

Acute Respiratory Distress Syndrome Acute Lung Injury

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This Presentation is Approved for
1 CRCE Credit Hour

Learning Objectives

- Explain the etiologies, manifestations, diagnostic techniques, & current management strategies for acute respiratory distress syndrome & acute lung injury

Definitions & Etiologies

Acute Lung Injury/ARDS

- ALI/ARDS is a syndrome that is a response to injury & not a disease
- There is much variability in pathology & pathophysiology
- Acute Lung Injury (ALI)
 - ❖ Hypoxemic respiratory failure
 - ❖ Severe version: Acute Respiratory Distress Syndrome (ARDS)

Characteristics

- Bilateral pulmonary infiltrates on chest x-ray
- Pulmonary Capillary Wedge Pressure < 18 mm Hg
- $\text{PaO}_2 / \text{FiO}_2 < 300 = \text{ALI}$
- $\text{PaO}_2 / \text{FiO}_2 < 200 = \text{ARDS}$

Characteristics

- Surfactant deficiency
- Decreased lung compliance
- Decreased lung volume

Symptoms (History)

- > Da Nang lung - Viet Nam
- > Shock lung
- > Non-cardiogenic pulmonary edema
- > Leaky capillary syndrome
- > Acute lung injury
- > Diffuse alveolar damage

Etiologic Mechanisms

- > Direct lung injury (pulmonary)
 - ❖ Inhalation injury
 - ❖ Pneumonia
 - ❖ Aspiration
- > Indirect lung injury (extrapulmonary)
 - ❖ Shock
 - ❖ Sepsis
 - ❖ Transfusion related injury
 - ❖ Pancreatitis

Predisposing Conditions

- > Trauma, shock
- > Aspiration
- > Oxygen toxicity
- > Toxic fumes
- > Sepsis

Predisposing Conditions

- > Narcotic overdose
- > Pancreatitis
- > Fat embolism
- > Near drowning
- > Transfusion-associated lung injury (TRALI)
- > Eclampsia/pre-eclampsia
- > Amniotic embolism

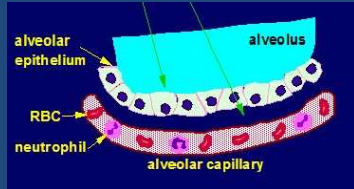
Pathophysiology

ARDS Pathophysiology

- > Initial insult
 - ❖ Directly to lung
 - ❖ Indirectly, via system
- > Pathology stages
 - ❖ Exudative (4 - 7D after onset)
 - ❖ Proliferative (1 - 3 wks)
 - ❖ Recuperative or fibrotic (3 - 4 wks)

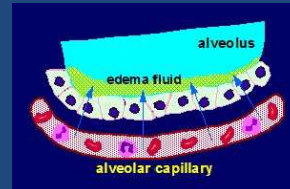
Exudative Stage

- > Injury to
 - ❖ Vascular endothelium or
 - ❖ Alveolar epithelium



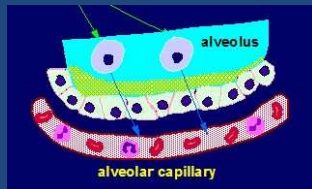
Exudative Stage

- > Leaky capillaries allow influx of proteinaceous fluid (edema)



Exudative Stage

- > Alveolar macrophages release cytokines



Exudative Stage

- > Cytokines attract neutrophils, that release
 - ❖ Tumor necrosis factor (TNF-a)
 - ❖ Free oxygen radicals



Exudative Stage

- > Cytokines attract neutrophils, that release
 - ❖ Tumor necrosis factor (TNF-a)
 - ❖ Free oxygen radicals
- > Inflammation
- > Cell death: type I pneumocytes

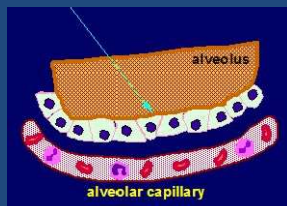
Proliferative Stage

- > Alveoli filled with
 - ❖ Cellular debris
 - ❖ Oxidants
 - ❖ Fibrin



Proliferative Stage

- ❖ Surfactant depleted/inactivated
- ❖ Hyaline membrane formation



Resolution or Fibrosis

- > Phagocytosis of debris or
- > Collagen deposition: fibrosis with lung like a liver

See links below for gross pathology of fibrosis following ALI/ARDS

Manifestations & Complications

Manifestations

- > There is variability in ARDS
 - ❖ Pulmonary vs. extrapulmonary etiology
 - ❖ Consolidation vs. edema
 - ❖ Post-traumatic vs. non-traumatic

Manifestations

- > There is variability in ARDS
 - ❖ Pulmonary vs. extrapulmonary dx: consolidation vs. edema
 - ❖ Post-traumatic vs. non-traumatic
 - ❖ Variability will affect
 - Duration of illness
 - Response to ventilation strategies, e.g. PEEP, recruitment maneuvers (RM), pronation
 - Prognosis

Manifestations

- > Onset: hours to days after initial insult
- > Physical signs
 - ❖ Tachypnea
 - ❖ Retractions, e.g. supraclavicular
 - ❖ Abdominal paradox: diaphragmatic fatigue
 - ❖ Crackles, rhonchi, bronchial sounds
- > Progressive, refractory hypoxemia
- > Decreased lung compliance (C_L)

Manifestations

- CXR
 - ❖ Decreased lung volumes
 - ❖ Fluffy alveolar infiltrates
 - ❖ Air bronchograms
 - ❖ Hyaline membrane

Manifestations

- CXR: ALI/ARDS

See links below for images of ARDS following pulmonary contusion, transfusion-associated lung injury, & acute lung injury with air bronchograms

Complications

- Ventilator-induced lung injury
 - ❖ ALI/ARDS is non-uniform
 - ❖ Posterior lungs edematous, collapsed
 - ❖ Normal lung units are subject to
 - Overdistension
 - Loss of perfusion

Complications

- Ventilator-induced lung injury
- Ventilator-associated pneumonia: prolonged intubation
- Multiple organ system failure: release of mediators from lung
- Hemodynamic compromise (shock)
- Sepsis
- Pulmonary fibrosis

Prognosis

- Mortality: about 40%
- Prognosis better for trauma victims
 - ❖ Younger
 - ❖ Less comorbidity
- Severity correlates with duration of precipitating injury, not type of injury

Prognosis

- 66% of survivors have lung dysfunction
- Psychiatric illness: depression
- Cognitive impairment

Diagnosis

Differential Diagnosis

- Cardiogenic pulmonary edema
- Inhalation injury
- Aspiration
- Pneumonia (many types)
- Hypersensitivity pneumonitis

Differential Diagnosis

- Cardiogenic pulmonary edema
- Inhalation injury
- Aspiration
- Pneumonia (many types)
- Hypersensitivity pneumonitis
- Drug toxicity, e.g. amiodarone
- Alveolar hemorrhage
- Severe acute respiratory distress syndrome (SARS): coronavirus

ARDS vs. Cardiogenic Pulmonary Edema

- ARDS: PAOP (PCWP) < 18 mm Hg
- ARDS: alveolar exudate (proteins)
- Cardiogenic: cardiomegaly
- Brain natriuretic peptide (BNP) does not accurately differentiate

FYI see links below for study on BNP for differentiation of ARDS from cardiogenic pulmonary edema

Diagnostic Studies

- CT scan
 - ❖ Determine anteroposterior distribution of consolidation
 - ❖ May predict effectiveness of pronation

Diagnostic Studies

- Bronchoalveolar lavage
 - ❖ Distinguish between transudate & exudate
 - ❖ Identify or R/O infection
 - ❖ Identify inflammatory cells
 - ❖ Identify inflammatory mediators

Diagnostic Studies

- Open lung biopsy
 - ❖ Identify pathologic process
 - ❖ Identify etiology

FYI see links below for article on open lung biopsy in ARDS

Management

General Strategies

- Treat underlying cause, if possible
- Conservative fluid management improves outcomes
- Pulmonary artery catheter monitoring
 - ❖ No improvement in outcomes
 - ❖ More complications

FYI see links below for FACTT study synopsis (requires free Medscape registration)

Ventilation Strategies

- Lung protective strategies
 - ❖ Open lung technique
 - Pressure control with volume guarantee (my recommendation)
 - Optimal PEEP
 - $TV < 7\text{mL/kg IBW}$
 - Recruitment maneuvers (RM)

FYI see links below for predicted body weight chart

Ventilation Strategies

- Effectiveness of PEEP & RMs
 - ❖ Contingent upon potentially recruitable alveoli
 - ❖ Fluid-filled alveoli are not recruitable

Ventilation Strategies

- Pressure-controlled inverse ratio ventilation
 - ❖ Effective
 - ❖ Pressure control with volume guarantee & inverse ratio ventilation may be effective

Ventilation Strategies

- > Airway pressure release ventilation
 - ❖ Effective in selected patients
 - ❖ Less likely to impair hemodynamics

FYI see links below for article on APRV & cardiac performance

Ventilation Strategies

- > Permissive hypercapnea
 - ❖ Allows non-advancement of settings
 - ❖ May reduce inflammation
 - ❖ May reduce mortality
 - ❖ Acidemia can be managed with Tromethamine (THAM)

Ventilation Strategies

- > Pronation
 - ❖ Transient improvements in oxygenation
 - ❖ Many studies found no changes in mortality
 - ❖ Mancebo et al: reduced mortality, if applied for 17H/d
 - ❖ CT may determine those who will benefit

FYI see links below for study of prolonged pronation (2013)

Ventilation Strategies

- > High frequency oscillatory ventilation
 - ❖ As good as conventional ventilation
 - ❖ No improvement in mortality

Non-Ventilatory Therapeutics

- > Surfactant instillation (children)
 - ❖ Decreased mortality
 - ❖ Decreased duration of ventilation

Non-Ventilatory Therapeutics

- > Surfactant instillation (adults)
 - ❖ No effects on mortality
 - ❖ Quantity of surfactant for adults: expensive
- > Surfactant aerosol: Aerosurf™ under study

Non-Ventilatory Therapeutics

- > Nitric oxide
 - ❖ Dilates vessels in ventilated alveoli
 - ❖ Short-term improvement in oxygenation
 - ❖ No effects on mortality
 - ❖ Very expensive
 - ❖ Off-label use: no payment
- > Aerosolized prostacyclin (Flolan)
 - ❖ Same effects as NO
 - ❖ Less costly than NO

FYI see links below for abstract on NO & ARDS

Partial Liquid Ventilation

- > Lungs filled to FRC with perflubron (LiquiVent), with these properties
 - ❖ High density - flows to dependent areas of lung
 - ❖ Low surface tension - increases compliance
 - ❖ High solubility for O₂ and CO₂ - transports gases
 - ❖ High volatility - quickly excreted

Up next: Video of mouse swimming in perflubron
(Caution: video includes strong language)

Partial Liquid Ventilation

- > Physiologic effects
 - ❖ Increased lung compliance due to
 - Decreased surface tension
 - Alveolar recruitment
 - ❖ Decreased VILI due to increased compliance
 - ❖ Decreased shunt due to alveolar recruitment & diffusion across perflubron

Partial Liquid Ventilation

- > Potential applications
 - ❖ RDS - neonates
 - ❖ Meconium aspiration - not effective for adults
 - ❖ Alveolar proteinosis (1 case)
 - ❖ ALI/ARDS

Partial Liquid Ventilation

- > Procedure
 - ❖ Perflubron instilled to FRC
 - ❖ Re-instillation required, due to evaporation

Partial Liquid Ventilation

- > Research findings
 - ❖ Neonates - non-responders to surfactant survived (n= 10)
 - ❖ Adults - most recent trial (2006) found negative for PLV
 - ❖ Earlier trials did not compare PLV with lung protective ventilation

FYI see links below for articles on PLV for neonates with RDS & PLV for adults with ARDS

Partial Liquid Ventilation

- Barriers to adoption
 - ❖ Expense
 - Perflubron
 - Time - dosing, re-dosing
 - ❖ Lack of positive research findings
- Opinion - PLV will not become a widely-used technique, at least for adults

Non-Ventilatory Therapeutics

- Corticosteroids
 - ❖ Many investigations (since 1970s)
 - ❖ No benefits
 - ❖ If started late, may increase mortality

Non-Ventilatory Therapeutics

- Enteral EPA + GLA + antioxidants
 - ❖ Increased lung compliance
 - ❖ Decreased duration of ventilation
 - ❖ No effects on mortality

Non-Ventilatory Therapeutics

- N-acetylcysteine (Mucomyst)
 - ❖ Intravenous infusion
 - ❖ Antioxidant properties
 - ❖ More research needed

Non-Ventilatory Therapeutics

- Albuterol aerosol
 - ❖ Increases C_{DYN} → decreased ventilation pressure
 - ❖ Decreases lung edema
 - ❖ Anti-inflammatory action: decrease TNF- α
 - ❖ Randomized trial (2011) found no benefit
 - ❖ Multi-center trial (2012) found that IV albuterol increased mortality

Summary & Review

- Definitions: ALI/ARDS
- Etiologies
- Characteristics
 - ❖ Infiltrates
 - ❖ Stiff lungs
 - ❖ Refractory hypoxemia
 - ❖ PCWP < 18 mm Hg

Summary & Review

- Pathophysiology
 - ❖ Insult
 - ❖ Capillary permeability: edema
 - ❖ Inflammation
 - ❖ Alveolar injury
 - ❖ Surfactant depletion
 - ❖ Fibrosis/resolution

Summary & Review

- Manifestations
 - ❖ Refractory hypoxemia
 - ❖ Increased WOB
 - ❖ CXR: consolidation, air bronchograms
- Complications
 - ❖ Sepsis
 - ❖ Ventilator-induced lung injury
 - ❖ Ventilator-associated pneumonia
- Prognosis

Summary & Review

- Diagnosis
 - ❖ Differential diagnosis: many conditions
 - ❖ Chest radiograph
 - ❖ Bronchoscopy
 - ❖ Open lung biopsy

Summary & Review

- Management
 - ❖ Treat underlying cause
 - ❖ Supportive measures
 - ❖ Lung protective strategies
 - ❖ Non-ventilatory measures

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