Signs of Upper Airway Collapsibility in Snoring Sounds*

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***Abstract*— We have shown that snoring fundamental frequency (F_0) contours have an oscillating pattern in patients with obstructive sleep apnea (OSA) as compared to the relatively smoother pattern in simple snorers. This points to the underlying upper airway instability and collapsibility in OSA. The 2 patterns were classified by 75% accuracy.**

I. INTRODUCTION

Obstructive Sleep apnea (OSA) is a serious breathing disorder affecting approximately 7% of adults [1]. It is characterized by repetitive partial (hypopnea) or complete (apneas) collapse of the upper airway (UA). Patients suffer from daytime sleepiness and impaired cognitive performance and at higher risk for vehicle accident, heart failure, and stroke. In OSA, upper airway collapse is caused by the normal attenuation of UA dilator muscles' tone in sleep superimposed upon an anatomically narrowed UA in the pharygeal segment. Subsequently, the airflow and negative lung pressure during inspiration induces vibration of the lax UA tissues resulting in the snoring sounds [2]. Therefore, vibratory features of snoring are expected to be influenced by the biomechanical properties of the UA. The goal of this study is to examine the evolution of intra-snore fundamental frequency (F_0) in OSA and compare it with simple snoring, in which UA collapse is relatively milder.

II. METHODS

We recruited 12 patients referred for overnight polysomnography. Breath sounds were recorded simultaneously using a microphone embedded in an open face frame. Patients were divided into 2 groups: 5 subjects with OSA (G_{OSA}) and 7 simple snorers without OSA (G_{SN}). Subsequently, 3 to 5 segments (S), each 5-7 minutes long, from various parts of the night were isolated from each subject. Each S contained either predominantly hypopneas in G_{OSA} or normal breathing with snoring in G_{SN}.

Snores are identified given their fundamental frequency (F_0) in each segment (S) with the Robust Algorithm for Pitch Tracking (RAPT). Each snoring episode with sound periodicity yielded an F_0 contour sequence (P). In order to test the differentiability between the 2 groups, P sequences were isolated and differentiated in a conditional random field (CRF) classifier [3]. CRFs are sequence classifiers that estimate the distribution of a class label (i.e., normal or apneic) given the observation data. The parameters define weights applied to *feature functions* on observation data. In Hidden CRFs (HCRFs), these functions are also applied to hidden states that produce the observations.

We performed a 5-fold cross validation of the given data. In each fold, 80% of the P sequences are randomized for training and 20% randomized for validation.

III. RESULTS AND DISCUSSION

We isolated 18 S segments with hypopneas from G_{OSA} and 21 with simple snores from G_{SN}. F_0 contours in the G_{SN} were found to be relatively flat indicating that snoring episodes had relatively stable F_0 values throughout individual snores. On the other hand, most P vectors from G_{OSA} showed a fluctuating (i.e., 'wavy') course of F_0 values over the individual snores than non-obstructive snores. Using CRF, the 5-fold cross validation mean accuracy of classifying previously unseen snores reached 75%. This shows the differentiability of the 2 different patterns of intra-snore F_0 vectors, and that they follow distinct time courses in simple snorers vs. snorers in OSA.

It stands to reason that the speed of tissue collision (F_0) is influenced by the biomechanical properties of the UA tissue flaps. The UA of simple snorers, although partially narrowed, is still more stable in the face of the inspiratory negative pressure. In OSA, it can be postulated that with the ensuing inspiration, the progressively negative airway pressure acts on the pliable UA tissues causing narrowing of the UA and bringing the vibrating flaps closer together. In turn, this modulates F_0 to give rise to the wavy F_0 contours observed in OSA.

Our results are in line with with previous works showing intra-snore pitch instability in OSA [4], but extends that by deploying sequence classifiers that characterize the relationship among all F_0 values in the entirety of each sequence. Future work will explore additional data, independent measures for UA biomechanics, and alternative classification schemes.

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