Anesthetic Challenges in Pediatric Obesity

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Objectives for today’s lecture

- Epidemiology of Pediatric Obesity
- Co-morbidities associated with pediatric obesity
- Anesthetic implications of pediatric obesity
- Establish framework for further exploration of pediatric OSA and pediatric bariatric surgery
Obesity Defined and Epidemiological Trends
Measurement of obesity in adults

- Body mass index
- Weight (kg)/height (m)²
- Health risk increased if:
  - Waist > 40” (male)
  - Waist > 35” (female)
Relationship Between BMI and Percent Body Fat in Men and Women

BMI calculation in adults

Adult Body Mass Index (BMI) Chart

<table>
<thead>
<tr>
<th>WEIGHT</th>
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<tbody>
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<td>95</td>
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<td>6'4&quot;</td>
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Under healthy weight: BMI < 18.5
Healthy weight: BMI 18.5–24.9
Overweight: BMI 25–29.9
# Pediatric Obesity

## BMI-for-Age Classification

<table>
<thead>
<tr>
<th>Underweight</th>
<th>BMI-for-age &lt; 5th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy weight</td>
<td>BMI-for-age 5th-85th %ile</td>
</tr>
<tr>
<td>Overweight</td>
<td>BMI-for-age 85th-95th %ile</td>
</tr>
<tr>
<td>Obese</td>
<td>BMI-for-age &gt; 95th percentile</td>
</tr>
</tbody>
</table>

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**Pediatric BMI-for-Age Classification Chart**

For 2 to 20 years: Boys

**Body mass index-for-age percentiles**

<table>
<thead>
<tr>
<th>Date</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>BMI**</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
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<td></td>
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**To Calculate BMI**: Weight (lb) / (Height (in) - 39) x 703

**Source**: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

[Published May 29, 2000 (revised 1/31/2002)](http://www.cdc.gov/growthcharts)
Trends in Overweight for Children Birth Through 19 Years


NOTE: Obesity is defined as body mass index (BMI) greater than or equal to sex- and age-specific 95th percentile from the 2000 CDC Growth Charts.

Percentage Obese High School Youth Risk Behavior Survey, 2011
Pediatric Obesity: Prevalence

- Overall, about 16% of children ages 2-19 are obese in the U.S.
- ≈ 12 million
- 5% of children are “severely obese” in U.S.
- > 99th percentile
- 45,000 adolescents with BMI > 50

JAMA, 2012; 308 (24)

• Following years of steady increases, the incidence of pediatric obesity ↓
Pediatric Obesity Tracks into Adulthood
Whitaker, NEJM, 2003

- BMI < 85th
- BMI >= 85th
- BMI >= 95th

<table>
<thead>
<tr>
<th>Age Group</th>
<th>BMI &lt; 85th</th>
<th>BMI &gt;= 85th</th>
<th>BMI &gt;= 95th</th>
</tr>
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<tbody>
<tr>
<td>Birth</td>
<td>16 17</td>
<td>15 19</td>
<td>26</td>
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<tr>
<td>1 to 3</td>
<td>12 36</td>
<td>11 11</td>
<td>52</td>
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<td>3 to 6</td>
<td>11 55</td>
<td>10 75</td>
<td>83</td>
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<tr>
<td>6 to 10</td>
<td>10 69</td>
<td>9 77</td>
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<td>10 to 15</td>
<td>9 67</td>
<td>8 67</td>
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<tr>
<td>15 to 18</td>
<td>8 77</td>
<td>7 77</td>
<td>77</td>
</tr>
</tbody>
</table>
Severe Pediatric Obesity Worsens

Princeton Cohort  BMI $> 40$ kg/m$^2$

- Slope $+1$/yr
- $p<0.001$
- 91% Remain Morbidly Obese

Dolan RO1 unpublished
Calle, NEJM, 1999
Years of Life Lost

Obesity-related Disease
Co-morbidities associated with pediatric obesity

Psychosocial
- Poor self-esteem
- Depression
- Eating disorders

Neurological
- Pseudotumor cerebri

Pulmonary
- Sleep apnoea
- Asthma
- Exercise intolerance

Gastrointestinal
- Gallstones
- Steatohepatitis

Cardiovascular
- Dyslipidaemia
- Hypertension
- Coagulopathy
- Chronic inflammation
- Endothelial dysfunction

Renal
- Glomerulosclerosis

Musculoskeletal
- Slipped capital femoral epiphysis
- Blunt’s disease
- Forearm fracture
- Flat feet

Endocrine
- Type 2 diabetes
- Precocious puberty
- Polycystic ovary syndrome (girls)
- Hypogonadism (boys)
Childhood BMI and risk of CAD risk in adulthood

- 276,835 schoolchildren
- Ages 7-13
- Followed into adulthood
- Correlation with development of adult CV event

- Disease risk evident in obese children
  - Boys ages 7-13
  - Girls ages 10-13

- Association was linear for each age, and increased across entire BMI distribution
Childhood Adiposity, Adult Adiposity, and Cardiovascular Risk Factors
Juonala, NEJM 2011

6328 Obese children
23 years follow-up

Obese Adults
5.4x T2DM
2.7x HTN
1.7x Atherosclerosis

Normal weight adults
Similar to adults who were normal weight children
Cardiovascular risk factors rise in obese children

Systolic blood pressure
Diastolic blood pressure
Cholesterol
Insulin levels

BMI >95%: 39% >2 risk factors
BMI >99%: 59% >2 risk factors
Independent of age

Freedman J Peds 2007

Dramatic increase in disease prevalence in children < 99th %ile
99th %ile represents “clinically relevant” obesity
Diabetes: Lifetime Risk

- Overall, 33-39% of healthy 3 year olds are predicted to develop diabetes in their lifetime
- Hispanic: 53%
- African-American: 45%

Pediatric Obesity: Orthopedic Implications

- Musculoskeletal trauma
- Blount Disease (tibia vara)
- SCFE
Pediatric Obesity: Musculoskeletal Trauma

- Higher incidence of forearm fractures and fracture complications
  - Taylor, Peds, 2006
  - Leet, J Bone Joint Surg Am, 2005
  - Weiss, J Child Orthop 2009
Blount’s Disease

- Blount’s disease: increased weight strongly correlated with magnitude of deformity, surgical complications, and surgical failure
  - McIntosh, J Bone Joint Surg Am, 2009
Pediatric Obesity: SCFE

• Typically diagnosed in early adolescents with long-standing knee or hip pain

• 80% of pts with SCFE have BMI > 95th %ile

• Higher incidence of bilateral disease in children with high BMI’s
Underlying diseases in Cincinnati bariatric surgery population

- OSA 28%
- T2DM 10%
- NASH/hepatic fibrosis 30%
- HTN 15%
- Depression 21%
- RAD 10%
- GERD 5%
- Cholesterol 5%
- PCOD, JRA, pseudotumor cerebri
Anesthetic Implications of Pediatric Obesity

- Peri-operative Risk
- Airway Concerns
- Pharmacology
  - Inhalational agents
  - Drug dosing
Incidence and Risk Factors for Perioperative Adverse Respiratory Events in Children Who Are Obese

Tait, et. al.
Anesthesiology 2008

- Evaluated large cohort of obese and normal weight children ages 2-18 yrs
- Prevalence of obesity 32% obese or overweight
- Increased prevalence of co-existing diseases
- Increased incidence of critical airway events in obese children
- Risk factors included
  - Obesity
  - Airway surgery
  - History of OSA
Airway issues in the morbidly obese

- Many consider obesity to be a strong risk factor for difficult airway
- Literature suggests up to 10% of obese patients may have difficult airway mgt
- CCHMC experience:
  - Mallampati 1:62%, 2:29%, 3:9%
  - 95% C and L score of 1
  - 5% C and L score of 2
  - No patients required airway adjunct

Samuels, International Anesthesiology Clinics, 2006
Childhood body mass index and perioperative complications

Nafiu, Peds Anes 2007

• 32% obesity rate

HTN, T2DM, asthma

Difficult mask airway, PACU airway obstruction, need for multiple anti-emetics

• Longer PACU stay in obese children
Perioperative outcomes of severely obese children undergoing tonsillectomy
Gleich, Peds Anes, 2012

- 100 children, ages 2-18, BMI > 98%ile
- Rate of asthma, significant co-morbidities
- Rate of peri-operative airway complications
- Rate of unplanned hospital admission
Overweight/Obesity and Gastric Fluid Characteristics in Pediatric Day Surgery: Implications for Fasting Guidelines and Pulmonary Aspiration Risk

Cook-Sather, Anes Analg, 2009

- Ages 2-12
- 14% overweight, 13% obese
- NPO after MN, clears up to 2 hrs pre-surg
- Corrected GFV no different in obese children
- No support for more rigid NPO guidelines in obese children
Perioperative Pharmacology in Pediatric Obesity

- Many factors impact anesthetic agents in morbid obesity:
  - Increased CO
  - Increased lean body weight
  - Increased fat mass
  - Increased extra-cellular fluid volume

- Unclear what dosing scalar is appropriate
  - TBW: what a scale says
  - IBW: what a table says
  - LBW: muscle, bone, organs
Drug Dosing Scalars

Lean body weight

- Fat
- Lean body mass

- Fat
- Lean body mass
Estimation of Lean Body Mass in Children
Peters, BJA, 2011

- LBW in adults [kg] =
  \[ (9270 \times TBW) \div (6680 + (216 \times \text{BMI})) \]
- LBW in children [kg] =
  \[ 3.8 \times (0.0215 \times W^{0.65} \times H^{0.72}) \]

http://www.medcalc.com/body.html
# Inhalational Agent Solubilities

<table>
<thead>
<tr>
<th>Agent</th>
<th>Blood/Gas</th>
<th>Fat/Blood</th>
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<tbody>
<tr>
<td>Nitrous oxide</td>
<td>0.47</td>
<td>2.3</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>1.4</td>
<td>45</td>
</tr>
<tr>
<td>Desflurane</td>
<td>0.42</td>
<td>2.7</td>
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<tr>
<td>Sevoflurane</td>
<td>0.65</td>
<td>48</td>
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</table>
Emergence and Recovery Characteristics of Desflurane Versus Sevoflurane in Morbidly Obese Adult Surgical Patients: A Prospective, Randomized Study

Sturm, Anes Analg, 2004 99(6)

Table 2. Emergence and Immediate Recovery Times After Discontinuation of Volatile Anesthetics in the Two Anesthetic Groups

<table>
<thead>
<tr>
<th>Time to (min)</th>
<th>DES</th>
<th>SEVO</th>
<th>P value (SEVO versus DES)</th>
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<tbody>
<tr>
<td>Eye opening</td>
<td>9.9 ± 4.5</td>
<td>18.5 ± 8.7 (87)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Hand grip</td>
<td>13.8 ± 7.1</td>
<td>22.4 ± 11.5 (62)</td>
<td>&lt;0.004</td>
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<tr>
<td>Tracheal extubation</td>
<td>14.2 ± 8.0</td>
<td>25.5 ± 12.0 (80)</td>
<td>&lt;0.0003</td>
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<tr>
<td>Telling name</td>
<td>18.4 ± 8.4</td>
<td>32.1 ± 13.7 (75)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Telling DOB</td>
<td>20.4 ± 8.8</td>
<td>34.5 ± 14.4 (69)</td>
<td>&lt;0.0003</td>
</tr>
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</table>

Values are expressed as mean ± SD (% difference).
DOB = date of birth.
The emergence times of the desflurane (DES) group were significantly less than those of the sevoflurane (SEVO) group.
Lean body Weight Scalar for the Anesthetic Induction Dose of Propofol in Morbidly Obese Subjects
Ingrande, Anes Analg, 2011

- 30 control, 60 MO subjects
- Measured induction doses based on TBW or LBW
- Dose to LOC 2.6 mg/kg vs 1.8 mg/kg
- LOC correlated with LBW dosing
The effect of obesity on the ED\textsubscript{95} of propofol for loss of consciousness in children and adolescents

Olutoye, Anes Analg, 2012

• 40 obese and 40 normal weight children
• 3-17 years
• Normal weight children: 3.2 mg/kg
• Obese children: 2 mg/kg
Evaluation of Propofol Anesthesia in Morbidly Obese Children and Adolescents
Chidambaran, in press

Population Pharmacokinetic Modeling of Propofol in Morbidly Obese Children and Adolescents
Diepstraten, Clin Pharmacokinet, 2012

- Induction dose correlated with LBW
- Infusion correlated with TBW
- Incidence of airway obstruction in PACU increased
- Higher BMI associated with increased likelihood of adverse airway event
Pharmacokinetics of Fentanyl and Morbid Obesity

• Pharmacokinetic models over-predicted fentanyl concentrations as patients became increasingly obese
• Used prediction error to calculate correction for actual body weight
• Called this correction “pharmacokinetic mass” (PM)
• PM closely correlated with LBM
• In adults, PM peaks at ~100 to 110 kg

Shibutani, Anesthesiology, 2004
Pharmacokinetic mass vs. Lean Body Weight
Non-depolarizing muscle relaxants in morbidly obese
Leykin, Anes Analg 2004

• Hydrophilic drugs
• Roc, when based on TBW rather than IBW, results in duration 2X longer
• Dose based on LBW
Succinylcholine and Morbid Obesity
Lemmens Anesth Analg 2006

- 45 obese adults
- BMI > 40
- 3 study groups
  - SCh IBW
  - SCh LBW (1.3 x IBW)
  - SCh TBW
- No differences in onset time
- Block duration slightly longer in TBW group
### Drug dosing in obese patients

<table>
<thead>
<tr>
<th>Drug Type</th>
<th>Dosing Characteristics</th>
<th>Reference Unit</th>
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<tr>
<td>Propofol induction</td>
<td>Lipophilic but small Vd</td>
<td>LBW</td>
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<tr>
<td>Propofol infusion</td>
<td>TBW close assoc with Clearance, little accumulation</td>
<td>TBW</td>
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<tr>
<td>Non-depol muscle relaxants</td>
<td>Prolonged if based on TBW</td>
<td>LBW</td>
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<tr>
<td>Succinylcholine</td>
<td>↑ Plasma cholinesterase</td>
<td>TBW</td>
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<tr>
<td>Narcotics</td>
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<td>LBW</td>
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Summary

• Public health issue
• More obese patients for all types of surgery, esp. T and A, SCFE
• More children with obesity-related co-morbidities
• More children on “adult” medications
• 99%ile represents “clinically relevant” obesity
• OSA is a common and significant co-morbidity
• Obesity surgery in the severely effected adolescent patient population