ARF, Mechaical Ventilation and PFTs: ACOI Board Review 2018

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No Disclosures

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Acute Respiratory Failure (ARF)

DEFINITION

ARF is the clinical state which occurs when the respiratory system (ie circulatory and lungs) is not able to meet the metabolic requirements of the organism.

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Acute Respiratory Failure

- ✓ Anatomic- Etiologic
- ✓ Physiologic- Etiologic
- ✓ Blood Gas
- ✓ Radiologic
- ✓ Tissue Oxygenation

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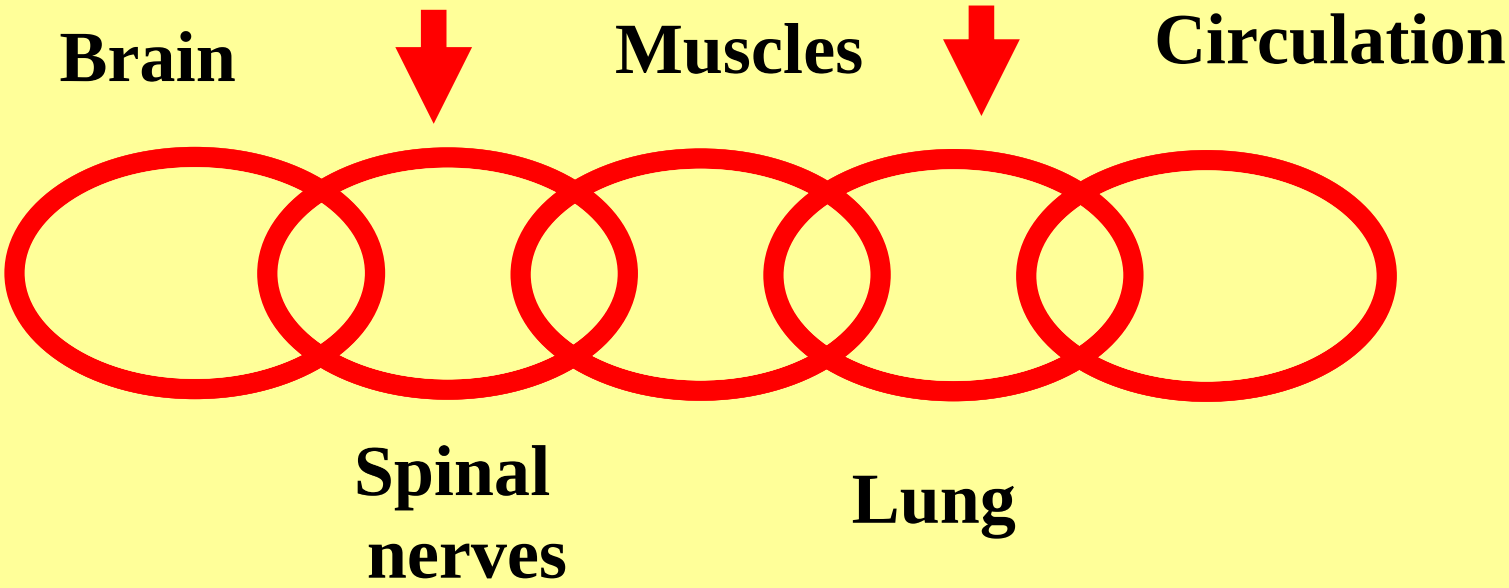
Anatomic Etiologic Classification



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Physiologic Etiologic Classification

ARF

- **Inadequate Muscle Function**
- **Excessive Workload**
- **Inadequate Respiratory Drive**

Neuro Muscular Disease

ARDS
COPD
IPF

OD
CVA
Alkalosis

Blood Gas Classification

Hypoxemic/Hypercapnic

- ✓ **Clinically useful**
- ✓ **Can be used to divide patients into distinct ETIOLOGIC and TREATMENT groups**
- ✓ **Readily available**

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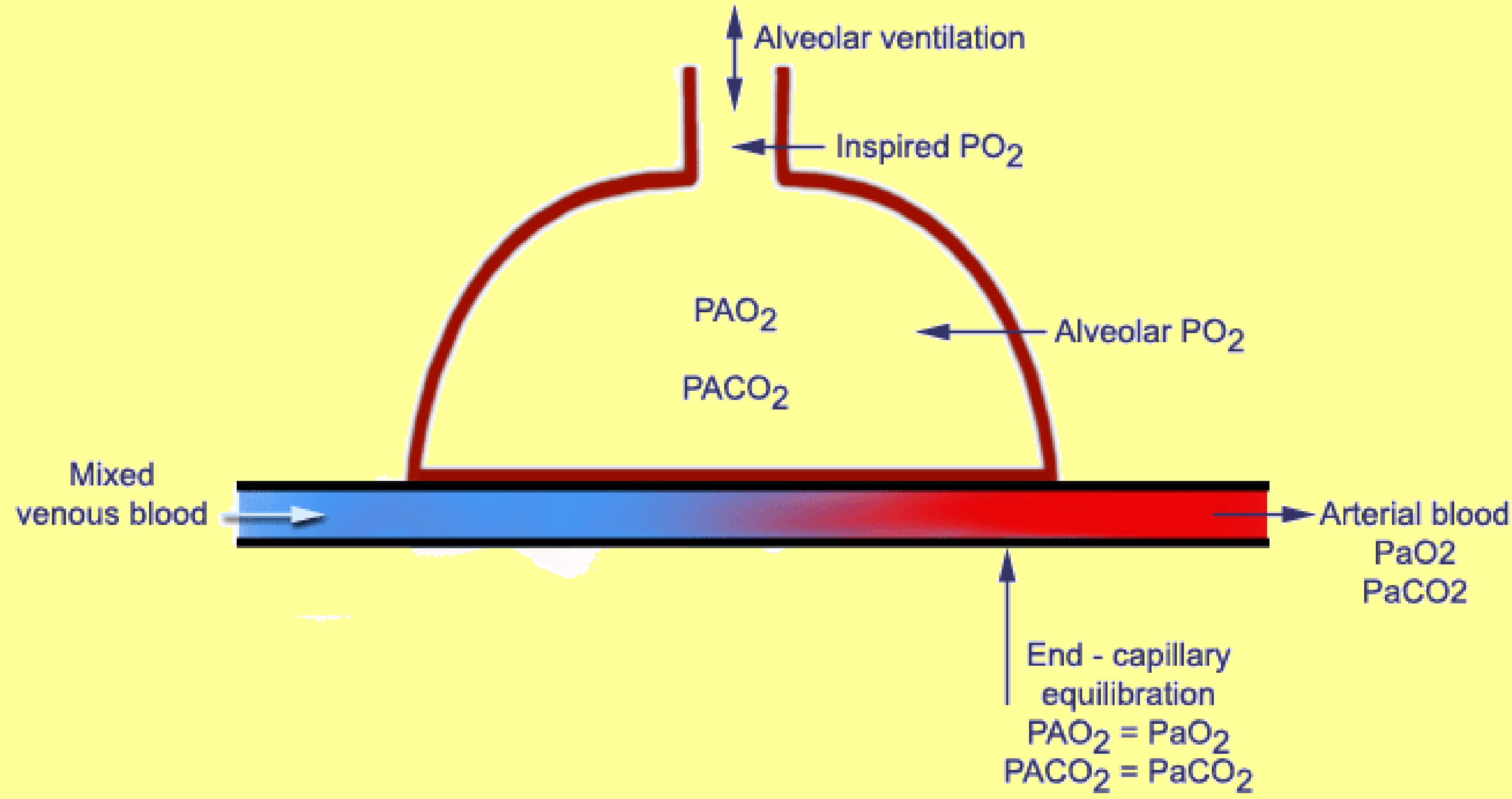

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Calculation of the A-a Gradient

PAO2 = FIO2 (Pb - 47) - 1.25 PaCO2

PaO2 = measured

A-a gradient should be less than 20 mmHg breathing room air OR
Less than 100 mmHg on 100 % O2

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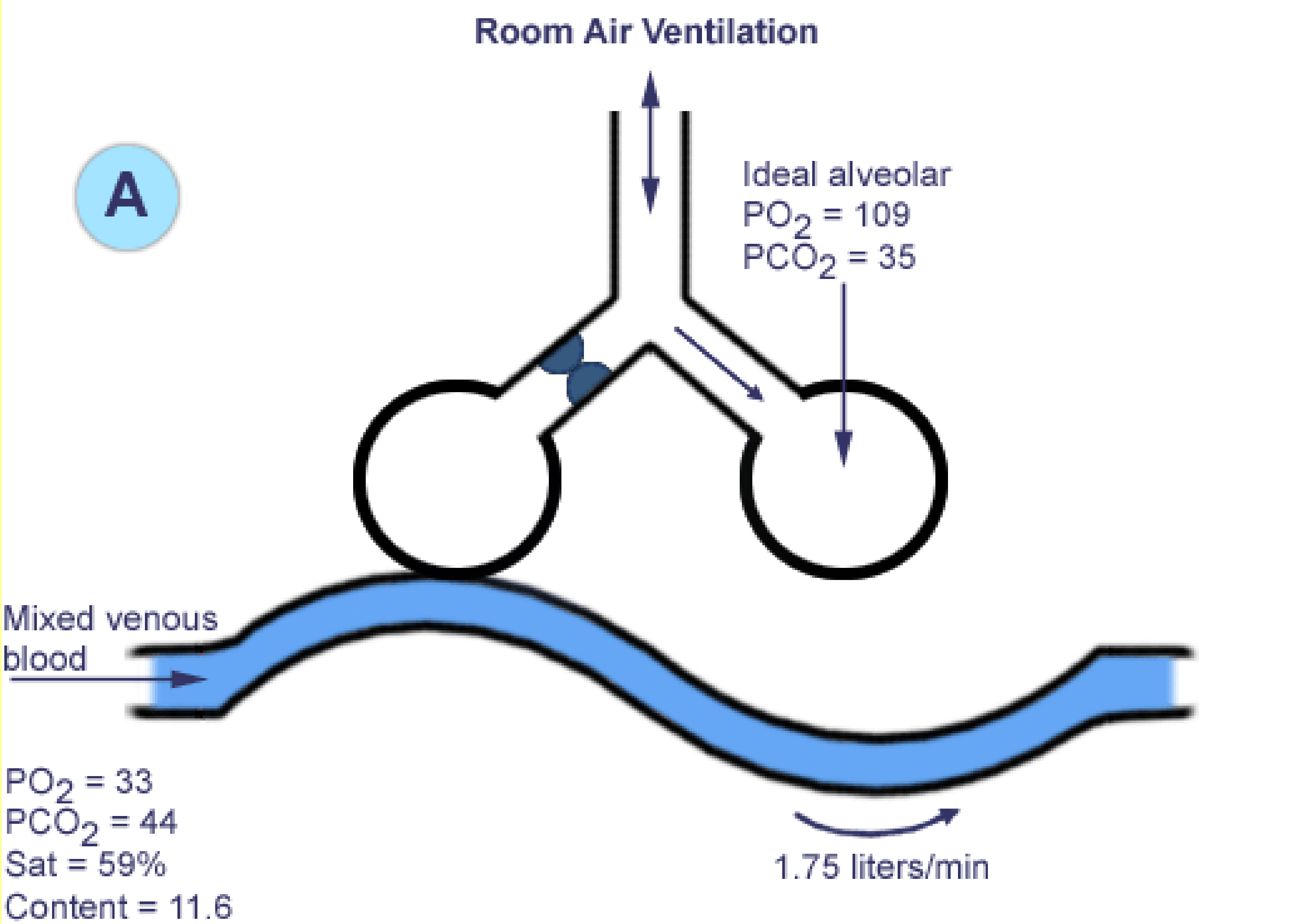
100% Oxygen and Pulmonary Shunt



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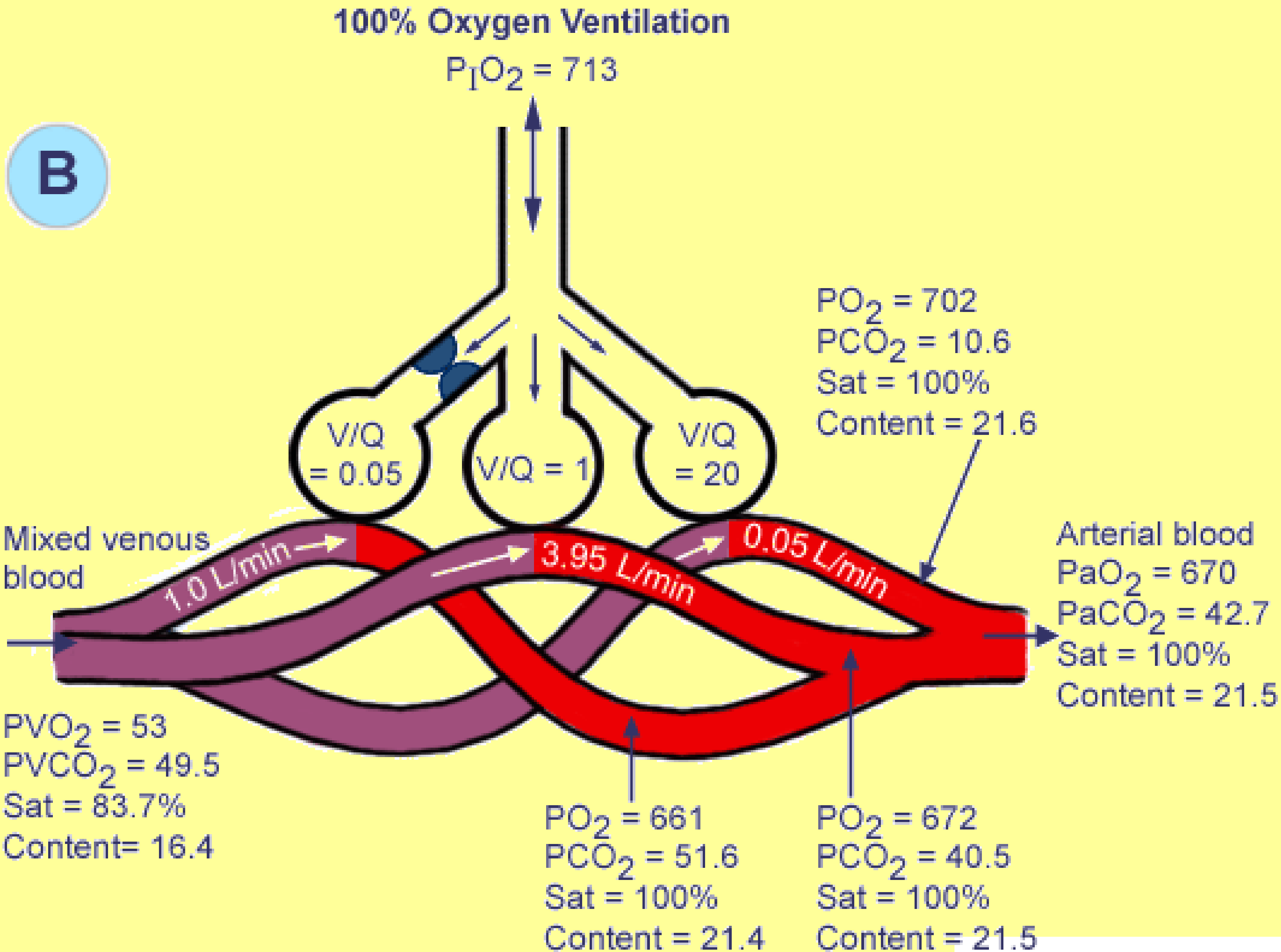

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Causes of Hypoxemia

CAUSE	A-a Gradient	PaCO2	Response to 100 % Oxygen
Low FIO2	Normal	Normal	Improved
Hypoventilation	Normal	Increased	Improved
Diffusion Impair	Increased	Normal	Improved
Low V/Q	Increased	Normal	Improved
Shunt	Increased	Normal	NOT Improved
Low PvO2	Increased	Normal	? Improved

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Mechanisms of Hypercapnia

$$PaCO_2 = K \frac{VCO_2}{V_a}$$

$PaCO_2$ = arterial CO_2 tension

K = proportionality constant

VCO_2 = CO_2 production

Va = Alveolar ventilation

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Causes of Hypercapnia

1. **Alterations in CO2 production**
2. **Disturbances in the Gas Exchanger (the lungs)**
3. **Abnormalities in the mechanical system (the bellows)**
4. **Changes in ventilatory control**

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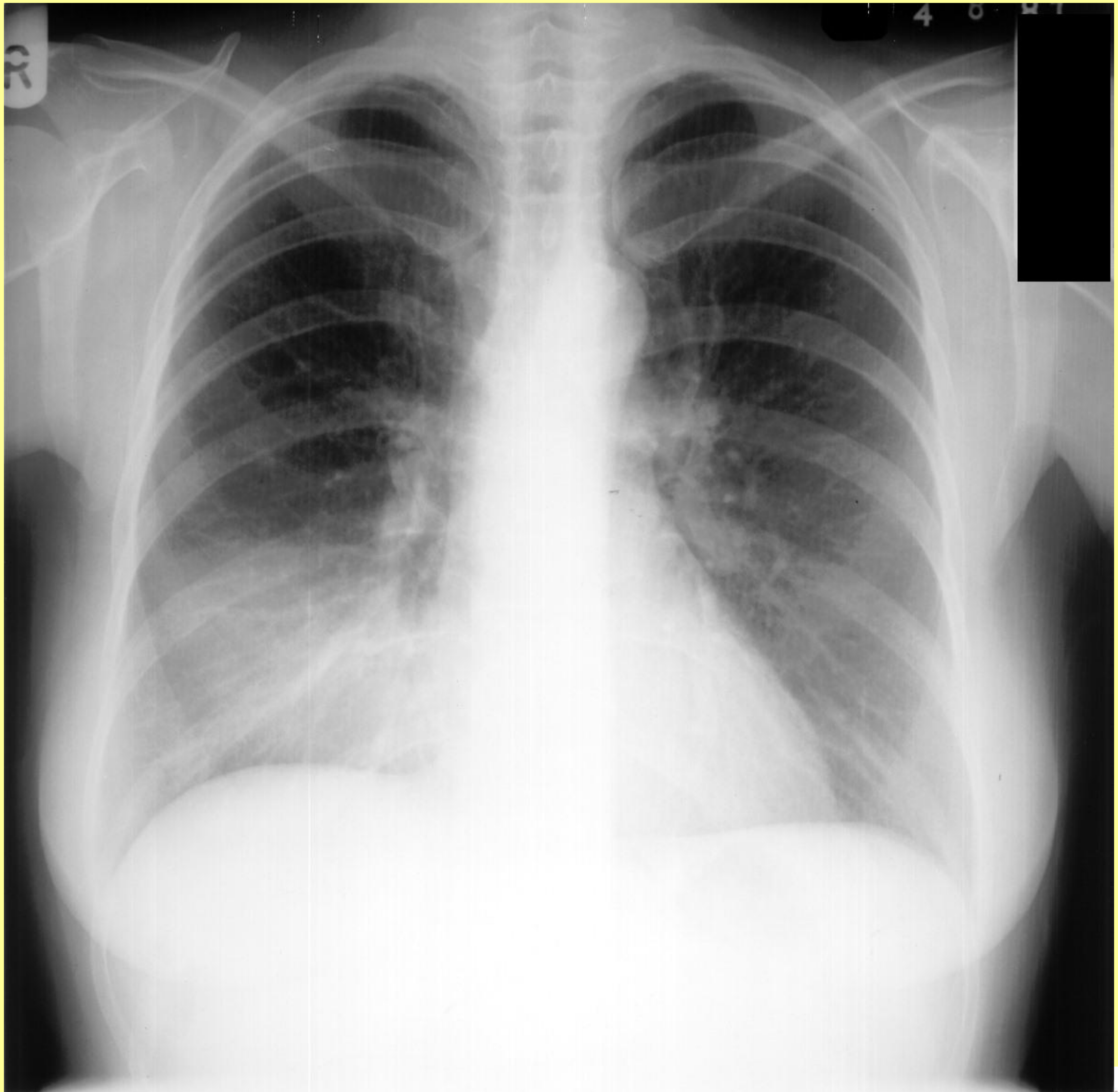
Radiographic Classification of ARF

WHITE LUNG	BLACK LUNG
Pneumonia	Asthma
Pulmonary edema	emphysema
Atelectasis	PE
Interstitial disease	microatelectasis
	R to L Shunt
	Ventilatory failure



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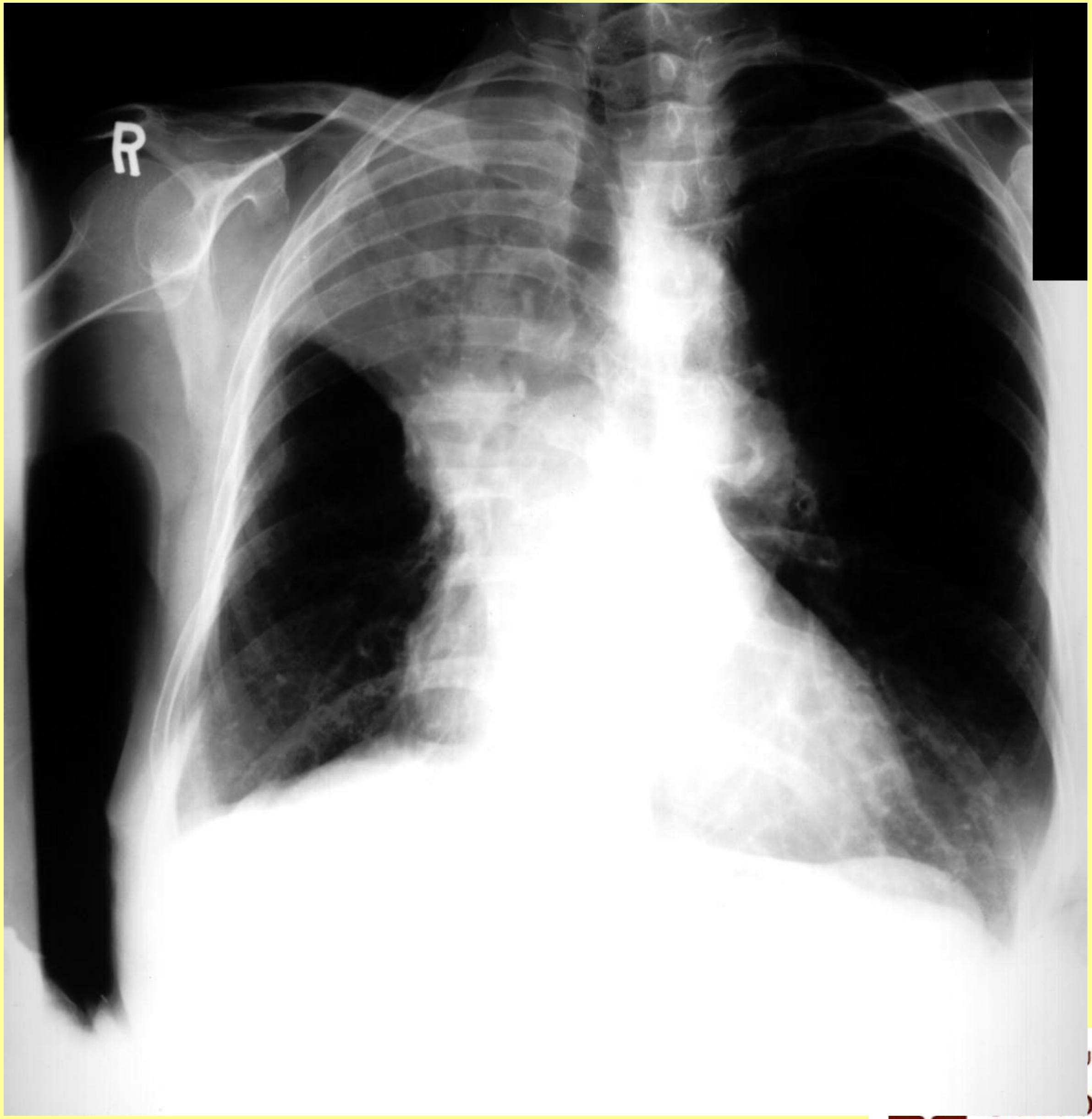
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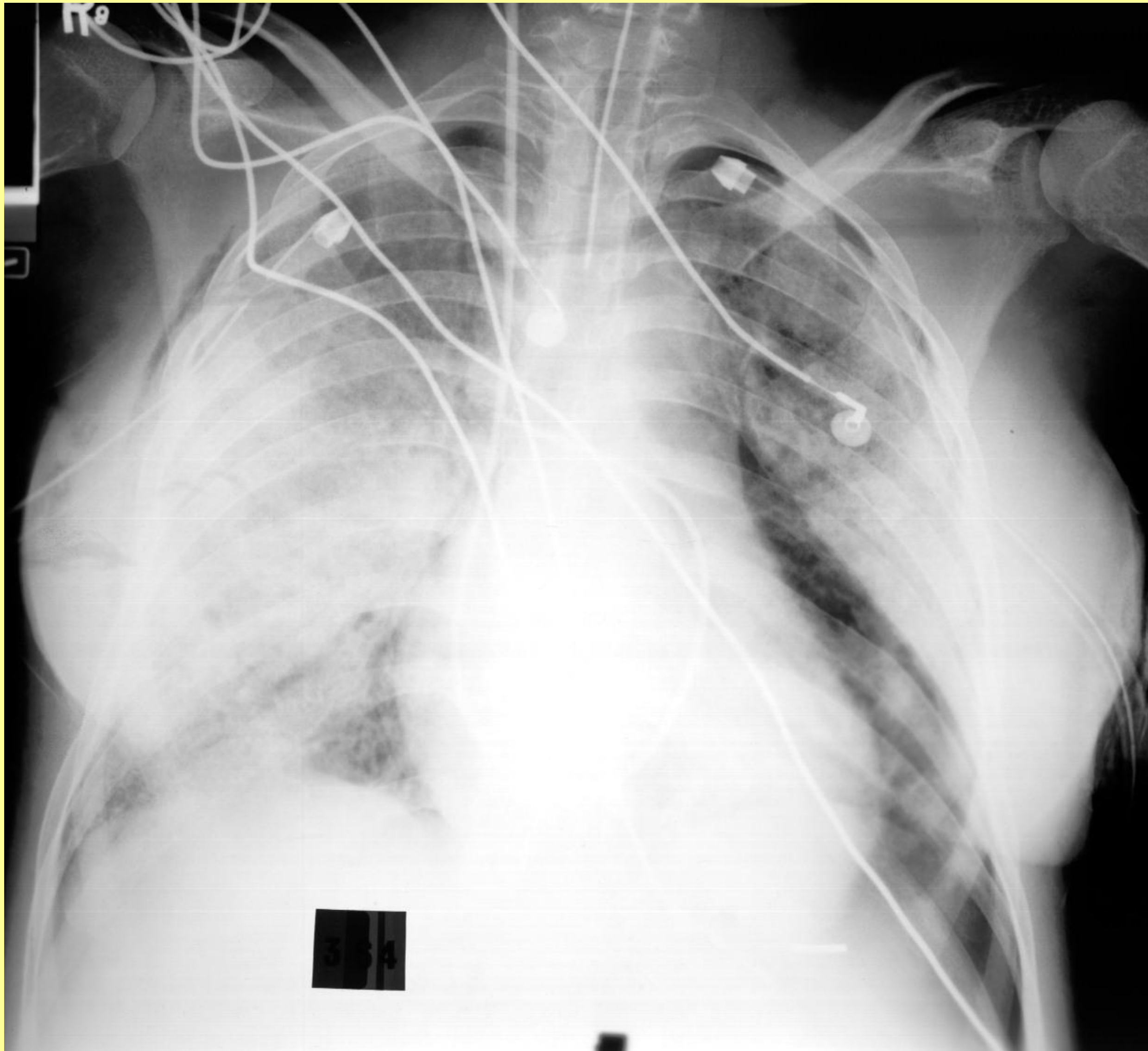

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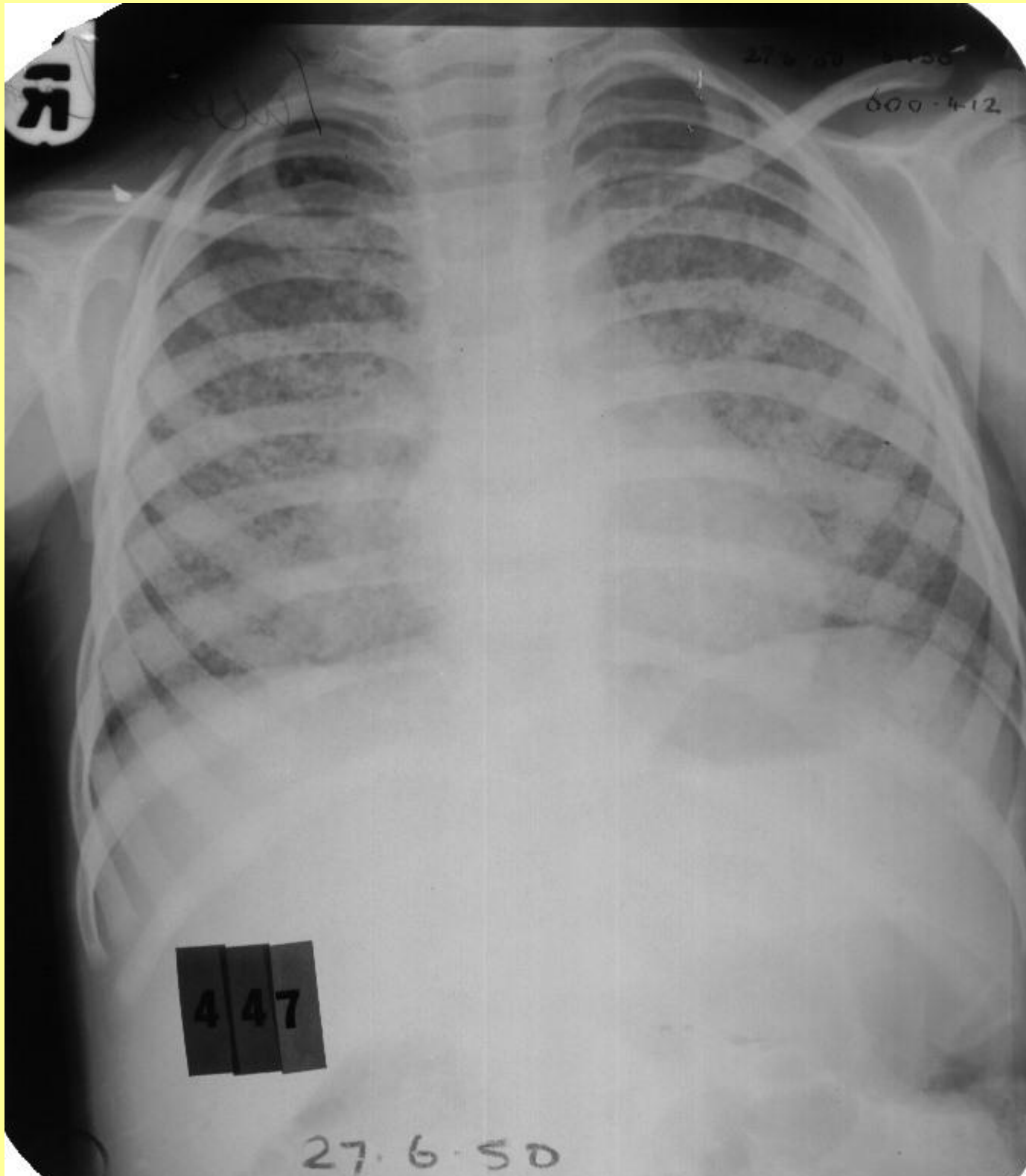
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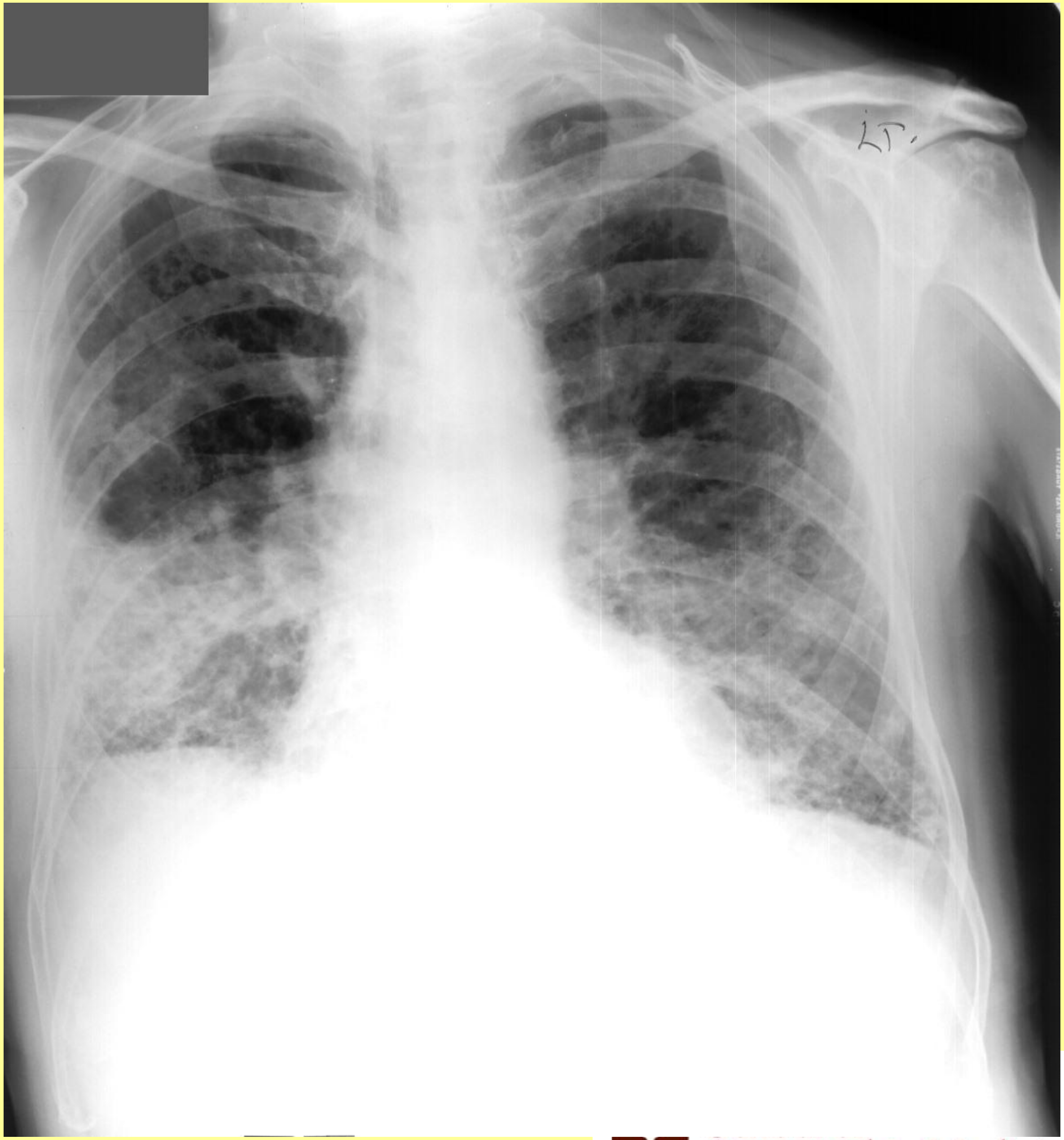
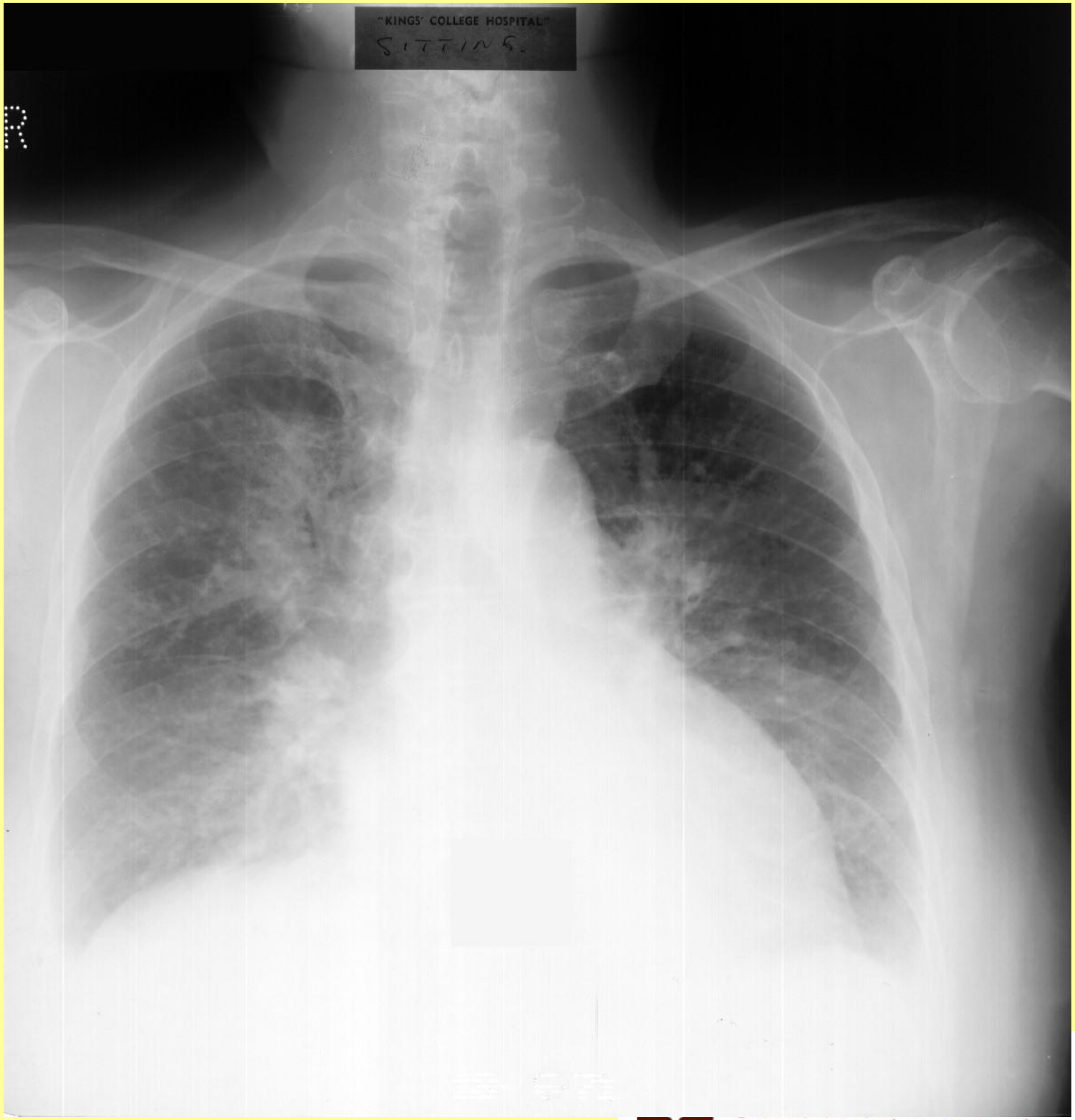
27·6·50

pulmonary fibrosis due to RA



76 yo
Female

SOB
Edema
Orthopnea



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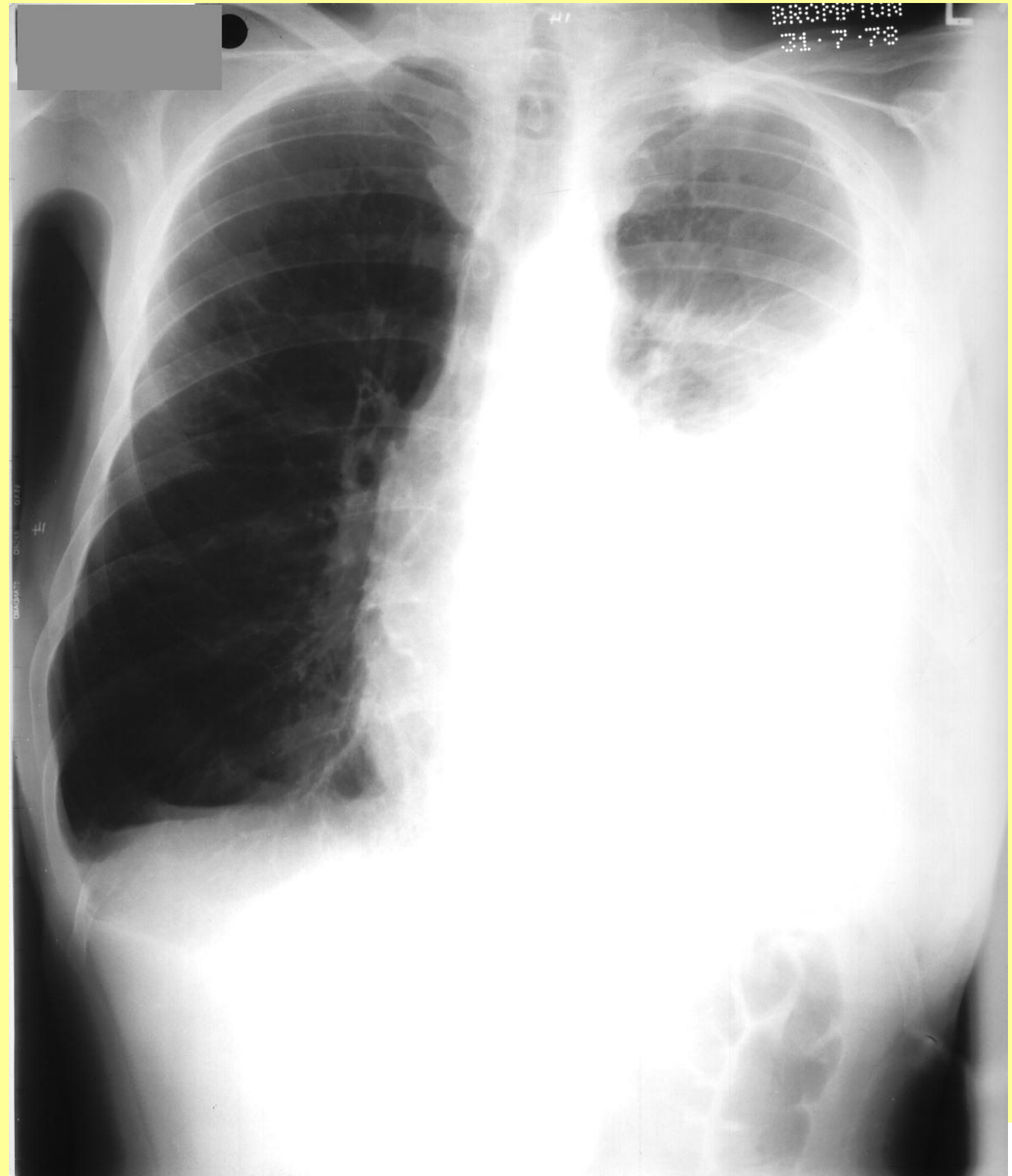
Male

SOB



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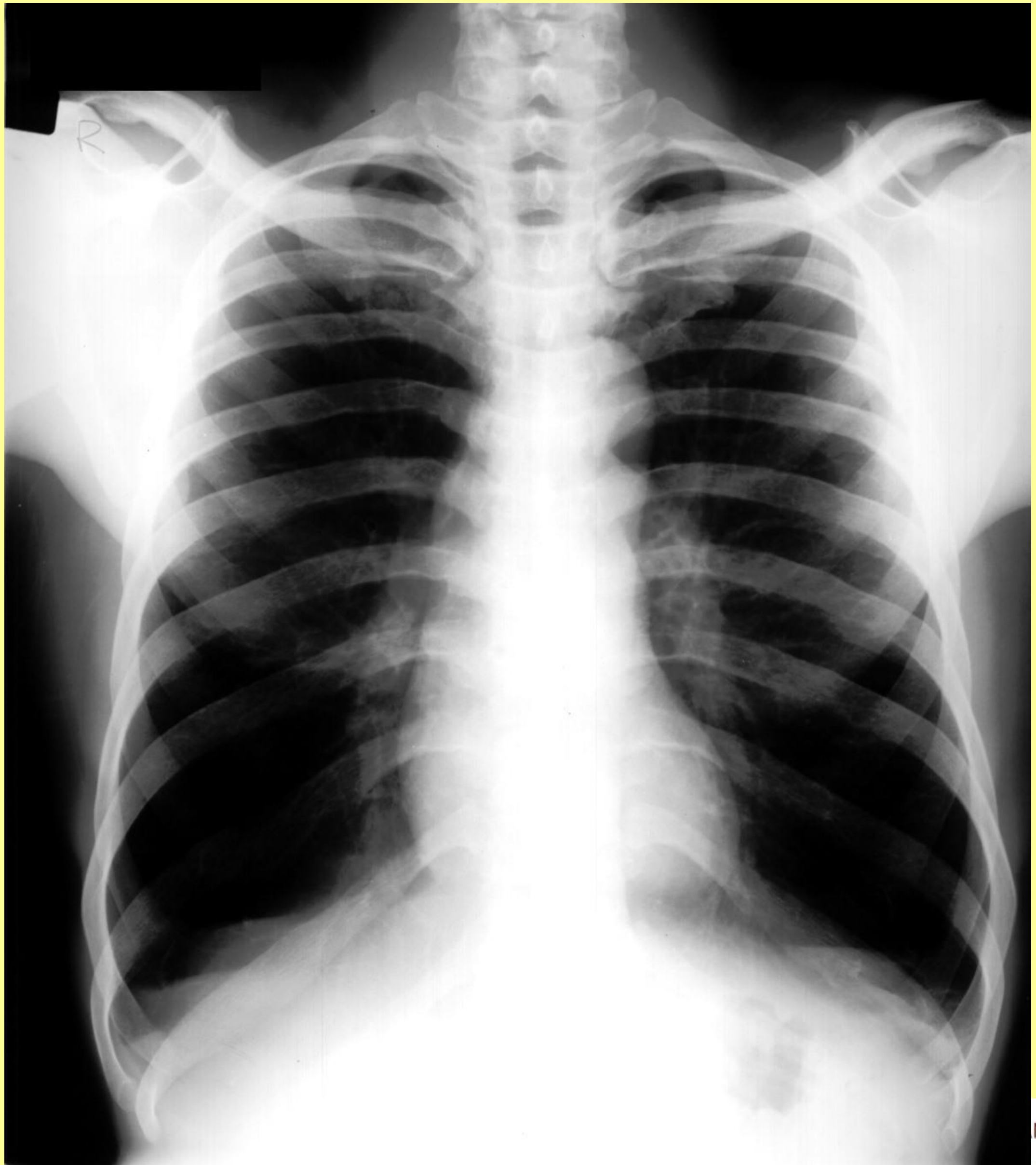

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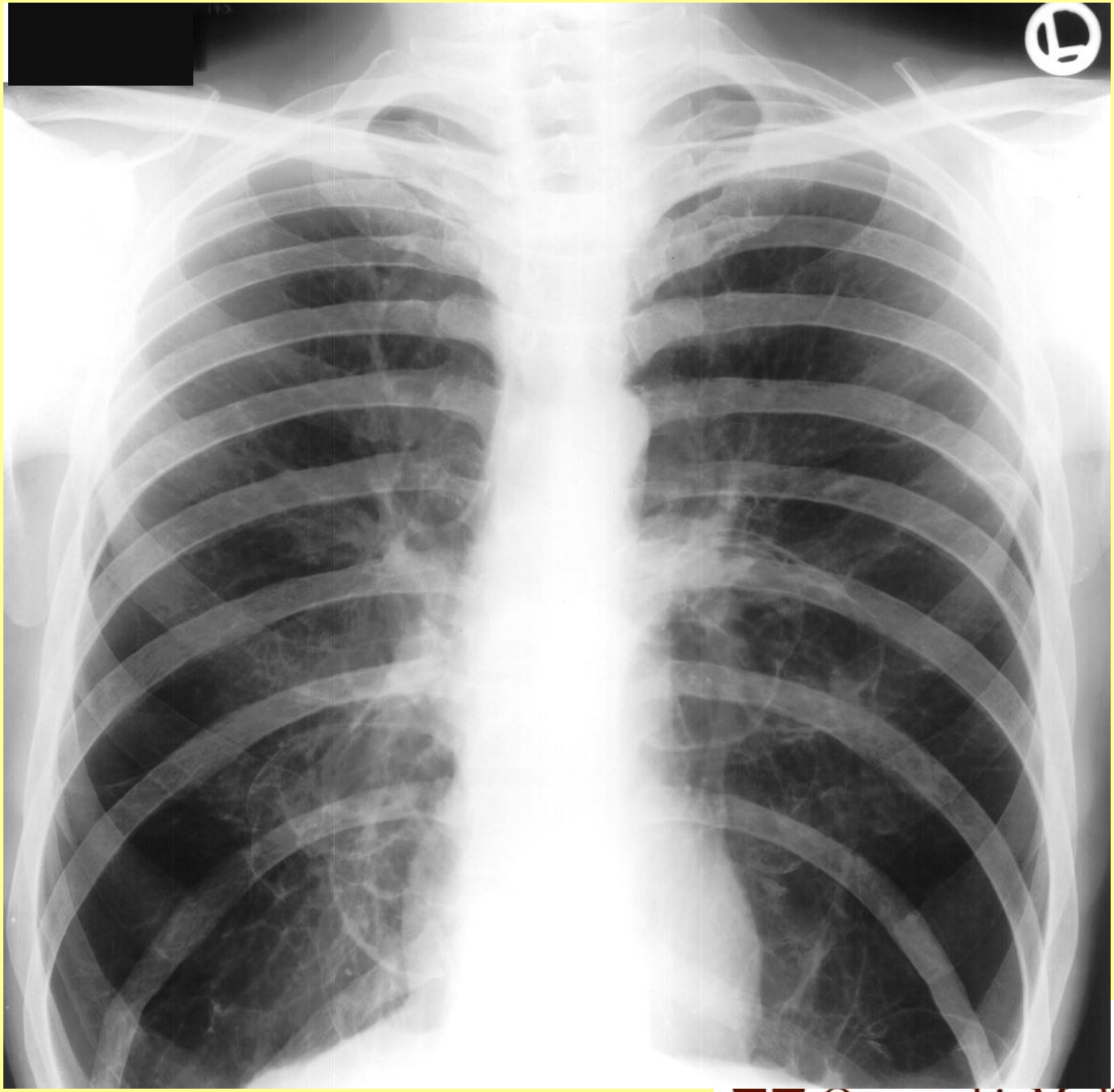
Male 40 yo

Dyspnea



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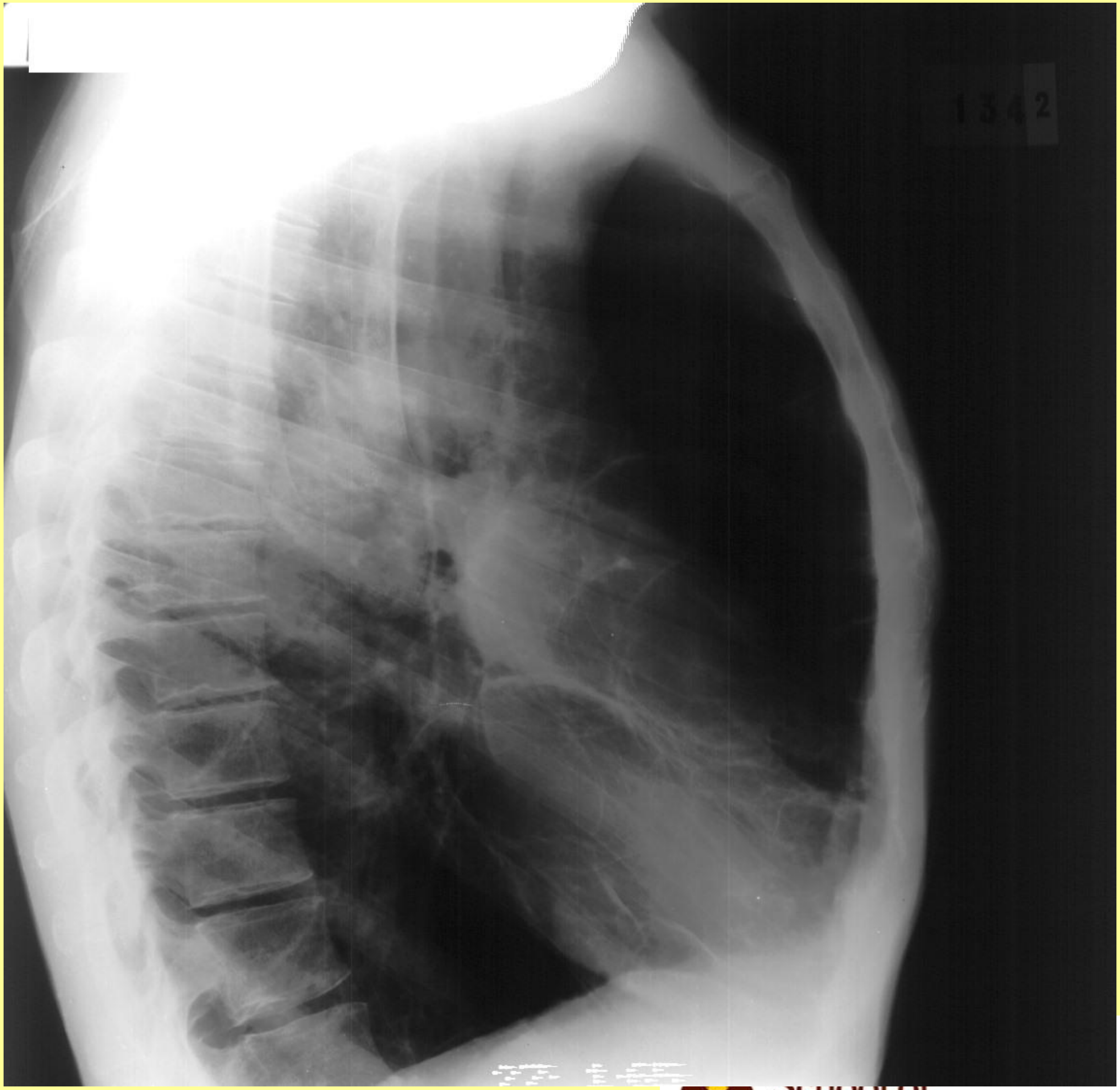
Male 40 yo

Dyspnea



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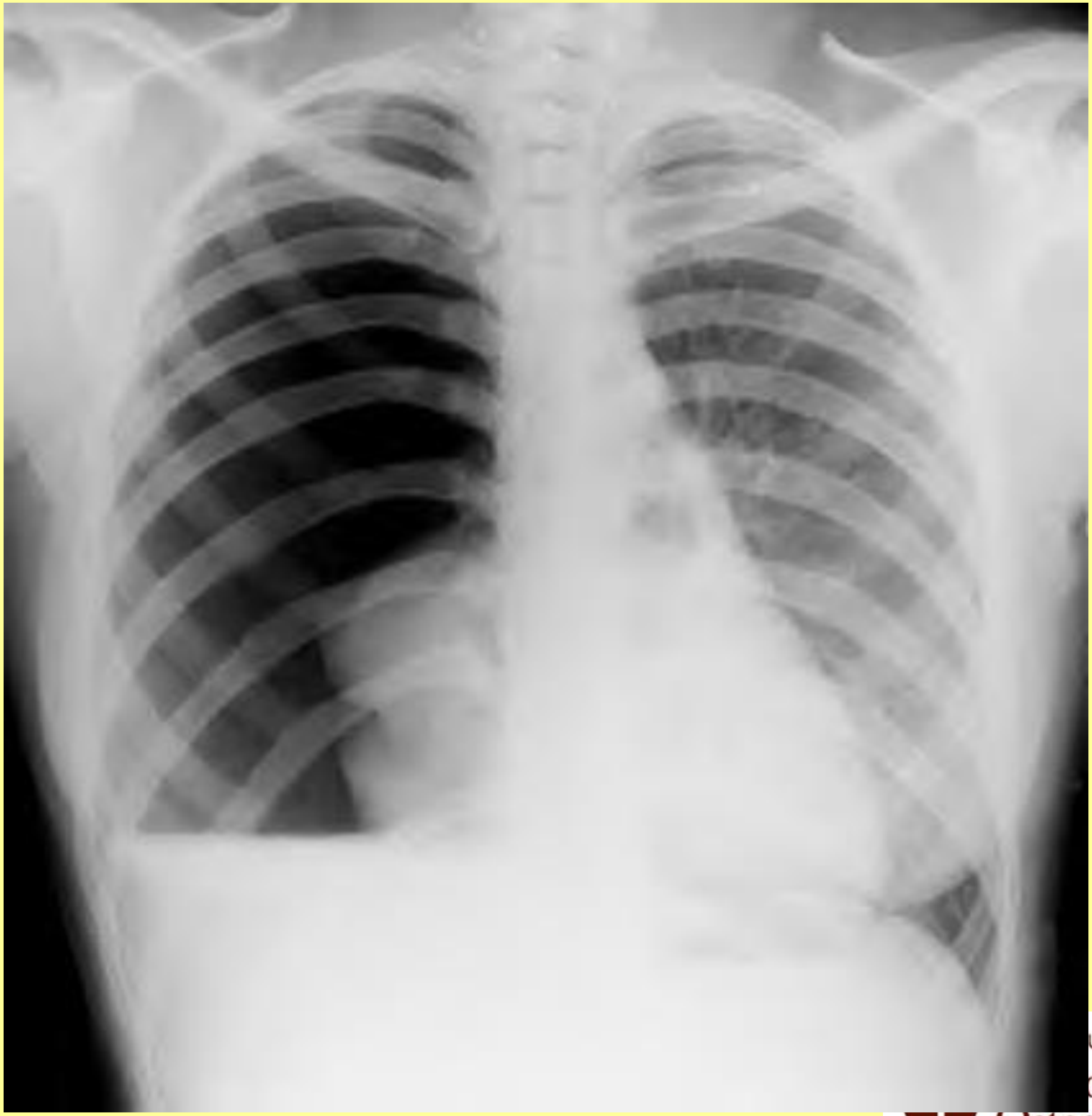

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CONDITION	DEFINITION	EXAMPLE	ABNORMALITY
Ventilatory Failure	Abnormal CO2 elimination by lungs	Drug overdose Asthma	$PaCO_2 > 50$ mmHg
Failure of Arterial Oxygenation	Abnormal O_2 uptake by lung	Pneumonia, ARDS	$PaO_2 < 50$ mm Hg
Failure of Oxygen Delivery	Abnormal O_2 delivery to the tissues	Cardiogenic shock Anemia, CO poisoning	$CvO_2 < 18$ cc/dl $PvO_2 < 30$ mmHg $SvO_2 < 60$ %
Failure of Oxygen Utilization	Failure of O_2 uptake by tissues	Cyanide poisoning septic shock	$CvO_2 > 18$ cc/dl $PvO_2 > 60$ mmHg $SvO_2 > 80$ %

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Objectives of Mechanical Ventilation Tobin MJ. NEJM 1994; 330:1056-61

- **Improve pulmonary gas exchange**
  - **Reverse hypoxemia**
  - **Relieve acute respiratory acidosis**
- **Relieve respiratory distress**
  - **Decrease the O2 cost of breathing**
  - **Reverse respiratory muscle fatigue**
- **Alter pressure-volume relations**
  - **Prevent/reverse atelectasis**
  - **Improve compliance**
  - **Prevent further lung injury**
- **Permit lung and airway healing**
- **Avoid complications**

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Treatment of ARF
Noninvasive Methods

CPAP

Pressure applied during entire respiratory cycle
Does NOT AUGMENT TIDAL VOLUME
Splint open the upper airway
Recruit collapsed alveoli

BiPAP

* **Different pressure during Ins and Exp**
I-PAP can AUGMENT tidal Volume
E-PAP can prevent airway closure and recruit collapsed alveoli

USEFUL FOR CHF, COPD, - May prevent need for INTUBATION

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Barotrauma

- Until recently it was believed that alveolar rupture was due to excessive proximal airway pressure

- If peak airway pressure exceeded 50 cm H_2O then the patient was considered to be at high risk for alveolar rupture.

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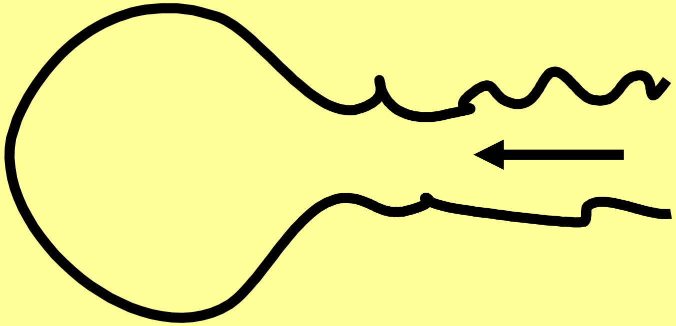
Barotrauma

- **If inspiratory resistance is HIGH DISTAL ALVEOLAR PRESSURE may be LOWER than PEAK AIRWAY PRESSURE !**

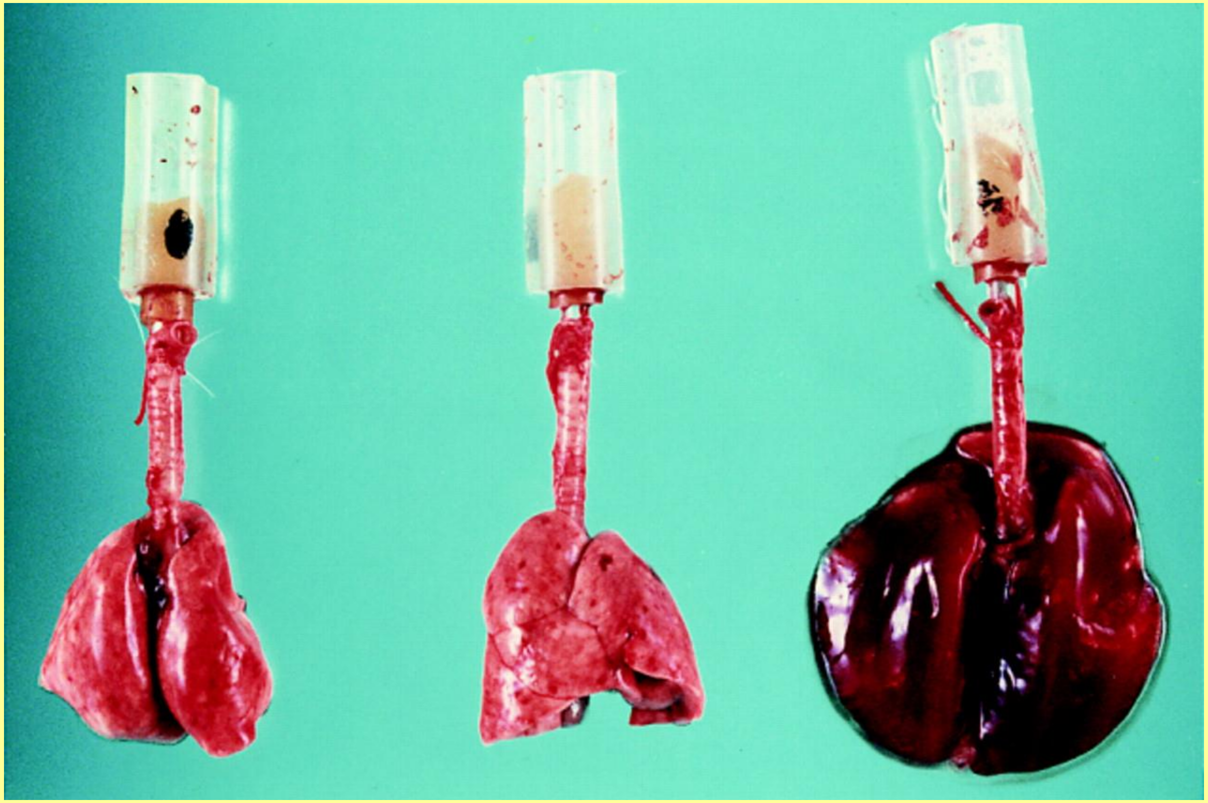
Alveolar Pres = 20 cm H20



PAP = 50 cm H2O

Ventilator-induced Lung Injury

Dreyfuss D, Saumon G. Ventilator induced lung injury: lessons from experimental studies. Am J Respir Crit Care Med 1998;157:294-323.
Mead J, Takishima



- **Macroscopic aspect of rat lungs after mechanical ventilation at 45 cm H2O peak airway pressure. *Left*: normal lungs; *middle*: after 5 min of high airway pressure mechanical ventilation. Note the focal zones of atelectasis (in particular at the left lung apex); *right*: after 20 min, the lungs were markedly enlarged and congestive; edema fluid fills the tracheal cannula.**

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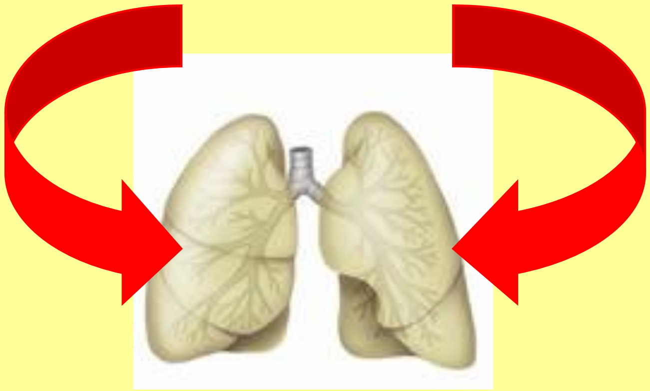
Animal Experiment – Same pressure is applied to both animal lungs

Banded lungs



Un-Banded lungs

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VOLUTRAUMA

- **Recent studies in animals with normal and diseased lungs suggest that it is alveolar *<u>OVERDISTENTION</u>* and *<u>NOT EXCESSIVE PRESSURE</u>* which leads to alveolar rupture.**
- **VOLUME NOT PRESSURE Causes alveolar rupture**

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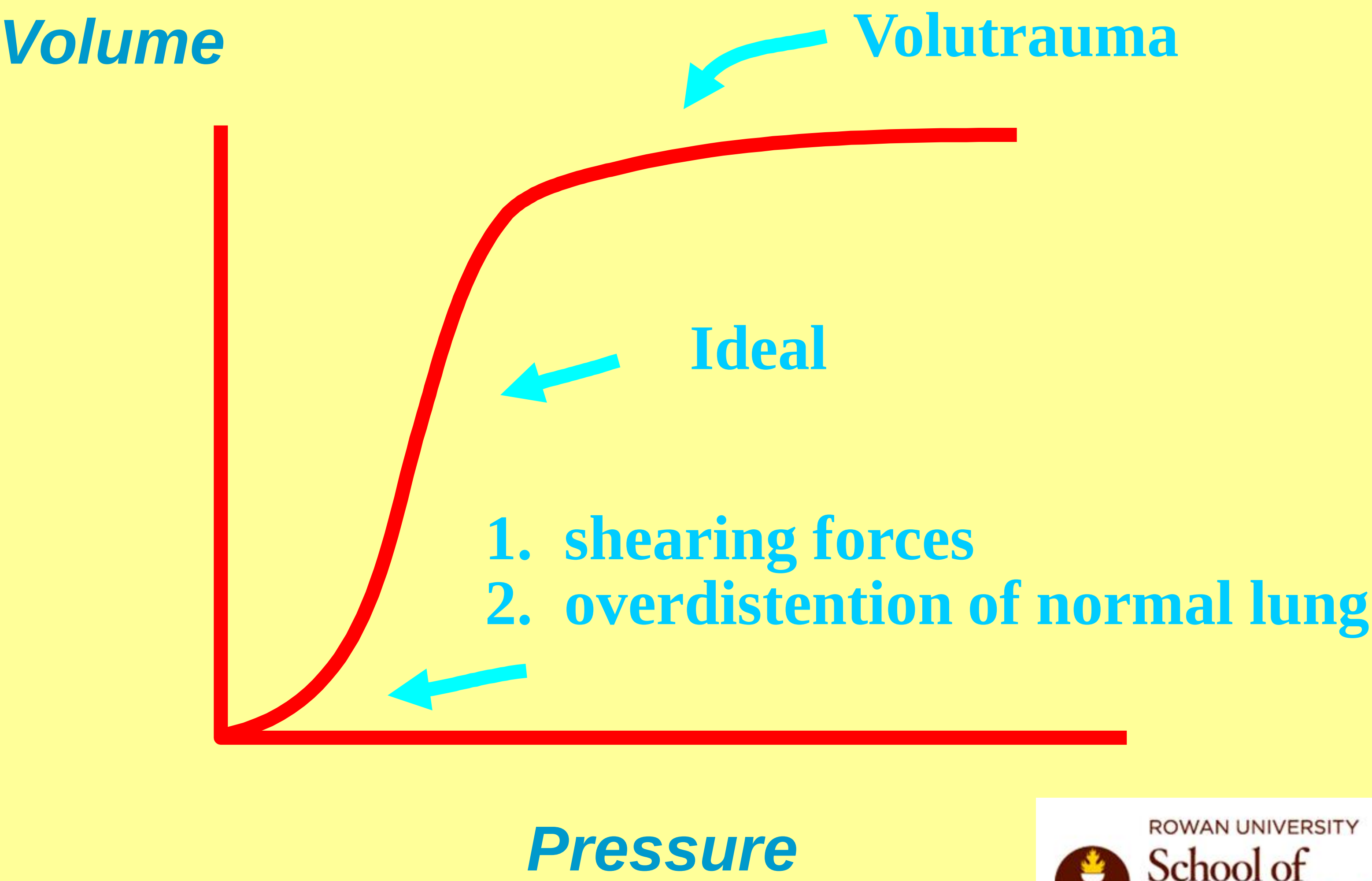
VOLUTRAUMA

What volume do we want ?



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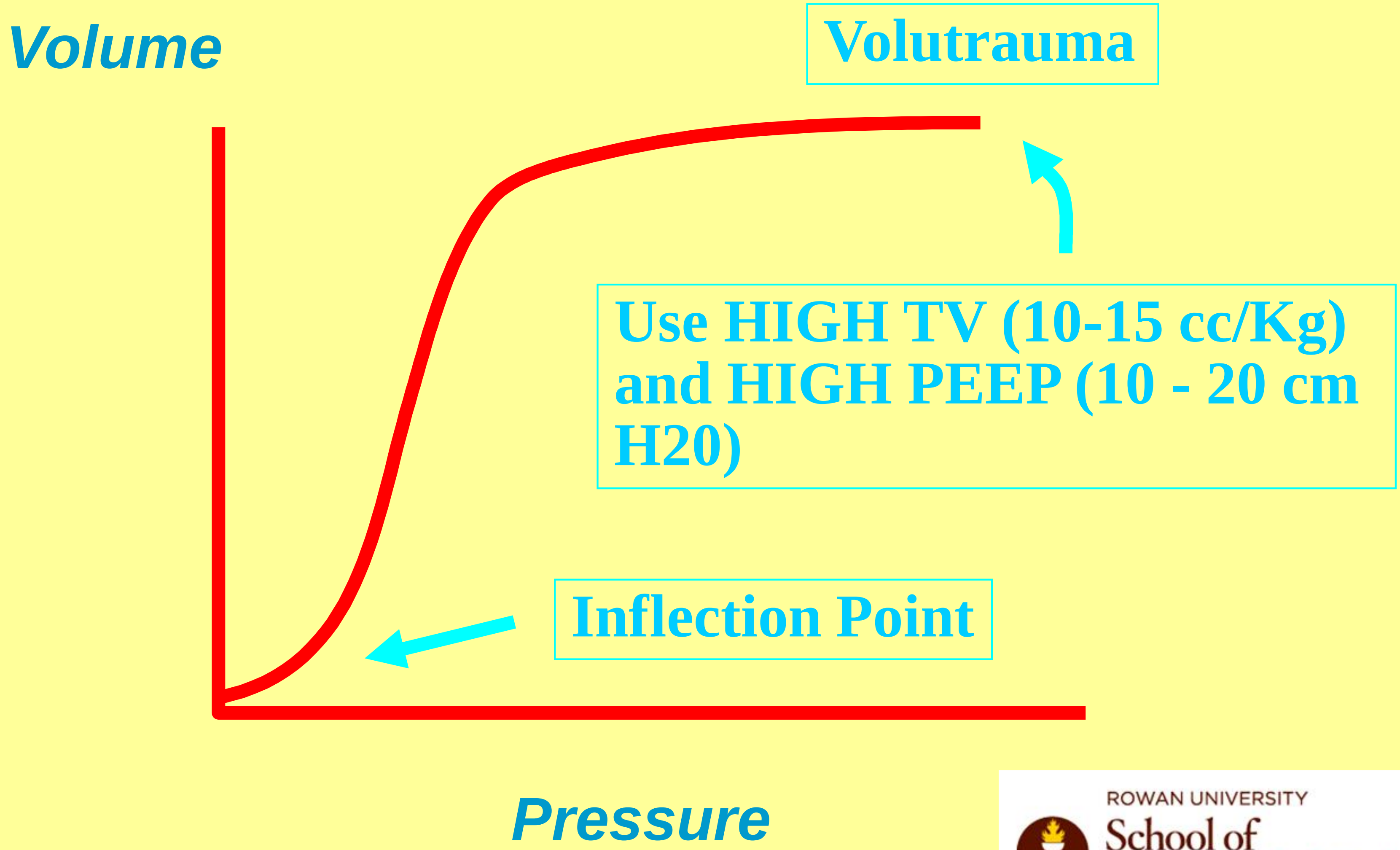
Classic Approach to MV
in Acute Lung Injury



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How do we measure Plateau Pressure

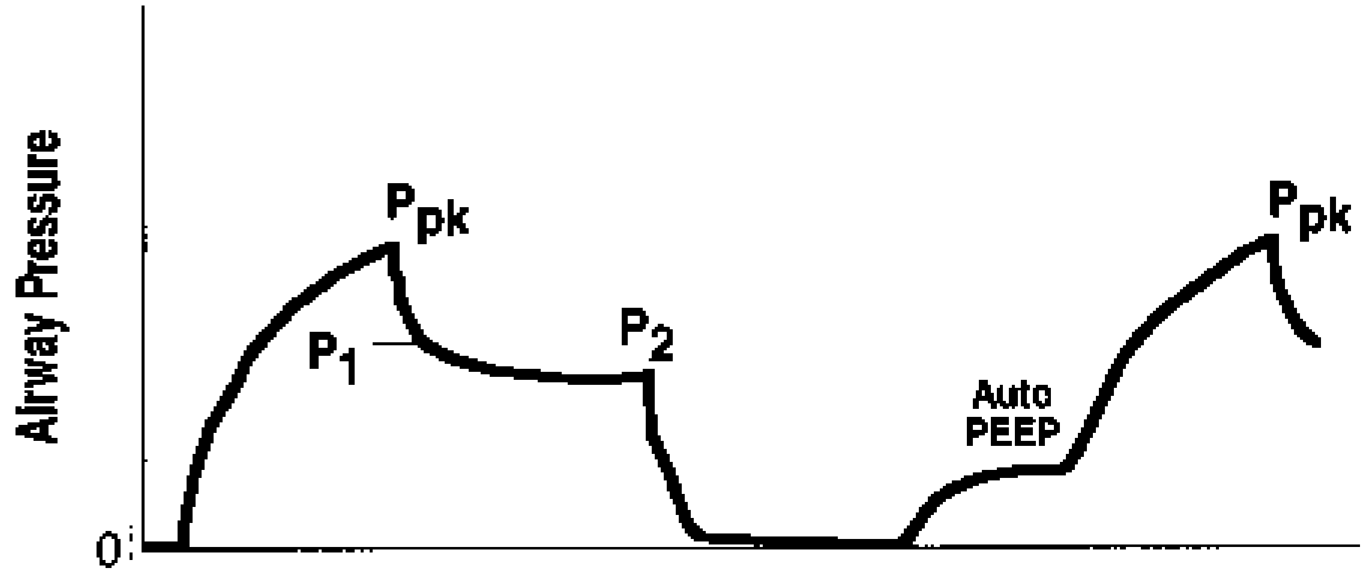

Figure 1. Proximal airway pressure recording during an end-inspiratory airway occlusion and during an end-expiratory occlusion.

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How should we approach MV in ARDS TODAY ?

- **TV smaller (5 cc/Kg) ideal body weight**
- **PEEP (above inflection point)**
- **Keep plateau pressure < 30 cm H20**
- **THIS MAY RESULT IN HYPERCAPNIA !**

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AutoPEEP
Definition

- **AutoPEEP is a pressure gradient between the alveoli and the central airways due to INSUFFICIENT EXPIRATORY TIME.**
- **Unlike applied PEEP which is deliberately set, AUTO-PEEP is inadvertent.**

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AutoPEEP

Incidence

- **Reported in 47 % of patients in medical ICU's (Wright. Heart and Lung 1990; 19:352-357)**
- **Occurs in 100 % of MV patients with Ve above 20 L/min (Brown. Respir Care 1986; 31:1069-74)**

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AutoPEEP (AP)
Causes

Type of AP	Causes
AP with Hyperinflation and Airway obstruction	Dynamic airway closure
AP with Hyperinflation and NO Airway obstruction	High Ve vent circuitry, valves or filters which delay exhalation
AP with NO Hyperinflation and NO Airway obstruction	Forced exhalation

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AutoPEEP
Methods for Detection

- Use of Flow Waveform (qualitative)
- Esophageal Balloon or inductive waveforms
- Block exhalation and allow alveolar and central pressures to equilibrate equilibrate (Total PEEP)

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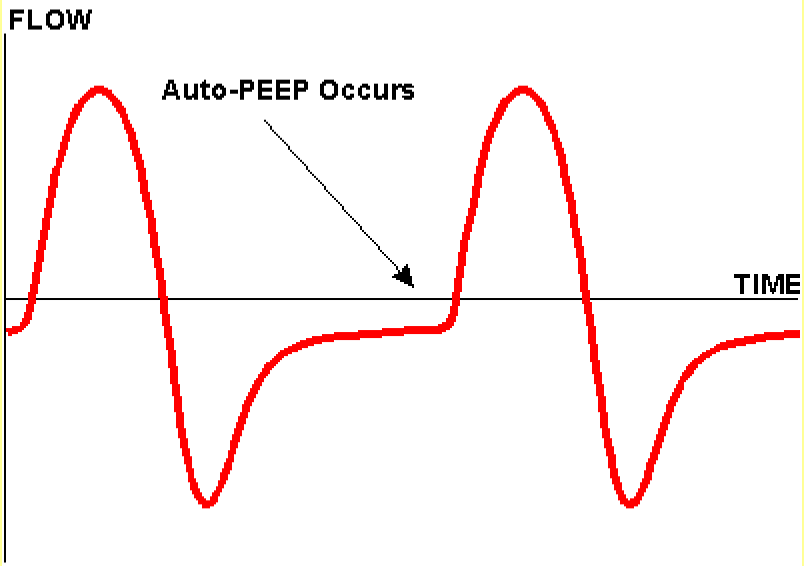
Auto PEEP detection	

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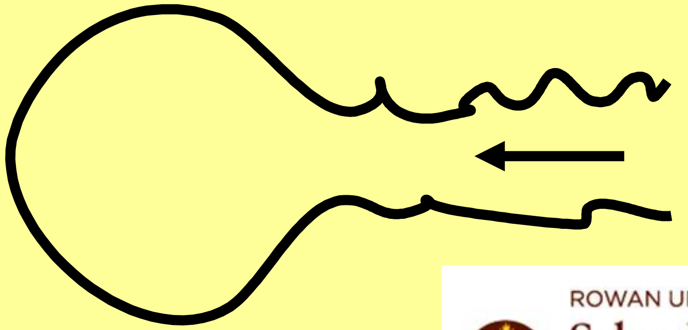
AutoPEEP

- AutoPEEP can be measured by blocking the airway at the END OF EXHALATION

- This allows the distal alveolar pressure to equilibrate with the Proximal airway pressure



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How do we measure AutoPEEP

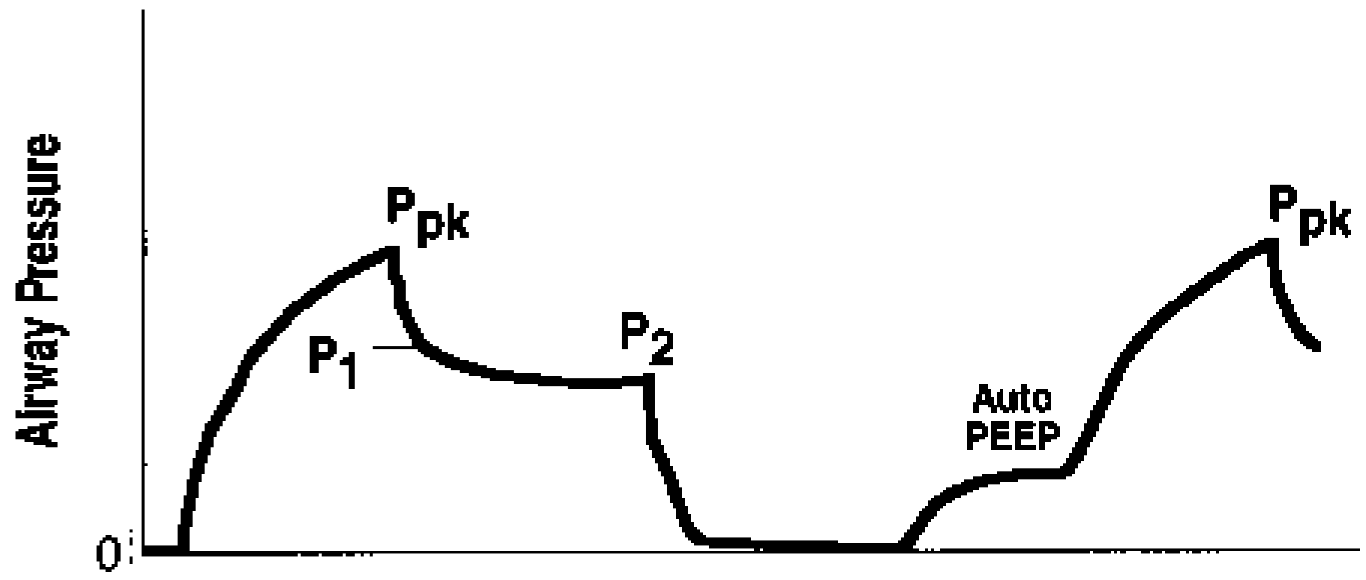

Figure 1. Proximal airway pressure recording during an end-inspiratory airway occlusion and during an end-expiratory occlusion.

AutoPEEP
Adverse Effects

Effect	Mechanism	Treatment
"Routine"	↑ PVR, ↓CO ↑ Vd/Vt	Decrease RR Increase Vt/Ti Decrease Vt
Triggering	Patient has to create a - pressure greater than AP to trigger a MV breath	Extrinsic PEEP to = AP

AutoPEEP
Methods to Reduce

Increase Expiratory Time	*Decrease Minute Ventilation*	*Decrease Expiratory Resistance*
Increase peak flow	*Decrease Rate*	*Medications*
Square Wave	*Decrease Tidal Volume*	*Remove kinks, secretions, casts*
		Larger ET tube
		Change filters

"New Berlin definition" ARDS

- **Predicted mortality is slightly better than the existing definition (created at the 1994 American-European Consensus Conference/AECC), when applied to a cohort of 4,400 patients from past randomized trials.**

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New ARDS Definition

ARDS Severity	PaO2/FiO2*	Mortality**
Mild	**200 – 300**	**27%**
Moderate	**100 – 200**	**32%**
Severe	**< 100**	**45%**
***on PEEP 5+; **observed in cohort**		

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"Berlin definition"

- **Onset of ARDS (diagnosis) must be acute, as defined as within 7 days**
- **Bilateral opacities may be detected on CT or chest X-ray**
- **"not fully explained by cardiac failure or fluid overload"**
- **JAMA online May 21, 2012.**

Pulmonary Function Tests

1. **Spirometry**
2. **Determination of Reversibility**
3. **Lung Volume**
4. **Bronchial Hyperreactivity (Methacholine Challenge)**
5. **Diffusing Capacity for CO**
6. **Exercise**

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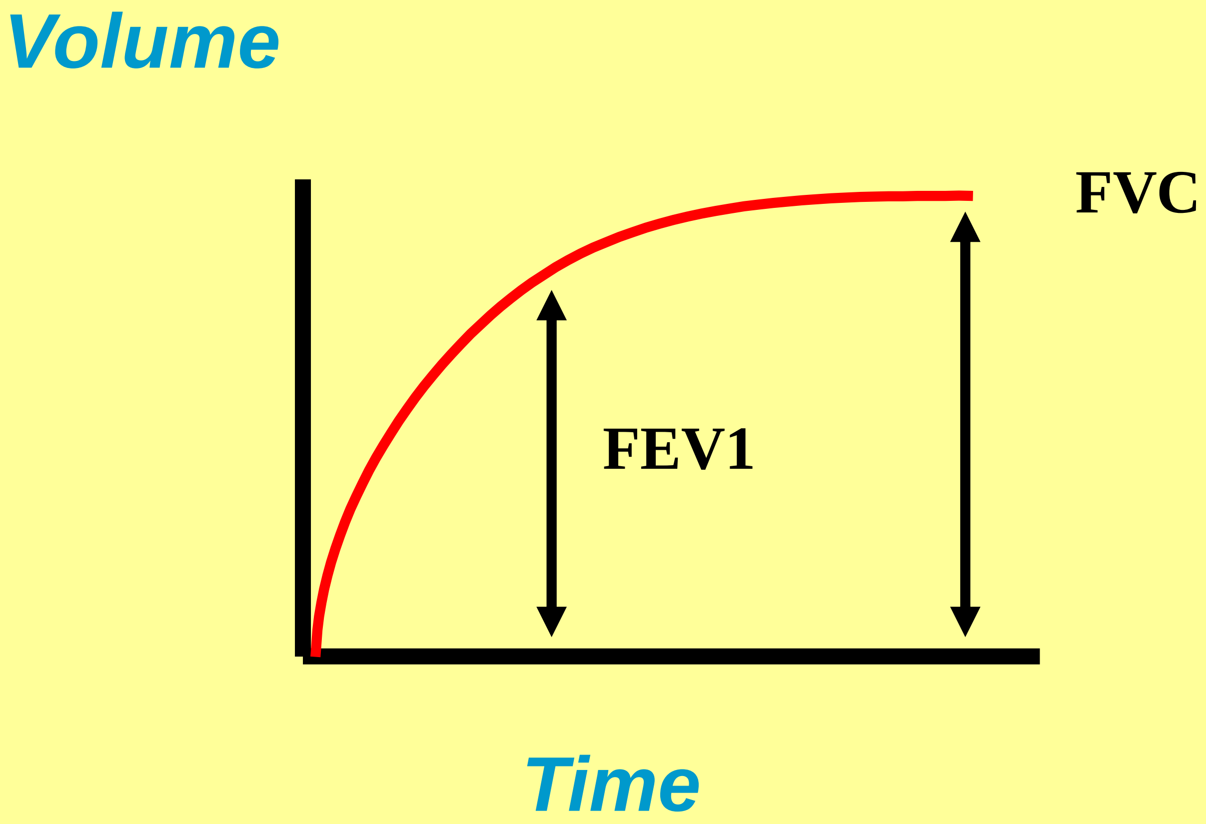
Pulmonary Function Tests

WHY ?

1. **To determine if lung disease is present**
2. **To screen for subclinical disease**
3. **To determine severity of known disease**
4. **To determine reversibility**
5. **To follow disease course**
6. **Pre-operative evaluation**

Volume/Time Curves
Definitions



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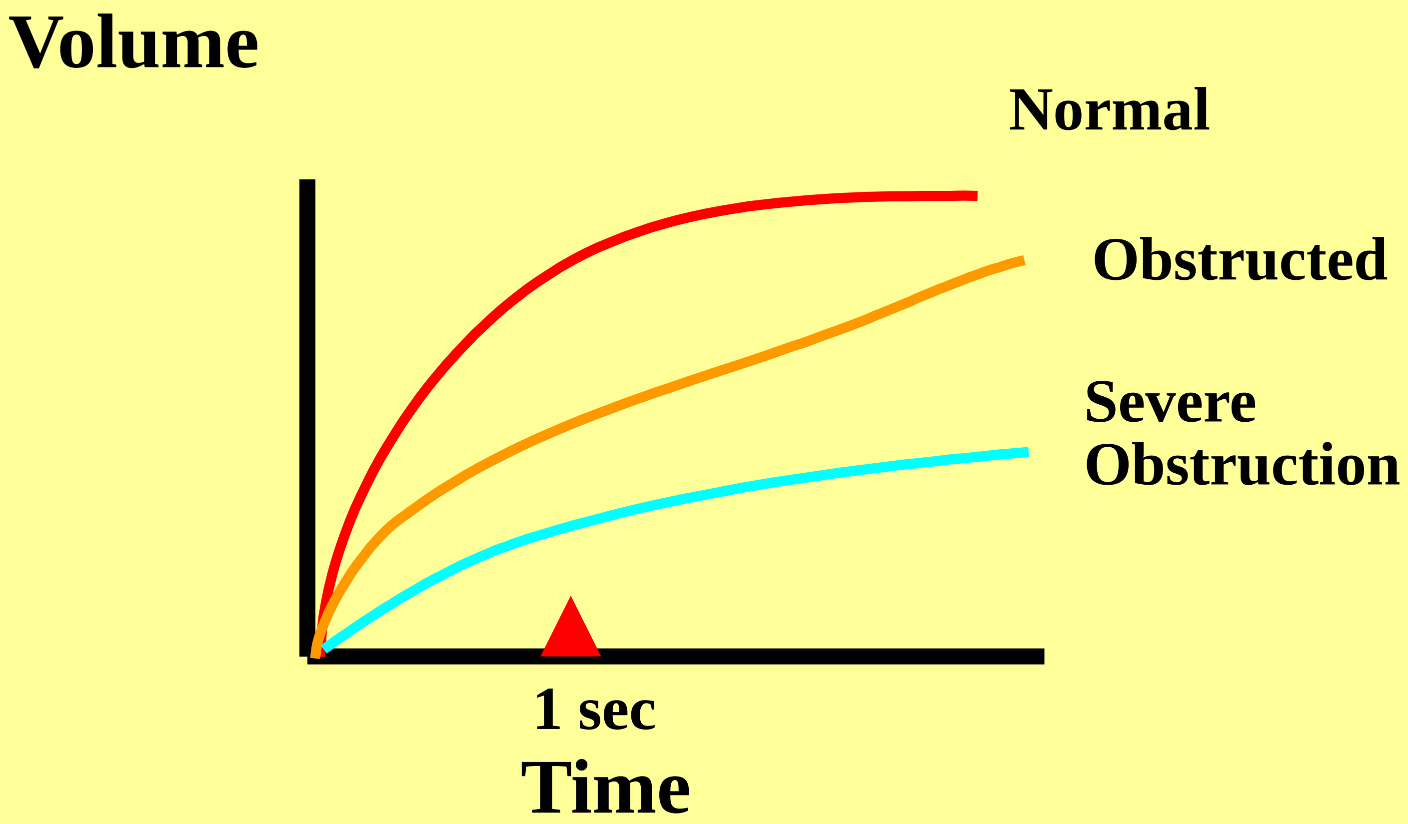
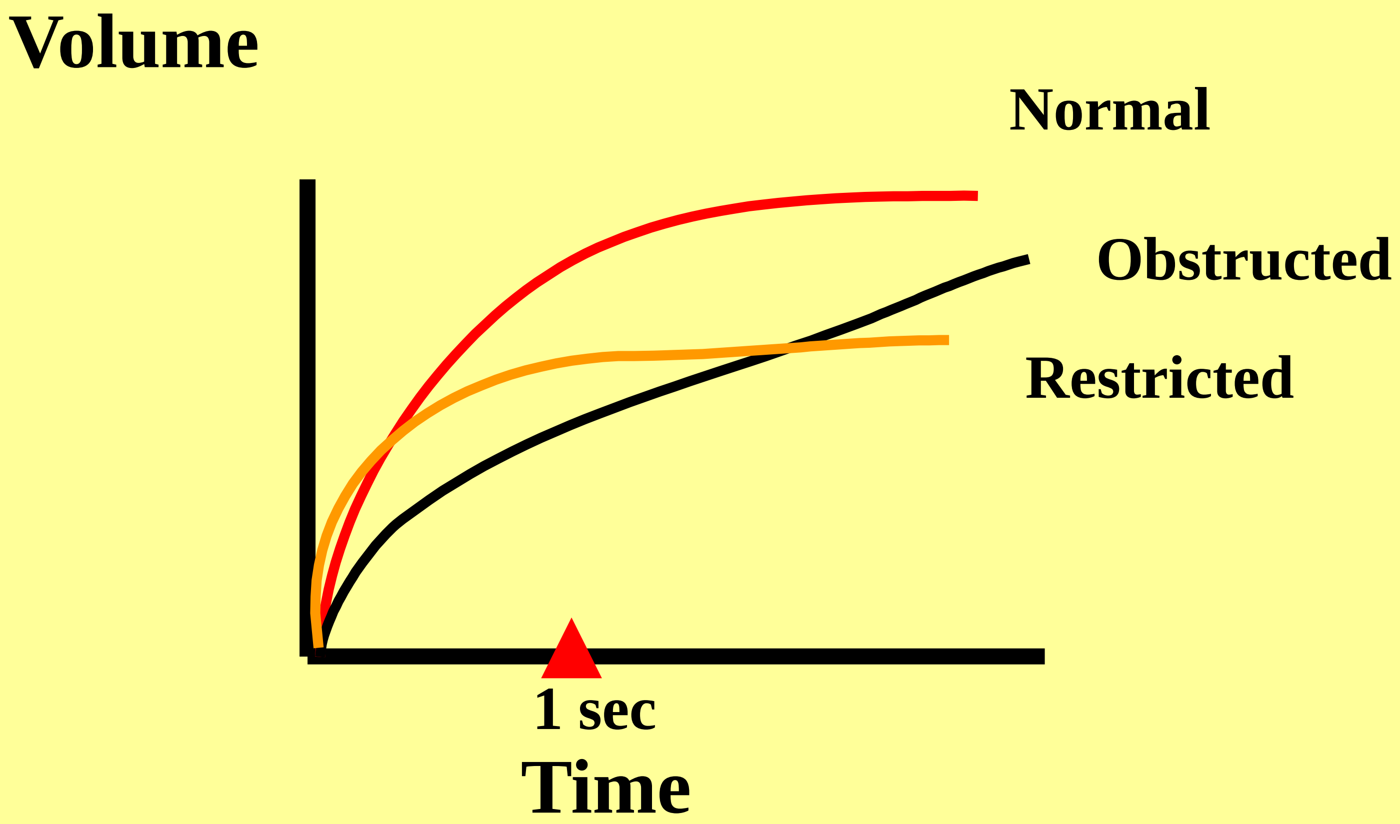
Volume/Time Curves
Obstruction



Volume/Time Curves
Obstruction versus Restriction



FEV1 can be reduced by Obst or Rest disease

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Differentiation of
Obstruction from Restriction

VARIABLE	*RESTRICTION*	*OBSTRUCTION*
FVC	*Reduced*	*N or Reduced*
FEV1	*Reduced*	*Reduced*
FEV1/FVC	*Normal*	*Reduced*
TLC/RV/FRC	*Reduced*	*N or Increased*

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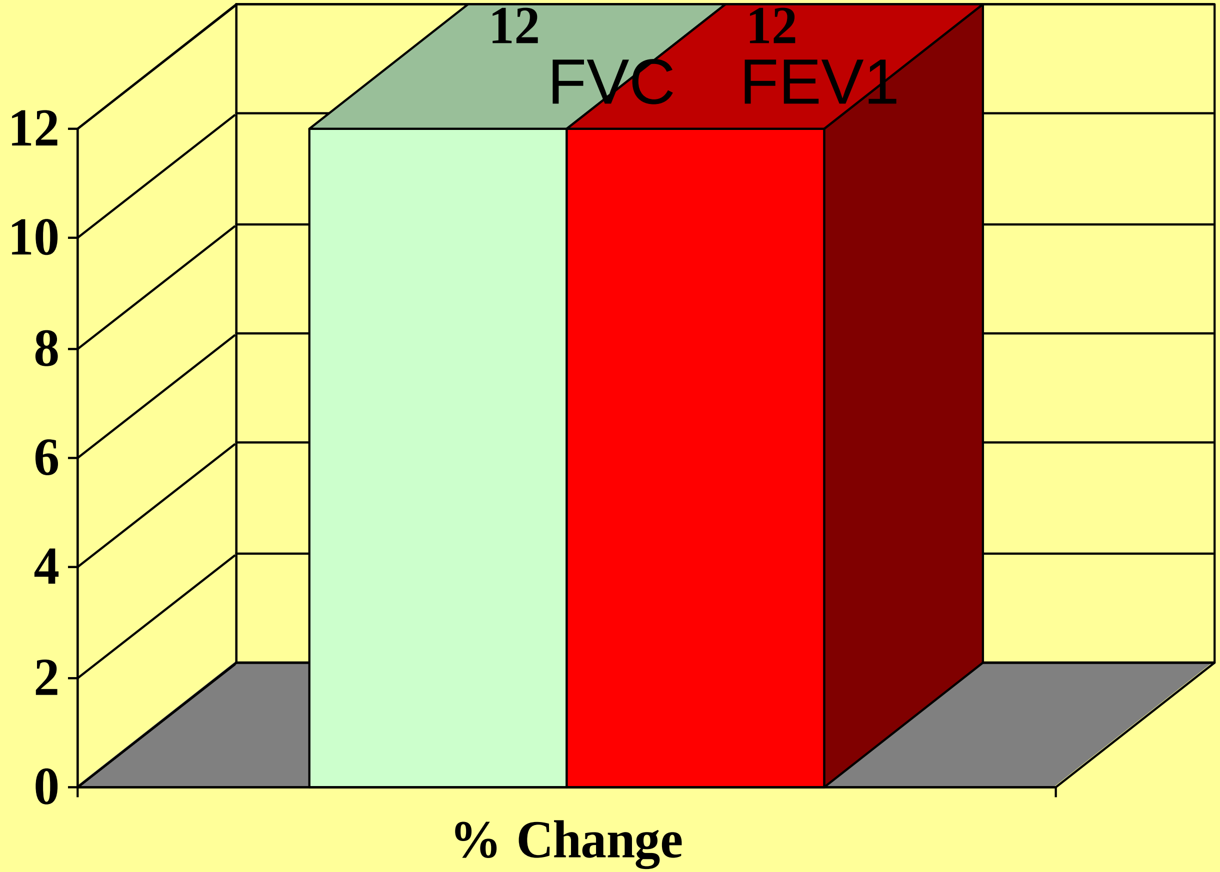
Response to Bronchodilator



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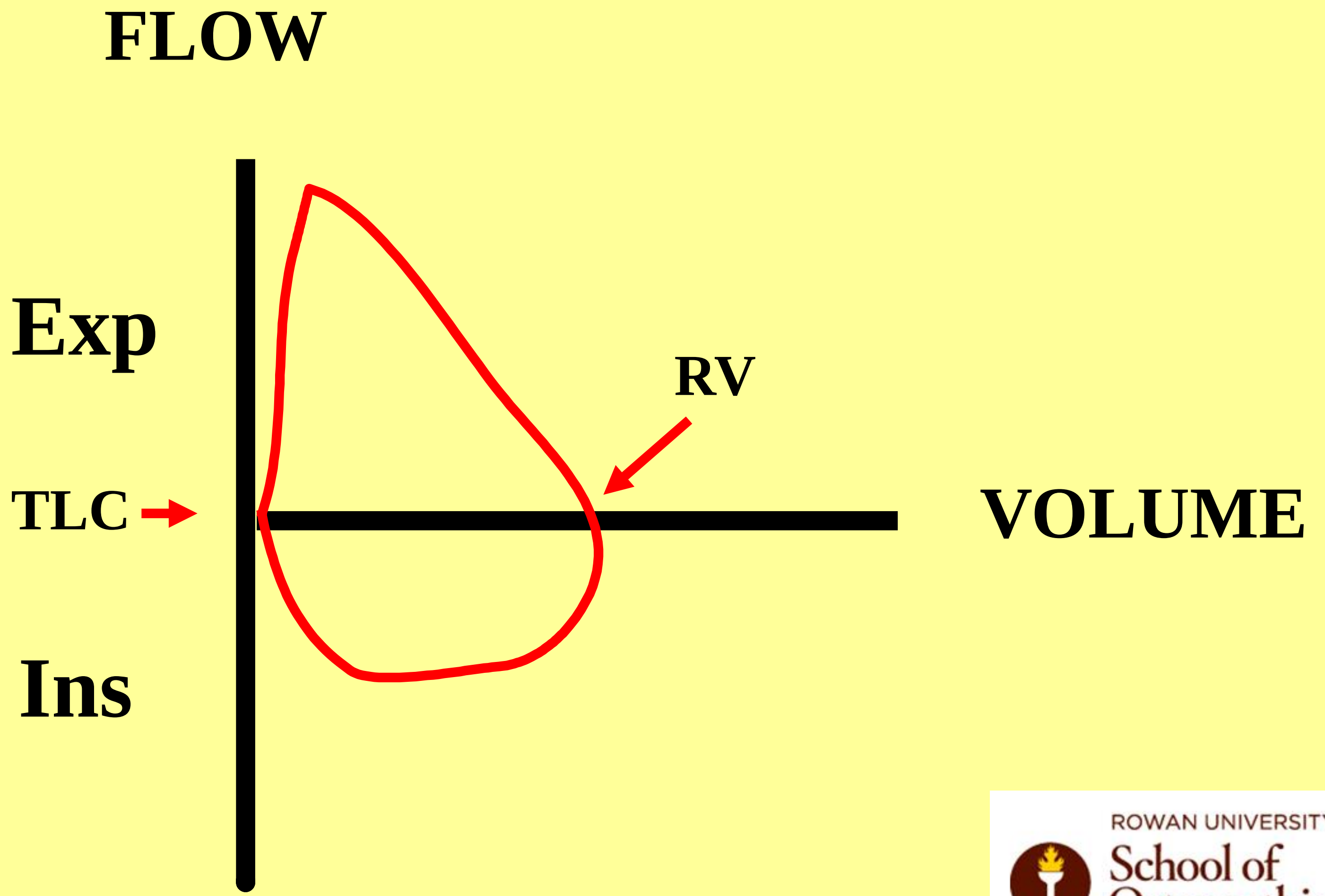
Flow-Volume Curve

Definitions



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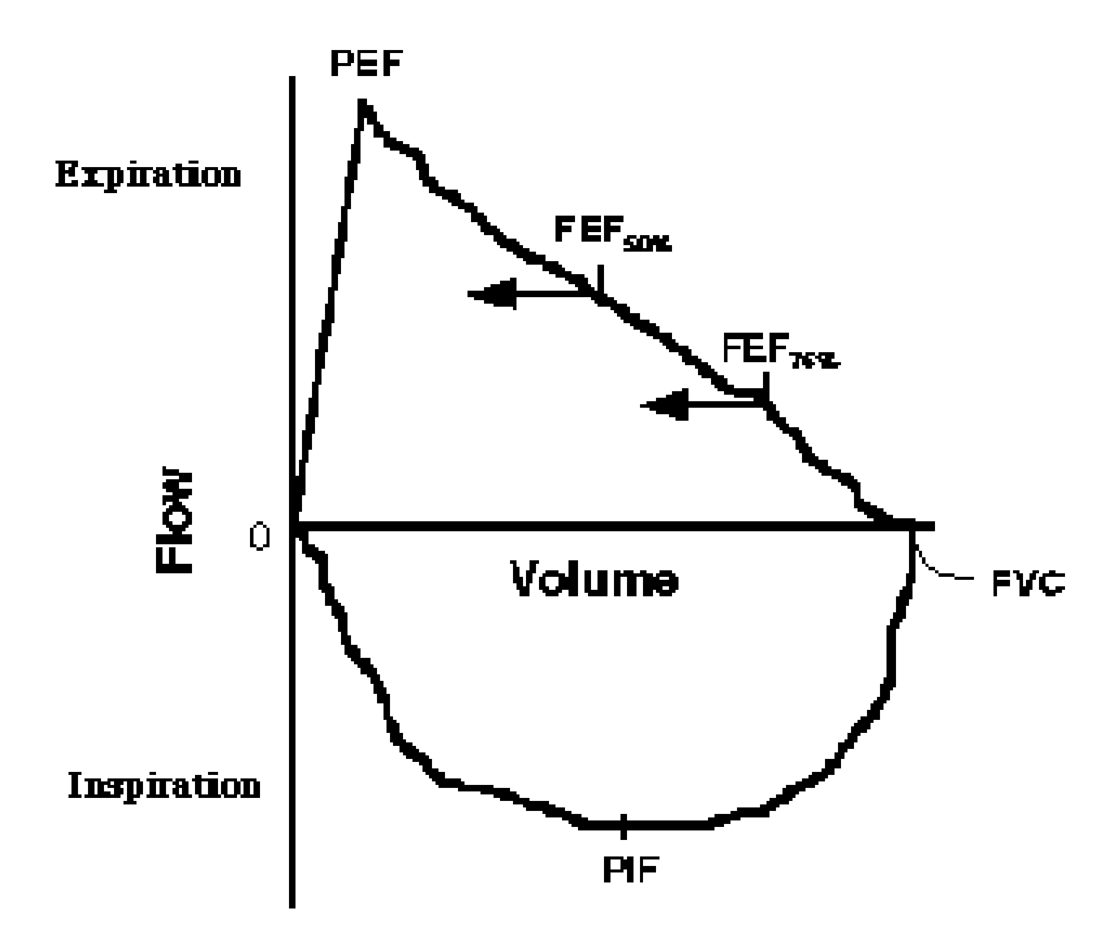
Flow-Volume Loop



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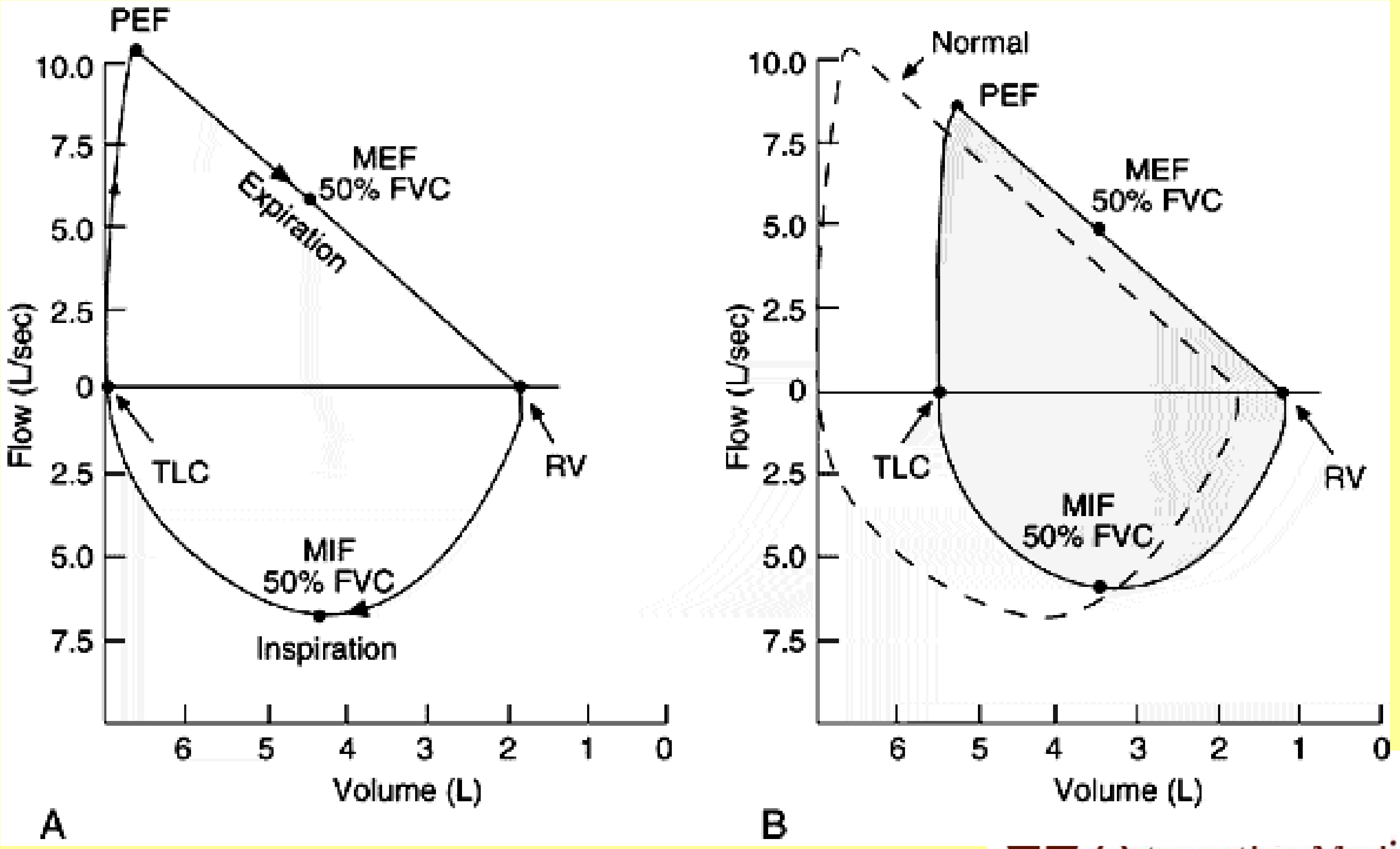
Normal and Restrictive FVL



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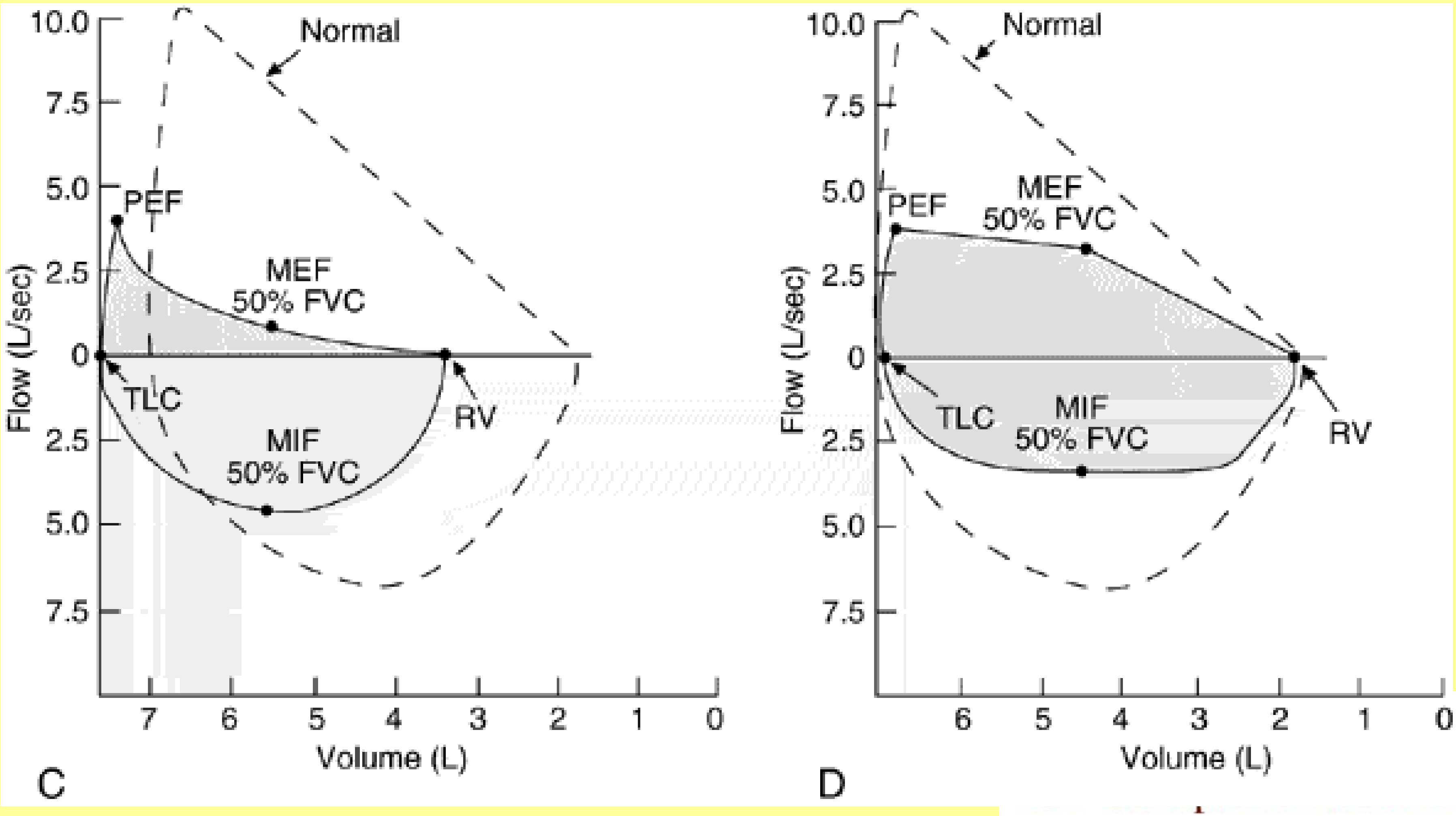
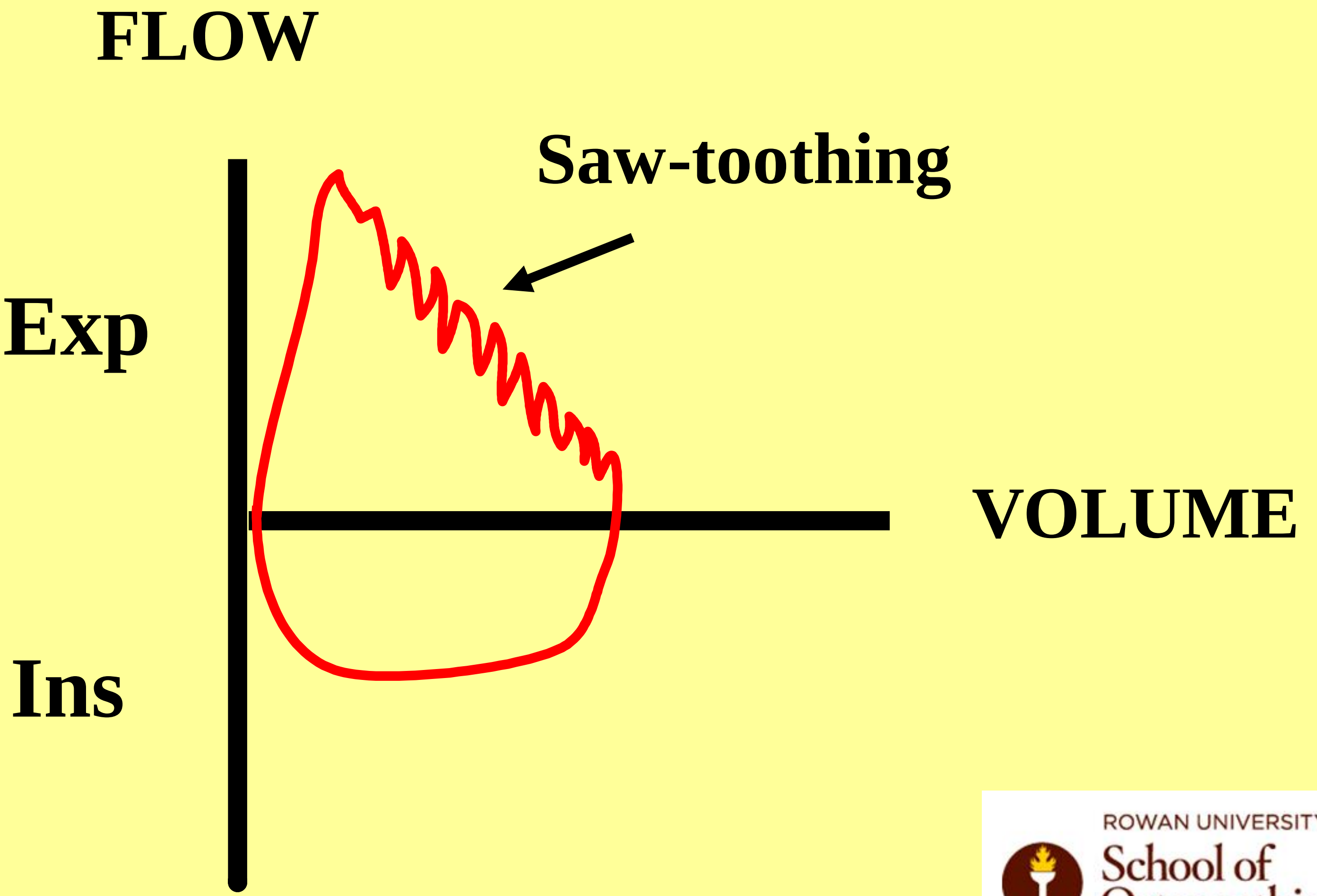
Obstructive FVL



Flow-Volume Curve
Sleep Apnea/ OHS



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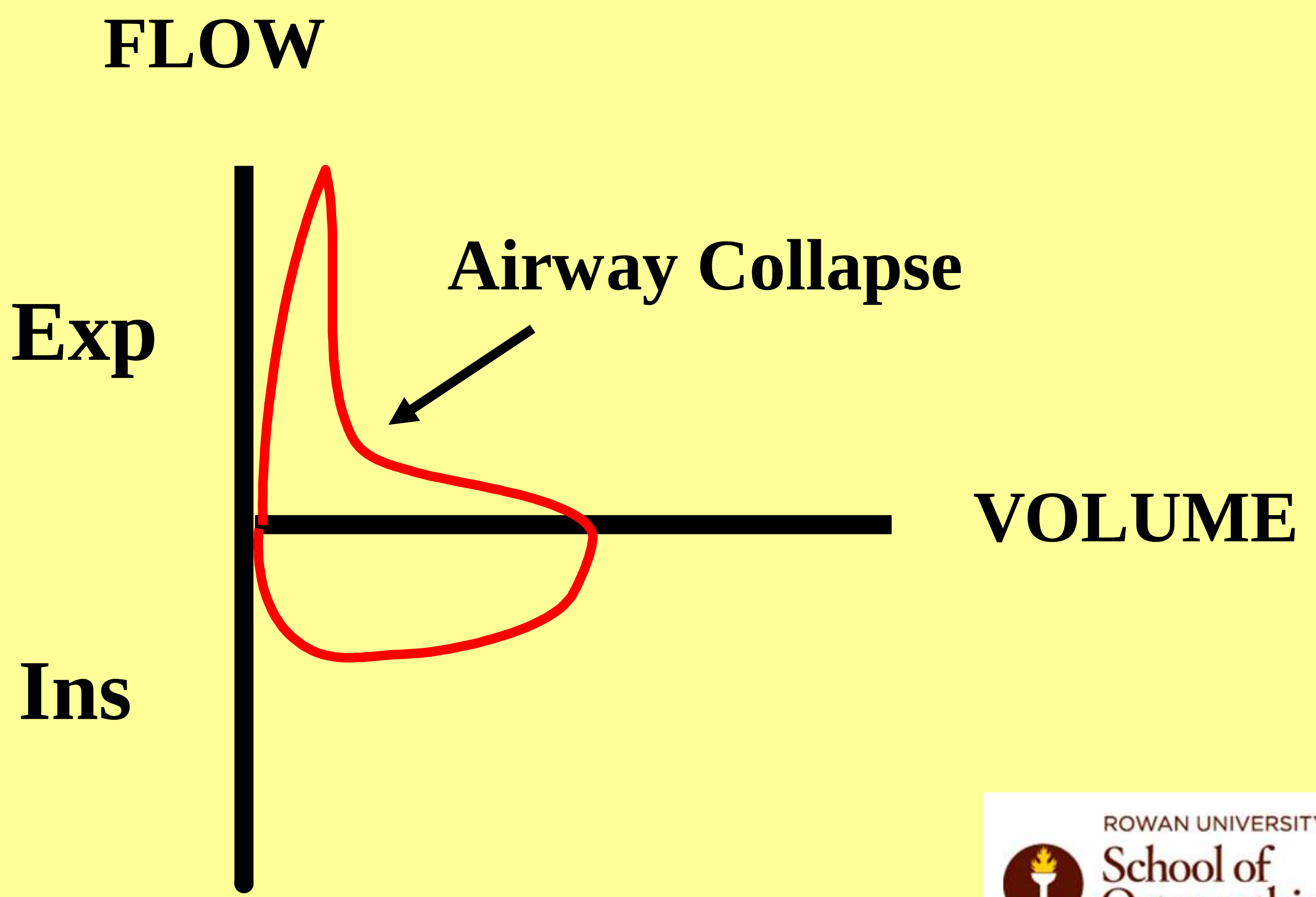
Flow-Volume Curve
Severe Airway Obstruction



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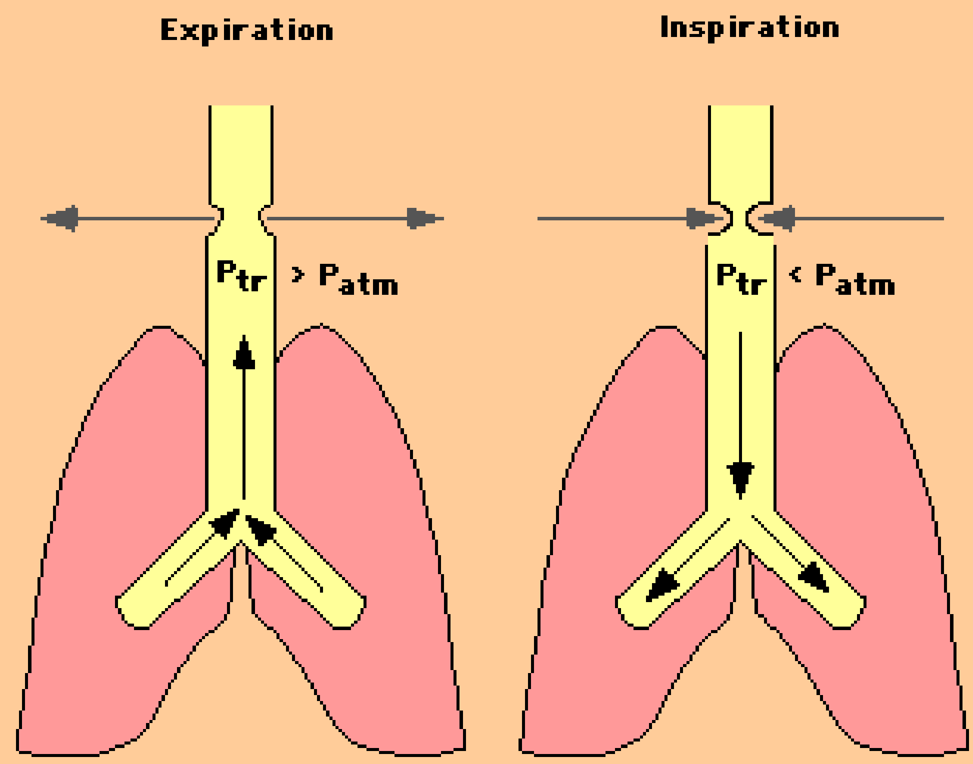

Effect of dynamic extrathoracic airway obstruction Effects of forced expiration and inspiration in dynamic extrathoracic airway obstruction. Left, during forced expiration, intratracheal pressure (Ptr) exceeds the pressure around the airway (Patm), lessening the obstruction. Right, during forced inspiration, when intratracheal pressure falls below the atmospheric pressure, the obstruction worsens resulting in flow limitation. (Redrawn from Kryger, M, Bode, F, Antic, R, et al, Am J Med 1976; 61:85.)

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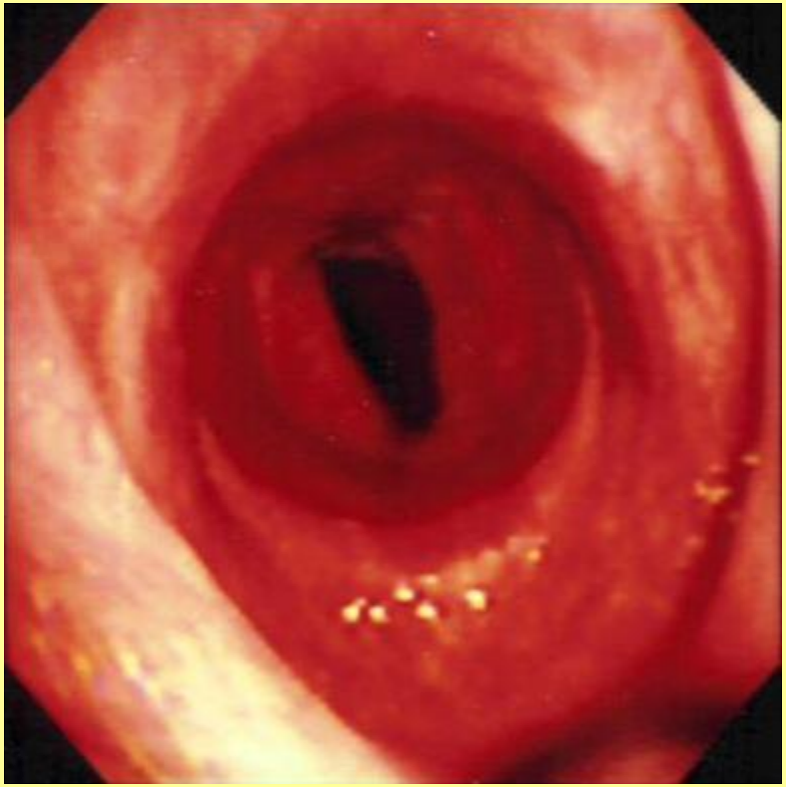
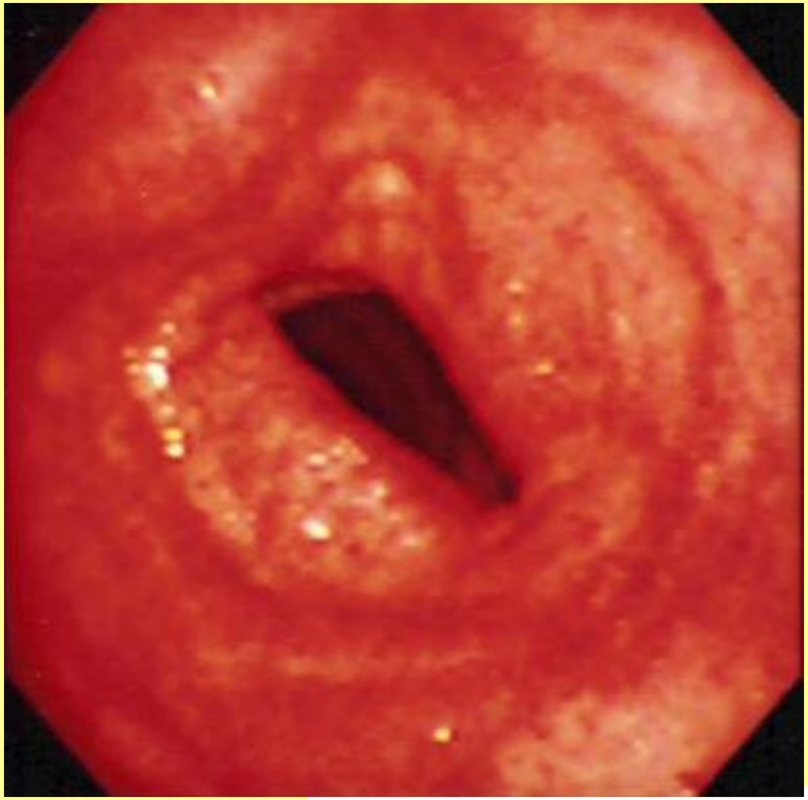
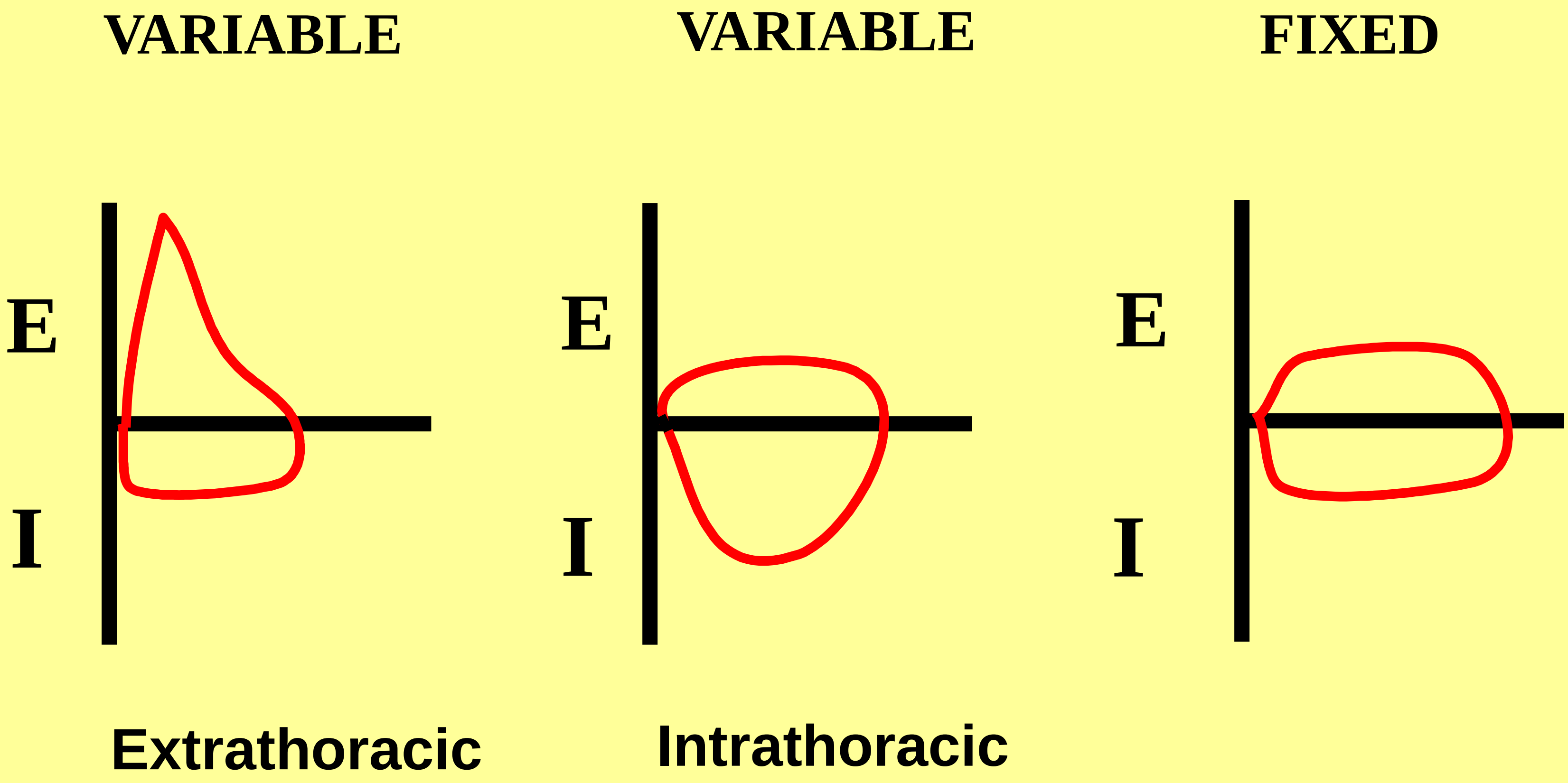
Subglottic Stenosis





Intra and Extra Thoracic Obstructions



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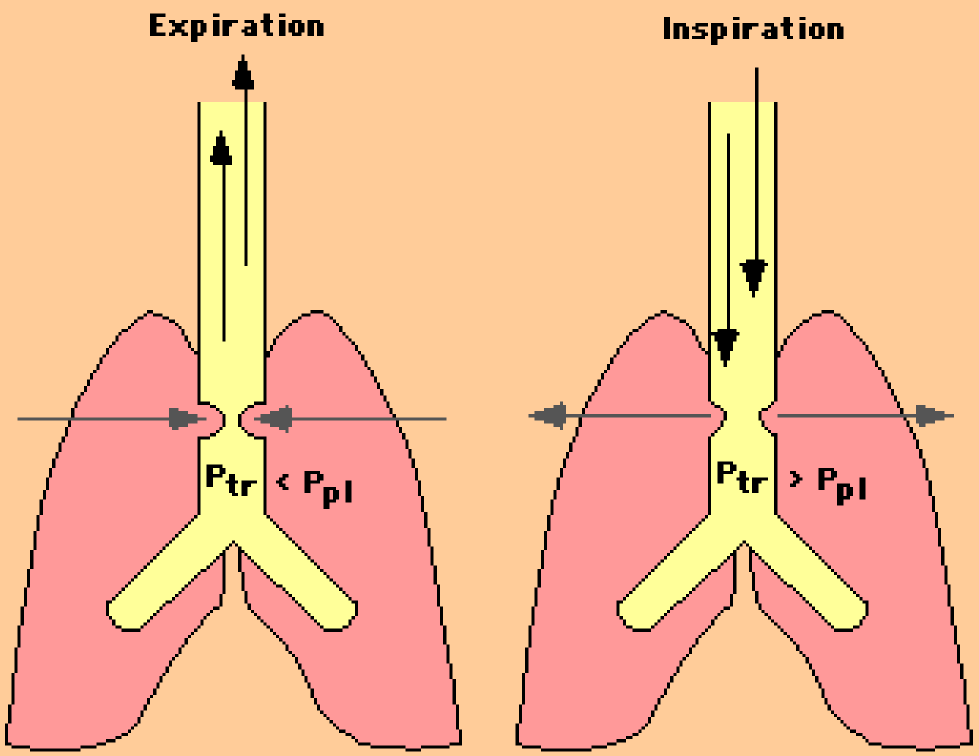

Effects of dynamic intrathoracic airway obstruction Left panel, during forced expiration, the intrathoracic intratracheal pressure (Ptr) is less than the pressure in the pleural pressure (Ppl), worsening the obstruction. Right, during forced inspiration, intratracheal pressure exceeds the pleural pressure, lessening the degree of obstruction. (Redrawn from Kryger, M, Bode, F, Antic, R, et al, Am J Med 1976; 61:85.)

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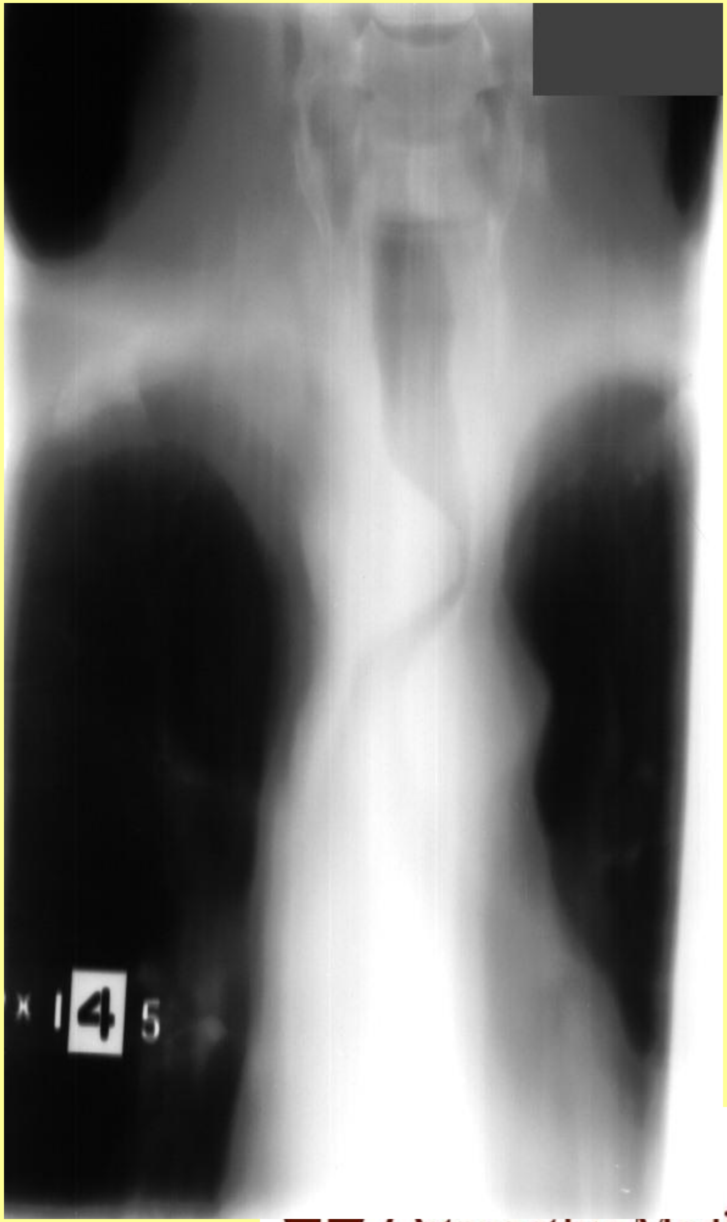
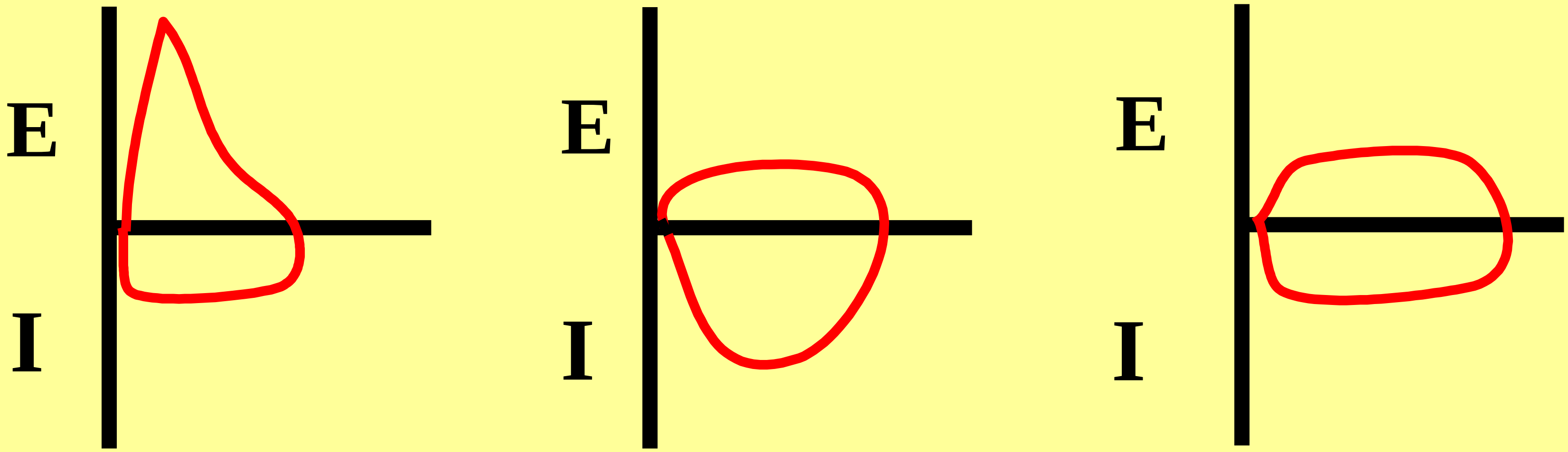
Intrathoracic

Tracheal Compression



Intra and Extra Thoracic Obstructions

VARIABLE VARIABLE FIXED



Extrathoracic **Intrathoracic**

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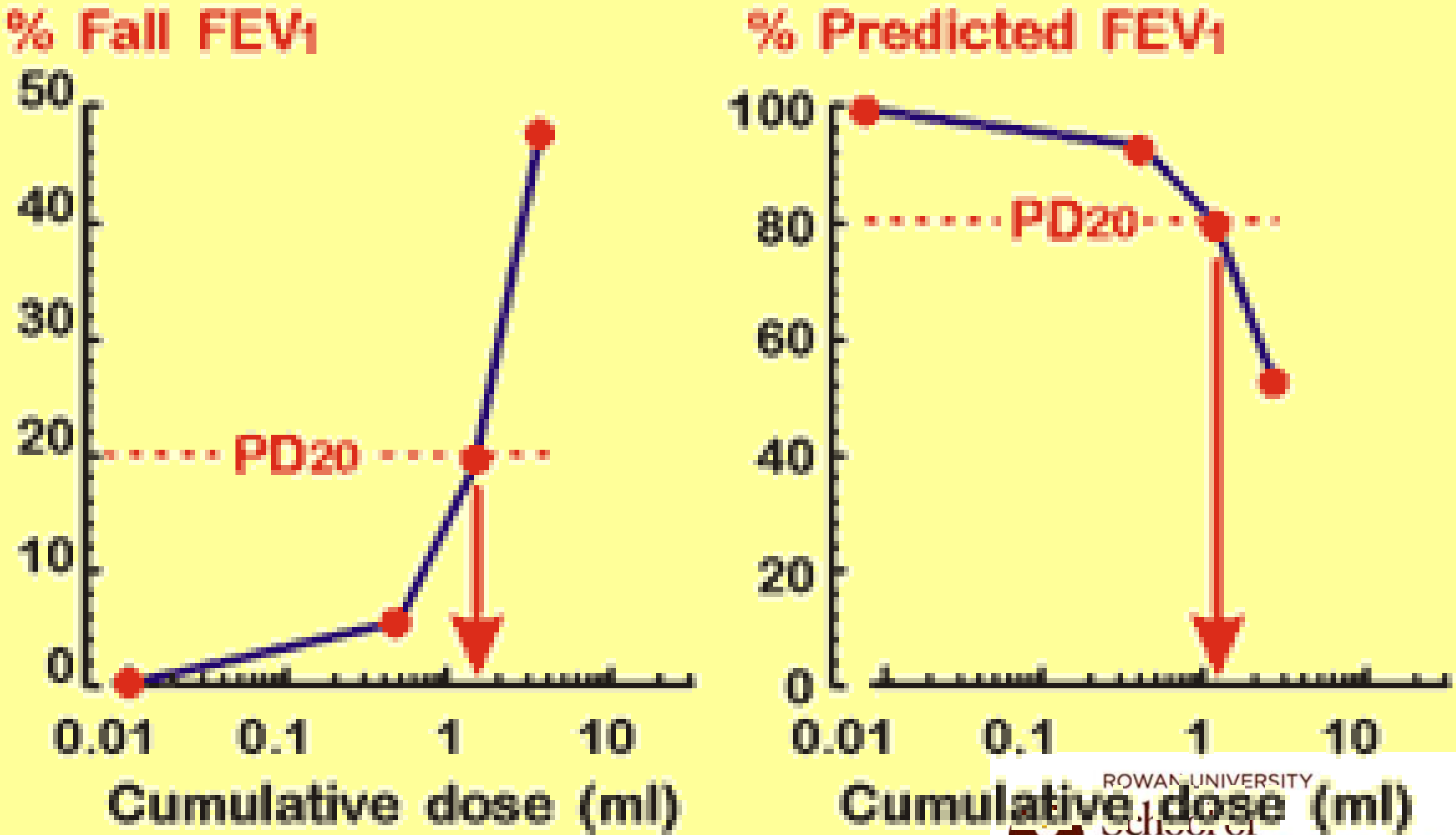
Bronchial Provocation Testing



Diseases associated with Nonspecific Bronchial Hyperresponsiveness

Asthma
COPD
Bronchiolitis
Viral URI
Hay Fever
Cystic Fibrosis
Foreign body aspiration
Near drowning
Smoke inhalation
Sarcoidosis
Post ARDS

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Osteopathic Medicine