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Snoring Analysis for the Screening of Sleep Apnea Hypopnea Syndrome with a Single-Channel Device Developed using Polysomnographic and Snoring Databases

Raimon Jané, *Member IEEE,* José A. Fiz, *Member IEEE,* Jordi Solà-Soler, Joana Mesquita, *Student Member IEEE* and Josep Morera

Abstract— **Several studies have shown differences in acoustic snoring characteristics between patients with Sleep Apnea-Hypopnea Syndrome (SAHS) and simple snorers. Usually a few manually isolated snores are analyzed, with an emphasis on postapneic snores in SAHS patients. Automatic analysis of snores can provide objective information over a longer period of sleep. Although some snore detection methods have recently been proposed, they have not yet been applied to full-night analysis devices for screening purposes. We used a new automatic snoring detection and analysis system to monitor snoring during full-night studies to assess whether the acoustic characteristics of snores differ in relation to the Apnea-Hypopnea Index (AHI) and to classify snoring subjects according to their AHI. A complete procedure for device development was designed, using databases with polysomnography (PSG) and snoring signals. This included annotation of many types of episodes by an expert physician: snores, inspiration and exhalation breath sounds, speech and noise artifacts, The AHI of each subject was estimated with classical PSG analysis, as a gold standard. The system was able to correctly classify 77% of subjects in 4 severity levels, based on snoring analysis and sound-based apnea detection. The sensitivity and specificity of the system, to identify healthy subjects from pathologic patients (mild to severe SAHS), were 83% and 100%, respectively. Besides, the Apnea Index (AI) obtained with the system correlated with the obtained by PSG or Respiratory Polygraphy (RP) ($r=0.87$, $p<0.05$).**

I. Introduction

Several studies have shown differences in acoustic snoring characteristics between patients with Sleep Apnea-Hypopnea Syndrome (SAHS) and simple snorers [1]. Usually a few manually isolated snores are analyzed, with an emphasis on postapneic snores in SAHS patients. Automatic analysis of snores can provide objective information over a longer period of sleep. Although some snore detection systems have recently been proposed [2]-[5], they have not yet been applied to full-night analysis devices for screening purposes.

To further explore the relationship between snoring and SAHS severity, the present study employed a validated automatic snoring analyzer to characterize the snores of a group of patients with different levels of Apnea Hipopnea Index (AHI) [6], [7]. The system was developed to work with a single sensor placed at the neck, thereby avoiding the recording of surrounding noise typical of ambient microphone recordings. It allowed to automatically detect snores throughout the night, analyzing their time, frequency and intensity characteristics (Figure 1).

II. Materials and Methods

We used a new automatic snoring detection and analysis system to monitor snoring during full-night studies to assess whether the acoustic characteristics of snores differ in subjects with or without SAHS, and to classify subjects according to their AHI.

Snoring and apnea episodes were identified by a trained and validated automatic detector and analyzer, developed by our group for the prototype of a single-channel device (Snoryzer-Uno (S1), SIBEL SA, Barcelona, Spain) that was used to record respiratory sounds during sleep. This device detects and analyses automatically the snoring intensity and frequency parameters (DLL Snore Analyser v.9.52). It was designed not only for snoring analysis but also for SAHS screening.

The snore detector was previously validated by comparing the automatic detection with blind annotations of snore episodes by a medical doctor while listening to the respiratory sounds [6]. In a second study [7], a complete procedure for validation was proposed, including annotation of many types of episodes: snores, inspiration and exhalation breath sounds, speech and noise artifacts. The objective was to validate the detector in order to estimate its sensitivity, specificity and positive predictive value. This approach permits to analyze the signal in a snore-by-snore basis and

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R.Jané, J.Solà-Soler and J.Mesquita, are with Dept. ESAII, Universitat Politècnica de Catalunya (UPC), Institut de Bioenginyeria de Catalunya (IBEC) and CIBER de Bioengenieria, Biomateriales y Nanomedicina (CIBER-BBN) Baldiri Reixac, 4, Torre I, 9 floor, 08028, Barcelona, Spain (raimon.jane@upc.edu; jordi.sola@upc.edu; jmgil@ibec.pcb.ub.es)

J.Morera is with Hospital Universitari Germans Trias i Pujol, Badalona (HUGTP), Spain (josepmorera.germanstrias@gencat.net)

J.A.Fiz, is with IBEC, CIBER-BBN and HUGTP, Spain (jafiz@msn.com)

not only with average values. In this way, different time and frequency domain parameters can be studied by every snore episode.

III. RESULTS

The developed S1 system, for snore analysis and monitoring, has recently been applied to assess whether the acoustic characteristics of snores differ in patients with and without SAHS, and to classify subjects according to their AHI [8]. There were significant differences in supine position between Group 1 (AHI <5) and Group 3 (AHI≥15) in: sound intensity; number of snores; standard deviation of the spectrum; power ratio in bands 0–500, 100–500, and 0–800 Hz; and the symmetry coefficient ($p < .03$). Patients were classified with thresholds AHI = 5 and AHI = 15 with a sensitivity (specificity) of 87% (71%) and 80% (90%), respectively [8].

Another study was designed to assess the utility of S1 system for screening patients with SAHS, by using mainly snoring information [9]. A full PSG or RP were used as a gold standard methodology for diagnosis of SAHS patients. PSG, or RP, and S1 recording were performed on 35 subjects (11 no SAHS subjects, 7 mild, 5 moderate and 12 severe patients). Both systems (PSG/RP and S1) were used independently at the hospital and at home, respectively, and the estimation of AHI diagnosis was compared. The S1 system classified subjects on 4 SAHS severity levels (No SAHS, mild, moderate and severe).

The S1 was able to correctly classify 77% of subjects in the 4 severity levels. The sensitivity and specificity of S1, based on snoring analysis and apnea detection, to identify healthy subjects from pathologic patients (mild to severe SAHS) were 83% and 100%, respectively. Besides, the apnea index (AI) obtained with S1 correlated with the obtained by PSG or PR ($r=0.87$, $p<0.05$).

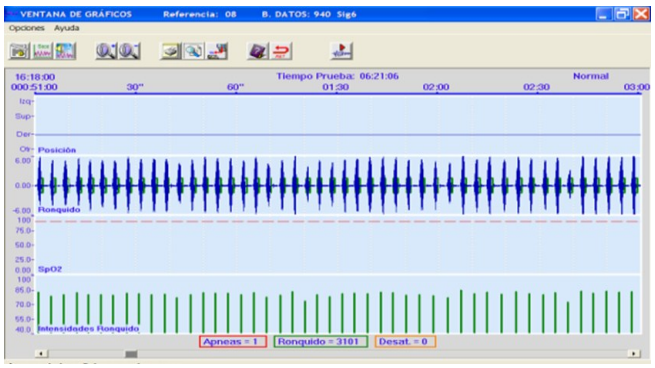
IV. DISCUSSION AND CONCLUSION

Our system for automatic snore detection and analysis seems to be a promising tool for screening of SAHS patients. Currently, it is being validated on a database with a greater number of subjects. It has allowed us to develop different studies to characterize the regularity of snores [10] and to improve the classification methodology of snoring subjects [11].

Automatic snoring analysis could also be helpful for the follow-up of snorers without SAHS before and after treatment therapies, and it can significantly improve the management of this pathology.

(a)

(b)



(c)

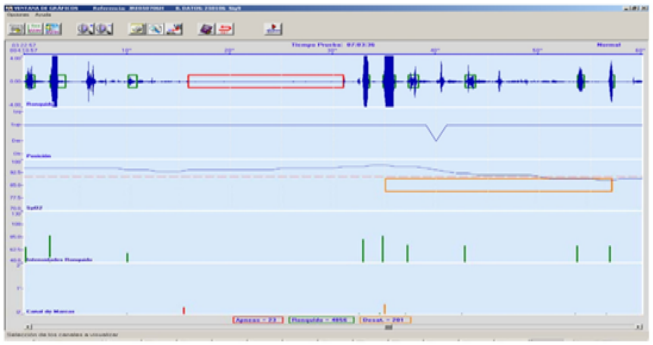


Fig. 1. (a) Snoring sound was acquired with a unidirectional electric condenser microphone encapsulated and placed over the trachea at the level of the cricoid cartilage using an elastic band.

(b) and (c) Snoring and apnea episodes were identified by a trained and validated automatic detector and analyzer, developed by our group for the prototype of a single-channel device (Snoryzer-Uno, SIBEL SA, Barcelona).

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REFERENCES

[1] D. Pevernagie, R.M. Aarts, and M. De Meyer, "The acoustics of snoring," *Sleep Medicine Reviews*, vol. 14, no. 2, pp. 131-144, Apr.2010.

[2] W.D. Duckitt, S.K. Tuomi, T.R. Niesler, "Automatic detection, segmentation and assessment of snoring from ambient acoustic data". *Physiol Meas*,vol.27, pp. 1047–1056, 2006.

[3] M. Cavusoglu, M. Kamasak, O. Erogul, T. Ciloglu, Y. Serinagaoglu, and T. Akcam, "An efficient method for snore/nonsnore classification of sleep sounds," *Physiol. Meas.*, vol. 28, no. 8, pp. 841–853, 2007.

[4] A.S. Karunajeewa, U.R. Abeyratne, C. Huking, "Silence-breathing-snore classification from snore-related sounds." *Physiol Meas*,vol. 29, pp.227–243, 2008.

[5] A. Azarbarzin, Z.M.K. Moussavi, "Automatic and unsupervised snore sound extraction from respiratory sound signals", *IEEE Trans on Biomed Eng*, vol. 58, no. 5, 2011.

[6] R. Jané, J. Solà-Soler, J.A. Fiz, J. Morera, "Automatic detection of snoring signals: validation with simple snorers and OSAS patients", *22nd Ann Intl Conf of the IEEE EMBS*, 2000, pp. 3129-3131, vol.4.

[7] R. Jané, J.A. Fiz, J. Solà-Soler, S. Blanch, P. Artís, and J. Morera, "Automatic snoring signal analysis in sleep studies," Proceedings of the 25th Annual International Conference of the IEEE, 2003, pp. 366-369.

[8] J.A. Fiz, R. Jané, J. Solà-Soler, J. Abad, M.A. García and J. Morera,.,"Continuous analysis and monitoring of snores and their relationship to the apnea-hypopnea index". *The Laryngoscope*, vol. 120, pp. 854–862, doi: 10.1002/lary.20815, 2010.

[9] R. Jané, J.A. Fiz, J. Rigau, J.F. Alonso, F. Sopena, J. Solà-Soler, I. Vilasseca, J. Abad, J.M. Montserrat, and J. Morera, "Sleep apnoea-hypopnea screening by snoring analysis using a single-channel device,", 36th Annual Congress of The European Respiratory Society (ERS), 2010.

[10] J. Mesquita, J.A. Fiz, J. Solà-Soler, J. Morera, and R. Jané, "Normal non-regular snores as a tool for screening SAHS severity". *Accepted* to the 33rd Annual International Conference of the IEEE-EMBS, 2011.

[11] J. Solà-Soler, J.A. Fiz, J. Morera and R. Jané, "Bayes Classification of snoring subjects with and without sleep apnea hypopnea syndrome using a kernel method". *Accepted* to the 33rd Annual International Conference of the IEEE-EMBS, 2011.