Bridging the Gap

Opening remarks by B. Tucker Woodson, MD
Professor and Chief
Division of Sleep Medicine and Surgery
Department of Otolaryngology and Communication Sciences
Medical College of Wisconsin
Director, Froedtert Hospital Center for Sleep Medicine

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DEPARTMENT OF BIOMEDICAL ENGINEERING
MARQUETTE UNIVERSITY
MEDICAL COLLEGE OF WISCONSIN

Conversations with Scientists

MCW MEDICAL SCHOOL | ADVANCING A HEALTHIER WISCONSIN ENDOWMENT

Obstructive sleep apnea

Guilherme J.M. Garcia, PhD
Assistant Professor
Department of Biomedical Engineering

B. Tucker Woodson, MD
Professor
Department of Otolaryngology and Communication Sciences

Outline

Part 1 – What is obstructive sleep apnea?

- (1.1) Basics of sleep
- (1.2) Anatomy of the upper airway
- (1.3) Diagnosis
- (1.4) Treatment
- (1.5) Challenges

Part 2 – The physics of obstructive sleep apnea

- (2.1) Flow in collapsible tubes
- (2.2) Computational Fluid Dynamics
- (2.3) Our research

Part 3 – Bridging the gap between technology and patient care

- (3.1) The Future: Virtual surgery planning

Part 1

What is obstructive sleep apnea?

B. Tucker Woodson, MD

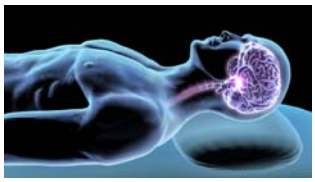
Video kindly provided by Dr. Jerome Dempsey (University of Wisconsin-Madison)

Why do we sleep?

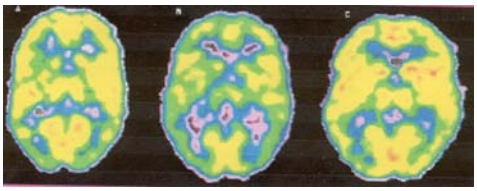
- Vital 1/3 of our existence
- Practically all animals sleep
- Complexly regulated
- If rodents kept awake for weeks they die…

Theories of sleep

- Energy metabolism - thermoregulation
- Memory
- Behavioral adaption to environment
- "If you don't sleep you get sleepy!"



Cerebral Blood Flow (CBF)



Awake	Non REM sleep	REM sleep
	Decreased CBF	Increased CBF

The problem of obstructive sleep apnea

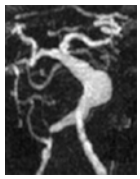
- Symptoms
  - Daytime sleepiness
  - Snoring
  - Gasping for air during sleep

The problem of obstructive sleep apnea

- High prevalence
  - 1 to 4% of children
  - 3 to 7% of adult men
  - 2 to 5% of adult women

The problem of obstructive sleep apnea

- Increased mortality
  - Hypertension
  - Cardiovascular disease
  - Cerebrovascular disease
  - Car accidents

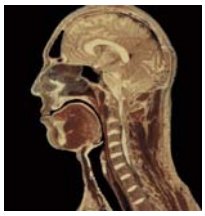


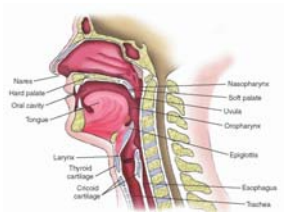
Diagnosis: Sleep study

- At home or in a sleep lab
- Disease severity is measured by the apnea-hypopnea index (AHI)

Normal:	AHI < 5
Mild OSA:	5 ≤ AHI < 15
Moderate OSA:	15 ≤ AHI < 30
Severe OSA:	AHI ≥ 30

Anatomy of human upper airway

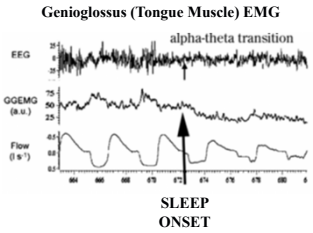




Muscle tone decreases during sleep

- Muscle tone decreases
- Airflow decreases

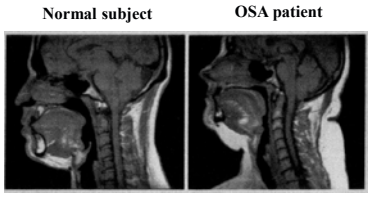
➡ Most people can maintain open airway despite lower muscle tone during sleep



Structural risk factors for OSA

- Soft tissue
- Skeletal

- Obesity
- Tongue size
- Tonsil size



Schwab et al. (1995)

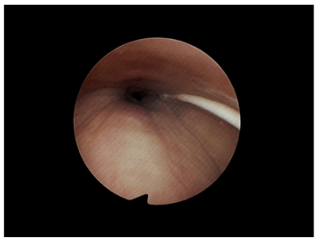
Structural risk factors for OSA

- The airway is longer in OSA patients
  - Adults vs. children
  - Men vs. women

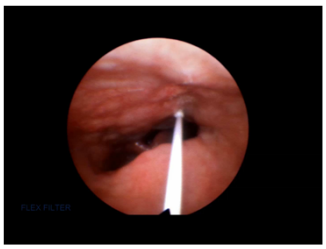
Distance from mandibular plane to hyoid bone < 20 mm

Continuous Positive Airway Pressure (CPAP)

Drug induced sedated endoscopy (DISE)



Effect of CPAP



Oral appliances

Surgery

Uvulopalatopharyngoplasty (UPPP or U3P)

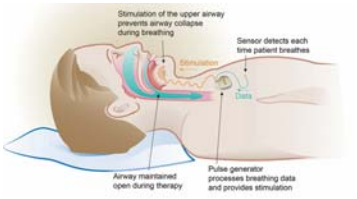
BEFORE

AFTER

Surgery

[redacted]

Upper Airway Stimulation



Challenges

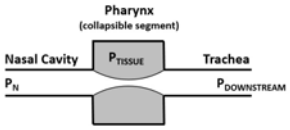
- OSA results from a combination of anatomy and physiology
  - Most medical interventions are directed at structure not physiology
- Need for more effective treatments
  - Many patients do not tolerate CPAP
  - Oral appliances often lead to teeth problems
  - Surgery improves symptoms, but often is not a cure
- Identifying optimal treatment for each patient

Part 2

The physics of obstructive sleep apnea

Guilherme Garcia, PhD

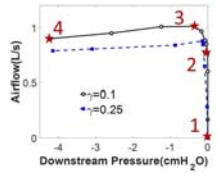
The Starling Resistor model

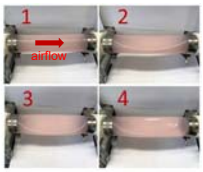


$$V_{f\,max} = \frac{1}{R}(P_N - P_{TISSUE})$$

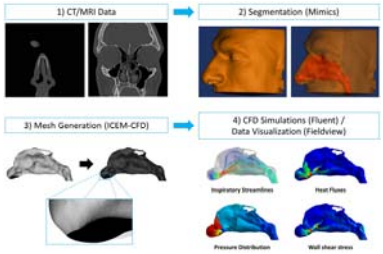
The Starling Resistor model

Airflow limitation in collapsible tubes

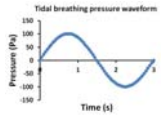




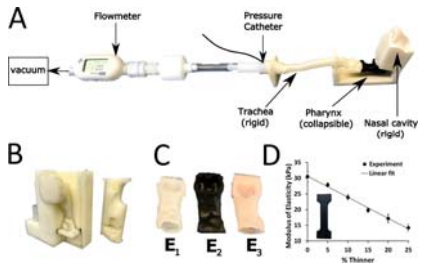
Computational Fluid Dynamics (CFD)



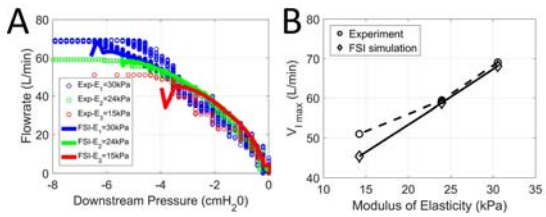
Fluid-Structure Interaction (FSI) simulations



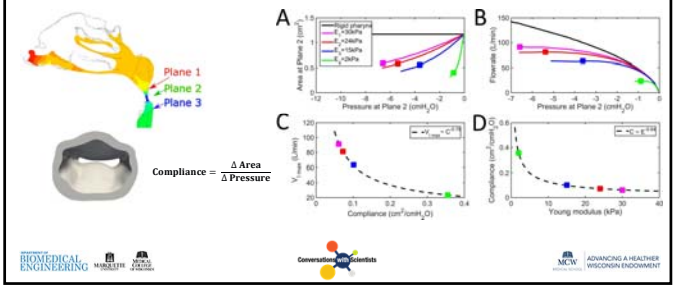
3D printed model of human upper airway



Validation of FSI simulations



Effect of modulus of elasticity



Next steps

- Develop mechanical models of pharyngeal structures
  - Tongue
  - Soft palate
  - Epiglottis
- Simulate surgery
- Correlate model predictions with clinical outcomes

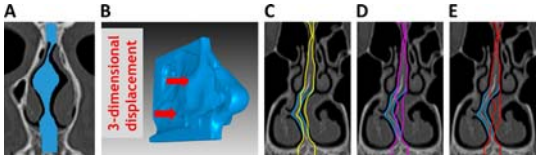
Part 3

Bridging the gap between technology and patient care

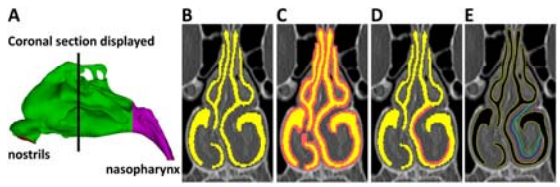
Guilherme Garcia, PhD

B. Tucker Woodson, MD

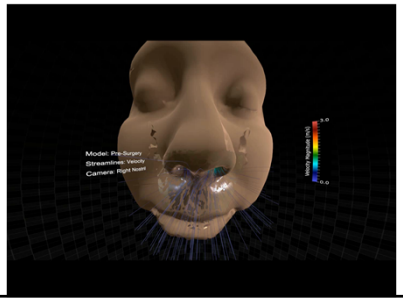
Virtual septoplasty



Virtual inferior turbinate reduction



Virtual surgery planning



Virtual surgery planning

- Future virtual surgery software may be able to
  - Identify which patients will benefit from surgery
  - Identify most effective surgical procedure for each patient
  - Quantify how much tissue should be removed during surgery

THANK YOU