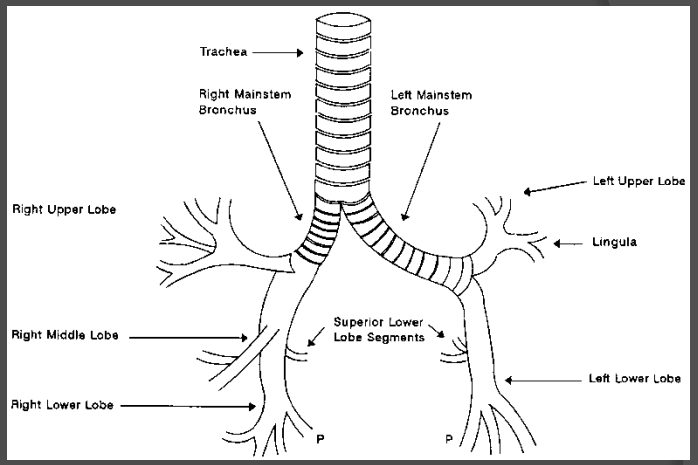
PULMONARY CONSIDERATIONS AND COMPLICATIONS IN NEUROSURGERY

Presented by
Harshit Mishra

Moderators
Dr. Manmohan Singh
Dr. G.D.Satyarthee

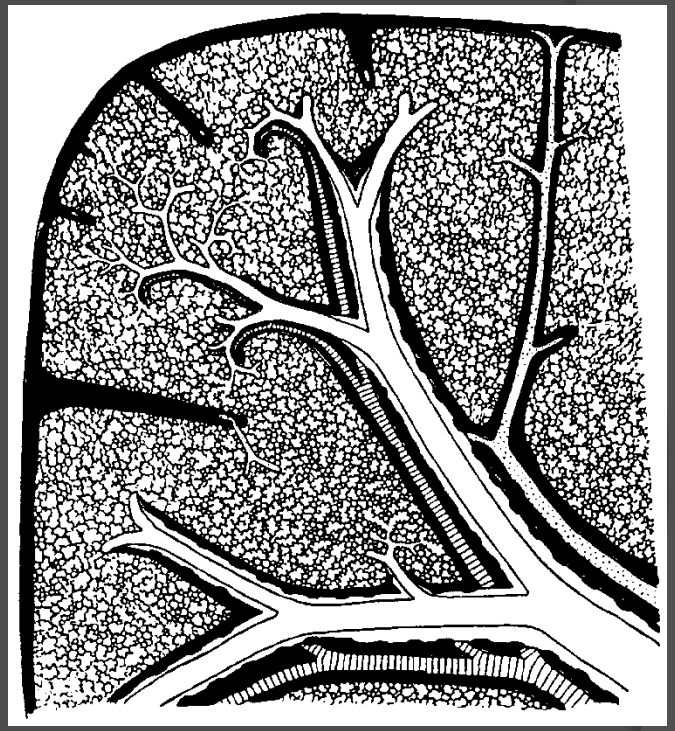
Anatomy

- Tracheobronchial tree
  - Dependent parts
    - Posterior and Superior Segments of Right and Left Lower lobes
    - Posterior Segment of Right Upper Lobe
  - Right main bronchus in direct alignment with trachea



Anatomy

- Vascular Supply
  - Pulmonary circulation
    - Low pressure (25/8 mm Hg)
    - Filter for micro emboli
  - Bronchial circulation
    - Small normal physiological shunt
  - Dual circulation reduces incidence of infarction



Anatomy

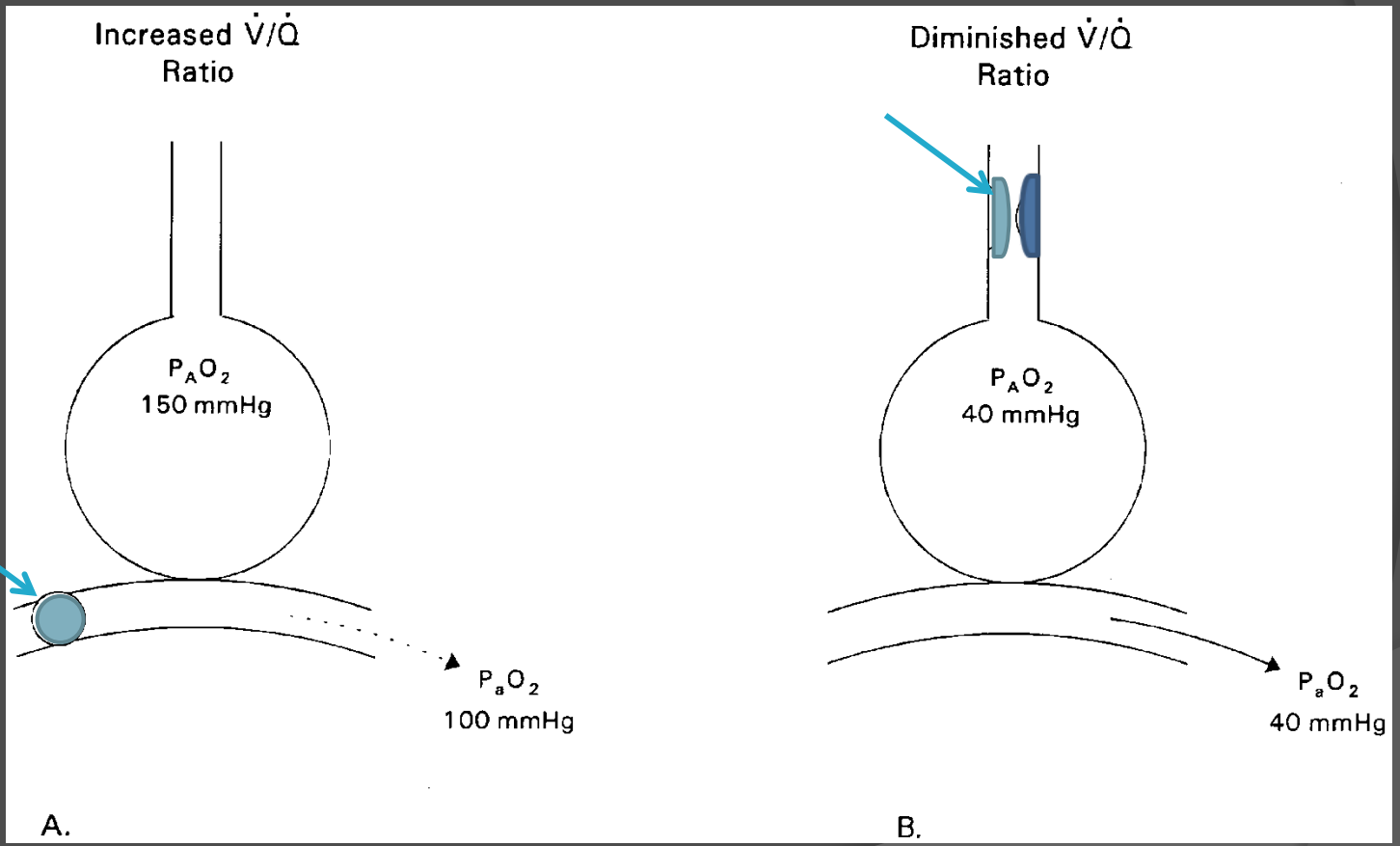
- Innervation
  - Afferent
    - Myelinated A fibers provide stretch feedback
    - Unmyelinated C fibers respond to chemical stimulation (e.g. bradykinnin)
  - Efferent
    - Sympathetic – vasoconstriction and mucus secretion
    - Parasympathetic -- bronchoconstriction and mucus secretion

Physiology

- Oxygen transfer is perfusion (Q) limited
  - Normal alveolar-arterial PO_2 gradient = 10 mmHg **[150 – ($PaCO_2$ /0.8)- PaO_2]**
- CO_2 transfer is Ventilation (V) dependent
- V/Q mismatch results in
  - ↓ed PaO_2
  - ↑ed $PaCO_2$ – may be corrected by hyperventilation

Physiology

Ventilation Perfusion Mismatch



Embolus

- Correctable with 100% O_2

- Right to Left Shunt
- Does not respond to 100% O_2

Physiology

- Dead space -to -Tidal Volume (**Vd/Vt**) ratio = $(PaCO_2 - PECO_2)/PaCO_2$ = 0.2 - 0.3
  - ↑ed Vd/Vt indicates **ventilator dependence**
  - Tracheostomy reduces Vd/Vt

- Oxygen delivery optimized by maintaining
  - PaO_2 90 – 100 mmHg
  - Hb >10g/dL

Physiology

- Control of Breathing
  - Rhythm and Pattern Generator
    - DRG and VRG located in medulla
  - Pneumotaxic center
    - Pons
    - Inspiratory cut off
  - Chemoreceptors
    - Central (near medulla) : CSF pH and $PaCO_2$
    - Peripheral (Carotid and aortic bodies) : O_2 delivery
  - Mechanoreceptors (feedback and irritant)

Physiology

- Breathing Patterns:
- Central Alveolar Hypoventilation
  - Slow and shallow; regular
  - Insult to brainstem
- Ataxic Respiration:
  - Slow and irregular
  - Injury to medulla/caudal pons

Physiology

- **BREATHING PATTERNS**:
  - Apneustic Respiration:
    - Extended inspiration
    - Injury to pons
  - Central Neurogenic Hyperventilation
    - Rapid and regular
    - Injury to rostral pons /midbrain
    - Raised ICP

Physiology

- **BREATHING PATTERNS:**
  - Cheyne Stokes Respiration
    - Regularly irregular
    - Cerebral /diencephalic dysfunction
  - Others
    - Kussmaul respiration (acidosis)
    - Central Hypoventilation due to drug over dosage

Excellence in Pulmonary Care

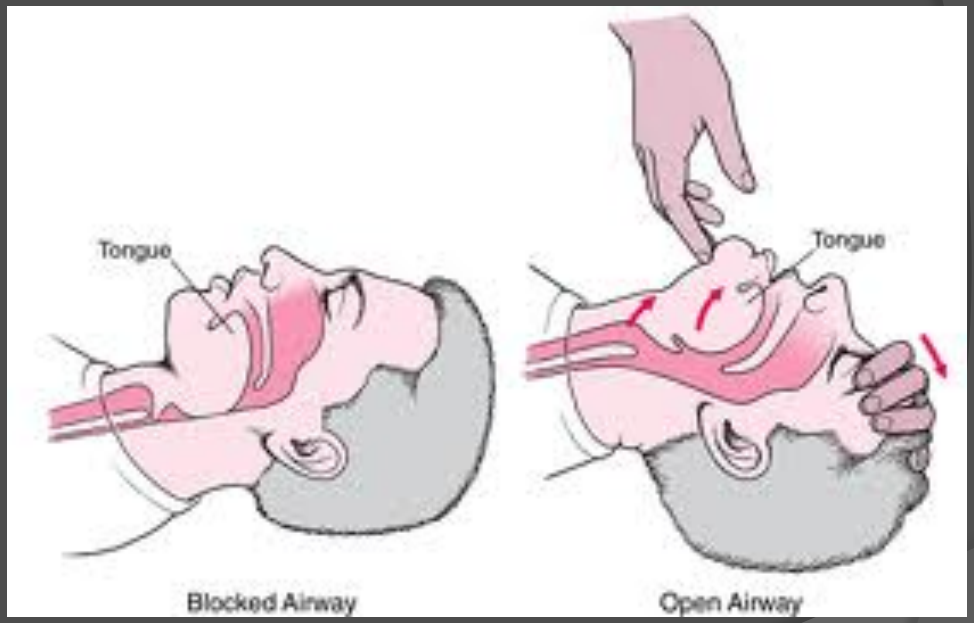
- Maintenance of airway
- Adequate alveolar ventilation
- Appropriate oxygenation

AIRWAY MAINTENANCE

- Intact Gag reflex does not confirm the ability of the patient to ---
  - Cough
  - Sigh
  - Clear secretions effectively
- Head and Upper Spine injury/ Unconscious patients have risk of:-
  - Aspiration
  - Atelectasis
  - Hypoventilation

AIRWAY MAINTENANCE

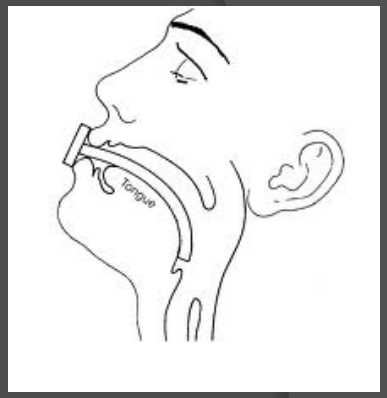
- Tongue fall is a common problem in supine patients
- "Sniffing position" is a temporizing measure

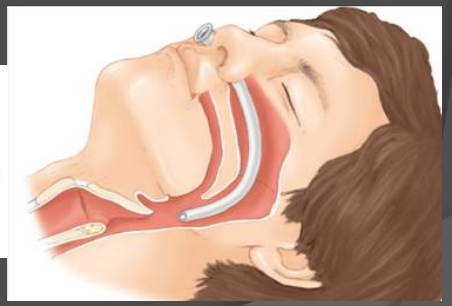


AIRWAY MAINTENANCE

- Airway keeps tongue anterior
  - May stimulate gag
- Nasopharyngeal airway
  - Bypasses tongue mechanism
  - Adequate size to be used

    (e.g. Size 34 or more for 70 kg adult)





AIRWAY MAINTENANCE
Endotracheal Intubation

INDICATIONS:

- Airway protection
  - CNS Depression
  - Risk of Aspiration
  - Procedures (e.g. bronchoscopy)
  - Acute Massive Hemoptysis
- Respiratory acidosis ($PaCO_2$ > 60 m Hg)
  - CNS depression
  - Increased work of breathing (RR > 40 or < 6/min)
- Hypoxia refractory to supplemental oxygen (PaO_2 <55 m Hg)
  - ARDS
  - Severe pneumonia
- Intentional Hyperventilation
  - Reduction of cerebral edema
  - Reduction of ICP

* Pontoppidan H, Geffin B, Lowenstein E. Acute respiratory failure in the adult. N Engl J Med. 1972 Oct 12;287(15):743-52. .

AIRWAY MAINTENANCE

Endotracheal Intubation

- Pre intubation 100% O_2 mask ventilation for 3-5 mins
- Size of endotracheal tube :
  - ≥8 mm for adult male; 7.5 mm for female
  - Selection of appropriate size to avoid pressure necrosis
- Route of intubation
  - Oral
    - Emergency
    - Allows Larger tube – work of breathing reduced
  - Nasal
    - Cervical spine injuries
    - Contraindicated in base of skull injuries

AIRWAY MAINTENANCE
Endotracheal Intubation

- Distal end of tube should be 20 -22 cm from teeth.
- Confirmation of tube position
  - Prominent breath sounds over both lung fields
  - Rise in Oxygen saturation
  - Condensation mist on inner tube lining
- Cuff pressure ≤25 mm Hg (smaller tubes require higher cuff pressure).

AIRWAY MAINTENANCE
Endotracheal Intubation

Complications

- Acute
  - Oral/nasal trauma
  - Vocal cord tear
  - Tracheal perforation (pneumothorax/ pneumomediastinum)
  - Accidental intubation of right main bronchus
    - Left lung collapse
- Long term
  - Tube block
  - Cuff site necrosis
  - Hoarseness
  - Tracheal stenosis
  - Tracheomalacia
  - Tracheal colonization (acinetobacter , pseudomonas)
  - Cuff leak

AIRWAY MAINTENANCE

Endotracheal Intubation

- **Extubation**
  - Patient Weaned off from ventilation
  - Purpose of intubation achieved
- Preferably in morning
- Stop Sedation/ tube feeding
- Prior chest physiotherapy; Upright position
- Suctioning of endotracheal /pharyngeal secretions before deflation of balloon
- O_2 by mask/nasal prong after extubation
- Observation for 6 – 24 hrs

AIRWAY MAINTENANCE

Tracheostomy

- Indications :
  1. Prolonged translaryngeal intubation (to prevent airway damage)
  2. Frequent suctioning and secretion removal (to allow easy access to the lower airway)
  3. Prolonged mechanical ventilation or oxygenation support (to provide a stable airway)

AIRWAY MAINTENANCE

Tracheostomy

ADVATAGES :

- Improved patient comfort
- Less need for sedation
- Lower work of breathing
- Improved patient safety
- Improved oral hygiene
- Oral intake more likely
- Earlier ability to speak
- Better long-term laryngeal function
- Faster weaning from mechanical Ventilation
- Lower risk of ventilator-associated pneumonia
- Lower mortality
- Shorter intensive care unit and hospital stay

AIRWAY MAINTENANCE

Tracheostomy : When ?

- Tracheostomy to be performed in 3-5 days in patients expected to require prolonged ventilation (~ 7 – 14 days)
  - Severe head injury
  - Brainstem dysfunction
  - Low GCS
  - Spinal cord injury at or above C4
- Most of laryngeal damage occurs in first 3 days of translaryngeal intubation
  - Early tracheostomy promotes healing

Durbin CG Jr. Tracheostomy: why, when, and how? Respir Care. 2010 Aug;55(8):1056-68

Durbin CG Jr et al . Should tracheostomy be performed as early as 72 hours in patients requiring prolonged mechanical ventilation? Respir Care. 2010 Jan;55(1):76-87

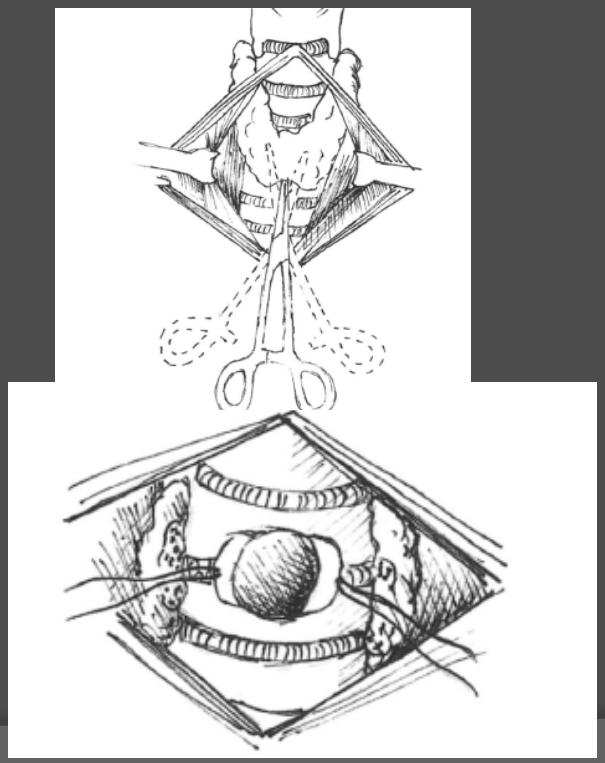
AIRWAY MAINTENANCE
Tracheostomy

- Benefits of early tracheostomy
  - Improved patient comfort and safety
  - Faster weaning - - shorter ICU/Hospital stay
  - Reduced incidence of VAP
- Intubation continued for longer in children
  - Concern for growing airway
  - Consequences of prolonged intubation are less severe

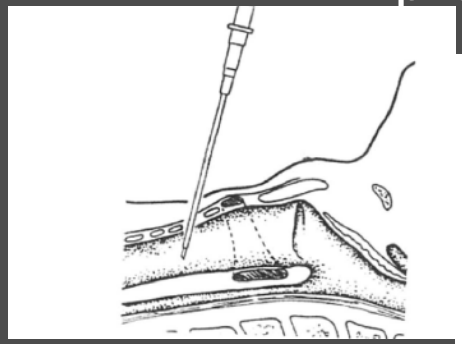
AIRWAY MAINTENANCE

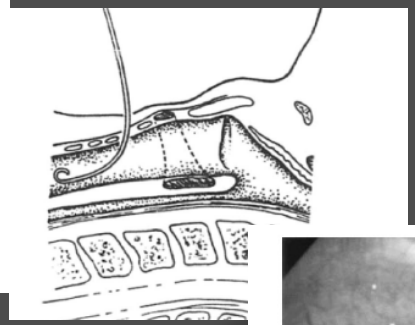
Tracheostomy : How?

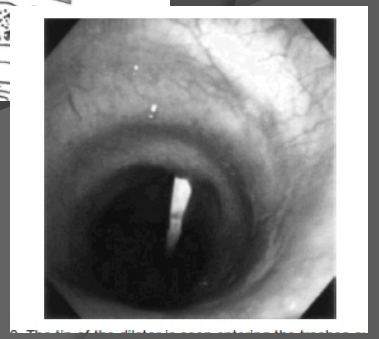
- **Open Surgical**
  - At the level of 2nd – 3rd tracheal rings



- **Percutaneous Dilation Technique**
  - Ultrasound / Fibreoptic Bronchoscopy for precision







AIRWAY MAINTENANCE

Tracheostomy : How?

- **Open Surgical**
  - Lesser risk of false passage
  - Lesser problems in decannulation / obstruction
- **Percutaneous Dilation Technique (PDT)**
  - Reduced procedure time
  - Reduced wound infection
  - Convenience
  - Better scarring
  - Lesser chances of major bleed

Durbin CG Jr. Tracheostomy: why, when, and how? Respir Care. 2010 Aug;55(8): 1056-68

AIRWAY MAINTENANCE

Tracheostomy : How?

Country	Routine use of Percutaneous Tracheostomy Technique (%)
France	21
Germany	86
Netherlands	62
Spain	72
Switzerland	57
UK	97

Durbin CG Jr. Tracheostomy: why, when, and how? Respir Care. 2010 Aug;55(8): 1056-68

AIRWAY MAINTENANCE

Tracheostomy

Complications

Early

- Bleeding
- Desaturation during procedure
- Hypotension
- Subcutaneous emphysema (2.2%)
- Aspiration pneumonia
- Pneumothorax/ pneumomediastinum
- Accidental decannulation (4.4%)

Delayed

- Tracheal stenosis
- Infection
- Tracheomalacia
- Tracheo – brachiocephalic fistula
- Tube obstruction
- Tube impaction

AIRWAY MAINTENANCE

Tracheostomy - Decannulation

Protocol criteria for decannulation attempt

- Absence of distress and normal ABG for 5days after prolonged ventilation
- Clinically stable
  - Hemodynamic stability
  - Absence of fever/sepsis
  - $PaCO_2$ < 60 mm Hg
- Endoscopy to rule out > 30% stenosis
- Absence of delirium
- Adequate gag/swallowing
- Patient able to expectorate on request
- Maximum expiratory pressure ≥ 40 mm Hg

* Ceriana et al. Weaning from tracheotomy in long-term mechanically ventilated patients: feasibility of a decisional flowchart and clinical outcome. Intensive Care Med 2003;29(5):845–848.

AIRWAY MAINTENANCE

Tracheostomy - Decannulation

Method

- Gradually downsize the tube to ≤ 6mm with cuff deflated
- Partial corking followed by full corking of metallic/portex tube (cuff deflated)
- Observation for at least 24 hrs
- If pH > 7.35 and < 5% $PaCO_2$ increase then decannulate

* Ceriana et al. Weaning from tracheotomy in long-term mechanically ventilated patients: feasibility of a decisional flowchart and clinical outcome. Intensive Care Med 2003;29(5):845–848.

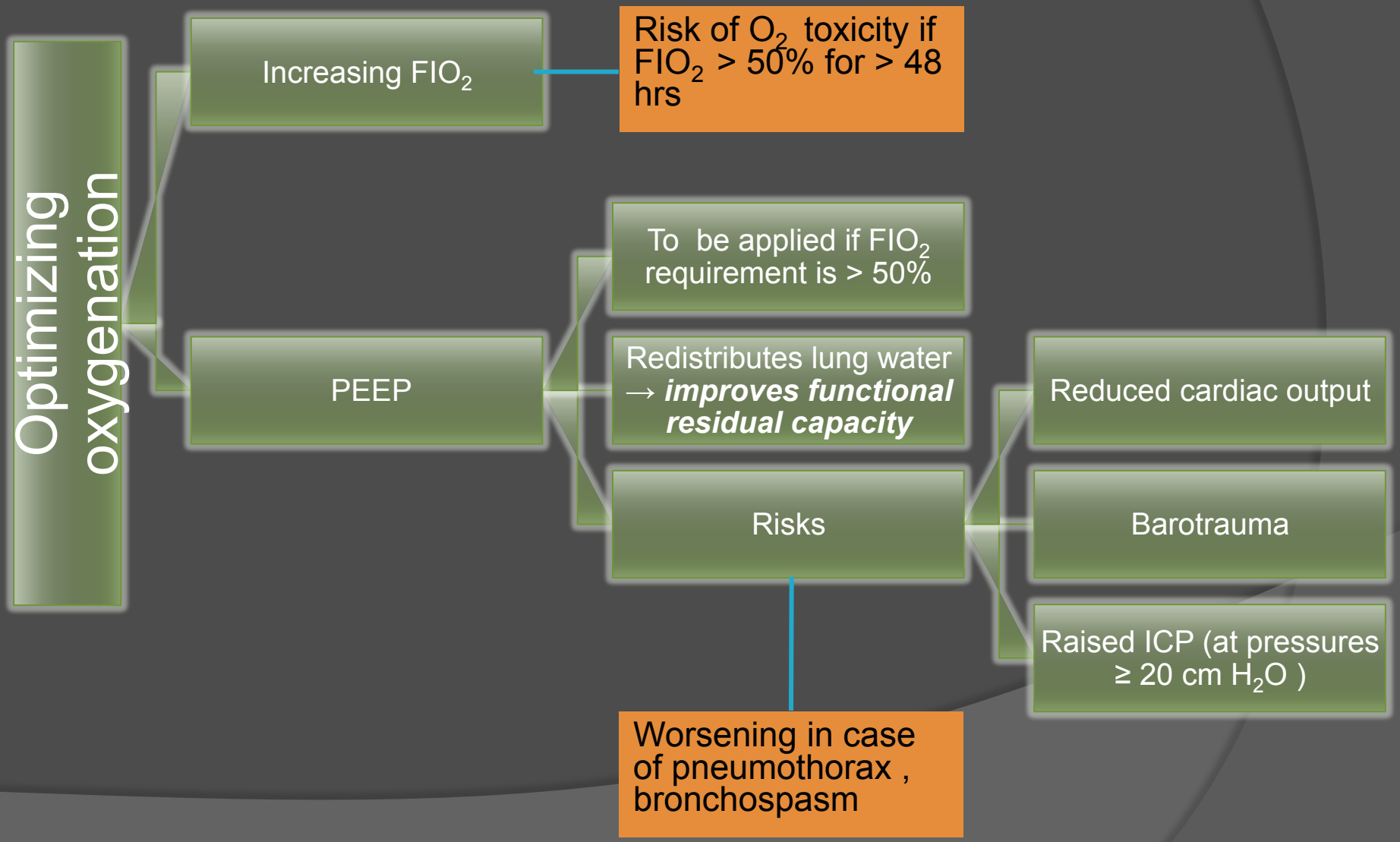
MECHANICAL VENTILATION

- Indications: same as those for intubation
- **Appropriate mode**
  - Awake patients → *Synchronized Intermittent Mandatory Ventilation (SIMV)* with pressure support
  - Perioperative management (extubation planned in 1- 2 days) → *Assist Control Ventilation (ACV)*
  - COPD, ARDS etc → *Pressure Control Ventilation (PCV)*

MECHANICAL VENTILATION

- Settings
- If pH< 7.3 and $PaCO_2$ > 50 mm Hg
  - RR 16 – 24/min
  - Tidal Volume 10 -15 ml /kg
- As the parameters normalize
  - RR to be reduced towards 10 -12 /min and tidal volume 10 ml/kg

MECHANICAL VENTILATION



MECHANICAL VENTILATION

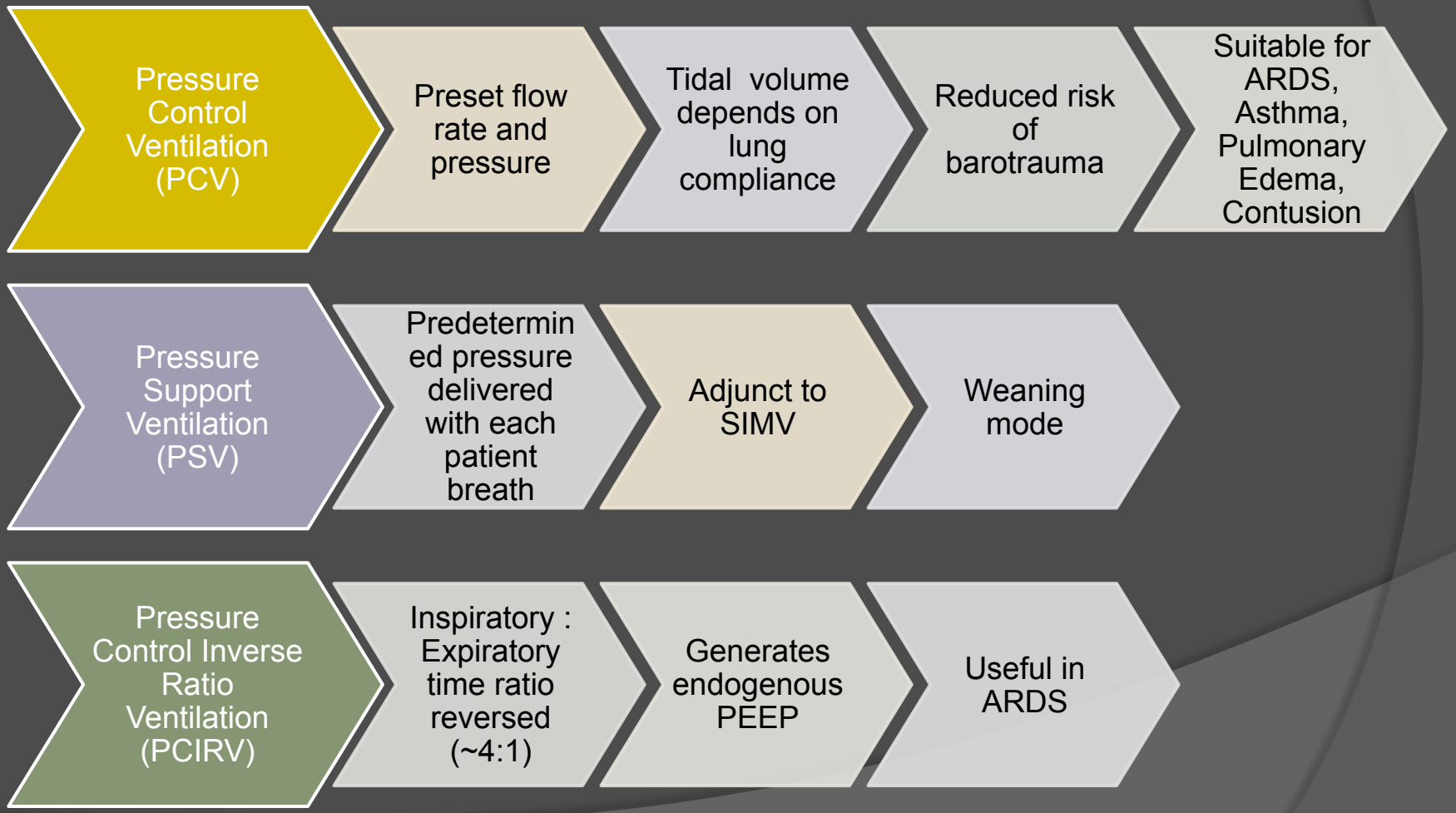
Modes

Volume Controlled
(Preset Tidal Volume And Rate)

Control Mode (CMV)	ACV		SIMV	
Paralyzed patients	Additional Fixed volume delivered on patient effort	Post op patients	Additional volume delivered according to patient effort	Patients who may require prolonged ventilation

MECHANICAL VENTILATION

Modes



MECHANICAL VENTILATION

Modes

High Frequency Ventilation

Allows adequate ventilation at lower peak airway pressures

Useful in

- ARDS
- Barotrauma
- Bronchopleural fistula

Continuous Positive Airway Pressure (CPAP)

Constant positive pressure is applied throughout the respiratory cycle to keep alveoli open in a spontaneously breathing patient

Used for wean without having to remove the ventilator and having to connect to additional equipment like T piece.

MECHANICAL VENTILATION
Weaning

Preparation

- **Lowest levels of FiO_2 and PEEP to maintain a PaO_2 of 80 – 100 mm Hg**

Candidates

- **Hemodynamically stable**
- **Adequate respiratory drive (preferably alert)**
- **$PaO_2 \geq$ 60 mm Hg at $FiO_2 \leq 40\%$**

Weaning parameters

- **Minute ventilation < 10L/min**
- **Vital Capacity > 10ml/kg**
- **Vd/Vt < 0.6** $(PaCO_2 - PECO_2)/PaCO_2$

MECHANICAL VENTILATION
Weaning – Methods

T – Piece

- Patient solely responsible for initiation and work of breathing
- Suitable for patients on ventilation for < 3-7 days
- ABG 30 mins and 2 hours after trial
  - pH ≥ 7.3 and increase in Pa CO_2 not > 5 mm Hg → extubate

CPAP

SIMV

- Reduce rate @ 2 breaths /min every 2 hrs up to 4 breaths /min → T piece

PSV

COMPLICATIONS
Mechanical Ventilation

Technical

- Disconnection
- Electronic malfunction
- Wrong settings
- Bed side Ambu Bag to be ready at all times

Hemodynamic

- Hypotension
- Rule out pneumothorax
- Responds to fluid bolus
- Reduce PEEP/Tidal Volume

COMPLICATIONS
Mechanical Ventilation

Ventilator Associated Pneumonia (VAP)

- 86% of all nosocomial pneumonias
- Upto 50% mortality
- **Acinetobacter** the commonest organism

- **Suspicion :** a new onset (<48hrs) or progressive radiographic infiltrate with at least 2 of :
  - Temp >38^{o} C or < 36^{o} C
  - TLC > 10000 or <5000/ml
  - Purulent tracheal secretions
  - Gas exchange degradation

COMPLICATIONS
Mechanical Ventilation

Ventilator Associated Pneumonia (VAP)

- Culture : Endotrachaeal Aspirate,BAL
- **Management :** Broad spectrum empirical Antibiotic (eg quinolones) with an anti pseudomonal drug(ceftazidime, imipenem, piperacillin)
- Specific antibiotic after culture reports
- Supportive care

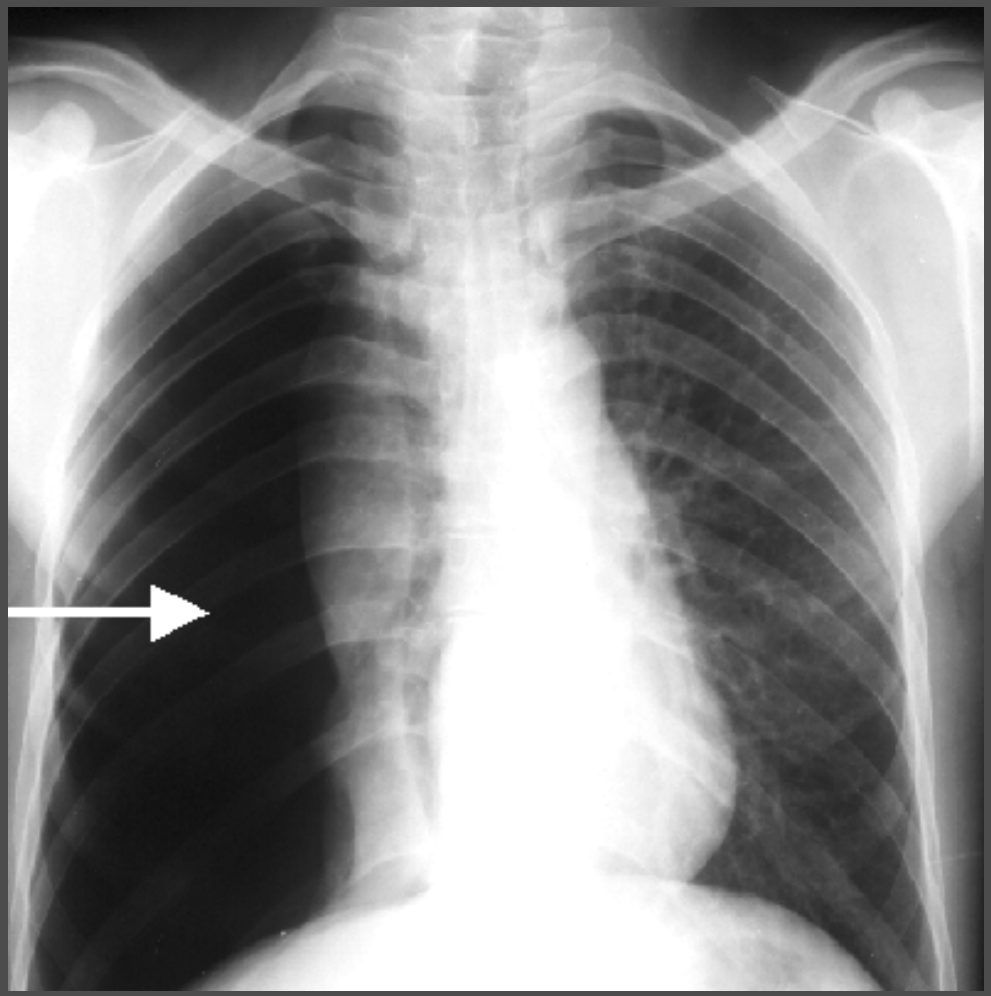
Koenig SM, Truwit JD.. Ventilator-associated pneumonia: diagnosis, treatment, and prevention. Clin Microbiol Rev. 2006;19:637–57

VAP

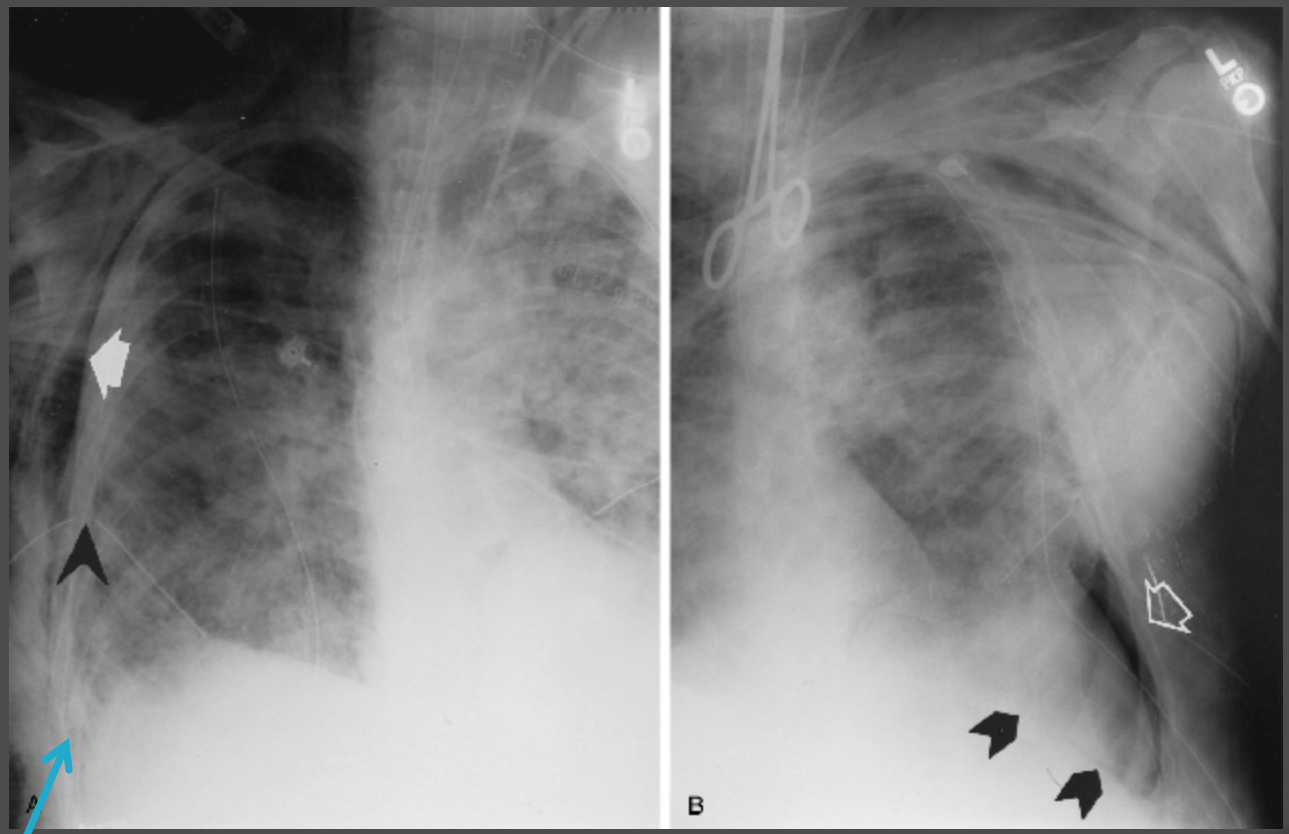
COMPLICATIONS
Mechanical Ventilation

Barotrauma : Associated with positive pressure ventilation. Incidence 5 -15%

- **Pneumothorax**
  - Dyspnea, sharp pleuritic chest pain
  - Tachypnea, tachycardia
  - Contralateral tracheal deviation , hyper resonant percussion
  - **Diagnosis** : chest radiograph
    - Erect film ideal
    - Deep sulcus sign on supine film
    - Lateral decubitus film for smaller quantities of air



PNEUMOTHORAX



Deep Sulcus Sign

PNEUMOTHORAX

COMPLICATIONS
Mechanical Ventilation

- Pneumothorax
  - Treatment
    - Emergent : 14 – 16 Gauge i/v needle in 2nd – 3rd IC space (midclavicular line)
    - Definitive : Tube Thoracostomy
      - To be kept in place till < 100 ml fluid drains /day
      - No air leak
      - Lung fully expanded
- Subcutaneous and Mediastinal Emphysema are other manifestations of barotrauma

COMPLICATIONS
Respiratory Failure

Primary Ventilation Failure

- pH < 7.3
- $PaCO_2$ > 50 mm Hg
- Alveolar – Arterial PO_2 gradient **[150 – ($PaCO_2$ /0.8)- PaO_2]** is ***normal***
  - **Central Causes**: Diminished Respiratory Drive
    - Altered consciousness
- **Neuromuscular Weakness**
  - Fatigue
  - Shortness of breath , tachypnea ⟹ obtundation

COMPLICATIONS
Respiratory Failure

Primary Oxygenation Failure:

- Pneumonia
- Pulmonary Edema
- Aspiration
- Pulmonary embolism
- Lung contusion

- **Intact respiratory drive**
  - Paradoxical thoraco-abdominal respiration

- **Respiratory alkalosis**
  - pH > 7.45
  - Decreased $PaCO_2$
  - PaO_2

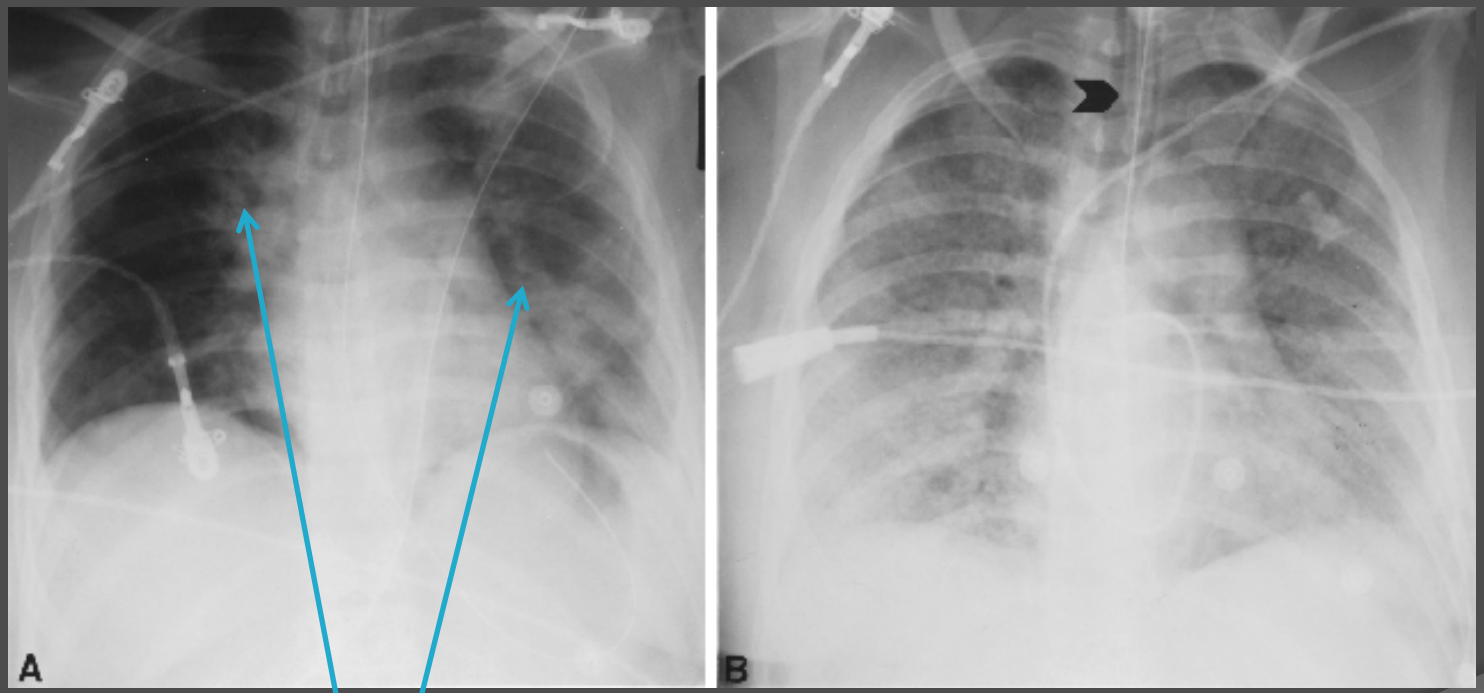
COMPLICATIONS

Aspiration

Aspiration occurs in 23 – 33% neurosurgical patients

Foreign Body Aspiration (eg teeth, food particles)	Chemical Pneumonitis			Aspiration pneumonia	
Majority lodged on right side	Aspiration of as little as 25 ml of gastric content	Often does not progress to bacterial pneumonia	Anti acidity drugs promote colonization	Fever (>102° F) 2-7 days after aspiration	Oral aerobic flora **(Strep. pneumoniae) involved in 66-87% cases** (others : bacteroides, staphylococcus , gram negative rods)

Aspiration Pneumonitis



Patchy Infiltrates

Diffuse Infiltrates

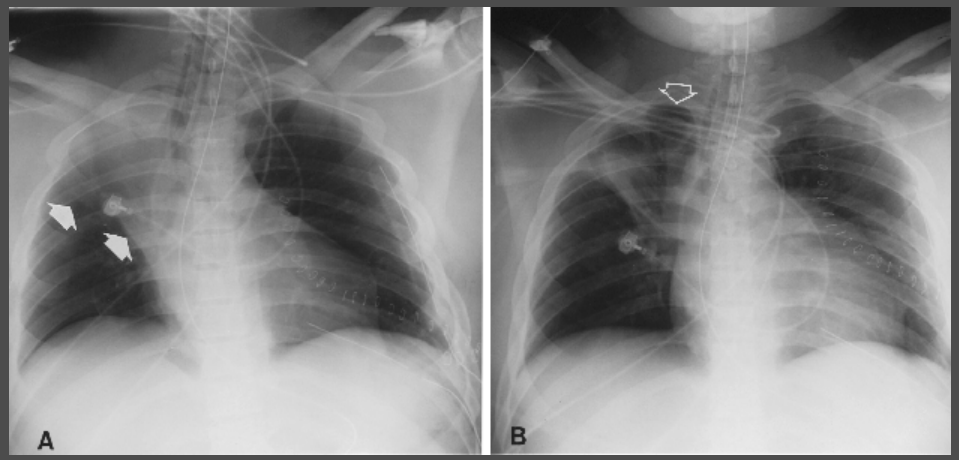
COMPLICATIONS
Aspiration

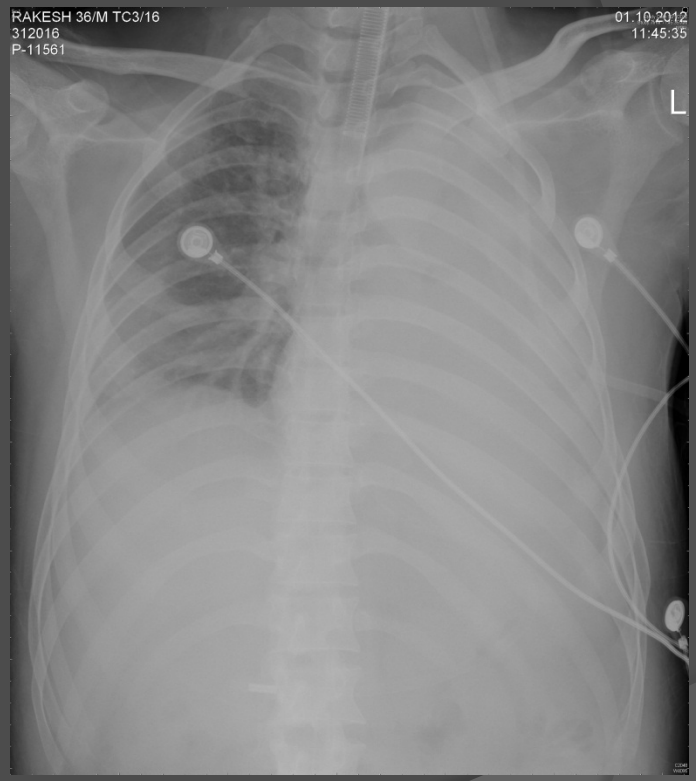
- Treatment
  - Bronchoscopy for foreign body
  - Empirical antibiotics
    - Penicillin group drugs for community acquired aspiration pneumonia
    - Piperacillin + aminoglycoside for nosocomial aspiration
  - Change as per culture reports
  - Empirical corticosteroids and PEEP may not be beneficial

COMPLICATIONS
Atelectasis

- Microatelectasis
  - May not be apparent on Xray
  - Intrapulmonary shunt → hypoxemia
- Lobar /Panlobar Atelectasis
  - Mucus plug
  - Foreign body
  - Intubation of main bronchus
  - Collapse
  - Parenchymal density on X ray; rib crowding

COMPLICATIONS
Atelectasis





COMPLICATIONS

Atelectasis – Treatment

Chest Physiotherapy

- Shifting position for gravity drainage
- Chest percussion
- Endotracheal / Nasotracheal suction

Instillation of saline / acetylcysteine

Tube adjustment

Ventilator settings

Fibreoptic Bronchoscopy

COMPLICATIONS
Pulmonary Edema

- Clinically:
  - Dyspnea
  - Cough
  - Bilateral crackles
  - Occasionally wheeze
- ABG
  - ↓ed PaO_2
  - Widened Alveolar- Arterial PO_2 Gradient

- Cardiogenic
- Non Cardiogenic

COMPLICATIONS
Pulmonary Edema

- **Cardiogenic**
  - Elevated Pulmonary Artery Wedge Pressure (> 18 mm Hg)
  - Diminished cardiac output
  - Jugular venous distension
  - Increased systemic vascular resistance
- Treatment
  - Pre load reduction
    - Loop diuretics (i/v furosemide 20 – 80 mg 6 hrly)
    - Morphine
  - Inotropes
  - Ventilation with PEEP as needed

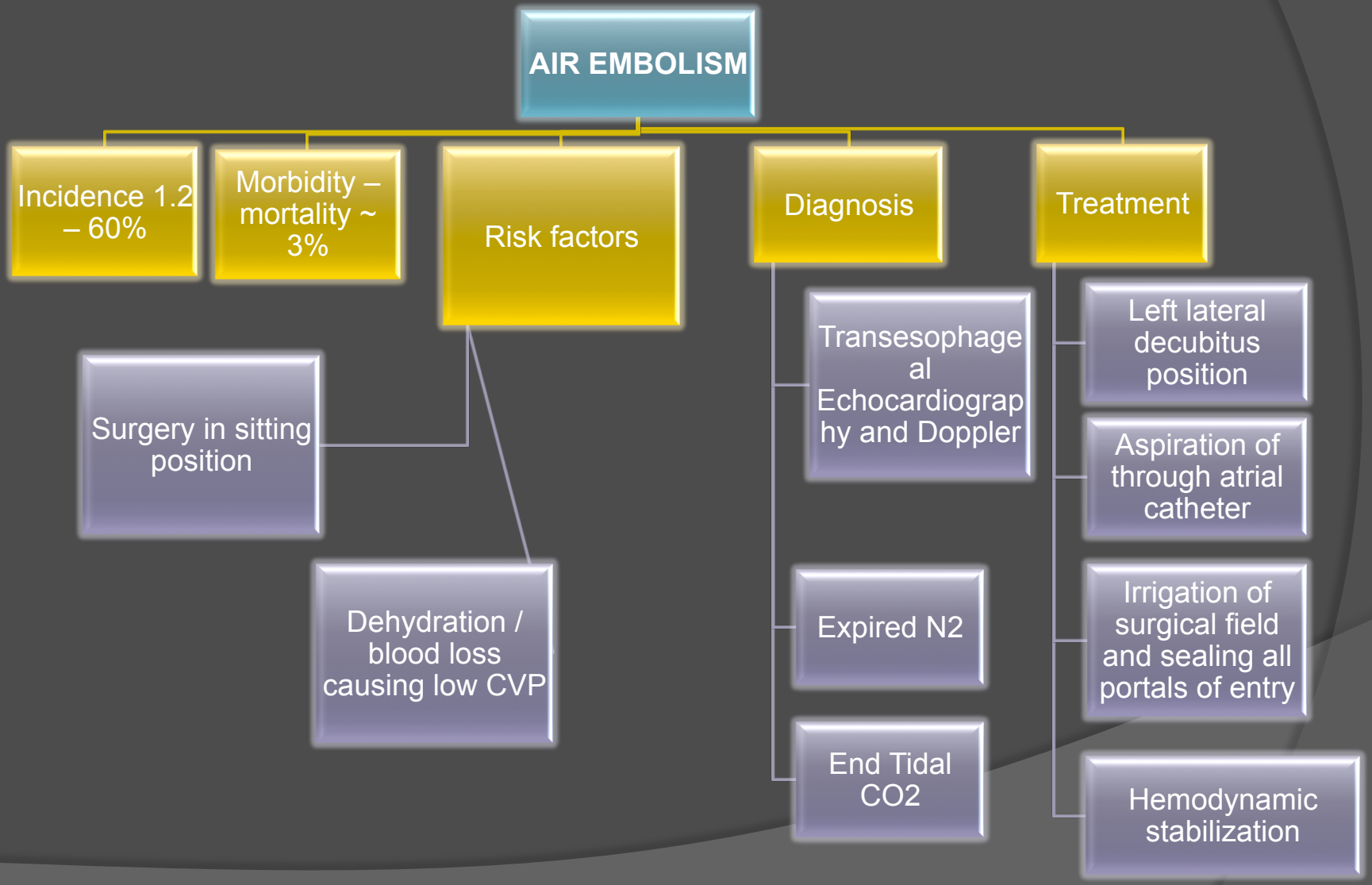
COMPLICATIONS
Pulmonary Edema

- **Non-Cardiogenic**
- ARDS
  - Pulmonary artery wedge pressure < 18 mmHg
  - No jugular venous distension
  - Mortality 60 – 70%
  - Treatment
    - Oxygenation - mechanical ventilation with PEEP
      - Pressure Control Inverse Ratio Ventilation
      - High Frequency jet ventilation

COMPLICATIONS
Pulmonary Edema

- **Non-Cardiogenic**
- Neurogenic Pulmonary Edema
  - Incidence 11 -71%
  - SAH, Head Injury
  - Mechanism :
    - Increased Sympathetic Discharge
    - Inflammatory mediators
  - Treatment : Supportive

COMPLICATIONS



COMPLICATIONS

Venous Thrombosis	• Incidence of DVT 29 – 43% • Thrombo Embolism occurs in 15% cases
Risk factors	• Prolonged surgery and immobilization, • Previous DVT • Malignancy • Direct lower extremity trauma • Limb weakness • Advanced age • Hypercoagulability
Clinically	• Ankle, calf swelling, calf tenderness, Homan's sign
Diagnosis	• Doppler ultrasound (sensitivity 90%)

COMPLICATIONS

Venous Thrombosis

- Treatment :
- Full anticoagulation with heparin (target partial thromboplastin time of 45 to 60 seconds)
- Acceptable 1- 3 weeks after surgery
- Followed by Warfarin (target international normalized ratio of 2)
- To be continued for 6 weeks to 3 months in uncomplicated cases

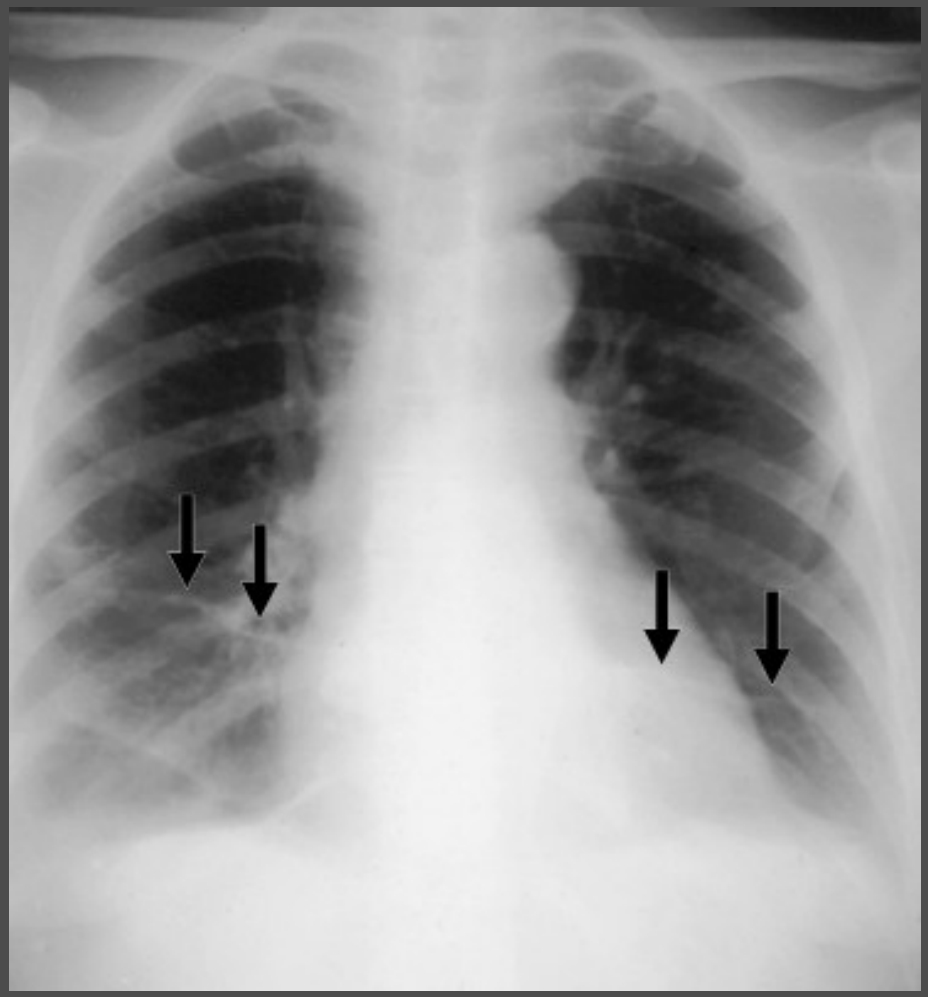
COMPLICATIONS
Pulmonary Embolism

Pulmonary Embolism: presentation

- Tachypnea
- Pleuritic chest pain
- Dyspnea
- Cough
- Jugular venous distension
- Fever
- Altered sensorium

Investigations

- Po_2 of < 80 mm Hg (85%)
- Right axis deviation on ECG
- Infiltrates on Chest X-ray
- Spiral CT (preferred)
- Angiography (Gold Standard)
- Radio nucleotide perfusion scan (sensitive)



Pulmonary Thromboembolism

Bilateral pleural effusions with long linear bands of atelectasis (Fleischner lines)

COMPLICATIONS
Pulmonary Embolism

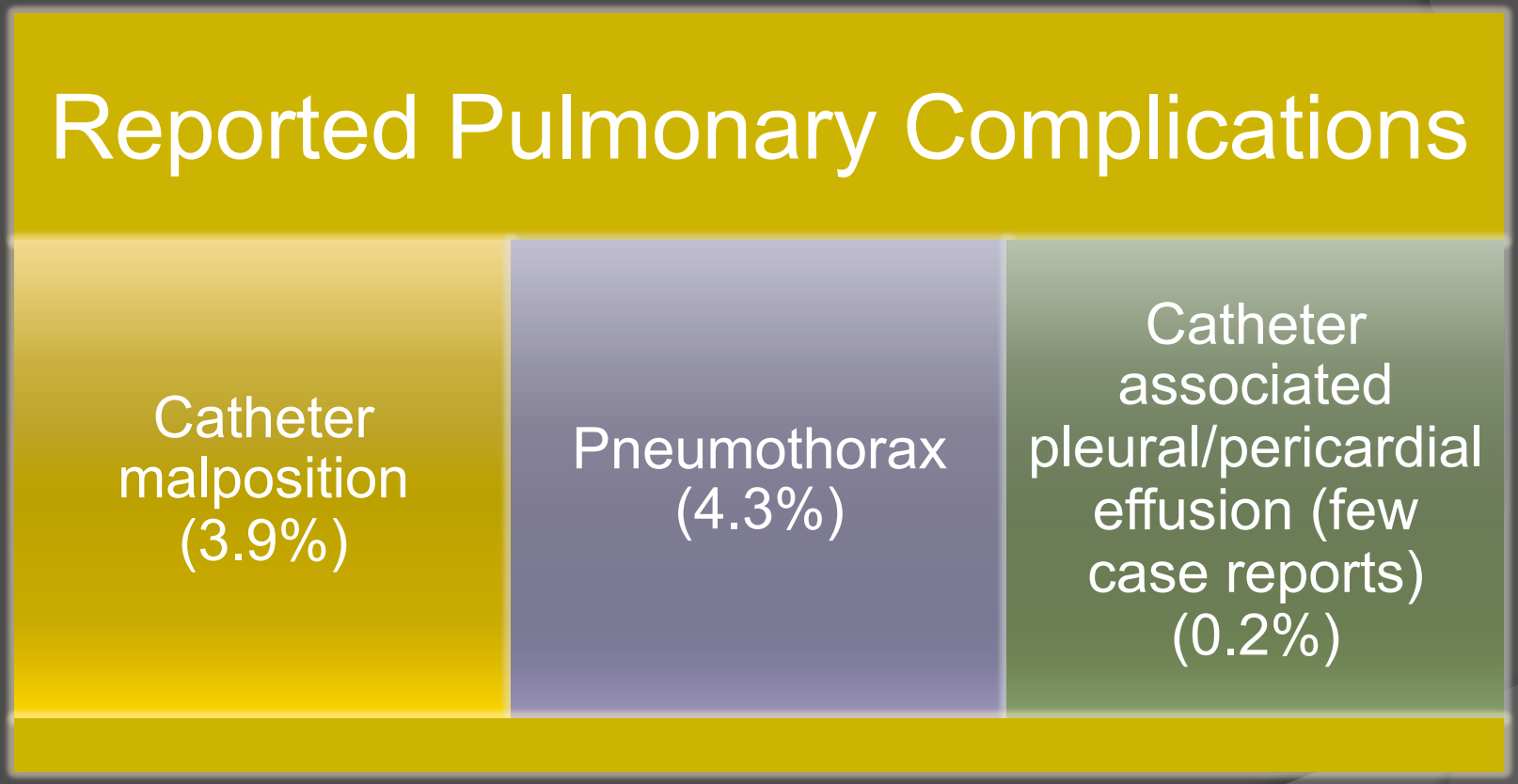
Treatment

- Ventilatory support
- Vasopressors
- Full anticoagulation with heparin infusion (target partial thromboplastin time of 45 to 60 seconds) *despite risk of intracranial bleed.*
- *i/v Heparin 5000-10000 IU bolus followed by 1000 IU/hr infusion*
- Pulmonary embolectomy (last resort)

COMPLICATIONS
Pulmonary Embolism

- DVT prophylaxis
  - Graded Compression Stockings; Intermittent Pneumatic Compression Devices
  - Low dose heparin (5000 IU twice daily)
  - Low Molecular Weight Heparin
  - IVC Filter
    - Greenfield filter

COMPLICATIONS
Central Venous Access



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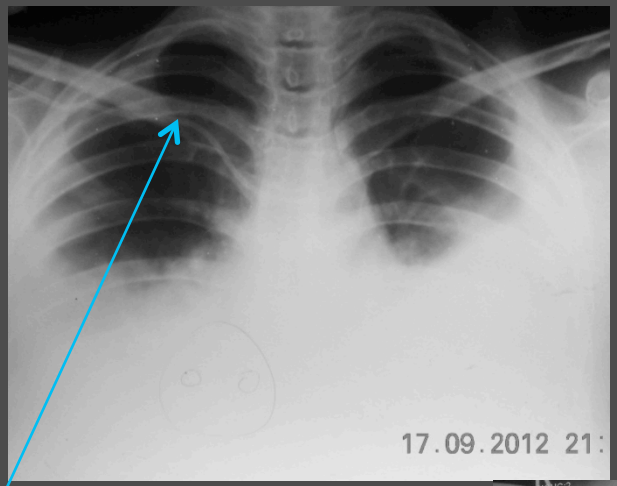
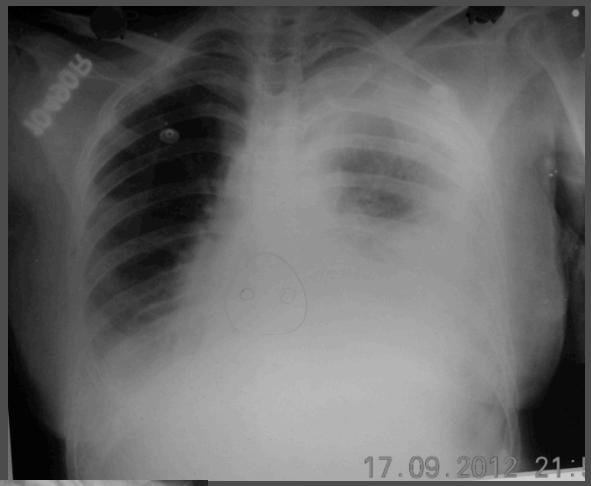
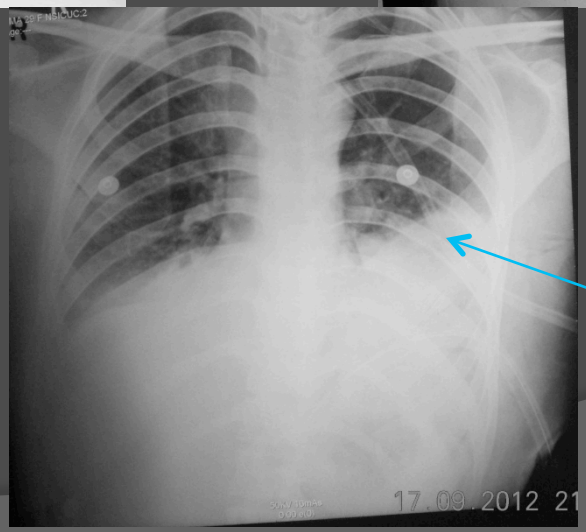
COMPLICATIONS
Central Venous Access



Central line





Chest Tube

CONCLUSION

- Pulmonary complications are one of the most common causes of morbidity and mortality in neurosurgical patients
- Many conditions require strong index of suspicion for timely diagnosis and treatment
- Serial Chest X rays and ABG are indispensable
- Timely intervention may help avert morbidity and mortality in many cases.