Respiratory Care for Specialized Pediatric Patients

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Wake Forest™ Baptist Health
Brenner Children's Hospital

Specialized Pediatric Patients

- Obesity
- Scoliosis
- Neuromuscular Diseases

Specialized Pediatric Patients

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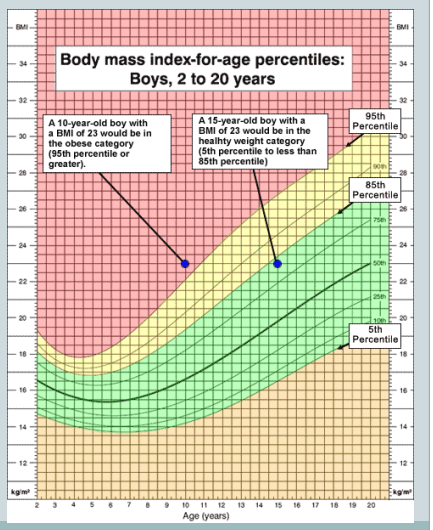
Epidemiology

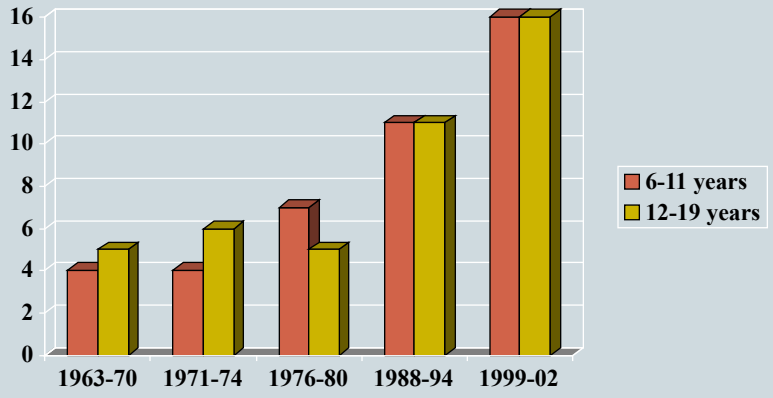
- 22 million children under 5 yo in US are overweight
- 31% of children and adolescents are overweight
- 16 % of adolescents are obese
- Pediatric obesity – most common chronic disease of childhood

Body Mass Index (BMI)

- [Weight ÷ (height x height)] x 703
- Overweight: 85 - 95%ile
- Obese: > 95%ile
- Adults:
  - 25-29 overweight
  - >30 obese



Percent of obese children and adolescents



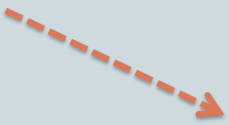
Healthcare economics

- 36% higher annual healthcare costs in US (obese vs non-obese individuals)
- Significant short-term and long-term health effects
- Psychosocial effects
- Indirect costs
  - Loss of lives, productivity, and income

Physiologic changes

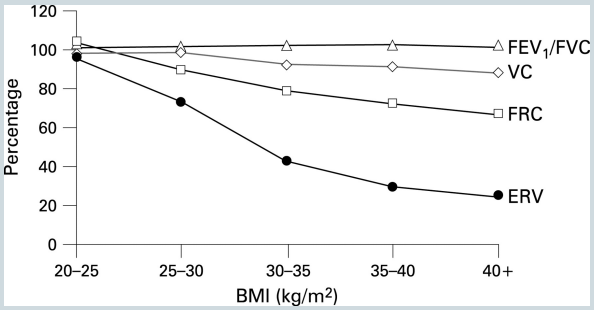
- Increased respiratory rates (Resp Phys Neurobio 2009;168)
  - 15.3 – 21 bpm compared to 10 – 12 in normal subjects
- % of daily O2 consumption used for work of breathing
  - 15% in morbidly obese vs 3% in normal subjects
- PFT changes

Effect of obesity on lung volumes



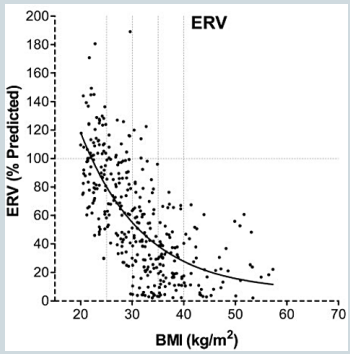
- FEV1 and BMI
  - Inverse relationship
- FEV1
  - Independent predictor of mortality
  - Risk factor for CV disease, stroke, and lung cancer

Effect of obesity on lung volumes



Chest 2006;130:827-33

ERV and BMI

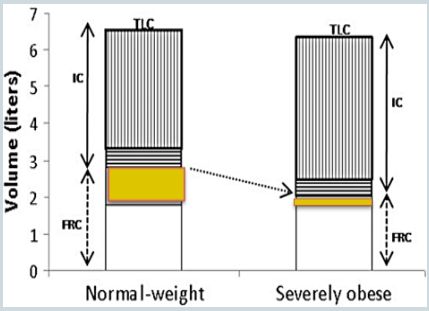


ERV falls below normal starting at BMI of 25 kg/m2 (overweight)

Chest 2006;130:827-33)

Effect of obesity on lung volumes

- ↓ Expiratory reserve volume (ERV)
- ↓ Functional residual capacity (FRC)



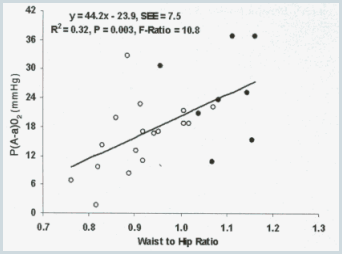
Leads to microatelectasis in dependent lung zones

↓ Lung compliance

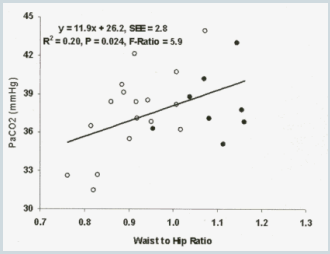
Fat Distribution

- Abdominal fat displaces diaphragm into the abdomen and restricts descent of diaphragm
  - Limits lung expansion
  - V/Q mismatch
    - Dependent zones overperfused and underventilated
  - Widening of A-aO2 gradient and possible arterial hypoxemia
- Waist-hip ratio and waist circumference

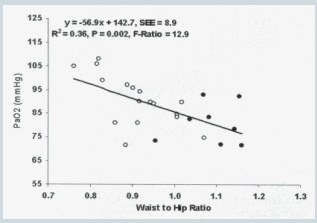
Waist-hip Ratio



A-a O2 gradient



PaCO2



PaO2

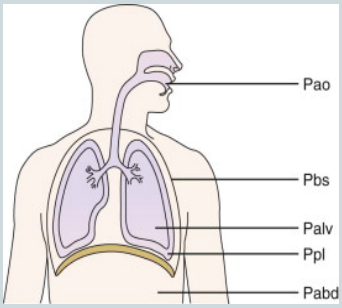
Chest 2007;131:362-7

Fat Distribution

- Waist-hip ratio > 0.95 (Chest 1997;111:891-8)
  - ↓ FVC, FEV1, and TLC
- Waist circumference negatively associated with FEV1 and FVC
  - 1cm of ↑ waist circumference leads to ↓ FEV1 by 13 mL and FVC by 11 mL

Obesity and chest wall compliance

Chestwall compliance

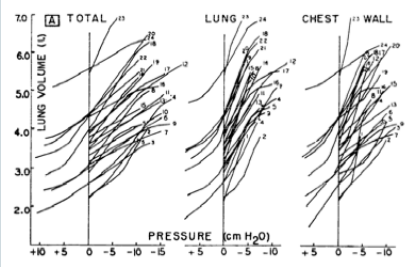


- Transpulmonary Press
  - Pao – Ppl
- Transchestwall Press (ie chestwall compliance)
- Ppl – Pbs
- ↓ Chest wall compliance
  - More significant in subjects with higher waist-hip ratios

Compliance of the respiratory system and its components in health and obesity[1]

A. NAIMARK[2] AND R. M. CHERNIACK[3]

J Appl Phys 1960;15:377-82



Normal weight

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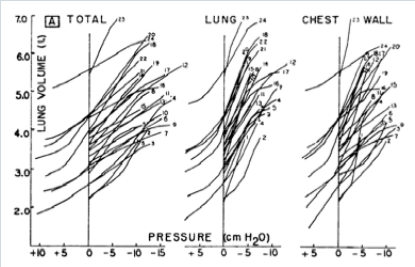
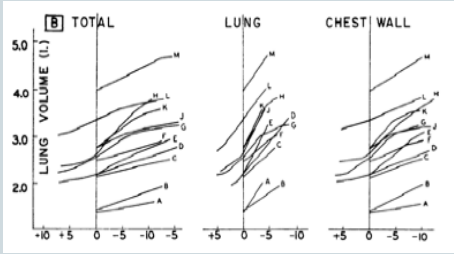


Normal weight



Obese

Work of breathing

TABLE 5. *Mechanical Work* of the Respiratory Muscles in Normal and Obese Subjects*

Subject	Total Work	Elastic Work†		
		Total	Lung	Thorax
Normal	.227‡	.090	.039	.051
Obese	.540§	.200	.050	.150

* Mechanical work in kg-m/l.

Associated Morbidities

- Diabetes (NIDDM)
- Cardiovascular disease
- Stroke
- Dyslipidemia
- Hypercoagulability
- Gallstones
- Osteoarthritis
- Back pain
- Pregnancy complications
- Cancer
- Chronic obstructive pulmonary disease
- Asthma
- Obesity hypoventilation syndrome
- Pulmonary embolism
- Aspiration pneumonia
- Obstructive sleep apnea

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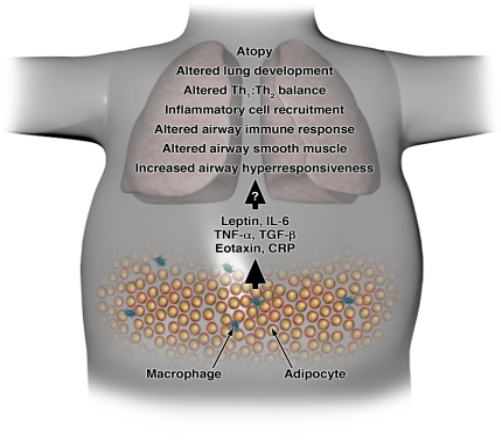
Obesity and asthma

- Rates of asthma 2.5 x greater than 20 years ago
  - 2 x # of overweight children
  - 3 x # of overweight adolescents
- Obesity ↑ risk of asthma
  - OR 1.6 – 3 in various studies
- Dose-response relationship

Ann Int Med 1990;828-32

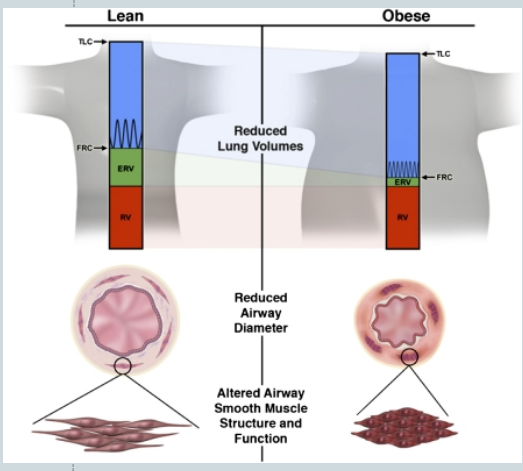
The proinflammatory adipocyte



AJRCCM 2006 174;2:112-9

Obesity and asthma

- Airways more narrow
- ↑ Airways resistance
  - 2 x normal



Obesity and asthma

- Obese children with asthma
  - More dyspnea
  - Greater risk of gastroesophageal reflux
  - More asthma-related prescriptions and healthcare visits
  - More difficult to control

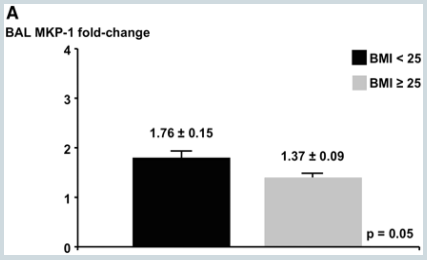
Int J Obesity 2010;34:599-605

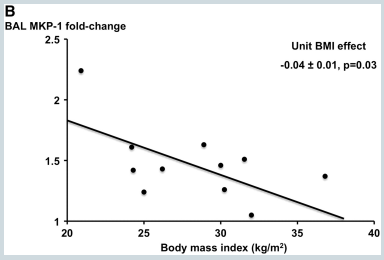
- Response to glucocorticoids in obese vs non-obese subjects

AJRCCM 2008;178(7):682-7

Response to glucocorticoids

Mitogen-activated kinase protein vs BMI





Similar results in BAL and blood

Obesity and sleep-disordered breathing

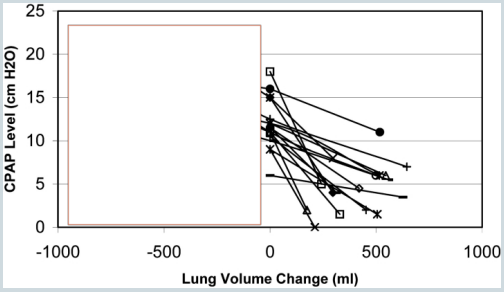
- 50-70% of pts with obstructive sleep apnea are obese
  - Fat deposition in pharynx
  - Reduced lung volumes
- 94% of obese children have abnormal sleep patterns

  Sleep 1989;12:430-8
- Obesity Hypoventilation Syndrome
  - Obesity, hypercapnea, sleep-disordered breathing
  - Respiratory drive affected by chronic resp acidosis
  - Risk of pulm hypertension and right heart failure
  - Underrecognized and underestimated

Effect of lung volume on pharyngeal collapsibility

- Goal
  - CPAP titration trial to assess the relationship between pharyngeal airway size / collapsibility and lung volume
- Obese OSA patients
  - Studied during non-REM sleep
  - Rigid shell with ability to control extrathoracic pressure as a means to change lung volume
  - Epiglottic cathether to monitor flow-limitation (assess pharyngeal patency)

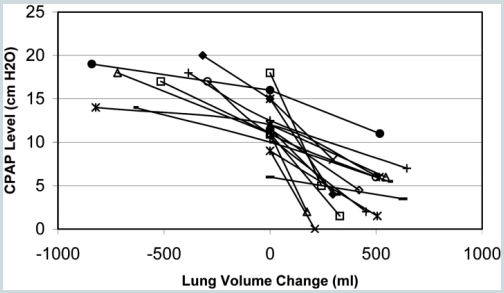
CPAP Titration Study



↑ Lung volumes leads to need for less CPAP
11.9 ± 0.7 cm H20 down to 4.8 ± 0.7 cm H20

AJRCCM 2005;172:114-7

CPAP Titration Study



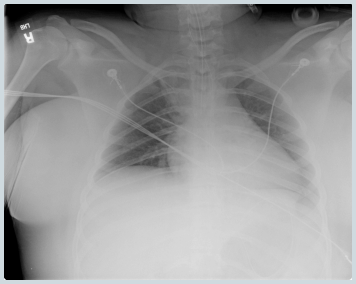
↓ Lung volumes leads to need for more CPAP
11.9 ± 0.7 cm H20 down to 17.1 ± 1 cm H20

AJRCCM 2005;172:114-7

Perioperative and ICU management

Perioperative and ICU management

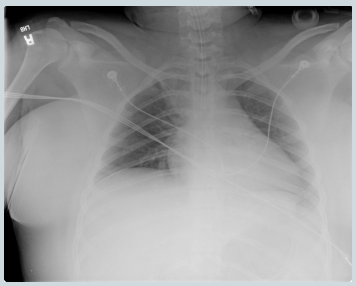
- 10 yo s/p T&A – tonsillar bleed at home
- 100 kg, 5’ 5” tall (BMI=37)
- Anesthesia intubation
- Airway evaluation and cauterization in OR
- Post-op sedation and analgesia



Perioperative and ICU management

- Fentanyl 4 mcg/kg/hr
- Precedex 1 mcg/kg/hr
- PRN paralytic

- Unplanned extubation following morning



Perioperative and ICU management

- Intubation and airway maintenance
- Anesthesia
- Atelectasis
- Deep venous thrombosis risk
- Procedures
- Extubation

Airway

- Anatomically difficult intubations
  - Limited mouth opening
  - ↓ neck mobility
  - Mallampati

Mallampati

Airway

- Anatomically difficult intubations
  - Limited mouth opening
  - ↓ neck mobility
  - Mallampati
- Maintaining airway prior to tube placement
  - ↓ FRC leads to ↓ O2 stores
  - Atelectasis leads to impaired gas exchange
  - ↑ risk of aspiration due to gastroesophageal reflux
- Expertise and planning
- Rapid sequence intubation

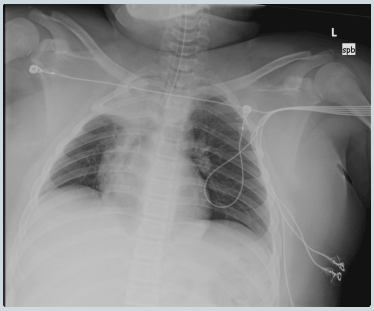
Anesthesia and obesity

- Altered pharmacokinetics
  - Drug absorption, distribution, metabolism, and excretion all affected by obesity
  - Dosing by ideal body weight vs actual weight
- Larger anesthetic doses may be needed
  - Larger doses or more frequent doses

Clin Pharm & Ther 2011;90:77-89

Atelectasis

- 16 yo admitted with status epilepticus
- 110 kg, 5' 7" (BMI=38)
- IBW 67 kg
- Intubated at outside ED
- Atelectasis on arrival
- SIMV/PRVC
  - TV 500, R 16, PEEP 8 (PIP 28)



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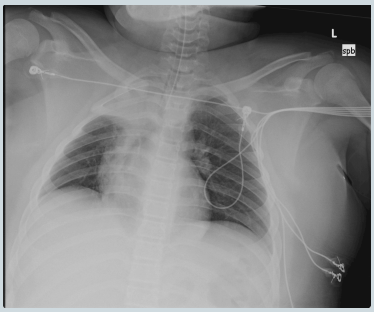
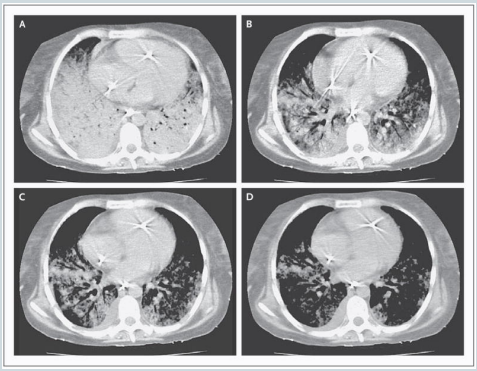


Ventilation strategies

- Atelectatic dependent lung zones
  - 45% of obese patients after abdominal surgery
  - ↑ PEEP
  - Recruitment maneuvers

Recruitment maneuvers



Ventilation strategies

- Atelectatic dependent lung zones
  - 45% of obese patients after abdominal surgery
  - ↑ PEEP
  - Recruitment maneuvers
- Esophageal pressure monitoring
  - Estimates pleural pressure
  - Higher PEEP may be needed to keep transpulmonary pressure positive ➔ keeps alveoli open

CCM 2006;34(5):1389-94

Ventilation strategies

- Higher PEEP to combat atelectasis
- Tolerance of higher plateau (or peak) inspiratory pressures to assist with oxygenation
  - Stiff chest wall ➔ pleural pressure may be much greater than body surface pressure
  - Plateau (or peak) inspiratory pressures then overestimates the distending pressure transmitted to the alveoli

Comorbidities

- Deep venous thrombosis and pulmonary embolism
  - Hypercoagulable
    - ↑ Fibrinogen, factor VIII, and von Willebrand factor
  - Venous stasis
- Procedures more challenging
  - Foley, venous access, etc

Extubation

- Airway maintenance post-extubation
  - Sedation
  - Narrow upper airways
  - Edema
  - Impaired consciousness

- Reverse Trendelenburg position
  - Improves end-expiratory lung volume and airway patency
- Non-invasive ventilation transition

Pediatric Pulmonology 46:1114–1120 (2011)

Non-Invasive Ventilation on a Pediatric Intensive Care Unit: Feasibility, Efficacy, and Predictors of Success

Christian Dohna-Schwake, MD,[1]* Florian Stehling, MD,[1] Eva Tschiedel, MD,[1] Michael Wallot, MD,[2] and Uwe Mellies, MD[1]

- Well-tolerated (73/74)
  - Improved HR, RR, ABG, and O2 sats
  - 23% required intubation for respiratory failure
- Transition post-extubation
  - 19 of 74 patients
  - Lower rate of NIV failure
- Early use for obese pts with acute resp failure
- Low threshold for use during extubation transition for obese pts

Respiratory Care for Obese Patients

- Differences during spontaneous respiration
- Incidence of asthma
- Difficulty with airway management / maintenance
- Prevalence of atelectasis
- Considerations during mechanical ventilation
- Role of NIV

Scoliosis

- Mild – moderate scoliosis
  - Few respiratory signs/symptoms
- Moderate – severe scoliosis
  - ↓ TLC, VC, and FRC
  - ↑ Vd / Vt (ratio of dead space to tidal volume)
- Higher curve - ↑ lung compression on convex side
- Xray may not tell the whole story
  - Rotational changes at thoracic level

Pulmonary effects

- V/Q mismatch
  - Atelectasis on concave side
  - ↑ alveolar ventilation on convex side
- Long-standing atelectasis ➔ lung atrophy and fewer pulmonary vessels

Neuromuscular Scoliosis

- Complication of any muscle weakness condition
  - More severe atelectasis due to muscle weakness
- More severe thoracic involvement
- Impaired clearance of airway secretions
  - Risk of chronic, recurrent aspiration and pneumonia

Long-term respiratory effects

- Untreated ➔
  - Chronic respiratory failure
  - Cardiovascular compromise
  - Pulmonary hypertension

- Airway clearance (Vest, cough-assist device)
- NIV
- Chronic ventilation

Postoperative and ICU management

- Predictors of postoperative resp failure and inability to extubate
  - Maximum inspiratory pressure (MIP) < 30 cm H2O
  - FVC < 40%
- Significant blood loss (≥ 1/3rd blood volume)
  - Significant fluid resuscitation intraop and post-op
  - Pleural effusion ± pulmonary edema
- 40% ↓ in vital capacity temporarily
- Significant pain
  - Shallow breathing, resp insufficiency, more atelectasis

Neuromuscular diseases

Neuromuscular diseases

- Spinal muscular atrophy
- Duchenne muscular dystrophy
- Spinal cord injury
- Guillain-Barre syndrome
- Myasthenia gravis
- Multiple sclerosis
- Postpolio syndrome
- Lambert-Eaton myasthenic syndrome
- Amyotrophic lateral sclerosis

Pulmonary effects

- ↓ lung and chest wall compliance
  - Respiratory muscle weakness, including diaphragm
  - ↓ VC and tidal volume
- Compensation:
  - ↑ resp rate; rapid and shallow
  - Accessory muscle use
- Impaired cough
  - weakness of abd and intercostal muscles, glottis weakness

Respiratory interventions

- American College of Chest Physicians recommendations:
  - Muscle strength training
  - Manual cough assist
  - Mechanical cough assist
  - ↑MIP and MEP, ↑ peak inspiratory cough flow

Chest 2005;128:1524-30

Respiratory failure

- Maximum inspiratory pressure (MIP)
- Maximum expiratory pressure (MEP)
  - followed as markers of resp muscle weakness
- Evidence of resp failure:
  - VC < 20 ml/kg, MIP < 30 cm H20, MEP < 40 cm H20

Specialized pediatric patients

- Respiratory challenges
  - Abnormal respiratory baselines
  - Marginal respiratory status
- Preplanning and critical thinking
  - Adjust mindset
  - Device availability
- Multidisciplinary approach

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Brenner Children's Hospital

Brenner FIT Program
'Families in Training'
to combat childhood obesity