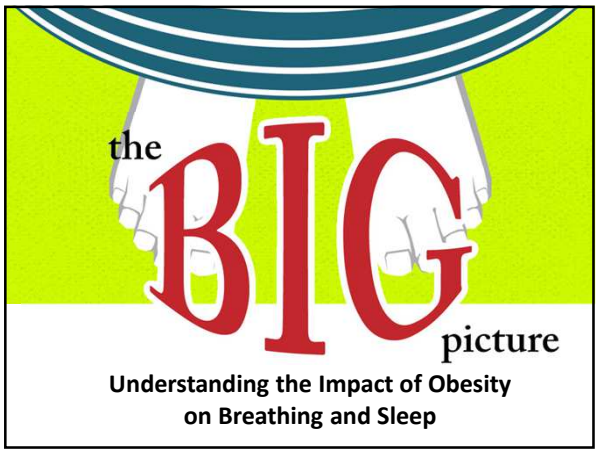


Understanding the Impact of Obesity on Breathing and Sleep

7 out of the TOP 10 leading causes of death and disability in the United States today are chronic disease. Prevention and treatment of most of these conditions must address the **close link with obesity** … Many professional organizations now classify **obesity independently as a chronic disease.**

Heymsfield & Wadden. NEJM, 2017

Is Obesity a Problem?

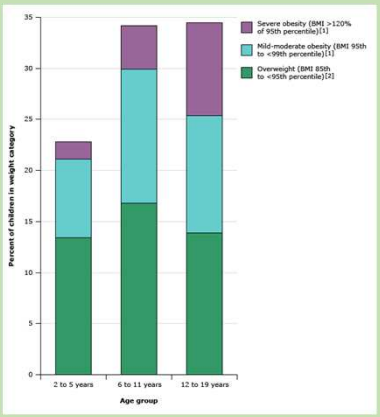
- Trends
- Diet
- Exercise
- Morbidity and Mortality

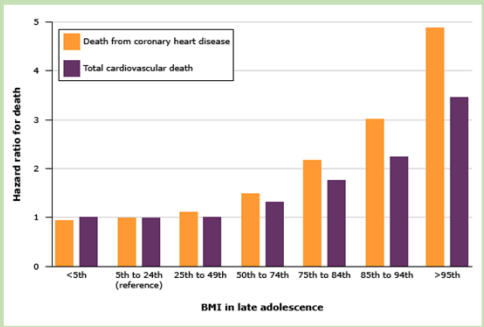
Is Obesity a Problem?

40% of adults in the United States are **obese**

69% of adults in the United States are **overweight**

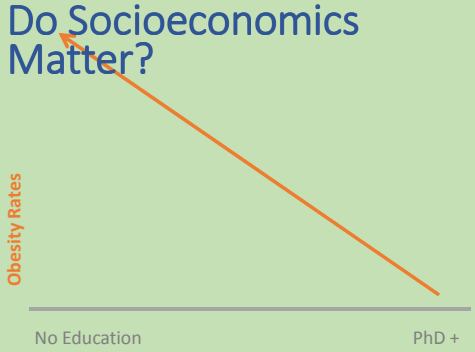
From CDC.gov





Twig G, Yaniv G, Levine H, et al. Body-mass index in 2.3 million adolescents and cardiovascular death in adulthood. N Engl J Med 2016; 374:2430.

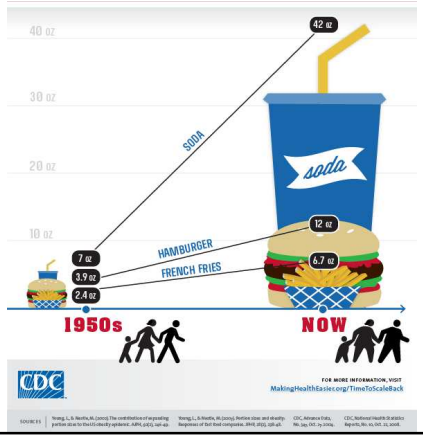
Do Socioeconomics Matter?



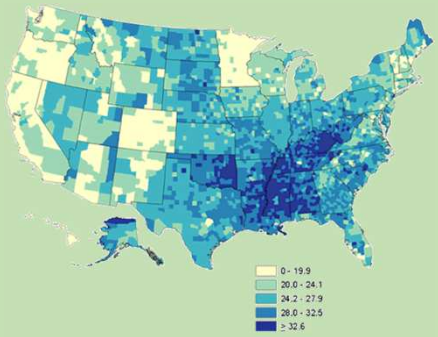
What Has Changed?

Portion Sizes have increased
Caloric Density has increased
Activity has decreased

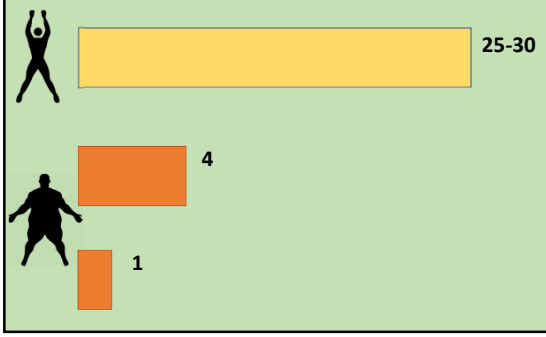
Attitudes about Obesity have changed



What Has Changed?



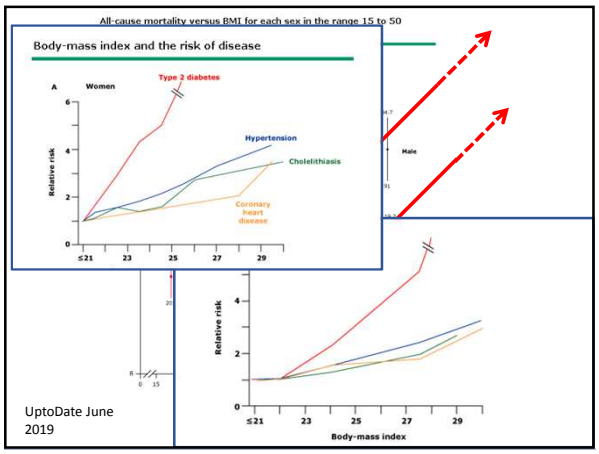
Average Hours of Physical Activity (Annual)

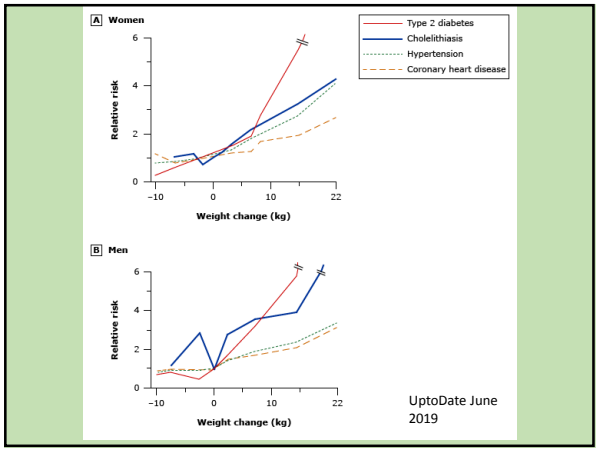


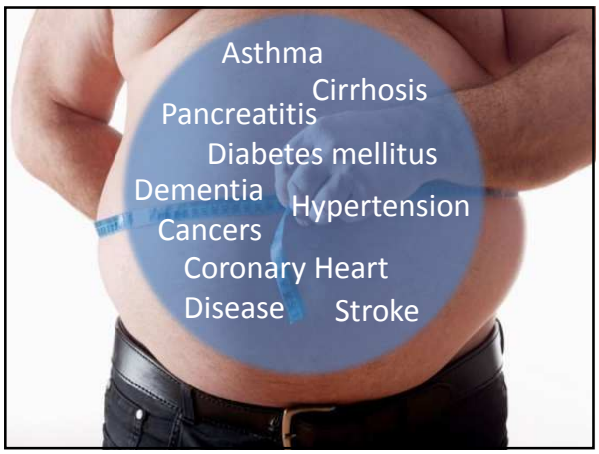
Does **BMI** have an effect on

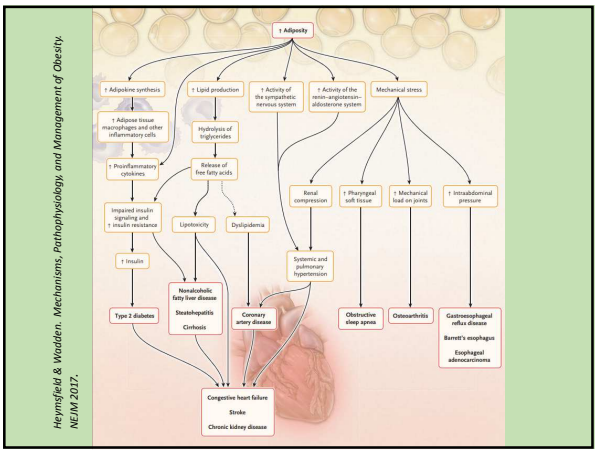
the three M's ?

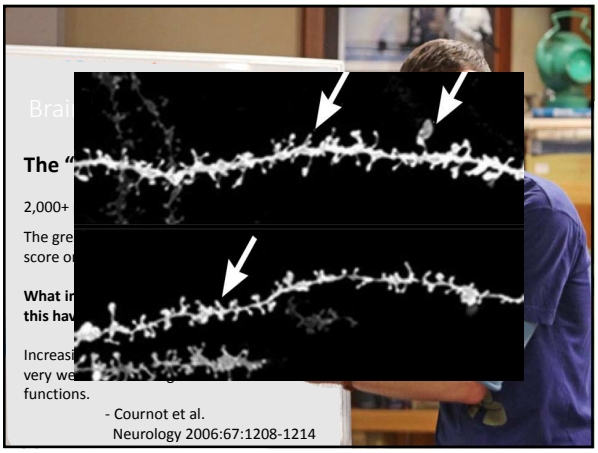
Morbidity Mortality
Money


All-cause mortality versus BMI for each sex in the range 15 to 50
Body-mass index and the risk of disease
A
Women
Type 2 diabetes
Hypertension
Cholelithiasis
Coronary heart disease
Relative risk
Male
Body-mass index
UptoDate June 2019


A Women
Type 2 diabetes
Cholelithiasis
Hypertension
Coronary heart disease
Relative risk
Weight change (kg)
B Men
Relative risk
Weight change (kg)
UptoDate June 2019


Asthma
Cirrhosis
Pancreatitis
Diabetes mellitus
Dementia
Hypertension
Cancers
Coronary Heart
Disease
Stroke





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- Cournot et al.
Neurology 2006:67:1208-1214

20% of the increase in Healthcare spending is obesity

200 Billion Dollars
in obesity related health costs

152 Billion Dollars
in lost productivity annually

$2741
the average amount extra paid to healthcare expenses

Does Money Matter?

Is Obesity a Problem?

Yes.

How do we fix it?

Portion Sizes have increased
Caloric Density has increased
Activity has decreased

Isn't it this easy?

Fixing It

from
hhs.gov/fitness

How to Define Obesity

- Body Mass Index
- Hydrostatic Weight
- Body Calipers
- Functionally

Expert Guidelines

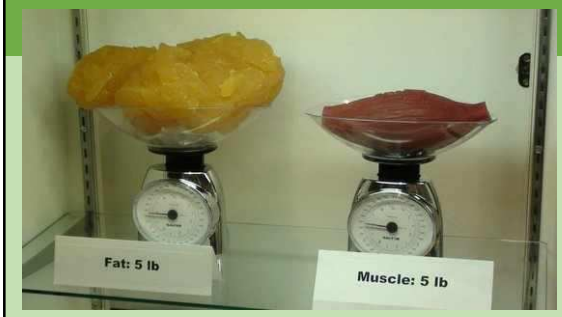
- ALL major guidelines recommend use of the BMI
  - WHO
  - AHA
  - ACCM
  - AMA
  - US Preventive Services Task Force
  - ACOG
- Many recommend the addition of waist circumference:
  - Women > 35 in
  - Men > 40 in
- There is little need to measure waist circumference when BMI > 35 (it is assumed that waist circumference will meet the definition)

Body Mass Index

$$\frac{\text{Body Weight (kg)}}{\text{Height (m}^2\text{)}}$$

Flaws	Strengths
•Indirect Measurement •Doesn't take muscle into account	•Noninvasive •Simple and effective when used in context

Both with a BMI in Overweight Zone



BMI – NIH/NHLBI Table

BMI	
< 18.5	Below normal weight
19-24	Normal weight
25-29	Overweight
30-34	Class I Obesity
35-39	Class II Obesity
40+	Class III Obesity

National Institutes of Health (NIH), National Heart, Lung, and Blood Institute (NHLBI). The practical guide: identification, evaluation, and treatment of overweight and obesity in adults. Bethesda: National Institutes of Health. 2000, NIH publication 00-4084.

Modifications to Class III

BMI	Classification
40-44.9	Severely Obese
45-49.9	Morbidly Obese
> 50	Super Obese

BMI doesn't stop at 50 . . . Some of us have taken care of people with BMI exceeding 80, 90, 100+

The Pathophysiology of Obesity

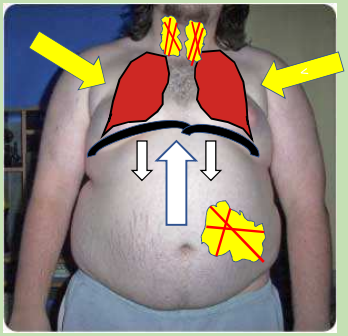
- Anatomical
- Hormonal Influences
- Lung Mechanics
- Obesity Paradox

Anatomical

- Excess adiposity is a slow process
- Lipids (especially triglycerides) build up
- Volume increases in skeletal muscle, liver, other organs and tissues

Resulting In:

- Larger fat mass AND Larger lean mass
- Higher REE
- Increased Cardiac Output
- Increased insulin



- Increase in pharyngeal soft tissues
- Weight on chest wall restricts expansion and diaphragmatic excursion
- Increase in intraabdominal pressure
- Adipose requires oxygen, increasing cardiac output

Hormonal Influence

- Correlations with **decreased Leptin** (Appetite Suppressant) with Obesity, OSA
- Correlations with **increased Ghrelin** (Appetite Stimulant) with Obesity, OSA – Treating OSA may decrease Ghrelin levels.

Systemic Proinflammatory State

Oversimplified:

Adipocytes synthesize adikopines and hormones. The more adipose, the greater the secretion. This results in a **low-grade systemic inflammatory state**.

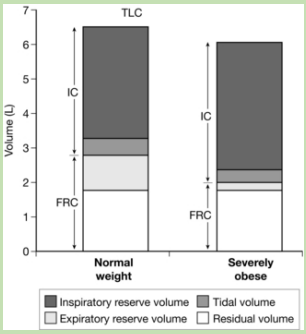
Other Significant Mechanics

- Decreased compliance
  - Normal weight range, sitting upright = 100-119 mL/cmH2O (Naimark)
  - Critical Care range varies, but usually 50 mL/cmH2O is fabulous
  - Obese patients, particularly supine, may have measured compliance below 20 mL/cmH2O

Other Significant Mechanics

- Increased Raw
- Increased WOB (Pelosi et al)
  - 0.52 J/L in lean patients
  - 1.30 J/L in obese patients
- Increased O2 consumption (Kress et al)
  - 221 mL/min in lean patients – sedated
  - 355 mL/min in obese patients – sedated
  - When paralyzed consumption dropped 16% in obese patients, while less than 1% in lean patients
- Increased CO2 production
  - Significantly more CO2 produced as a result of increased O2 consumption

Pulmonary Function



PFT Pattern: Adults vs Children

Value	Obese Adults	Obese Children
FEV1	Lower	Unchanged
FVC	Lower	Unchanged
TLC	Lower	Slightly Lower
RV	Lower	Slightly Lower
FEV1/FVC	Some deficit	Pronounced deficit

Forno, et al. Journal of Allergy and Clinical Immunology, 2018

The Start of a Paradox

- LOS / BMI are directly related statistically
- Greater BMI may have a "protective effect"
- Longer LOS may be due to difficulty in diagnosis and treatment, not mobilizing pt as often
- Longer LOS = Increased Mortality (long-term)

Akinnusi et. al (2008) Critical Care Medicine

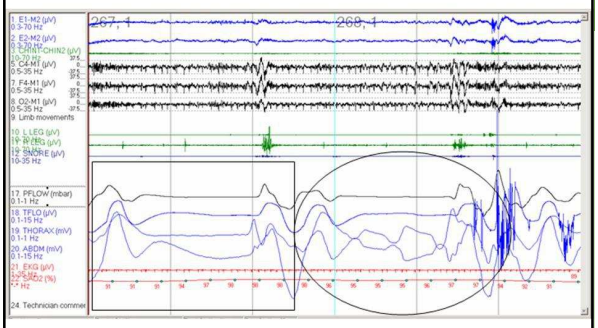
Trauma

- Retrospective study of 275,000 trauma patients
- Obesity correlated positively with cardiovascular and respiratory complications (12.6% vs. 5.2%)

- Is there merit in being MORE proactive with obese trauma patients? Initiate NPPV before it is needed? Intubate earlier? Trach earlier?

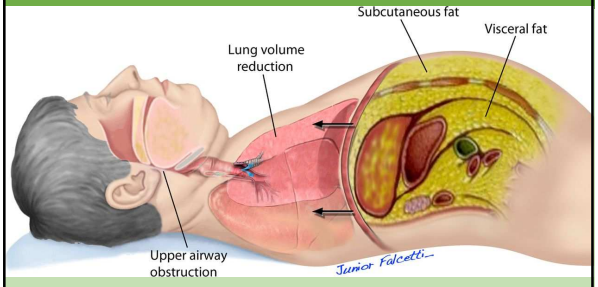
Related Diseases/Disorders

- Obstructive Sleep Apnea
- Obesity Hypoventilation Syndrome



Wickramasinghe, Medscape.com, 2019

Obstructive Sleep Apnea



From Journal of the American College of Cardiology

What is Obstructive Sleep Apnea

Recurrent episodes of obstruction of the upper airway leading to sleep fragmentation and intermittent hypoxia during sleep. (Drager, et. al., 2013)

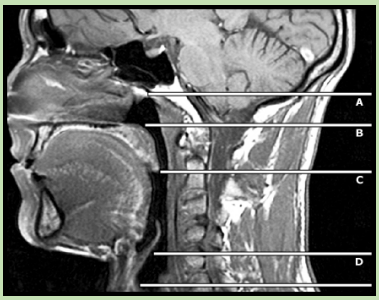
Prevalence of OSA

- MOST studies use an AHI > 5/hr
- Upwards of 20%
- Higher in males (22%/17%) *(Franklin, 2015; Senartna, 2017)*
- Increases with age (up to 90%/78% in elderly)
- Increases with BMI *(Franklin, 2015; Senartna, 2017)*
- Prevalence has increased over time *(Franklin, 2015)*

Obesity and OSA

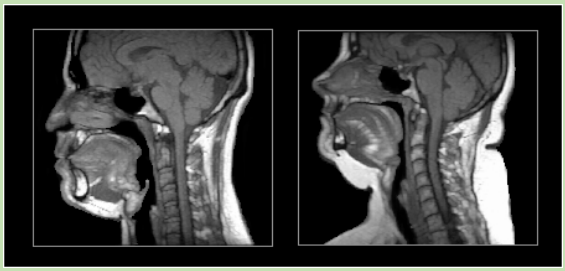
- Mass Loading in the Upper Airway
  - **More fat in the tongue** (not all obese people, but …)
  - Increased volume in upper airway soft tissue, including the lateral pharyngeal walls, and total soft tissue
  - Adolescents: usually more related more to tonsil and adenoid size *(Schwab, 2015)*

MRI: Normal Upper Airway



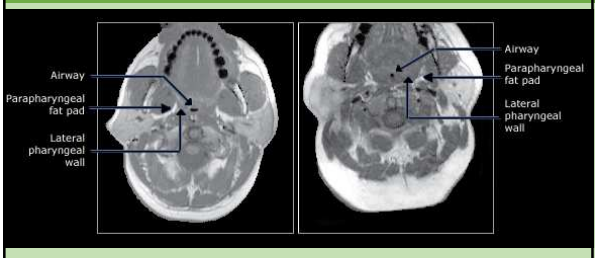
Schwab. Uptodate, 2019

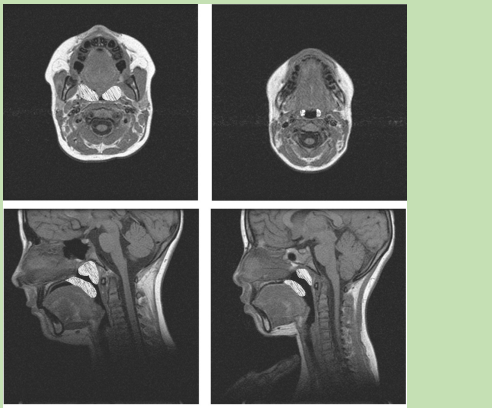
MRI: Normal Upper Airway

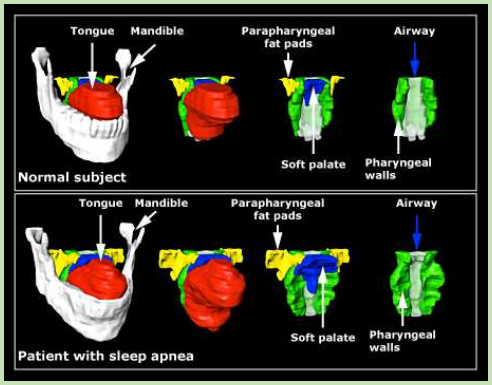


Schwab. Uptodate, 2019

MRI: Normal vs OSA







Definitions (there is some variation)

- **Apnea**:
  pause in respiration for more than 10 seconds
- **Hypopnea**:
  reduction in airflow that causes a decrease in SpO2:
  - 50% flow reduction with 3% decrease in SpO2
  - 30% flow reduction with 4% decrease in Spo2
- **RERA** (Respiratory Effort Related Arousal):
  The EEG shows alpha wave form (awake) of at least 10 sec with increased respiratory effort … not technically an apnea or hypopnea (esophageal manometry is preferred method of measuring)

Apnea Hypopnea Index (AHI)

$$AHI = \frac{\text{Apneas + Hypopneas}}{\text{Total Sleep Time in Hours}}$$

Respiratory Disturbance Index (RDI)

$$RDI = \frac{\text{Apneas + Hypopneas + RERAs}}{\text{Total Sleep Time in Hours}}$$

Classifying Severity

AHI or RDI	Severity	
5-14/hr	Mild	Minimal symptoms + risk HTN
15-30/hr	Moderate	Reduced QOL + HTN possible + Sleep fragmentation
> 30/hr	Severe	Marked interference with QOL + greatest risk for mortality + morbidity

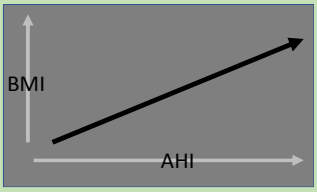
CMS Clinically Significant Criteria

- 5 or more predominantly obstructive respiratory events per hour (obstructive, mixed, hypopneas, RERAs)
  + at least one:
  - Sleepiness, fatigue, nonrestorative sleep, insomnia
  - Waking up breath-holding, gasping, choking
  - Habitual snoring
  - Hypertension, Mood or Cognitive Issues, Diabetes Type 2, Afib, CHF, Stroke, etc.
- 15 or more predominantly obstructive respiratory events per hour

CMS.gov

Obesity and OSA: Correlation

- 1-SD increase in BMI = 4x increased risk for OSA (Young, et. Al)
- BMI > 40 = 40-90% prevalence (Rajala, et. Al)
- 10% change in body weight = 30% change in AHI



Obesity and OSA

- 70% of those with OSA are Obese (Malhotra, et al. 2002)
- Higher BMI associated with higher prevalence
  - BMI> 40: 98% prevalence of OSA with AHI > 5

Fat Distribution and OSA

Apnea-hypopnea index, events/h					
Non-REM	54.1	38.2	23.6	32.9	<0.001
REM[†]	56.8	28.5	38.0	29.0	0.014
Total	54.6	36.1	26.4	31.6	<0.001

	Males (n = 23)		Females (n = 91)		
	Mean	SD	Mean	SD	P Value
Age, yr	40.9	8.9	41.9	9.3	0.653
Anthropometrics					
BMI, kg/m^2	51.5	7.5	49.1	0.9	0.207
Neck, cm	47.7	4.7	40.8	0.4	<0.001
Waist, cm	151.6	16.4	130.0	1.7	<0.001
Hip, cm	150.2	18.7	142.7	2.0	0.088
Waist-to-hip ratio	1.01	0.09	0.93	0.02	0.104
Girth, cm[‡]	35.2	5.0	31.8	4.2	0.002

Schwartz, et al. Annals of the ATS, Feb 2008

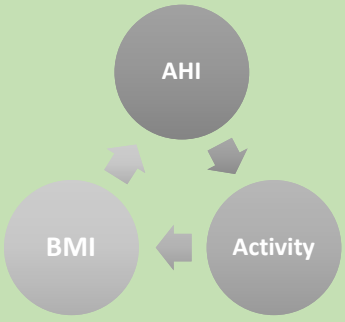
BMI and Disease Risk

Classification of Overweight and Obesity by BMI, Waist Circumference, and Associated Disease Risks

			Disease Risk* Relative to Normal Weight and Waist Circumference	
	BMI (kg/m^2)	Obesity Class	Men 102 cm (40 in) or less Women 88 cm (35 in) or less	Men > 102 cm (40 in) Women > 88 cm (35 in)
Underweight	< 18.5		-	-
Normal	18.5 - 24.9		-	-
Overweight	25.0 - 29.9		Increased	High
Obesity	30.0 - 34.9	I	High	Very High
	35.0 - 39.9	II	Very High	Very High
Extreme Obesity	40.0 +	III	Extremely High	Extremely High

* Disease risk for type 2 diabetes, hypertension, and CVD.
+ Increased waist circumference can also be a marker for increased risk even in persons of normal weight.

Is Obesity Caused by OSA?



Does treating OSA result in weight loss?

- 2 months of compliance w/ CPAP = reduced serum leptin (but no weight loss) *Harsch 2003*
- No change in weight *Vgontazas 2008*
- **Weight gain with CPAP** *Redenius 2008*

Obesity Hypoventilation Syndrome

A Definition

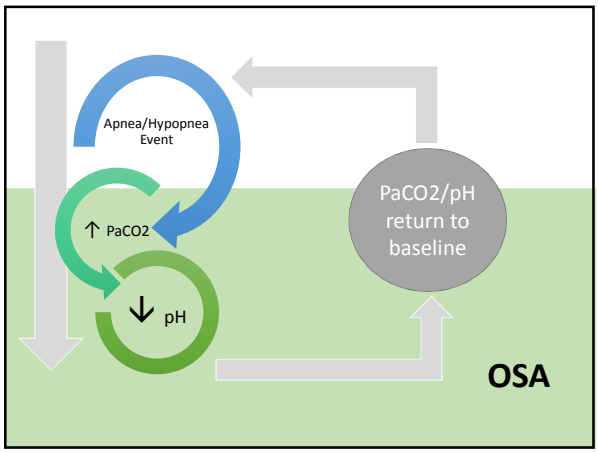
BMI > 30 kg/m2 with hypoxemia during sleep, and hypercapnia during the day

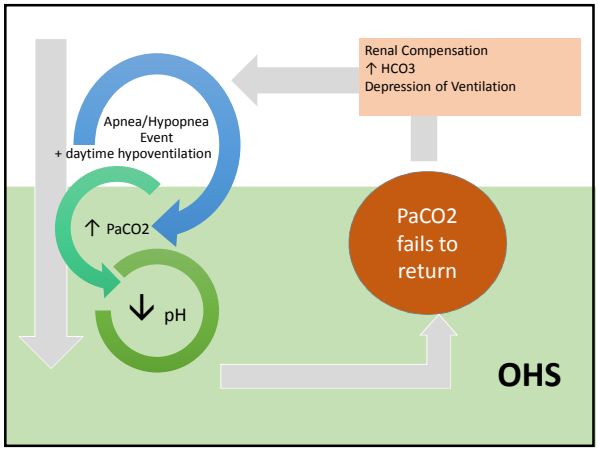
So …

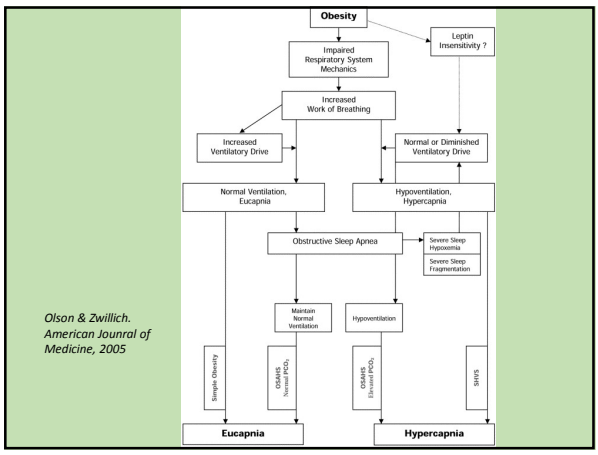
OSA with Daytime Hypoventilation that results in chronic respiratory failure

Or …

Ultimately these people perpetually “underbreathe”


Apnea/Hypopnea Event
↑ PaCO2
↓ pH
PaCO2/pH return to baseline
OSA


Renal Compensation
↑ HCO3
Depression of Ventilation
Apnea/Hypopnea Event
+ daytime hypoventilation
↑ PaCO2
↓ pH
PaCO2 fails to return
OHS

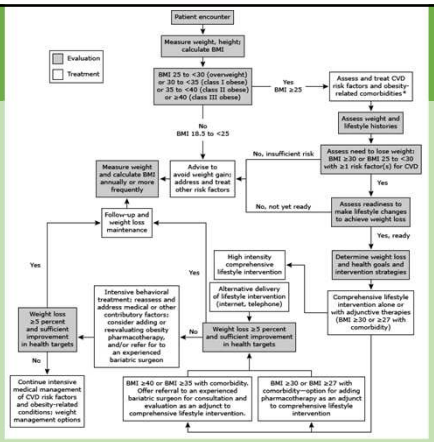

Olson & Zwillich. American Jounral of Medicine, 2005
Obesity
Leptin Insensitivity ?
Impaired Respiratory System Mechanics
Increased Work of Breathing
Increased Ventilatory Drive
Normal or Diminished Ventilatory Drive
Normal Ventilation, Eucapnia
Hypoventilation, Hypercapnia
Obstructive Sleep Apnea
Severe Sleep Hypoxemia
Severe Sleep Fragmentation
Maintain Normal Ventilation
Hypoventilation
Simple Obesity
OSAHS Normal PCO2
OSAHS Elevated PCO2
SHVS
Eucapnia
Hypercapnia

Clinical Implications of OHS

- Obvious need for sleep study
- CPAP/BiPAP is nearly definite
- Weight loss is most helpful
- Increased risk: pulmonary hypertension with resulting right-sided heart failure (cor pulmonale) … really heart failure in general, polycythemia as a compensation
  TREAT EACH AS NEEDED
- Acute Care: Abnormal ABG baseline … treat to a normal pH, not a normal PaCO2
- Severe cases: Consideration for tracheostomy/vent support

Strategizing

- The Big Question
- Diagnostics
- Airways: Intubating
- Noninvasive Management
- Airways: Tracheostomies
- Ventilator Management



Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS Guideline for the Management of Overweight and Obesity in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. J Am Coll Cardiol 2013 Nov 7;

Dilemmas in Diagnostics

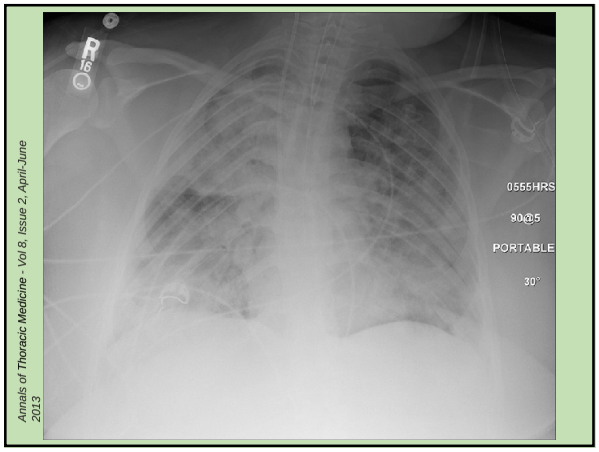
Diagnostics become increasingly difficult – *everything*:

- The X-Ray
- CT Scanning
- Ultrasound
- Access for blood-related lab tests
- Clinical confusion of multiple comorbidities

Let's Play a Game

Fig. 1. Preoperative chest X-ray shows cardiomegaly, dual lumen catheterization and central vein catheterization in the morbidly obese patient.


PORTAE
SUPI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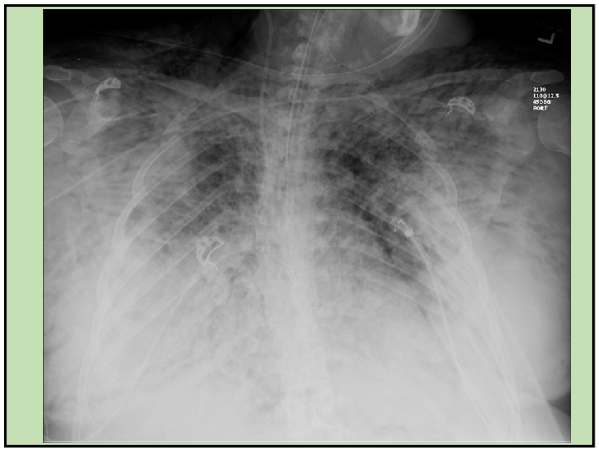
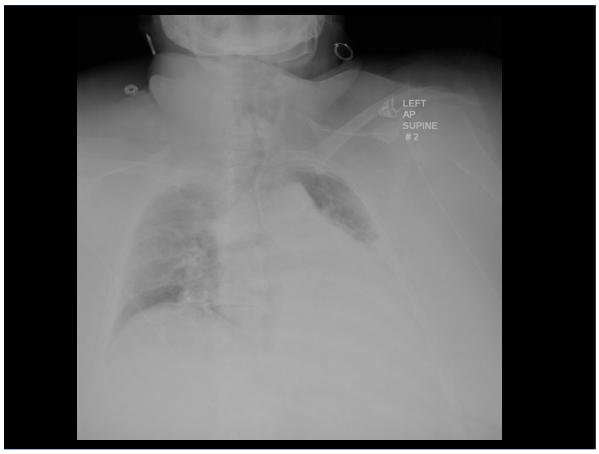
Annals of Thoracic Medicine - Vol 8, Issue 2, April-June 2013

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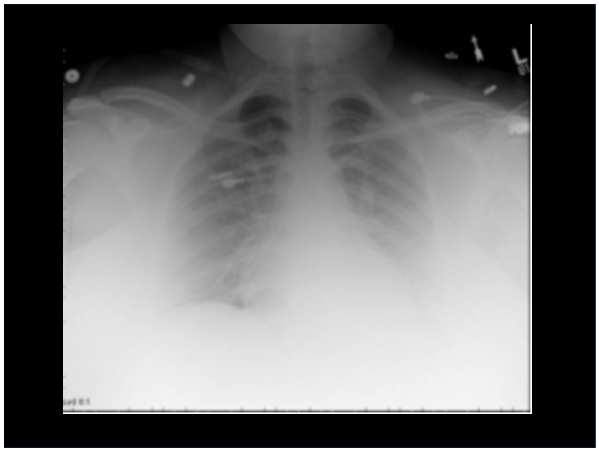
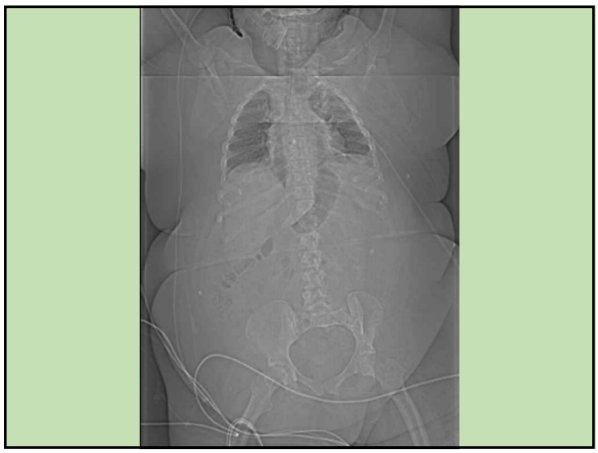
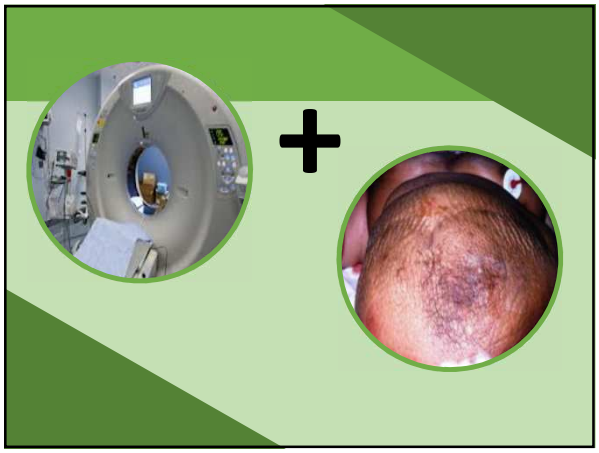






The Limitations

- General X-ray: must use higher speed film
- CT Scan: bore length/diameter may noy accommodate patient
- MRI: bore length/diameter may not accommodate patient + larger cross-sectional area means more time in the scanner (increases resources + increases risk of movement)
- Flouroscopy: limitations on equipment, may need serial radiographs
- Interventional: typical sizing might not work
- Ultrasound: need to determine thickness of subcutaneous fat in order to decipher readings

The Challenges are Real

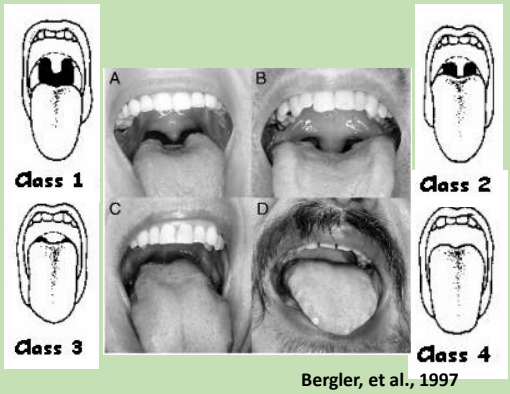
- Some types of imaging require extensive amounts of radiation with obese patients
- Some equipment (tables) don't technically support morbidly obese patients
- CT (and other) images may be of lesser quality due to something called "photon starvation" … voltage/current can be increased but at the cost of additional radiation dosage.
- Imaging can require an increase in the amount of people needed to safely (safely for the patient and safely for healthcare workers) position/move the patient.
- If sedation is needed, may require higher doses

Airway Strategies

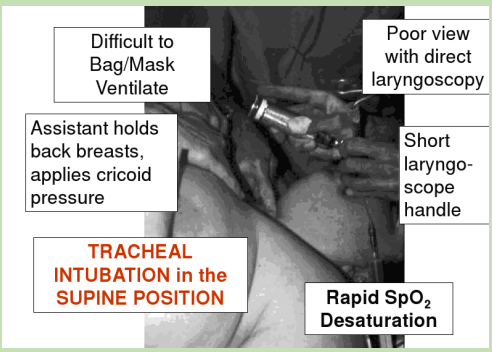
- Planning ahead is a valuable tool … play the "what if" game
- Analyze every airway like it is potentially a difficult one.
- Treat every airway like it is a potentially difficult one.
- Position the patient for optimal anatomical alignment.
- Don't lose the airway if you can help it
  - Awake intubation
  - RSI with extreme caution
- Know what tools you have access to:
  - Difficult Intubation equipment
  - Positioning equipment (wedges, pillows, blankets)

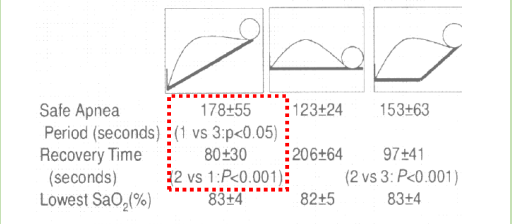
Analyzing the Difficult Airway

- Mallampati Scores
- Thyromental Distance
- Upper Lip Bite Test
- History of difficulty with airway



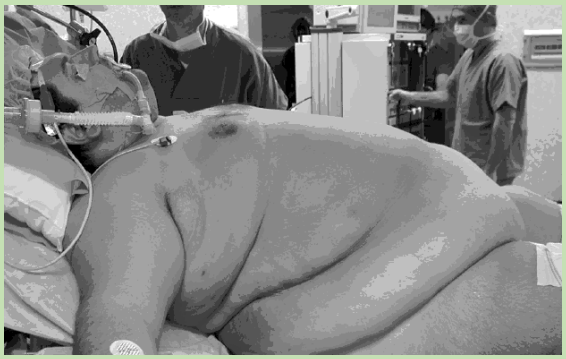
Bergler, et al., 1997





Safe Apnea Period (seconds)	178±55 (1 vs 3:p<0.05)	123±24	153±63
Recovery Time (seconds)	80±30 (2 vs 1:*P*<0.001)	206±64	97±41 (2 vs 3: *P*<0.001)
Lowest SaO_2(%)	83±4	82±5	83±4

Boyce et al. A preliminary study of the optimal anesthesia positioning for the morbidly obese patient. Obes Surg 2003; 13: 4-9



The Nutrition Balance

- Caloric Restrictions
  - Catabolic-induced muscle loss impairs wound healing
  - Weakens diaphragmatic muscles – delays ventilator weaning
  - Moderate restriction may be okay
- Excessive Calories
  - **Increases production of CO_2 which will increase minute ventilation (tachypnea) -> failed SBT -> potential delays in weaning**

First, the Easy Evaluation

If the patient is not protecting their airway, we intubate.

Challenges with NPPV

- Too often we don't view it as a trial and leave patients on NPPV until they are in respiratory arrest/cardiac arrest?
  NPPV is not a "set it and forget it" therapy!
- Interface issues – fit, tolerance

Use of NPPV instead of intubation

- Why not? May play a role to support work of breathing during an acute process such as pneumonia, flu, etc.
- All NPPV should be seen as a TRIAL … if the patient doesn't look better (and the numbers should support this), the patient has failed the trial.
- Obese patients in Asthma exacerbation did well on NPPV, 80% not requiring intubation (Thapamagar, et. al. Am J Ther, 2018)

Use of NPPV to Preoxygenate before Intubating

- The data is a little mixed
- Some studies have shown that noninvasive ventilation for 3 minutes before intubated ensured better oxygenation compared to BVM.
- A study of 200 published in 2018 did not support this … *Baillard, et al, 2018*

What Evidence seems to support:

- If the patient is on NIV already, don't take them off to bag them
- If the patient is not on NIV, don't initiate NIV just to prepare to intubate
- Having NIV available with awake intubations might be advisable

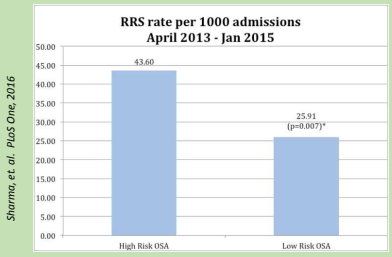
Respiratory Failure post-extubation

- Reintubation is associated with increased mortality
- ANY strategy aimed at minimizing the risk of reintubation should be considered. Ultimately it comes to down to At-Risk vs Not At-Risk.
- For Obesity, it is reasonable to extubate directly to noninvasive ventilation. Supported by ATS consensus statement.
- We double-down on this in patients with OHS!

Summarized from American Thoracic Society/European Respiratory Society Clinical Practice Guidelines

Assuming High BMI = OSA

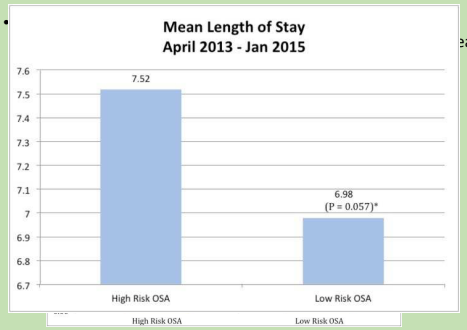
- One study (perhaps not peer-reviewed) showed that screening patients with a BMI > 30 with a sleep questionnaire and then treating with PAP if high-risk resulted in less rapid response calls …



Sharma, et. al PloS One, 2016

Assuming High BMI = OSA

- …eating



Tracheostomy Considerations

- Team consideration for long-term tracheostomy, particularly to support intermittent ventilatory support (OHS)
- Studies have shown that patients who are obese and need critical care are more likely than non-obese patients to need vent support at discharge (and are more often discharged to a facility than home, by the way)
- Use caution with trach changes – assess and plan!

Is a trach safe in super obese patients?

- A rare study looked at patients with a BMI > 50 needing a trach
- There was a higher rate of complications with the trach itself, but this is true of all procedures int his population.
- Overall the study found that trachs were needed (it was hard to wean/decannulate these patients) and were overall safe.

Marshall, et. al. JAMA Otolaryngol Head Neck Surg., 2016

When should we trach these patients?

- Not all that different than what most of us do clinically already:
- Within first 9 days may reduce ventilator days and decrease nosocomial pneumonias. Mortality was no different with early consideration. *Alhajhusain, et. al, Critical Care Research and Practice, 2014*
- Patients requiring more than 10 days on a vent may benefit from tracheostomy, including obese patients. Protocols involving early trach placement did not improve outcomes *Brice, et. al. Semin Respir Crit Care Med, 2015*
- Traching at 7-days (versus 14-days which is the national average) results in improved weaning, shorter LOS, less pneumonia, but the same survival rate. *Terragni, et. al, JAMA, 2010*

Other Tracheostomy Strategies

- Changing trachs of patients with high BMI can be a challenge … PLAN ahead, consider an OR change
- Specialized trachs or adapters may be needed if patients spend time not on a ventilator. If on a ventilator, ensure adequate alarms as you may not notice vent disconnects!

Early Mobility

- Laying in a hospital bed quickly results in muscle wasting, and it is much more difficult to get it back once it is gone
- Early mobilization is a key (yes, even if the patient is in the ICU, and on a vent, and on high FIO2, and on high PEEP)
- Use of adapted mobility equipment
- Study from 2012 (31 patients) showed that once patients are relatively stable, mobilization improves SpO2, has no negative effects on hemodynamics (Genc et al.)

FACT or FICTION?

Obese people should be mechanically ventilated like people with normal BMI

Ventilation Strategies

What we know:

- High pressures hurt the lungs
- Large volumes hurt the lungs
- Raw and Cl are altered in pts who are obese
- There is a greater incidence of later-onset ARDS in patients who are obese than there are in leaner patients (Gong, et al.; *Thorax.* 2010;65(1):44-50)

Ventilation Strategies

The Big Question:

Appropriate VT should be set by:

a.) Height
b.) Weight
c.) Waist circumference
d.) An incalculable number based upon a complex relationship of height and actual weight.

How do we offset, then, the opposing abdominal and external chest wall pressures caused by the adipose tissue?

Which Mode is Best for Obesity?

- Four different trials compared PC versus VC
- Outcome: No meaningful conclusions
- Interestingly VT was generally set at 10 cc/kg IBW

High PIPs: How to Strategize

Question: What causes the high Peak Inspiratory Pressures?

Answer: At least partially due to atelectasis, chest mass.

Strategy: PEEP or Recruitment Maneuver?

Brit Jnl of Anaesthesia 109 (4): 493-502 (2012)

PEEP versus RM

- PEEP of 5-10 cmH2O
  Versus
- PEEP with Recruitment Maneuver (varied)

- PEEP with RM consistently resulted in improved P/F ratio, improved compliance, no change in BP

Brit Jnl of Anaesthesia 109 (4): 493-502 (2012)

Ventilator Pressures

Lung Protective Strategy says:
Maintain Pplat < 30 cmH2O

Obese Patients:
There can be a battle between maintaining safe pressures and maintaining adequate ventilation (and oxygenation).

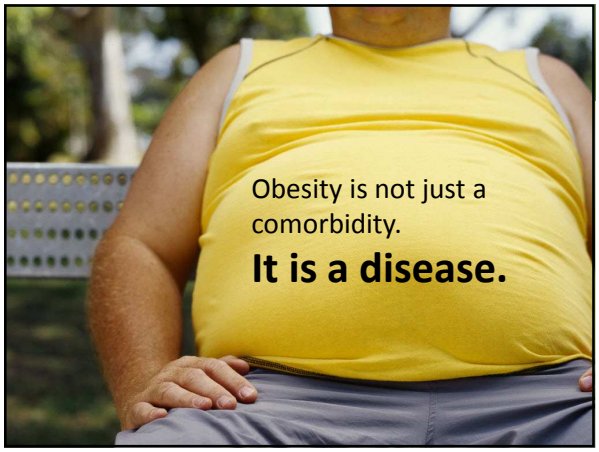
What about Transpulmonary Pressures?

Advanced Modes

- Most of the studies that have been done exclude patients above a set BMI
- Smaller study done showed that there outcomes for morbidly obese patients on APRV were similar to those of non-morbidly obese patients on APRV (2013, Testerman et al.)

Weaning Considerations

- Adequate Support
- Provide adequate hemodynamic support (think LV function)
- Consider tracheostomy with subsequent wean
- Consider specialized unit and systemized approach
- Future direction of weaning



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