

KEY FACTS

TERMINOLOGY

- Chronic, reversible, paroxysmal airway hyperresponsiveness leading to airflow obstruction
- Umbrella term for numerous phenotypes in which normally harmless environmental allergens cause airway hyperresponsiveness due to pathologic immune-mediated host response (i.e., not single disease)

IMAGING

- Usually normal; may have symmetric hyperexpansion with flattened hemidiaphragms & ↑ retrosternal airspace
- Not necessary; helpful to identify complications & mimics
 - Consider chest radiograph if poor response to therapy

TOP DIFFERENTIAL DIAGNOSES

- Viral bronchiolitis: May occur in concert with & be impossible to differentiate from asthma
- Foreign body aspiration: Static asymmetric lung volumes on bilateral decubitus or inspiratory/expiratory imaging

- Cystic fibrosis: Focal disease with bronchiectasis & mucous plugging, most common in upper lobes
- Croup: Barky cough &/or stridor (vs. wheezing in asthma) due to subglottic airway narrowing

PATHOLOGY

- Risk factors include frequent symptoms in 1st year of life, maternal smoking or history of asthma, & signs of atopy

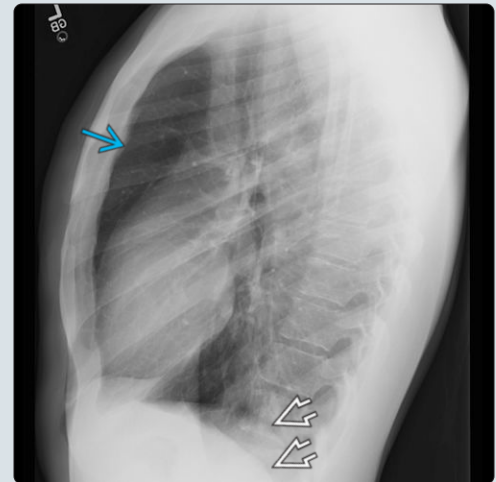
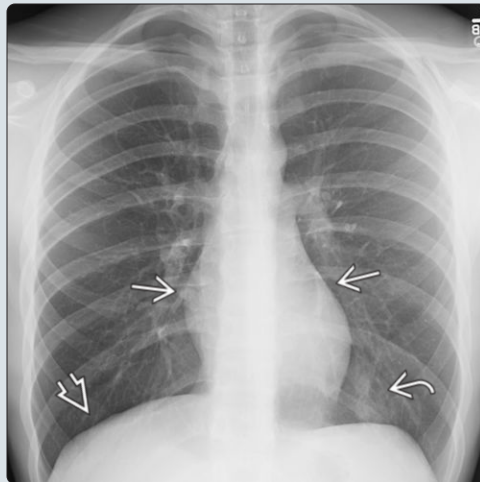
CLINICAL ISSUES

- Intermittent wheezing before age 6 is usually benign & typically resolves within few years
- Severity of asthma symptoms between ages of 7-10 years predicts persistence into adulthood

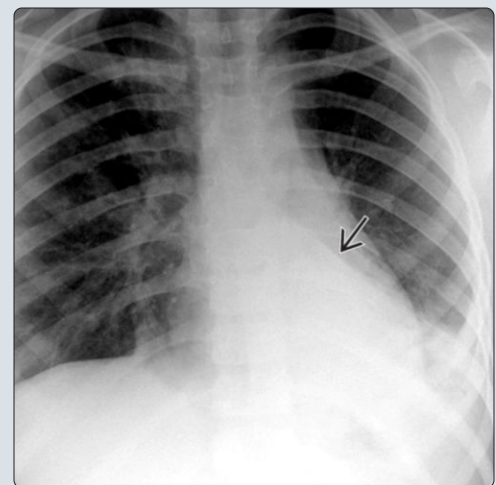
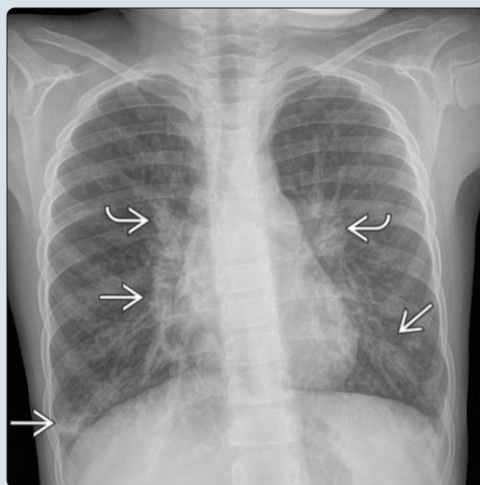
DIAGNOSTIC CHECKLIST

- Radiographs are usually normal but are indicated to exclude suspected alternate diagnosis, complication, or poor response to therapy

(Left) Frontal radiograph in a 17-year-old during an asthma attack shows hyperexpanded lungs, resulting in a narrow cardiac silhouette & flattening of the diaphragm. Subsegmental opacity in the left lower lobe was favored to represent atelectasis. **(Right)** Lateral image in the same patient reveals prominence of the retrosternal clear space & diaphragmatic flattening caused by air trapping. Imaging is often near-normal in asthma patients & is best used to identify complications or alternative diagnoses.



(Left) Frontal radiograph in a 6-year-old with an asthma exacerbation caused by *Mycoplasma pneumoniae* shows peribronchial airway thickening & scattered subsegmental opacities in the perihilar & lower lungs. Infection from *M. pneumoniae* is a common cause of asthma exacerbation. **(Right)** Frontal radiograph in a child with shortness of breath shows a dense, triangular-shaped opacity from left lower lobe collapse. Lobar collapse & atelectasis are common findings in patients with asthma exacerbation.



TERMINOLOGY**Synonyms**

- Airway hyperreactivity
- Reactive airways disease

Definitions

- Chronic disease characterized by bronchial hyperresponsiveness, reversible airway obstruction, & chronic airway inflammation
- Umbrella term for numerous phenotypes in which normally harmless environmental allergens lead to pathologic immune-mediated host response (i.e., not single disease)
- Airway hyperresponsiveness → contraction of bronchial wall smooth muscle & cascade of inflammation → acute, reversible airway narrowing & airflow obstruction
- United airway disease (UAD): Concept that upper & lower airways function immunologically as single organ
 - Overwhelming majority of asthmatics have rhinitis; less commonly, nasal polyps & other sinonasal disorders

IMAGING**General Features**

- Best imaging clue
 - Symmetric lung hyperexpansion: Flattening of hemidiaphragms, ↑ retrosternal airspace

Radiographic Findings

- Not part of most acute childhood asthma algorithms; reserved for those with fever, suspected foreign body (FB) aspiration, failure to improve with treatment, or focal findings on physical exam
- Most common finding: Normal chest radiograph
- Next most common: Subtle & nonspecific signs of hyperinflation, usually symmetric
 - Flattening of hemidiaphragms
 - ↑ AP diameter of chest & retrosternal airspace
 - ± bulging intercostal spaces
- Less common findings
 - Peribronchial thickening/cuffing
 - Irregular cardiac contour ("shaggy heart")
 - Atelectasis & lobar/partial lobar collapse
 - Peripheral oligemia
- Chronic findings
 - Bronchiectasis, mucous plugging
- Complications: More frequent in younger children as smaller bronchi are more easily narrowed or occluded & more likely to have concurrent viral bronchiolitis
 - Barotrauma (pneumomediastinum, subcutaneous emphysema, & rarely pneumothorax)
 - Lobar collapse, segmental & subsegmental atelectasis
 - Secondary allergic bronchopulmonary aspergillosis
 - Pneumonia

CT Findings

- HRCT
 - Signs of airway narrowing
 - Bronchial wall thickening
 - Narrowing or dilation of bronchial lumen
 - Mucous plugging
 - Signs of abnormal aeration

- Mosaic attenuation due to combination of regional air-trapping & oligemia
- Focal peripheral air-trapping on expiratory images
- Signs of airspace disease
 - Segmental & subsegmental atelectasis
 - Centrilobular opacities
- Bronchiectasis suggests asthma mimics (cystic fibrosis, ciliary dyskinesias, or immune deficiencies)
- CT is generally not indicated; quantitative studies show ↑ airway thickness & ↓ mean lung density

MR Findings

- Not used clinically; hyperpolarized noble gas MR can measure ventilation volumes
- Findings also correlate with disease severity, lung function, symptom control, & level of inflammatory marker elevation

Imaging Recommendations

- Imaging is generally not recommended except in
 - Febrile children (for possible complicating pneumonia)
 - Suspected foreign body (FB) aspiration
 - Those who fail to improve with treatment
 - Suspected barotrauma or lung collapse

DIFFERENTIAL DIAGNOSIS**Viral Bronchiolitis**

- Often acts as precipitating trigger for asthma & may be impossible to differentiate radiographically or clinically
- Look for preceding or concurrent symptoms of viral upper respiratory infection (e.g., nasal congestion or fever)

Foreign Body Inhalation or Ingestion

- Vast majority of aspirated FBs are not radiopaque
- Persistent air-trapping or collapse on serial radiographs, usually unilateral
- Static lung volumes on bilateral decubitus or inspiratory/expiratory imaging
- Persistent symptoms that do not respond to bronchodilator therapy

Croup

- Stridor rather than wheezing
- Barky cough
- Narrowed subglottic trachea

Cystic Fibrosis

- Early bronchial wall thickening that progresses to bronchiectasis
- Persistent hyperinflation or recurrent consolidation
- Mucous plugging of dilated bronchi
- Focal disease, most common in upper lobes

Ciliary Dyskinesias

- Situs inversus or dextrocardia (50%), paranasal sinusitis, & bronchiectasis
- Recurrent pneumonias

Immune Deficiencies

- Recurrent pulmonary infection → bronchiectasis

Vascular Slings

- Symptoms are often present from birth
- No response to bronchodilator therapy

- Abnormal impression of left pulmonary artery coursing between trachea & esophagus
- Often has associated complete cartilage rings of trachea (appearing round & narrow in cross section)

PATHOLOGY

General Features

- Etiology
 - Exact etiology is unknown; due to interplay of environmental triggers & host factors
 - Environmental associations & triggers
 - Maternal exposure to tobacco smoke, fine (<2.5 μm diameter) particulate matter, antibiotics
 - Antibiotic use during infancy ↑ asthma risk
 - Respiratory infections, especially Mycoplasma pneumonia
 - Poor air quality: Both indoor (tobacco smoke, cockroach & pet dander, dust mites, household chemicals, molds) & outdoor (fine & coarse particulate matter, pollen, ozone)
 - Changes in weather, especially cold & dry conditions
 - Host factors
 - Genetic predisposition
 - Upper respiratory tract viral illnesses
 - Exercise & strong emotional states (anger, anxiety, fear)
 - Hormonal fluctuations & menses
 - Complex response to these triggers causes release of inflammatory mediators from mast cells, macrophages, eosinophils, epithelial cells, & activated T lymphocytes
 - Bronchospasm
 - Airway edema
 - ↑ mucus production
- Risk factors
 - ↑ IgE levels; often associated with seasonal allergies & eczema (atopic triad)
 - Frequent symptoms in 1st year of life
 - Family history of asthma
 - Low birthweight
 - Male sex

Gross Pathologic & Surgical Features

- Bronchial edema & wall thickening
- Mucous plugging of airway lumen

Microscopic Features

- Inflammatory cell infiltration & edema of airway wall
- Mucous gland hyperplasia

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
 - Chronic &/or recurrent cough, wheezing
 - Shortness of breath
 - Chest tightness
- Other signs/symptoms
 - ↓ peak expiratory flow rates & forced expiratory volume in 1-second (FEV₁) values
 - Symptomatic improvement with bronchodilator therapy

- Use of accessory muscles to breathe at rest
- Exercise limitation

Demographics

- Age
 - Prevalence peak is between 6-11 years
- Gender
 - M > F = 1.5:1.0 before puberty
 - M < F = 1.0:1.5 after puberty
- Epidemiology
 - Most common chronic disease of childhood
 - Prevalence of 1-30% worldwide
 - Positive correlation with urbanization
 - Increasing incidence worldwide with increasing mortality
 - In USA, asthma is more common in African American & Hispanic children

Natural History & Prognosis

- Prognosis is usually excellent with appropriate treatment
- Wheezing before age 6 is usually benign & typically resolves within few years
- Severity of asthma symptoms between ages of 7-10 years is predictive of persistence into adulthood
 - Small subgroup (30%) of children is characterized by signs of atopy, severe & persistent symptoms at young age, & maternal history of smoking or asthma

Treatment

- Avoid exposure to known precipitating environments
- Inhaled β-agonists for bronchospasm
- Inhaled & oral corticosteroids that dampen inflammatory response
 - Used to prevent acute exacerbations & for treatment of chronic asthma
- Inhaled mast cell stabilizers that prevent release of mediators from mast cells that cause airway inflammation & bronchospasm

DIAGNOSTIC CHECKLIST

Consider

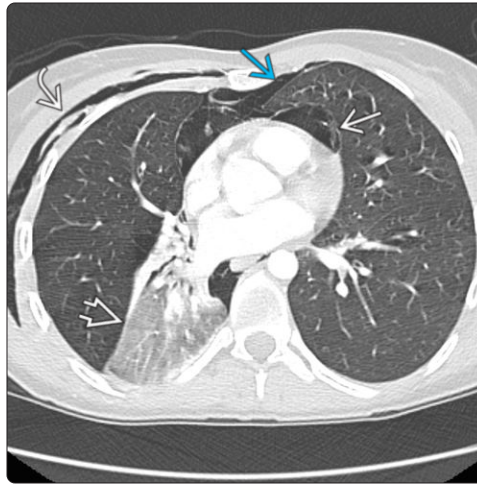
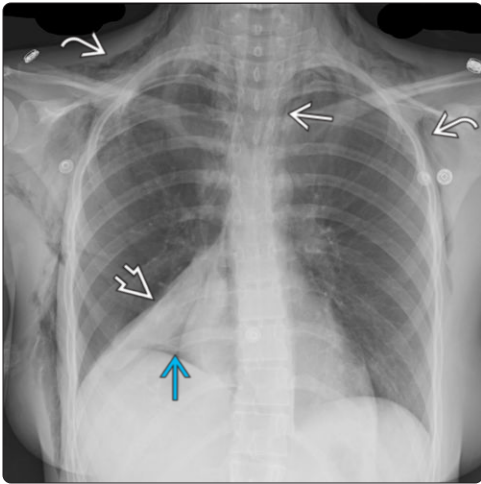
- Radiographs are usually normal but indicated with poor response to therapy, suspected complication, or concern for alternate diagnosis
- Hyperinflation with varying degrees of atelectasis
- Difficult to distinguish from viral bronchiolitis









Image Interpretation Pearls

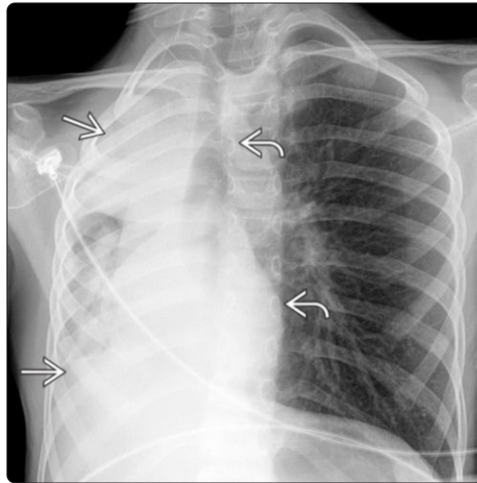
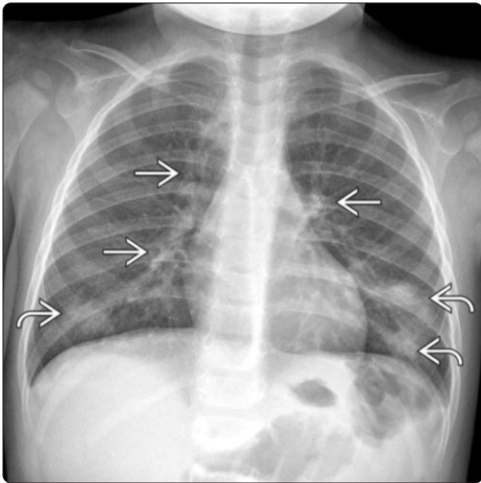
- Look for asthma mimics & signs of complication





SELECTED REFERENCES

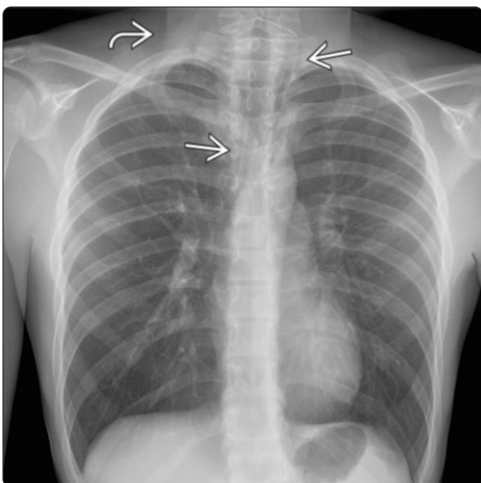
1. Silva TKBD et al: High-resolution CT pulmonary findings in children with severe asthma. *J Pediatr (Rio J)*. ePub, 2020
2. Dharmage SC et al: Epidemiology of Asthma in Children and Adults. *Front Pediatr*. 7:246, 2019
3. Wu J et al: Effects of particulate matter (PM) on childhood asthma exacerbation and control in Xiamen, China. *BMC Pediatr*. 19(1):194, 2019
4. Yii ACA et al: Precision medicine in united airways disease: A "treatable traits" approach. *Allergy*. 73(10):1964-1978, 2018





(Left) Frontal radiograph in a 17-year-old with a severe asthma attack precipitated by rhinovirus infection shows extensive subcutaneous emphysema , pneumomediastinum , right pneumothorax , & right lower lobe collapse . **(Right)** Axial CECT in the same patient shows extraventilatory gas in the soft tissues , & mediastinum  as well as a small left pneumothorax  & right lower lobe collapse . Barotrauma is a common complication in asthma patients.



(Left) Frontal chest radiograph from a young child with wheezing (who was later diagnosed with asthma) shows peribronchial airway thickening , & multifocal atelectasis  bilaterally. **(Right)** Frontal radiograph from a child with chronic asthma complicated by plastic bronchitis (which is the development of luminal casts, in this case due to inflammation) that caused bronchial occlusion & near total right lung collapse shows widespread opacity  & shift of the mediastinum to the right .



(Left) Frontal chest radiograph in a 14-year-old with a severe asthma exacerbation shows subcutaneous emphysema in the neck , & streaky lucencies in the mediastinum  from pneumomediastinum. **(Right)** Axial sinus CT in a 14-year-old with asthma & allergic rhinitis reveals extensive sinonasal polyposis. The united airway disease hypothesis underscores how sinonasal disease & airway hyperreactivity seen in asthma are manifestations of the same inflammatory process.