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
April 23, 2019

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

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

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)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal:</td>
<td>AHI &lt; 5</td>
</tr>
<tr>
<td>Mild OSA:</td>
<td>5 ≤ AHI &lt; 15</td>
</tr>
<tr>
<td>Moderate OSA:</td>
<td>15 ≤ AHI &lt; 30</td>
</tr>
<tr>
<td>Severe OSA:</td>
<td>AHI ≥ 30</td>
</tr>
</tbody>
</table>
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

Normal subject  OSA patient

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

Upper Airway Stimulation

Challenges

- OSA results from a combination of anatomy and physiology
  - Most medical interventions are directed at structure and 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

\[ V_{\text{flow}} = \frac{1}{R} (P_{a} - P_{\text{obstruct}}) \]
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

- Coronal section displayed

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