Contents

- Review the pathophysiology and ECG signs of pulmonary dysfunction
- Review the ECG findings in patients with:
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  - Common Congenital Cardiac Defects as seen in adults: ASD, VSD, PDA, and VPS

RAE vs. P Pulmonale: Are they the same?

- Right atrial enlargement
  - P-wave axis ≥75° (low specificity)
  - P-wave > 0.15mV in V1 or V2 (best criteria)
- P Pulmonale (frequently indicative of transient PA strain/dilatation)
  - Peaked P-waves ≥0.25mV in II, III, or aVF
  - P-wave axis ≥75°
- Note:
  - Degree of P-wave axis correlated better with lung disease severity than P-wave amplitude
  - P-wave amplitude correlates better with RA strain (may be transient)
  - Overlap of the two criteria

Lead II P-Wave Amplitude during COPD Exacerbation and after Treatment (50 pts.)

Assad et al. Chest 2003
44 yo Male with 60 pack-year smoking: P Pulmonale (P >0.25 mV in II) No RAE by V1 criteria or by echo

Right Ventricular Hypertrophy Criteria
- RAD ≥ +110 degrees
- R/S ratio in V1 or V3R > 1
- qR in V1 or V3R (usually seen in severe RVH)
- rSR’ in V1 with R’ > 0.7 Mv
- R/S ratio in V5 or V6 ≤ 1
- R-wave in V1 > 0.7 mV
- S-wave in V2 < 0.2 mV
- Onset of intrinsicoid deflection in V1 > 35 ms
- **Note:** Need at least two criteria for definite dx.

Right Ventricular Hypertrophy
- The types of RVH correlate with severity and specific disorders (but with a lot of overlap):
  - **Type A** – severe RVH as seen in severe PAH, endstage COPD, severe VPS
  - **Type B** – mild to moderate RVH (must differentiate from true posterior MI)
  - **Type C** – moderate RVH as seen Mitral Stenosis, or moderate COPD and occasionally in ASD
  - **IRBBB** – moderate RVH or RVOT hypertrophy as seen in ASD, moderate COPD
  - **Note:** All types of RVH are usually associated with some degree of RAD

Normal Horizontal Vector Loop with Projection on the Precordial Lead Axis

Type A RVH: Horizontal Plane VCG

34 yo Female with Severe PA Hypertension RAD, RVH (with 20 ST abnormality), RAE
Pathophysiology and the ECG in COPD

- Intermittent hypoxia and pulm. asoconstriiction
- Right atrial “strain”
- Right atrial enlargement
- “Clockwise” rotation of the heart
- RVH (usually mild or mod. unless end-stage)
- Lung hyperinflation
- Depressed diaphragms

- Rightward QRS axis
- P Pulmonale (peaked & >0.25 mV) in II, III, Avf
- Shift of transition leftward*
- Low voltage in limb leads
- Type B or C RVH (late)
- Transient atrial arrhythmias (MAT is pathognomonic) during decompensation.

* The “poor precordial R-wave progression” sign is least specific
ECG Criteria for COPD (Chou)

- P pulmonale (peaked P ≥ 0.25 mV in II, III, aVF)
- P wave axis ≥ +80°
- QRS amplitude ≤ 0.5 mV in all limb leads
- QRS axis > +90°
- QRS amplitude ≤ 0.5 mV in V5, V6
- S1S2S3 pattern with R/S < 1 in I, II, III
- Atrial arrhythmias (especially MAT)

◆ COPD likely to be present if one P and one QRS criterion present

ECG Criteria for COPD (other investigators)

- P-wave axis > +70° = 89% sensitive and 96% specific
- Degree of QRS RAD correlated with but QRS axis > +90° in only 8%
- Others report P axis > + 60° in 60% of cases
- S1S2S3 pattern in only 25 % of
- Leftward QRS transition with R/S < 1 in V5 V6 (type C RVH) = severe (end-stage) COPD

◆ Reasons for differences: Most studies are observational with no echo or anatomic correlation and COPD is a dynamic disease

Sensitivity and Specificity of these ECG Criteria

- For single criterion – specificity is low (54% false positive)
- With two or more criteria specificity much better.
  Example: With P-wave axis ≥ +80° and QRS axis ≥ +90° or low voltage QRS or R/S in V5/V6 <1, specificity was 100% in study of Kamper et al

63 yo Male with Severe Emphysema:
(Residual Volume: 171% of predicted)
P Pulmonale, P axis +85°, limb lead QRS≤0.5 mV

69 yo Male with COPD
QRS axis > +90°, Limb Lead Low Voltage, Transition Shifted Leftward

Multifocal Atrial Tachycardia with Block in Patient with COPD
(note at least 3 different P Wave Morphologies)
Acute Pulmonary Embolism: Pathophysiology and ECG Findings

- Sympathetic stimulation
- Acute pulmonary hypertension
- RA & RV strain/dilatation
- Spatial changes (clockwise rotation)
- ↑ RV wall stress leading to RV ischemia
- RV dysfunction
- Sinus tachycardia
- P Pulmonale
- RBBB (complete or incomplete)
- Acute rightward axis shift
- S1Q3T3 pattern (7 IMI)
- ↓ RV wall stress leading to RV ischemia
- RV dysfunction
- Atrial arrhythmias (AFib or A Flutter)

Acute Pulmonary Embolism: Incidence of ECG Findings (various series)

- Sinus tachycardia: 8-73%
- P Pulmonale: 6-33%
- Rightward axis shift: 3-66%
- Inverted T-waves in ≥ 2 Rt chest leads: 50%
- S1Q3T3 pattern: 11-50%
- S1 – 60%, Q3 – 53%, JT – 20%
- Clockwise rotation: 10-56%
- RBBB (complete or incomplete): 6-67%
- AF or AFlutter: 0-35%
- No ECG changes: 20-24%

These changes are frequently transient resulting in a wide range of incidence.

Pulmonary Embolism: ECG Score

Score > 9 suggests PA syst. Pressure>50 (Daniel; Chest 2001) and correlates with amount of perfusion deficits (Iles; Chest 2004)

39 yo M with Major PE (Thrombi in both R. & L. main PAs, RV Dysfunction by Echo)

Sinus tachycardia and shift in transition the only ECG abnormality

57 yo F. with Massive PE (Severe RV dysfunction by Echo) DDx: Anterior wall ischemia

↓ T-waves in V1-V4 and leftward displaced transition are the only ECG findings here

Prognostic Significance of T Wave Inversion in Acute PE

- Number of Leads with T Wave Inversion:
  - ≤ 3: 47%
  - 4-6: 92%
  - ≥ 7: 100%

Kosuge et al. Circ J 2006
67 yo Male with Massive PE; no MI

Initial diagnosis was acute anterior STEMI

Post Pneumonectomy Changes
New IRBBB, New ST & T Abnormalities V1-V3

ECG Changes in Pneumothorax
- Depend on the size of the pneumothorax
- Caused by displacement of the heart
- Most often RAD, independent of the pneumothorax site
- Low voltage frequently present
- QS complexes in precordial leads also common
- T-wave inversions simulate ischemia
- Occasionally ST elevations mimic injury

44 yo Male Developed Severe Chest Pain and Dyspnea while Jogging

ECG Findings Pulmonary Hypertension
- Depend on:
  - Severity and duration of the process
  - Whether PH is primary (PAH) or secondary to other conditions (e.g. Mitral Stenosis)
  - Primary: various degrees of RVH
  - Secondary: combination of RVH and other findings (e.g. in MS: RVH and LAE)

Same Patient after Left Chest Tube Inserted
ECG Changes in Selected Congenital Defects

ECG Findings in ASD
- Secundum: RAD and IRBBB type RVH (RV volume overload) in ≈ 60%
- Primum: LAFB (almost 100%) ± IRBBB (depending on shunt magnitude)
- Sinus Venosus: Ectopic atrial rhythm (inverted P waves II, III, AVF in ≈30%)

ECG Findings in VSD
- LVH or BVH depending on site of the VSD and magnitude of the L-R shunt
- RVH (usually severe type A) with pulmonary vascular disease (Eisenmenger syndrome)

ECG of 44 YO Man with VSD and L-R Shunt (Qp:Qs= 1.9)
16 yo Male with VSD and Eisenmenger Syndrome: RAD, RVH with 20 ST-T abnormality

Valvar Pulmonic Stenosis ECG: 40 yo Man (RV systolic pressure 70 mmHg)

Thanks for Your Attention