dysfunction. The strengths and weaknesses of each reviewed study are analyzed and suggestions for direction of future research for physical therapists are provided.

Key Words: Infant, newborn; Pulmonary disorders; Respiratory therapy; Physical therapy.

As the quality of care provided to perinatal patients improves, an increasing number of high risk newborns survive the neonatal period. Optimal treatment of the high risk neonate requires a high level of care by a well-trained health care team. The extent of physical therapy involvement depends upon the willingness of physical therapists to recognize their role in the neonatal intensive care unit (NICU).

Chest physical therapy (CPT) for neonates is under as much scrutiny as the therapy is for other groups of patients. The “state of the art” is incomplete and distorted because of a lack of accurate and relevant research. Pringle, Kaminski, and Raymond reported that approximately 59 percent of physical therapists who responded to their survey did not evaluate or treat infants under three months of age for pulmonary or other problems. Yet, CPT is often described as part of the routine care of neonates with respiratory problems. The purpose of this article is to provide information and direction for physical therapists interested in the CPT component of neonatal care.

Chest physical therapy in this article refers to the bronchial drainage techniques of positioning, percussion, vibration, and airway suctioning. Choice and modification of the techniques are based on specific indications and contraindications at any given point in time for each individual infant. Additional techniques usually considered part of CPT—breathing exercises and pulmonary rehabilitation—do not apply to newborn infants.

ANATOMIC AND PHYSIOLOGIC DIFFERENCES

Several structural and functional differences from older children and adults make neonates more vulnerable to respiratory distress. A newborn has a high larynx enabling the epiglottis to guide the larynx up behind the soft palate to produce a direct airway from the nasal cavity to the lungs. Newborns are, therefore, obligate nose breathers who can almost simultaneously breathe and swallow until two to three months of age. A newborn infant’s ribs are positioned horizontally, and the intercostal muscles are weak, resulting in a predominantly abdominal (diaphragmatic) pattern of breathing.

A neonate’s lungs are less compliant, but his chest wall is more compliant than that of an adult. This difference can lead to an increase in both airway resistance and obstruction. The narrow diameter of the infant’s airway and a weak or absent cough reflex can also lead to airway obstruction. The newborn or premature infant is highly susceptible to diaphragm fatigue and compensates for respiratory difficulty by increasing the rate rather than the depth of ventilation. All the above factors, although normal for a neonate, contribute to respiratory distress and possible respiratory failure.
DISEASES

Chest physical therapy should not be prescribed merely in association with a diagnosis, but for any situation that might interfere with a neonate’s ventilation, airway clearance, or work of breathing. Several diseases and conditions of the neonate, especially the premature neonate, may decrease airway clearance and ventilation, or may increase the work of breathing. When the above problems are expected or anticipated in association with a specific disease, prophylactic use of CPT may be indicated. Some major diseases and conditions of the neonate in which CPT is indicated are described below.

Idiopathic respiratory distress syndrome (IRDS—hyaline membrane disease), the most common cause of respiratory distress in the newborn, is related to insufficient levels of surfactant in the lung.1 Idiopathic respiratory distress syndrome is most often associated with prematurity, Caesarean section delivery, maternal diabetes, perinatal asphyxia and shock, and the second born of twins. Symptoms usually appear within 2 to 3 hours after birth with progressive deterioration occurring within 24 to 48 hours.13 Prominent clinical signs include increased respiratory rate, expiratory grunting, intercostal and sternal retractions, nasal flaring, and a seesaw pattern of ventilation between the chest wall and abdomen.14 Most mortalities from IRDS occur within 72 hours after birth and recoveries begin after 72 hours.13 The major pathophysiologic manifestation of IRDS is hypoxemia resulting from perfusion of atelectatic air spaces.15

Medical treatment of infants with IRDS is supportive and generally includes oxygen therapy, thermal regulation, humidification, nutrition, and assisted ventilation using some type of continuous distending airway pressure (CDAP).13 If mechanically assisted ventilation is required, generally the course of the disease is prolonged and severe and the incidence of complications increases. Common pulmonary complications secondary to intubation, mechanical ventilation, and oxygen administration include oxygen toxicity, bronchopulmonary dysplasia, pneumothorax, pneumonia, sepsis, increased mucous production, mucous plugging, and residual pulmonary disease.9,16-18

Chest physical therapy for infants with IRDS is directed toward prevention of complications that affect airway clearance. Bronchial drainage techniques are begun when signs of atelectasis, infiltrate, or uncontrolled secretions are noted clinically or by radiographs.

Meconium aspiration syndrome (MAS) results from aspiration by the fetus or neonate of meconium-stained amniotic fluid.19 The syndrome occurs most frequently in full-term, postmature, and intrauterine growth-retarded infants.3 Passage of meconium by the fetus is the result of intrauterine distress, usually hypoxia, which also stimulates deep gasping and subsequent aspiration of meconium stained amniotic fluid. The severity of the syndrome depends on the amount of meconium that enters the lungs.19 Respiratory distress usually develops within 12 to 24 hours after birth. Tachypnea is the most prominent sign of respiratory distress.3 Many infants are neurologically depressed at birth and have low Apgar scores due to fetal asphyxia.2 Infants with MAS have hyperinflation of the lungs with a characteristic barrel-chested appearance. Bronchiolitis, pneumonitis, cor pulmonale, atelectasis, air leaks, and persistent fetal circulation are possible complications of MAS.19 Most infants with MAS who survive recover within 7 to 10 days.

Medical treatment is largely supportive. Prompt suctioning, under direct view, of the pharynx and trachea immediately after delivery may be preventive.20 Antibiotic therapy, assisted ventilation with positive end expiratory pressure (PEEP), and supplemental oxygen are often used.19 Close monitoring for signs of pneumothoraces is essential.

Types of CPT include immediate positioning, percussion, vibration, and suctioning. Bronchial drainage techniques should be continued until the secretions are free from meconium. Therapy may need to continue for several days to ensure optimal clearance of airway and to help prevent secondary lower respiratory tract infection.

Bronchopulmonary dysplasia (BPD) is a chronic lung disease often preceded by an acute respiratory problem, high concentrations of inspired oxygen, positive pressure ventilation, and pulmonary interstitial emphysema.21 The disease progresses from an acute stage (similar to IRDS) in the first three days to a chronic phase with atelectasis, emphysema, and cystic formations in the lung after one month.21 Ironically, though oxygen therapy may be an etiologic factor, the requirement for supplemental oxygen increases as the disease progresses and a vicious cycle is established. Morbidity and mortality rates are very high in BPD, but the lesions may be reversible if the infant can be protected from complications and provided with sufficient time to grow new lung tissue.3

Prevention is the hallmark of medical care for BPD. If prolonged ventilation and oxygenation are required, CDAP, reversing the inspiratory to expiratory ratio, ventilating with low peak pressures, and PEEP may retard the progression of BPD. Frequent bronchial drainage is beneficial in treating infants with BPD.5,21

Surgery on the chest and upper abdomen increases the patient’s risk of developing pulmonary complications. Neonates who have undergone surgical repair for abnormalities including, but not limited to, dia-
phragnostic hernia, esophageal atresia, and tracheo-
esophageal fistula often require CPT.23

Neonatal pneumonia should be considered in the differential diagnosis for any neonate with respiratory distress.5 Pneumonia may develop at any point in the neonatal period. Conditions that increase the neonate's risk of developing pneumonia include: 1) premature rupture of the membranes, 2) intrauterine asphyxia, 3) prematurity, 4) intubation and mechanical ventilation, and 5) thoracic or upper abdominal surgery with general anesthesia. Clinical symptoms of pneumonia in a neonate resemble those of IRDS.24 The most common organism responsible for neonatal pneumonia is β-hemolytic streptococcus (group B), followed in frequency by Listeria monocytogenes, toxoplasmosis, cytomegalic virus, respiratory syncytial virus, Streptococcus pneumoniae, Streptococcus bovis, and haemophilus influenzae.3 Broad spectrum antibiotics are used to treat neonatal pneumonia. Preventive measures include routine cultures, strict aseptic airway management, and antibiotic prophylaxis.3 The value of bronchial drainage techniques has been questioned in treating patients with uncomplicated lobar pneumonia.25 However, the author and others believe that CPT is beneficial in patients with pneumonia and compromised airway clearance, especially in the last clearing-up stages of the infectious process.26

COMPLICATIONS

Some complications of infant respiratory diseases, syndromes, and their treatments that may affect CPT are 1) airleaks—pneumothorax, pneumomediastinum, pneumopericardium, 2) osteoporosis and rickets, 3) patent ductus arteriosus and congestive heart failure, 4) persistent fetal circulation, 5) tracheal and bronchial stenosis, 6) intracranial hemorrhage, and 7) apnea and bradycardia. (Two common complications—BPD and pneumonia—have been discussed previously.) The complications listed above require the physical therapist to reassess the treatment techniques used with the affected infant. Close monitoring and modifications in treatment, as described below, are necessary when these complications occur.

Pneumothorax, pneumomediastinum, and pneumopericardium are the three most common results of alveolar air leaks. Pneumopericardium usually occurs in association with pneumothorax and pneumomediastinum and may produce cardiac tamponade. Pneumomediastinum is often benign and requires no special therapy.3 Pneumothorax is the result of an alveolar rupture into the pleural space. This rupture may cause a localized collection of air, or may increase pressure within the intrapleural space, which results in decreased cardiac output, mediastinal shift, and severe respiratory distress.

Pneumothorax may be identified by a combination of clinical signs: irritability, cyanosis, tachypnea, rib cage retractions, nasal flaring, thoracic hyperresonance, abnormal chest radiograph, transillumination, shifted cardiac impulse, or a deviation of the trachea within the sternal notch.3 Breath sounds may be distant or absent on the affected hemithorax; however, sounds are easily transmitted throughout the chest of an infant so this is not a reliable sign. Treatment of a large pneumothorax requires insertion of a chest tube attached to an underwater seal.3 A pneumothorax or other form of air leak is not a contraindication for CPT. The presence of a chest tube may, however, necessitate the use of vibration rather than percussion during bronchial drainage to adjacent bronchopulmonary segments.

Osteoporosis and rickets result when calcium, phosphorus, and vitamin D and vitamin C requirements are not met. Hypocalcemia, hypophosphatemia, and vitamin deficiency syndromes are not uncommon in infants who cannot be fed orally because of immaturity or respiratory distress.5 With these nutritional deficits, the bones are demineralized and more likely to fracture. When either osteoporosis or rickets is present, the fragility of the chest wall may contraindicate use of percussion during bronchial drainage.

A. Clinical signs indicating problems with airway clearance
   1. Rales and rhonchi on auscultation
   2. Infiltrates or atelectatic areas on chest roentgenogram, or both
   3. Palpable crackles (rhonchol fremitus)
   4. Audible crackles without stethoscope
   5. Increased volume, viscosity, or purulence of secretions suctioned
   6. Apnea and bradycardia that do not respond to stimulation or increased FiO2
B. Clinical signs indicating problems with ventilation
   1. Decreased or bronchial breath sounds on auscultation
   2. Areas of atelectasis on chest roentgenogram
   3. Signs of respiratory distress
   4. Depressed CNS function
   5. Recent abdominal or thoracic incision
C. "Situations" that may affect airway clearance, ventilation, or work of breathing
   1. Endotracheal intubation
   2. Tracheostomy
   3. Mechanical ventilation
   4. Oxygenation >50%
   5. Restriction of positioning due to restraints, type of assisted ventilation such as nasal CDAP
   6. Hypothermia

Fig. 1. Criteria for chest physical therapy in neonates. One or more of these criteria should be present before initiating treatment.

PHYSICAL THERAPY
TABLE 1

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trendelenburg’s Position</th>
<th>Prone Position</th>
<th>Percussion</th>
<th>Vibration</th>
<th>Endotracheal Suctioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute CHF</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rib fracture</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal CDAP</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent tracheo-esophageal fistula repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(deep)</td>
</tr>
<tr>
<td>Recent eye or intracranial surgery</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemothysis</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated tension pneumothorax</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intracranial hemorrhage</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

 Patent ductus arteriosus (PDA) may be present and persistent at birth or may occur in response to hypoxemia. Shunting through the PDA may be in a right-to-left or left-to-right direction. This shunting of blood may exacerbate poor lung compliance by increasing pulmonary blood flow or by causing congestive heart failure (CHF). When CHF is present, the Trendelenburg’s position may be poorly tolerated.

Persistent fetal circulation (pulmonary hypertension of the newborn) is associated with 1) acute pulmonary vasoconstriction secondary to hypoxia, acidemia, or increased blood viscosity; 2) increased pulmonary vascular smooth muscle development secondary to chronic hypoxia, fetal pulmonary artery hypertension, or specific congenital heart lesions; and 3) decreased cross-section area of the pulmonary vascular bed secondary to congenital hypoplasia or impaired lung growth. The result of persistent fetal circulation is right-to-left shunting of blood through the PDA and foramen ovale. The shunt causes venous admixture and greater hypoxemia. These infants are hemodynamically unstable until the pulmonary vascular resistance can be decreased. Infants with persistent fetal circulation may not tolerate CPT well or at all. They must be constantly monitored if treatment is begun.

Tracheal and bronchial stenoses are produced by trauma, granulation tissue, and fibrosis secondary to prolonged endotracheal (ET) intubation and repeated ET suctioning in neonates. The type of suction catheter and suction techniques used are critically important in delaying or preventing stenosis and subsequent lobar atelectasis. Tracheostomy may be an alternative to prolonged ET intubation, but this approach is controversial.

Intracranial hemorrhage (ICH) is most common in premature infants with respiratory distress. Coagulopathy and hemorrhage are complications in very small premature infants. These problems can lead to decreased hematocrit levels, bruising, and ICH. Great care must be taken to rule out ICH before placing a small premature infant in Trendelenburg’s position. Coagulation status must be normal before administering a manual bronchial drainage technique, such as percussion.

Apnea and bradycardia are common in premature infants. Bradycardia often occurs if apnea persists for more than 30 seconds. Apnea and periodic breathing may be caused by poor central respiratory drive or mechanical difficulties in the lungs. Apnea may also be secondary to hypothermia or hyperthermia, airway obstruction, vasovagal response to feeding or ET suctioning, sepsis, ICH, IRDS, hypoglycemia, and hypocapnea. Mild apnea may be stopped by physically stimulating the infant. Severe apnea and bradycardia require assisted ventilation with an inspired oxygen concentration (FIO2) of 100 percent and ET suctioning to clear an obstructed airway.

Small and premature infants have a higher oxygen cost of breathing when compared with larger mature infants. Work of breathing increases with respiratory distress. The net effect of increased work of breathing in small, sick neonates is hypoxemia. Any manipulation of the infant, including routine procedures, such as changing diapers, feeding, or auscultation of the chest, may result in further drops in arterial oxygen tension.

INDICATIONS FOR CPT

Specific indications for CPT intervention in an NICU should be present before any treatment is begun whether treatment is directed toward solving an existing problem or preventing a potential problem. For the neonate, CPT focuses on assisting airway clearance, improving ventilation, and decreasing work of breathing. One or more of the criteria listed in Figure 1 should be present before initiating treatment.

CONTRAINDICATIONS AND PRECAUTIONS

While there are few absolute contraindications for CPT (Tab. 1), there are many situations in which necessary precautions affect the therapist’s assessment and treatment. The benefits of CPT must be weighed carefully against the potential risks incurred by spe-
cific techniques, and the infant’s response to treatment must be carefully monitored at all times.

CHEST PHYSICAL THERAPY EVALUATION

Evaluation of the neonate with, or at risk for, pulmonary dysfunction should include review of the medical records, observation, auscultation, palpation, and review of current reports from the physician and nurse.

Review of the medical records should include the hospital chart, bedside flow sheets, arterial blood gas reports, chest radiograph reports, and any information pertinent to the infant.

Observation includes the following:
1) Signs of respiratory distress—intercostal and substernal retractions, nasal flaring, tachypnea or apnea, expiratory grunting, cyanosis or pallor, seesaw motion between the abdomen and chest wall, or head bobbing.
2) Skin condition—observe for such signs as breakdown, bruising, or incisions.
3) Vital signs—compare against expected normal standards
   • Heart rate (120 to 140 bpm with a beat-to-beat variation).
   • Respiratory rate (about 40 breaths a minute and irregular).
   • Blood pressure (systolic 80 ± 16 and diastolic 46 ± 16).
4) Posture and muscle tone—flexion should predominate.
5) Behavior—can range from eyes closed with regular respirations and no movement to eyes open, crying, and gross movement.
6) Temperature—the isolettes or warming beds have a servo-controlled mechanism to regulate the infant’s temperature within the neutral thermal temperature zone (32-35°C).

Auscultation of the chest of a neonate, especially a premature infant, may not indicate localized changes in lung segments. Rapid respiratory rate, small tidal volume, thin chest wall, and ventilator noise are some factors that complicate auscultation for breath sounds and adventitious sounds. A gross assessment can be made and auscultation is still a vital component of the chest evaluation.

Palpation of the chest may reveal edema, subcutaneous emphysema, palpable crackles or wheezes, position of trachea in suprasternal notch (position of mediastinum), or rib fractures.

A verbal or written report from the infant’s physician or nurse may provide the most current information regarding the condition of the infant.

The physical therapist should also note the FIO₂, type of equipment (such as oxyhood, pressure ventilator, nasal CDAP), and mode of administration of ventilation (such as intermittent mandatory ventilation, assisted, controlled, PEEP).

CHEST PHYSICAL THERAPY

Chest physical therapy techniques for neonates with pulmonary dysfunction include bronchial drainage (positioning, percussion, and vibration) and ET suctioning. Positioning for bronchial drainage uses the effect of gravity to move secretions from distal airways to larger, more central airways. Manual percussion and vibration of the chest wall are techniques to augment the movement of secretions within the airways. Positioning alone for drainage may require up to 30 minutes a position to be effective. With the addition of percussion or vibration, the time for each position is decreased to 3 to 5 minutes. If an infant’s tolerance to CPT techniques is low, treating fewer lung areas a session is recommended rather than shortening the time for each position. Adequate time is especially important when attempting to clear se-

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trendelenburg’s Position</th>
<th>Prone Position</th>
<th>Percussion</th>
<th>Vibration</th>
<th>Suctioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fragment skin (eg, sores, bruising)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic (treated) CHF</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of chest tube</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoporosis/Rickets</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent fetal circulation</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Hyperactive airways</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyperactive gag</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent thoracic or abdominal surgery</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac arrhythmias</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apnea and bradycardia</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Severe respiratory failure</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child who cries and acts irritated</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(continuously) during procedure</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcutaneous emphysema of head and neck</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
cretions from the narrow diameter airways of the neonate.

**Positioning**

Bronchial drainage (BD) may be used for neonates whether the positions for drainage are classical or modified. Contraindications and precautions for tilting a newborn into a head-down position are included in Tables 1 and 2. When a specific lung, lobe, or segment is treated, the position used should be as close to the classical drainage position as possible to be most effective. Neonates being mechanically ventilated and those with umbilical artery catheters may be placed prone. A chest tube may necessitate modification of the prone position to semiprone. Infants receiving nasal CDAP may not be positioned prone, and sidelying is often difficult also. A neonate in the Trendelenburg’s position should never be left unattended.

**Percussion**

Manual chest percussion using the full hand, heel of the hand, or three to five tented fingers may be applied, when appropriate, to even the smallest infant. Several other methods of chest percussion requiring adapted equipment are also used. Examples of equipment are infant anesthesia masks, padded nursing nipples, padded medicine cups, and a nipple in a test tube (Figs. 2a and 2b). Regardless of the method used for chest percussion, the important technical considerations are maximizing control, enlarging the surface area to absorb the blow, and maintaining the cupping effect. Chest percussion is administered with motion primarily from the wrist, with firm support applied to the side of the thorax opposite that being percussed. Chest percussion should always be done with a thin blanket or towel covering the area being treated.

Percussion is well tolerated by most infants, but several contraindications and precautionary situations (Tabs. 1, 2) may necessitate using vibration in lieu of percussion.

**Vibration**

Vibration of the chest is done manually by placing the fingers on the chest wall over the segment being drained and isometrically contracting the muscles of the forearm and hand to cause a vibratory motion. Excessive pressure against the chest wall should be avoided. When possible, vibration should be timed with the expiratory phase of respiration, although this is often impractical with the high respiratory rate of the newborn. Vibration can be generated mechanically using a variety of implements. One of the most common vibrators is a padded electric toothbrush. When any electric motor is used near high concentrations of oxygen, as in an isolette, extreme caution must be taken to avoid the hazards of explosion or fire. Both percussion and vibration are often used together with positioning for bronchial drainage when neither technique is contraindicated.

**Endotracheal Suctioning**

Suctioning is always a potentially dangerous procedure. Endotracheal suctioning should be done only when needed—after bronchial drainage, when secretions are audibly bubbling within the ET tube or tracheostomy tube, when congestion is evident in the upper airway as noted by auscultation and palpation over the trachea, and during apnea and bradycardia unresponsive to physical stimulation and increased oxygen intake. All equipment should be set up and ready for use prior to initiating a CPT treatment in case an immediate need for suctioning occurs. A suggested procedure for suctioning is shown in Figure 3. This procedure, developed to minimize the hazards of ET suctioning, is based on a review of the literature and clinical experience.

**Monitoring**

Vital signs and clinical signs should be continually monitored during treatment. Transcutaneous oxygen (TcPO₂) should be measured, when possible, to monitor the infant’s response to treatment and to provide
a warning of deterioration. The values for TCPO₂ correlate with values for Pao₂ unless peripheral blood flow is decreased, for instance in shock. Transcutaneous carbon dioxide and pH monitors are also proving to be reliable, simple, noninvasive monitors that are invaluable in a NICU.

REVIEW OF LITERATURE: EFFECTS OF CPT IN NEONATES

Positioning for Bronchial Drainage

About three to five days after birth, newborn infants exhibit changes in heart rate and blood pressure values with position change similar to those seen in adults. Moss and associates concluded that vaso-motor regulatory mechanisms are intact in premature and full term infants at birth. A study comparing four different combinations of CPT techniques found slightly higher systolic blood pressure in infants treated in the head down position. In that study, neither heart rate nor blood pressure increased beyond normal ranges.

The effects on arterial blood gases of sidelying or head down positioning may be significant in neonates. Finer and Boyd found no significant difference in Pao₂ 5 minutes before and 15 minutes after 20 minutes in the Trendelenburg’s position in prone and supine. Crane and associates found no significant difference in TCPO₂ between two groups who were treated in the Trendelenburg’s position (20-30°) and two groups who were treated with the bed flat. Neither study included infants with unilateral lung disease. Zack and co-workers, however, found that position may have an effect on blood gas values in acutely ill patients with specific unilateral lung involvement. If arterial oxygen is low prior to treatment, the effects of positioning on oxygenation may necessitate compensatory measures.

Mellins stated that changing body position, as in bronchial drainage, may significantly affect the distending pressure of the lung, and hence adversely affect the lung volume. He noted that functional residual capacity is greatest in the prone position, reduced in supine, and lowest in a head-down position. Therefore, transpulmonary pressure, which will affect lung volumes, will vary depending upon position. Menkes and Brit, however, stated that position changes with bronchial drainage may improve the ventilation-to-perfusion relationship in obstructed areas of the lungs.

No other studies of CPT in neonates have based comparisons on positioning. Some studies do not mention the drainage positions employed.

Percussion and Vibration

All studies that have examined the effects of CPT on neonates use some method of percussion or vibration as a major component of the treatment. It is difficult to compare the results of these studies because the treatment was administered differently in each.

In most studies evaluating the effect of CPT on Pao₂ or TCPO₂ chest percussion was manually applied. Two studies combined percussion and vibration over each lung area drained. Holloway and associates reported a drop in Pao₂ and PacO₂ and a wider alveolar-arterial (A-a) oxygen gradient after CPT and suctioning. The suction procedure used did not include hyperventilation and hyperoxygenation. Once hyperventilation was provided, after suctioning, Pao₂ returned to the pretreatment level.

Raval and associates found a significant decrease in TCPO₂ in seven infants who received CPT, three different methods of ventilatory assistance, and ET suctioning. The CPT consisted of percussion and vibration for one minute with the infant in a head-up position and an additional minute in the head-down position. Endotracheal suctioning was done after the...
bronchial drainage. All subjects were intubated and mechanically ventilated. The \( \text{TcPO}_2 \) dropped to a mean of 65 ± 4.5 mmHg and returned to base-line within four minutes. Increasing the \( \text{FiO}_2 \) 10 percent above that being delivered by intermittent mandatory ventilation, plus hyperventilating the infant, resulted in no mean drop in \( \text{TcPO}_2 \). Hyperventilation of the infants with 100 percent oxygen resulted in hyperoxemia.

In their investigation of the effects of CPT on the weight of secretions removed by suctioning, Etches and Scott used a combination of percussion and vibration.\(^{33}\) They reported a significant improvement in \( \text{Pao}_2 \) for the group receiving bronchial drainage with percussion. Because the final arterial blood gas sample was taken only 15 minutes after treatment, long-term effects of treatment were not evaluated.

Curran and Kachoyeanos compared using a padded nipple for the percussion method with mechanical vibration using an electric toothbrush.\(^{38}\) They found significantly higher \( \text{Pao}_2 \), better color, and clearer breath sounds in two infants who received vibration with the electric toothbrush than in two who received percussion with a padded nipple and two who received no CPT. The small number of subjects, however, makes the results of this study questionable.

Vibration was the only manual technique used in two studies that evaluated the effects of CPT in neonates. Fox and associates used a mechanical vibrator for 30 seconds over the anterior chest wall of infants in the supine position.\(^{36}\) Before the vibration, CDAP and supplemental oxygen were disconnected and 1.0 cc of saline was instilled into the trachea. The \( \text{Pao}_2 \), \( \text{PaCO}_2 \), \( \text{pH} \), airways resistance, lung compliance, and functional residual capacity were measured before and after treatment. A decrease in \( \text{Pao}_2 \) immediately following vibration and suctioning was noted. Hyperventilation of the neonates was postponed until after the posttreatment measurements, and, as in other studies, the \( \text{Pao}_2 \) returned to pretreatment range after hyperventilation. Airways resistance during expiration was decreased after CPT and suctioning but the \( \text{PaCO}_2 \), \( \text{pH} \), lung compliance, and functional residual capacity did not change significantly.

Finer and colleagues compared “routine” CPT—five minutes of vibration over the lung segment being drained—with no CPT.\(^{37}\) Subjects included neonates who had been intubated for 24 hours or more. The incidence of postextubation atelectasis was noted based upon chest radiograph evaluation. The group that received CPT had a significantly lower incidence of postextubation atelectasis and reintubation. The 42 subjects in this prospective study are a larger sample than in any other study reviewed here.

**DISCUSSION**

The results of the studies described were as varied as the techniques used, dependent variables measured, and points at which they were measured. Major problems in determining the effects of CPT in neonates include:

1) lack of well-controlled studies
2) small number of subjects studied
3) differences in CPT techniques
4) lack of consensus on variables that indicate either effectiveness or safety
5) difficulty in studying a homogeneous group of subjects because of the many complications occurring in acutely ill neonates
6) disparity in experimental designs regarding the time at which dependent variables are measured
7) difficulty in measuring pulmonary function without highly technical or invasive procedures

Although these problems are not all unique to infants, they seem especially apparent in studies related to neonatal CPT.

**DIRECTIONS FOR FUTURE RESEARCH**

Although CPT for neonates appears to be beneficial, well-designed and carefully controlled studies of larger numbers of infants are needed to justify fully and validate our treatments. Physical therapists, respiratory therapists, and nurses who deliver neonatal care must increase their efforts to develop and document safe, effective techniques for treating these unique infants.

Accurate, workable operational definitions of CPT must be established. Strict definitions would not preclude comparing differing techniques, but would clarify what methods were used in treatment. Standard definitions would also provide direction to researchers not routinely involved in neonatal care. Research measuring the effects of CPT in neonates should include ET suctioning with hyperventilation and hyperoxygenation as part of the treatment. This stand-
ardization will avoid biased results caused by different combinations of techniques used as treatment. Continuous monitoring of physiologic values may also help to eliminate the bias caused by collecting data on varied techniques and in different sequences.

Research in neonatal CPT requires larger numbers of subjects to improve the validity of studies. The diagnoses, stage of disease, gestational age at birth, and cardiopulmonary signs and symptoms must be more homogeneous in future studies. Collaboration among several NICU may help solve the problem of small numbers of subjects.

The merits of percussion versus vibration, and advantages or disadvantages of bronchial drainage positioning should receive further study. The manner of delivering percussion and vibration must be examined definitively. Are mechanical devices or manual techniques superior in administering percussion and vibration to neonates?

The long-term effects of CPT have not been explored in any study discussed here, with the report by Finer and colleagues as a possible exception.37 Does CPT change rates of morbidity or mortality in neonates with pulmonary dysfunction? How long do the effects of treatment last? Also, there are little data by which to determine an optimal frequency of treatments.

These topics should be considered when planning research in neonatal CPT. The problems are not insurmountable. Pilot studies might help clinicians unaccustomed to working with infants. A pilot study can help perfect skills and increase knowledge, and permits evaluation of the research design. Most clinical research starts with a question, an idea, and a willingness to search systematically for an answer. Neonatal intensive care and its associated procedures are constantly developing. Physical therapists have an opportunity to be in the forefront of this exciting and challenging area of health care.

REFERENCES


NEONATAL CPT QUIZ

1. Insufficient levels of surfactant in the lung may be responsible for neonatal respiratory distress in
   a. bronchopulmonary dysplasia.
   b. idiopathic respiratory distress syndrome.
   c. meconium aspiration syndrome.
   d. transient tachypnea of the newborn.
   e. All of the above.
2. Auscultation of the chest is not a very sensitive evaluative tool in the tiny neonate because
   a. neonates normally have decreased breath sounds.
   b. increased chest wall compliance of the neonate contributes to adventitious breath sounds.
   c. breath sounds and adventitious sounds are easily transmitted throughout the thorax in a neonate.
   d. a and c above.
   e. None of the above.
3. The CPT treatment of a neonate
   a. should always include both percussion and vibration manual techniques during bronchial drainage maneuvers.
   b. is appropriate for neonates with documented diagnoses of hyaline membrane disease.
   c. should always include airway suctioning.
   d. should include modified positioning whenever possible.
   e. None of the above.

Answers
1. c 2. c 3. d