

## Mini-Symposia Title:

New developments in Sleep Bioengineering: 2. Novel diagnostic markers for sleep apnea

### Mini-Symposia Organizer Name & Affiliation:

Michael C.K. Khoo, PhD, University of Southern California, Los Angeles, USA. and Thomas Penzel, PhD, Charite University

### Mini-Symposia Speaker Name & Affiliation 1:

Zahra Moussavi, PhD, Dept of Electrical and Computer Engineering, University of Manitoba, Winnipeg, Canada

### Mini-Symposia Speaker Name & Affiliation 2:

Azadeh Yadollahi, PhD, Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto, Canada.

### Mini-Symposia Speaker Name & Affiliation 3:

Philip de Chazal, PhD, Charles Perkins Centre and The School of Biomedical Engineering, University of Sydney, Sydney, Australia.

### Mini-Symposia Speaker Name & Affiliation 4:

Thomas Penzel, PhD, Interdisciplinary Center of Sleep Medicine, Charite University Hospital, Berlin, Germany.

### 5 Mini-Symposia Speaker Name & Affiliation 5:

### Mini-Symposia Speaker Name & Affiliation 6:

## Theme:

- 01. Biomedical Signal Processing
- 02. Biomedical Imaging and Image Processing
- 03. Micro/ Nano-bioengineering; Cellular/ Tissue Engineering &
- 04. Computational Systems & Synthetic Biology; Multiscale modeling
- 05. Cardiovascular and Respiratory Systems Engineering
- 06. Neural and Rehabilitation Engineering
- 07. Biomedical Sensors and Wearable Systems
- 08. Biorobotics and Biomechanics
- 09. Therapeutic & Diagnostic Systems and Technologies
- 10. Biomedical & Health Informatics
- 11. Biomedical Engineering Education and Society
- 12. Translational Engineering for Healthcare Innovation and Commercialization

### Mini-Symposia Synopsis— Max 2000 Characters

Insufficient sleep has been identified as an epidemic of global proportions, with chronic insomnia and sleep apnea being the most prevalent forms of sleep disorders. Due to the close association between sleep regulation and the key physiological organ systems, disruption of sleep continuity can adversely affect cardiorespiratory and metabolic function, leading to associated morbidities such as cardiovascular disease and diabetes. The pathological changes in the cardiorespiratory and metabolic systems can subsequently “feed back” to impact sleep quality. The dynamic interactions between these systems give rise to the spontaneous variabilities evident in measurements of respiration, heart rate, blood pressure and sleep-wake state. Clever analysis of these signals, using novel algorithms and new technologies, can yield insight into the underlying mechanisms for the pathologies that result from these sleep disorders, and also lead to improved diagnostic and therapeutic approaches. In this series of 3 mini-symposia, an interdisciplinary panel of experts in the field will present state-of-the-art advances in our understanding of these complex phenomena and the quantitative tools that have been developed to better characterize them. This series of minisymposia follows in the tradition of similarly themed minisymposia series on sleep that we have organized for EMBC over the past several years, which have attracted considerable interest among EMBC attendees. The second minisymposium session will focus on novel diagnostic markers for sleep apnea, using modalities that range from breathing sounds to peripheral arterial tone.

Synopsis of Talk #1:

**AwakeOSA: Predicting obstructive sleep apnea through breathing sounds analysis**

**Zahra Moussavi, PhD**

*Biomedical Engineering Program, Department of Electrical and Computer Engineering,  
University of Manitoba, Winnipeg, Manitoba, Canada..*

Obstructive sleep apnea (OSA) is an underdiagnosed common disorder. Undiagnosed OSA, in particular, increases the perioperative morbidity and mortality risks for OSA patients undergoing surgery requiring full anesthesia. OSA screening using the gold standard, Polysomnography (PSG), is expensive, in need of expert skills and time-consuming.

In this talk, I will present the research on developing objective and accurate alternative tools for screening OSA during daytime (wakefulness) by a few minutes of breathing sounds analysis. In particular, I will explain our new algorithm, AWakeOSA, that extracts an optimized set (3-4) of breathing sound features specific to each anthropometric feature (i.e. age, sex, etc.), and uses a two-level diagnostic classification to predict OSA severity for each subject.

## Synopsis of Talk #2:

# Investigating the Feasibility of Ultrasound Imaging in Assessment of the Upper Airway Dimensions

Azadeh Yadollahi, PhD

KITE, Toronto Rehabilitation Institute – University Health Network, Toronto, Canada  
Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto, Canada

**Abstract—** In this talk, we will demonstrate the feasibility of ultrasound imaging for assessment of the upper airway dimensions.

### I. INTRODUCTION

Sleep apnea is a chronic respiratory disorder which involves repetitive intermittent collapse of the upper airway during sleep. Assessment of the underlying upper airway dimensions is one of the necessary factors in understanding the pathophysiology of sleep apnea. However, available modalities (MRI, CT, and Nasal Endoscopy) for upper airway assessment are either invasive or costly. Hence, it is hard to assess the upper airway by aforementioned modalities not only during sleep but also during wakefulness. Therefore, there is an absence of an imaging technique that is easily accessible and safe. Previous studies have shown that ultrasonography can provide detailed anatomical information of upper airway during normal respiration (1). However, usage of ultrasonography to assess the upper airway dimension in sleep apnea patients has not been explored. The primary goal of this study is to investigate the feasibility of ultrasound imaging to determine the upper airway dimensions in patients with sleep apnea during normal respiration.

### II. METHODS

Participants underwent in an ultrasound examination of their upper airway at Toronto Rehabilitations Institute. All patients provided signed informed consents. The lateral and anterior posterior (AP) diameter of the upper airway were measured using Toshiba ultrasound machine Aplio i700 (Canon Medical, Tochigi, Japan) while the participants were breathing normally (Figure 1-a and 1-b). The upper airway cross sectional area during normal breathing was measured by acoustic pharyngometry. Sleep apnea of the patients was determined by using NoSAS score (2). NoSAS score stands for neck circumference, obesity, snoring, age and sex which shows 80% accuracy to determine the group with severe sleep apnea.

### III. RESULTS

Data from 27 subjects (17 healthy) showed the anterior posterior (AP) diameter of pharyngeal airway was significantly correlated with the average cross sectional area of the airway during normal respiration (Figure 1-c).

Furthermore, we found that the AP diameter was significantly lower in patients with sleep apnea than healthy subjects (Figure 1-d).

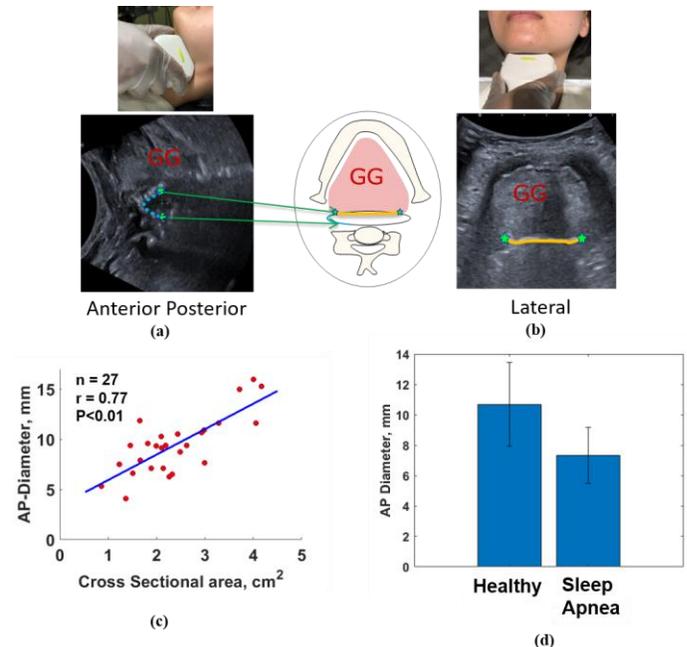


Figure 1. (a) The anterior posterior (AP) view (Blue line) and placement of the transducer. (b) The lateral view (Yellow line) (c) Correlation between cross sectional area of the upper airway and AP diameter. (d) AP diameter was smaller in patients with sleep apnea than healthy controls

### IV. DISCUSSION & CONCLUSION

Our study has shown that ultrasound imaging of the upper airway dimensions during normal breathing can provide vital information of the upper airway area. The AP diameter from the ultrasonography has the potential to be used as a tool to screen the sleep apnea.

### V. REFERENCES

1. Lun H-M, Zhu S-Y, Liu R-C, Gong J-G, Liu Y-L. Investigation of the upper airway anatomy with ultrasound. *Ultrasound quarterly*. 2016;32(1):86-92.
2. Marti-Soler H, Hirotsu C, Marques-Vidal P, Vollenweider P, Waeber G, Preisig M, et al. The NoSAS score for screening of sleep-disordered breathing: a derivation and validation study. *The Lancet Respiratory Medicine*. 2016;4(9):742-8.

Synopsis of Talk #3  
**Novel methods of predicting cardiovascular outcomes from overnight oximetry signals**

**Philip de Chazal, PhD**  
*Charles Perkins Centre and The School of Biomedical Engineering,  
University of Sydney, Sydney, Australia*

I. INTRODUCTION

The polysomnogram provides a detailed overnight sensor data of key physiological systems including the circulatory system, the respiratory system, limb movement and neural activity. Most of this information is discarded when a sleep study is summarized using the apnoea hypopnoea index, so novel methods that provide additional patient outcome insight from this sensor information are clearly beneficial.

Periods of hypoxia typically occur towards the end of an apnoea event and repetitive hypoxia events can negatively impact the heart function. In this study we implement novel hypoxia measures derived from the overnight oximetry signal and investigate their ability to predict future cardiovascular events.

I. METHODS

The Sleep Heart Health Study (SHHS) database contains polysomnogram (PSG) data and cardiovascular (CV) outcome data over a 10 year plus time period. Overnight oximetry data was extracted from the 5804 polysomnogram and standard oximetry hypoxia parameters including average oxygen saturation (meanO2), the oxygen desaturation index at 3% (ODI3) and 4% (ODI4) cutoffs, cumulative time below 90% saturation (CT90) and lowest SpO2 values (MinO2) were calculated. Novel measures of hypoxia including hypoxic burden and hypoxic load were also calculated. The death due to CV disease outcome data was used to produce Kaplan-Meier survival curves and Cox's proportion analysis was used to look at the ability of parameters to infer risk levels of CV death.

I. RESULTS AND DISCUSSION

Our preliminary analysis shows that the risk level of death due to CV disease is approximately 3 times higher for patients with high hypoxia parameters suggesting that hypoxia parameters are a very useful tool for stratifying CV death risk.

Synopsis of Talk #4:

**Recognition of central and obstructive apnea events by a new analysis of peripheral arterial tone**

**Thomas Penzel, PhD**

*Interdisciplinary Center of Sleep Medicine, Charite University Hospital, Berlin, Germany*

I. STUDY OBJECTIVES

To Assess the accuracy of WatchPAT (WP- Itamar-Medical, Caesarea, Israel), enhanced with a novel systolic upstroke analysis coupled with respiratory movement analysis derived from a dedicated snoring and body position (SBP) sensor, to enable automated algorithmic differentiation between Central and Obstructive Sleep Apnea based on simultaneous in-lab sleep studies with polysomnography (PSG).

II. METHODS

Eighty four patients with suspected sleep disordered breathing, (SDB), underwent simultaneous WP and PSG studies in 11 sleep centers. PSG scoring was blinded to the automatically analyzed WP data.

III. RESULTS

Overall WP Apnea Hypopnea Index (WP-AHI; mean  $\pm$  SD) was  $25.2 \pm 21.3$  (range 0.2-101), vs. PSG-AHI,  $24.4 \pm 21.2$  (range 0-110), ( $p=0.514$ ), and correlation was 0.87, ( $p<0.001$ ).

Using a threshold of  $AHI \geq 15$  the sensitivity and specificity of WP vs. PSG for diagnosing Sleep Apnea were 85.1% and 70.3% respectively and agreement was 78.6% (KAPPA=0.867).

WP Central Apnea Hypopnea Index (AHIc), was  $4.2 \pm 7.7$  (range 0-38), vs. PSG-AHIc;  $5.9 \pm 11.8$  (range 0-63), ( $p=0.034$ ), while correlation was 0.90 ( $p<0.001$ ).

Using a threshold of  $AHI \geq 15$  the sensitivity and specificity of WP vs. PSG for diagnosing CSA were 66.7% and 100% respectively with agreement of 95% (KAPPA=0.774), and ROC Area under the Curve of 0.866, ( $p<0.01$ ).

Using a threshold of  $AHI \geq 10$  showed comparable Overall Sleep Apnea and CSA diagnostic accuracies.

IV. CONCLUSIONS

These findings show that WP can accurately detect overall AHI and effectively differentiate between CSA and OSA.