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Pulmonary diagnostics

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A B S T R A C T

Term infants with respiratory distress may have extremely varied etiologies of their illnesses. These range from anatomical malformations to infectious or inflammatory conditions to genetic, metabolic, or neurological abnormalities. This article reviews the present array of diagnostic studies available to the clinician, including the physical examination, imaging (radiography, computed tomography, magnetic resonance imaging, ultrasound, and nuclear scanning techniques), lung mechanics and function testing, evaluation of gas exchange (blood gases, pulse oximetry, transcutaneous monitoring, and end-tidal carbon monoxide measurements), and anatomical studies (bronchoscopy and lung biopsy). These tests and procedures are reviewed and a stepwise approach recommended.

1. Introduction

The image of the modern neonatal intensive care unit (NICU) is that of a facility filled primarily with premature infants with respiratory distress syndrome (RDS). Although preterm infants do comprise the majority of NICU patients, the number of term infants is not insignificant, and most of these patients suffer from respiratory failure. A recent European survey (Box 1) documented the reasons for mechanically ventilating NICU patients [1]. Among the 54% of non-RDS patients, the majority of conditions occur in the term population. These babies present an interesting array of diagnostic challenges, which include congenital malformations of the lungs and airways, infectious and inflammatory conditions, and lung disease secondary to underlying metabolic, genetic, and neurological abnormalities. The approach to these patients should begin with a thorough physical examination and proceed systematically, beginning with the least invasive procedures.

2. Physical examination

The examination of the lungs consists of the basic elements of physical diagnosis: inspection, palpation, percussion, and auscultation. Inspection is accomplished by careful observation of the baby [2]. Is the baby breathing comfortably, or is breathing labored? Is the baby pink or cyanotic? Are chest excursions symmetrical? Are the signs of respiratory distress present (see below)? Is there a scaphoid or distended abdomen?

Whereas percussion and palpation are less important than for older children, they may present clues to the pathology. Is the trachea midline or deviated? Do the chest excursions feel symmetrical? Is there dullness or hyper-resonance on percussion? Are there abnormal findings on palpation, such as rattling?

Auscultation should be carefully performed. Breath sounds should be assessed for bilateral equality. Is air entry and exit easy? Are there adventitious sounds, such as rales, rhonchi, or wheezes? Is there prolongation of inspiration or expiration? Is stridor present?

Because of the interdependence of the cardiac and pulmonary systems, and the often difficult task of differentiating heart disease from lung disease, a careful examination of the cardiovascular system is also imperative. Babies with cardiac disease often display "comfortable tachypnea." Assess perfusion. Are cardiac sounds normal, or is there a murmur or abnormal splitting of the second heart sound? Is capillary refill brisk or sluggish?

3. Signs of respiratory distress

The infant in respiratory distress will try to compensate and will show cardinal signs: flaring of the ala nasi, grunting on expiration, retractions (also known as recessions), and tachypnea. Severe cases will also show cyanosis if the concentration of deoxygenated

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Box 1
Reasons for mechanical ventilation in the neonatal intensive care unit.

Respiratory distress syndrome	46%
Sepsis	13%
Malformations	7%
Apnea of prematurity	5%
Asphyxia	5%
Pneumonia	4%
Surgery	4%
Aspiration	3%
Air leak	3%
Patent ductus arteriosus	2%
Other	8%

Adapted with permission from Van Kaam et al. [1].

hemoglobin is > 5.0 g/dL.

Newborns are obligate nasal breathers. Observation of the ala nasi can give clues to the underlying disorder. Flaring is an attempt to increase the cross-sectional area of the nostrils, thus reducing upper airway resistance. Attempted mouth breathing may indicate choanal atresia or stenosis.

Grunting is an attempt to provide intrinsic positive end-expiratory pressure. This, in turn, helps to increase functional residual capacity and to decrease the work of breathing by improving lung compliance. It may also help (in surfactant deficient babies) to maintain some degree of alveolar inflation at end-expiration and decrease the pressure necessary to overcome surface tension in accordance with LaPlace's law.

Retractions (recessions) indicate the use of accessory muscles of respiration to facilitate gas exchange. They may also be clues as to the anatomical location of the problem. Intercostal retractions tend to suggest parenchymal lung disease, whereas subcostal and supraclavicular contractions are frequently observed with airway diseases or disorders.

Tachypnea is breathing at an excessive rate. For term newborns, this is usually >60 breaths/min. Tachypnea is an attempt by the infant to improve minute ventilation (and thus gas exchange). It is frequently seen in situations where inspired tidal volume is subphysiologic. It may also represent compensatory respiratory alkalosis to an underlying metabolic acidosis.

Additional signs that may be present include “see-saw” respirations, “head bobbing,” gasping respirations, and apnea (cessation of breathing >20 s). Clubbing is generally not seen in the newborn infant.

4. Imaging

4.1. Conventional radiography

Conventional radiography is the frontline diagnostic tool for virtually any form of respiratory distress in the term newborn. Digital radiology systems now allow bedside portability, producing almost instantaneous images, which can be enhanced by visualization options, magnification, electronic transfer, and allow easy archiving and remote accessing. The primary projection is anteroposterior, and lateral or cross-table lateral views may add important information in situations such as air leaks, pleural effusions, or evaluation of the placement of tubes or catheters.

Interpretation of the chest radiograph should include assessment of lung expansion and volume, aeration, symmetry, presence of infiltrates or effusions, and evaluation of vertebrae, ribs, and the diaphragm. The size and position of the heart and great vessels should also be assessed [3,4].

4.2. Computed tomography

Computed tomography (CT) involves the projection of a thin X-ray beam through the body. Detectors opposite the site of projection measure the incident radiation. The projectors and detectors are rotated around the patient, who is moved through the scanner by an automated table. Images are then reconstructed by a computer and made available on a display.

Indications for chest CT include developmental anomalies of the lung or heart, tracheal anomalies, vascular rings, acute or chronic parenchymal lung disease, postoperative evaluation, and guidance during the performance of percutaneous procedures.

Computed tomography offers some advantages over conventional radiography, including excellent thoracic tissue characterization, and three-dimensional and multi-planar capabilities. Disadvantages include the need for higher radiation exposure, nonportability, and the potential need for iodinated contrast. Whereas sedation and/or anesthesia is often needed, newer multi-detector scanners have reduced acquisition times and decreased the need for sedation and/or anesthesia [5].

4.3. Magnetic resonance imaging

Because protons of different tissues resonate at different frequencies when they are subjected to a magnetic field, magnetic resonance imaging (MRI) is able to produce distinct anatomic images without the need for ionizing radiation. It may be used to augment echocardiography in the evaluation of vascular rings and other lesions, to delineate mediastinal masses, and to further characterize congenital malformations detected on prenatal sonography.

The major advantage is the avoidance of ionizing radiation, but MRI also has multi-planar and three-dimensional capabilities, excellent tissue characterization, allows dynamic assessment of the heart and lungs, and may be performed on the pregnant patient. It is not particularly good at evaluating the lung parenchyma, requires transport from the NICU to the scanner (and monitoring of the patient during the procedure may be difficult), cannot be performed without sedation/anesthesia, acquisition times are long, it is expensive and not universally available, and ferrous metals must not be placed in close proximity to the magnet [5].

4.4. Ultrasonography

Ultrasonography (US) utilizes the properties of the propagation of sound waves and their interaction with tissues to create an image from the ensuing echo. It has been used mostly to evaluate pleural and pericardial effusions, detection of pneumothorax, delineation of mediastinal and thoracic masses, evaluation of diaphragmatic activity, and guidance during vascular access and other invasive procedures. More recently, investigation of its use in evaluating parenchymal lung disease has been reported [6].

Ultrasonography can be done at the bedside, obviating the need for transport and sedation/anesthesia. It does not require ionizing radiation and thus enables serial scanning. Dynamic evaluation of the heart, lungs, and diaphragm is possible. US is more operator-dependent than other imaging modalities. Points of access (“acoustic windows”) and limited scan planes may hinder the field of view, and dressings, air, hardware, and osseous structures may produce imaging artifacts.

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