Pulmonary Hypertension

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Pulmonary Hypertension

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Huntington Beach, California, March 13, 2011

Faculty Disclosure

I have no relevant commercial interests

Objectives

- To outline the role of CT and MR imaging in the diagnostic work-up and management of pulmonary hypertension (PH)
- To review CT and MRI features of PH
- To highlight diseases which cause PH that have typical imaging findings

Outline

- Introduction
- Pathophysiology
- Classification
- Diagnosis
- CT and MR features of PH
- Diseases that have specific imaging findings

Introduction

- PH comprises a variety of conditions that lead to elevated pulmonary arterial pressure
- PH defined as resting mPAP ≥ 25 mm Hg
- PAH further defined as elevation of precapillary pulmonary resistance with normal pulmonary venous pressure (wedge pressure ≤15 mm Hg)

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• Pathophysiology
• Classification
• Diagnosis
• CT and MR findings of PH
• Diseases that have specific imaging findings

Diagnosis of PH in Four Stages

1. Suspicion
   - Non-specific symptoms
   - Dyspnea (60%), fatigue (19%), syncope & chest pain (8%)
   - Median survival without treatment - 2.8 years

2. Detection
   - Screening test of choice
   - Sensitivity 79-100%, specificity 68-98%

3. Classification
   - Physical exam
   - ECG
   - Chest x-ray
   - Pulmonary function tests
   - Transthoracic Echo

4. Evaluation
   - Assessment of RV function at baseline & f/u
   - Confirmation of PH

Dana Point 2008 Classification of Pulmonary Hypertension

- Group I - Pulmonary arterial hypertension (PAH)
  - Idiopathic pulmonary arterial hypertension (IPAH)
  - Heritable
  - BMPR2
  - ALK1, endoglin (with or without hereditary telangiectasia)
  - Unknown
  - Drug- and toxin-induced
  - Associated with (APAH): connective tissue disease, congenital heart disease, portal hypertension, HIV, schistosomiasis, chronic hemolytic anemia, persistent pulmonary hypertension of the newborn
  - *Pulmonary veno-occlusive disease and/or pulmonary capillary hemangiomatosis

- Group II – PH due to left heart disease

- Group III – PH due to lung disease

- Group IV – Chronic thromboembolic pulmonary hypertension

- Group V – Pulmonary hypertension with unclear multifactorial mechanisms

Dana Point Classification Simplified

Group I - Pulmonary arterial hypertension
- Idiopathic or genetic
- Drug-induced
- Associated with (APAH)
  - CHD, CTD, portal hypertension, HIV

Group II - PCH, PVOD

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Group IV - PH due to lung disease

Group V - PH due to CTEPH

Group V - PH due to multifactorial or unclear causes
**Imaging Algorithm in Suspected PH**

1. PA RV dilatation
   - Underlying pulmonary or cardiac disorder
   - First line for diagnosis: Detect PH
   - Rule out CTEPH

2. Right Heart Catheterization
   - Confirm Dx
   - Pressure measurements
   - Response to vasodilators
   - Rule out specific cause
   - Anatomic assessment of CTEPH
   - PVOD/PCH
   - ILD
   - Intra/extracardiac shunt

3. Functional analysis of RV pulmonary circulation
   - at baseline and follow up

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**Pulmonary Hypertension Computed Tomography**

- Key role in classification of PH
- Vessels - CTEPH, extracardiac left to right shunt
- Heart - CHD, left heart disease
- Lungs - ILD, emphysema
- Functional assessment
  - Right ventricular functional parameters
  - PA distensibility

**CT Features of Pulmonary Hypertension - Vascular**

- MPA dilatation > 29 mm
  - Sensitivity - 87%
  - Specificity - 89%
  - No correlation with mPAP in pulmonary fibrosis

- Segmental artery to bronchus ratio > 1 in 3 of 4 lobes
  - Specificity - 100%
  - Correlates with severity of PH
  - Highly reproducible

- Composite index of CT parameter dPA/dAA with echo-derived RVSP
  - mPAP = dAA + RVSP x 0.34 - 8.3
  - Better correlation with mPAP than CT or echo measurements alone
CT Features of Pulmonary Hypertension - Vascular

- Contrast reflux into dilated IVC+/- hepatic veins - specific sign of RV failure at low contrast injection rates (<3 cc/sec)

CT Features of Pulmonary Hypertension - Cardiac

- Right ventricular dilatation
  - RV/LV > 1.0
- Straightening of interventricular septum

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CT Features of Pulmonary Hypertension - Cardiac

- RV hypertrophy:
  - wall thickness > 4 mm
- Septal bowing - leftward bowing of interventricular septum

CT Features of Pulmonary Hypertension - Parenchyma

<table>
<thead>
<tr>
<th>CT Finding</th>
<th>Pathologic/Physiologic Correlation</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrilobular ground-glass nodules</td>
<td>Cholesterol granulomas / Proliferation/lesions</td>
<td>IPAH, Eisenmenger</td>
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<tr>
<td>Centrilobular ground-glass nodules</td>
<td>Capillary proliferation</td>
<td>PCH</td>
</tr>
<tr>
<td>Serpiginous centrilobular arterioles</td>
<td>Neovascularity</td>
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<tr>
<td>Mosaic attenuation</td>
<td>Decreased attenuation (underperfusion)</td>
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<tr>
<td>Mosaic attenuation</td>
<td>Increased attenuation (overperfusion)</td>
<td>CTEPH/IPAH/Eisenmenger</td>
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</tbody>
</table>

Centrilobular Groundglass Nodules

- Cholesterol granuloma, plexogenic arteriopathy, capillary proliferation

Serpiginous Centrilobular Arterioles

- Neovascularity
Mosaic Attenuation

Cardiac MRI

- Essential modality in evaluation of PH
- Gold standard for morphological and functional assessment of RV
  - Prognostic determinant
- Complete picture of right heart/PA morphology and function

Morphologic MRI Features of PH - Cardiac

- RV dilatation
- RV hypertrophy
- Interventricular septal (IVS) flattening or bowing
- Spherical RV
- D-shaped LV
- Tricuspid regurgitation
- RA dilatation
- IVC/hepatic vein dilatation

Cine Imaging: Volumes, Mass & Function

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Clinical Significance</th>
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</thead>
<tbody>
<tr>
<td>RV dilatation</td>
<td>RV volumes &amp; stroke volumes at baseline predictors of mortality &amp; treatment failure</td>
</tr>
<tr>
<td>RV hypertrophy</td>
<td>Ventricular mass index &gt; 1.5 Correlation with RHC for PH detection</td>
</tr>
</tbody>
</table>

RV dilatation

Phase Contrast Imaging

- Encoding MR signal phase for velocity - flow velocities and volumes
- Obtained in any plane (vs. echo)
- Altered MPA dynamics
  - Average velocity < 11.7 cm/sec (sens. 93%, spec. 82% for PH)
  - PA distensibility
- Qp/Qs = shunt
- Cardiac output/stroke volume – no response to vasodilators

Delayed Contrast Enhancement

- Anteroseptal and inferoseptal RV
- Extent correlates with RV dysfunction and inversely proportional to RVEF

Increased mechanical tissue damage and inflammation
Magnetic Resonance Imaging

Summary

- Detection – does not replace right heart cath
- Estimation of mean PAP – contradictory evidence
- Assessment of treatment response
  - Most promising
  - End-point for research trials

Benza R et al JACC 2008; 52(21):1683-1692

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With permission

Longstanding Left to Right Shunt

- Systemic to pulmonary shunts
- PH common - prevalence 5-10%
- Treated surgically (Qp/Qs > 1.5 and PAP < 2/3 systemic)

Missed on echocardiography

- Atrial septal defect (ASD) - sinus venosus defect
- Anomalous pulmonary venous return (APVR)
- Patent ductus arteriosus (PDA)

Sinus Venosus Defect

With permission Pena E et al Radiographics 2012; 32:3-32
Pulmonary Veno-occlusive Disease

- Idiopathic disease
- Tobacco exposure, connective tissue disease, cytotoxic drugs, bone marrow transplantation, HIV, sarcoid, Langerhans cell histiocytosis and thoracic radiotherapy
- Accounts for 5-10% of PAH
- Age range 7-70 years (mean 39 years)
- Males:females
- Triad – Severe PAH, pulmonary edema on CXR, normal PA occlusion pressure
- Pathology
  - Intimal fibrosis of interlobular veins and venules leading to venous obstruction and interlobular septal edema


Pulmonary Capillary Hemangiomatosis

- Idiopathic disease with similar predisposing factors to PVOD
- HRCT features similar to PVOD except ground-glass centrilobular nodules more common
- Pathology
  - Proliferation of capillary channels within alveolar walls that progress to nodular lesions which compress venules

Frazier AA et al. Radiographics 2007; 27:867-882

With permission Pena E et al Radiographics 2012;32:9-32

Patent Ductus Arteriosus

Anomalous Pulmonary Venous Return

Pulmonary Veno-occlusive Disease

• Septal thickening, centrilobular ground-glass nodules and mediastinal lymphadenopathy
• 2 or 3 signs – sens 74%, spec 85%
• Absence of findings does not rule out disease

Montani D Medicine (Baltimore) 2008;87:220-233

With permission Pena E et al Radiographics 2012;32:9-32

Pulmonary Capillary Hemangiomatosis

With permission Pena E et al Radiographics 2012;32:9-32
PCH and PVOD
• Clinical presentation indistinguishable
• Prognosis worse than in other forms of PAH
• PVOD and PCH may represent different components of a spectrum of single disease
• 38 lung specimens from 35 patients diagnosed with PVOD (30) and PCH (5) retrospectively reviewed
  – PCH identified in 24 (73%) diagnosed with PVOD
  – PVOD identified in 4/5 patients diagnosed with PCH
• Important to recognize CT findings of PCH/PVOD as fatal pulmonary edema may develop if treated with vasodilator agents

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Left Heart Disease
• Elevated left atrial filling pressures lead to elevated pulmonary venous and arterial pressures
• Right heart cath to establish diagnosis
  • mPAP > 25 mm Hg
  • High pulmonary capillary wedge pressure > 15 mm Hg

Left Heart Disease
• Common cause of PH
• PAH medications not recommended in left heart disease since safety and efficacy not proven
• Causes
  • Left ventricular diastolic/systolic dysfunction
  • Left sided valvular disease
  • Left heart tumours/obstruction

Aortic Stenosis
• Fibromuscular diaphragm divides LA into posterior and anterior chambers
• Posterior chamber receives pulmonary veins
• Anterior chamber leads to mitral valve
• Variable size of communication between posterior and anterior chambers may cause obstruction

Cor Triatriatum
• Fibromuscular diaphragm
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Lung Disease

- Includes COPD, ILD, hypoxemia (chronic high altitude, sleep disordered breathing)
- High prevalence in COPD (50%) and ILD (43%)
- PH associated with worse prognosis

Lung Disease

- PA dilatation occurs in absence of PH in pulmonary fibrosis
- No relationship between extent of pulmonary fibrosis and mPAP - remodeling of small PA

PH - Lung Disease

- COPD - high prevalence of mild PH
  - Predicts mortality
- Combined centrilobular emphysema and UIP
  - High prevalence of PH and survival

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Chronic Thromboembolic Pulmonary Hypertension (CTEPH)

- Surgically treatable cause of PH
- Approximately 4% of patients after acute pulmonary embolism
- Incomplete resolution and organization of pulmonary emboli
- Asymptomatic until 60% of pulmonary arterial bed obstructed
**CTEPH – CTA Vascular Findings**

<table>
<thead>
<tr>
<th>Complete occlusion</th>
<th>Bands</th>
<th>Webs</th>
<th>Collateral systemic supply</th>
<th>Mural filling defect</th>
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**CTEPH - CT Parenchymal Findings**

- Mosaic perfusion pattern
- Scars from prior infarction

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**Pulmonary Hypertension with Unclear Multifactorial Etiologies**

- Pulmonary artery sarcoma
- Tumour embolism
- Mediastinal fibrosis

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**Pulmonary Artery Sarcoma**

- Most common primary tumor of the pulmonary artery
- Begins in main pulmonary artery and grows antegrade and/or retrograde into right ventricle
- Nodular filling defects may expand arterial lumen
- May enhance with contrast
- May invade into hila

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**Pulmonary Artery Sarcoma**

- Courtesy of John Veinot MD
Peripheral and Central Tumour Embolism

- Tumour fragments stay and grow in pulmonary arteries
- Indistinguishable from bland thromboembolism
- Autopsy > antemortem (6%)
- Common – hepatocellular, renal cell, breast, gastric and prostate CA


Peripheral and Central Tumour Embolism

- Central - mimic acute or chronic PE
- Peripheral - multifocal beading and dilatation
- Ancillary findings
  - Lymphadenopathy
  - Lymphangitis carcinomatosa
  - Intrabdominal masses

Mediastinal Fibrosis

- Excessive fibrotic reaction
- Etiology - Histoplasmosis > other fungi, tuberculosis, sarcoid, idiopathic
- Localized form - calcifications
- Diffuse form - no calcifications
- Narrowing - pulmonary arteries, veins, large airways

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Summary and Teaching Points

- There are specific signs of PH on CT and MRI
- CT and MRI are important in classification
- cMRI provides prognostic information and can be used at baseline and to monitor treatment
- Groundglass opacities and septal lines - consider PCH/PVOD as can respond adversely to vasodilator drugs