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 (apnea) 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 pharyngeal 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 $G_{SN}$.

Snore sounds 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. snores in OSA.

It stands to reason that the speed of tissue collision ($f_0$) is influenced by the biomechanical properties of the UA flaps. The UA of simple snores, 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 airflow 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 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.

REFERENCES


