# **Acoustic Features of Cough in COVID-19**

Clare M. Davidson, *Member, IEEE*, Oswaldo A. Caguana, Luis Estrada-Petrocelli, *Senior Member, IEEE*, Mariela Arita-Guevara, Manuel Lozano-García, Ignasi Ferrer-Lluis, Yolanda Castillo-Escario, Pilar Ausín, Joaquim Gea and Raimon Jané, *Senior Member, IEEE* 

*Abstract*— Respiratory illness is experienced by many patients infected with SARS-CoV-2 (COVID-19), with a dry cough one of the most common symptoms. Analysis of cough sounds provides a way to diagnose, assess and monitor respiratory diseases. This study analyzes differences in cough signals recorded using a smartphone in 24 patients hospitalized with COVID-19 at different disease stages. Frequency variability and the percentage power in three bands (0-250 Hz, 1000-1250 Hz and 3750-4000 Hz) in the first cough sound were higher in patients at their most severe stage of the disease compared to patients prior to this point in the disease trajectory. Several frequency-based features of the second cough sound were higher in female patients compared to males. Results presented support the prognostic potential of cough sounds.

*Clinical Relevance*— Differences observed in features of cough signals recorded in patients with SARS-CoV-2 infection both prior to and at the most severe stage suggest a possible relationship between these features of cough and disease status.

## I. INTRODUCTION

Many patients with SARS-CoV-2 infection (COVID-19) will experience respiratory illness, with a dry cough one of the most common symptoms. Advancing age and male gender are both considered risk factors for more serious illness and worse outcomes. Cough sounds provide important information about respiratory function in both healthy and patient populations, and are often used in the detection, assessment, and monitoring of respiratory disease. In this study we explore acoustic characteristics of cough signals recorded using a smartphone [1] in hospitalized COVID-19 patients. The relationship between extracted features and the subsequent health status (worsening/improvement) of the patient, including differences between males and females is explored.

## II. METHODS

Voluntary cough sounds were recorded in 24 hospitalized COVID-19 patients. Cough recordings of patients in group A (N=12, 3 female, 53 (47-65) yrs.) occur at the most severe stage of the disease, and recordings of patients in group B (N=12, 3 female, 53 (46-63) yrs.) occur prior to the

\*Funded the Spanish Grant RTI2018-098472-B-I00 bv MCIU/AEI/FEDER, UE, Catalan Grant GRC 2017 SGR 01770 and a BEST postdoctoral fellowship from MSCA COFUND scheme (GA 712754) and the Severo Ochoa programme (SEV-2014-0425). C. M. Davidson, M. Lozano-García, L. Estrada-Petrocelli, I. Ferrer-Lluis, Y. Castillo-Escario and R. Jané are with the Institut de Bioenginyeria de Catalunya, the Barcelona Institute of Science and Technology, Universitat Politècnica de Catalunya, and CIBER-BBN (cdavidson@ibecbarcelona.eu). L. Estrada-Petrocelli is also from Universidad Latina de Panamá. O.A. Caguana, M. Arita-Guevara, P. Ausín and J. Gea are with the Dept. Respiratory Medicine, Hospital del Mar, IMIM., the DCEXS, UPF, and CIBERES, ISCIII, Barcelona, Spain.

deterioration of the disease. Approval from the ethics committee and informed oral consent from each patient were obtained. Cough sounds were recorded at 48 kHz using the built-in microphone of a smartphone. Individual cough signals were manually segmented into 3 parts; the first cough sound, the intermediate part and the second cough sound (if present) [2]. For each segment, and the signal as a whole, the percentage power in each 250 Hz band was calculated and several frequency-based features were examined.

### III. RESULTS

Three-way ANOVA (factors: disease status, gender, age group) revealed significant differences between the frequency variability in the first cough sound (F=5.27, p=0.034) for disease status, with the mean value of group A higher than B (670.77±193.72 Hz vs 512.24±140.82 Hz). The percentage power in each of three bands was significantly higher in group A compared to B also: 0-250 Hz (F=6.13, p=0.024), 1000-1250 Hz (F=5.93, p=0.026) and 3750-4000 Hz (F=6.97, p=0.016). Interaction effects of disease status, gender and age group were non-significant. The peak frequency of the intermediate part of the cough sound was significantly higher in female patients compared to male patients (F=7.38, p=0.014), as well as some features of the second cough sound: the median frequency (F=4.99, p=0.04) and the frequency at both the 25<sup>th</sup> percentile of signal energy (F=4.58, p=0.046) and the 75<sup>th</sup> percentile of signal energy (F=4.61, p=0.048).

## IV. DISCUSSION & CONCLUSION

The results outlined suggest that there are differences in the acoustic characteristics of the cough signal recorded in COVID-19 patients at different disease stages. However, differences between male and female patients analyzed here appear to be unrelated to disease status, with no significant interaction effects revealed. This work suggests that further exploration of the prognostic potential of the cough sound recorded in patients with COVID-19 holds promise. Future work, including a larger patient cohort, increased number of female patients, and time-frequency based analysis will address some limitations of this present study.

#### REFERENCES

- Y. Castillo-Escario, I. Ferrer-Lluis, J. M. Montserrat, and R. Jane, "Entropy analysis of acoustic signals recorded with a smartphone for detecting apneas and hypopneas: A comparison with a commercial system for home sleep apnea diagnosis," *IEEE Access*, vol. 7, pp. 128224–128241, 2019, doi: 10.1109/ACCESS.2019.2939749.
- [2] J. Korpáš, J. Sadloňová, and M. Vrabec, "Analysis of the cough sound: An overview," *Pulmonary Pharmacology*, vol. 9, no. 5–6, pp. 261–268, 1996, doi: 10.1006/pulp.1996.0034.