Acoustic Speech Feature Changes in Patients Hospitalized with Acute Heart Failure

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***Abstract*— This paper presents a quality-controlled acoustic analysis pipeline for repeated vowel recordings collected in a pilot study of patients hospitalized with acute heart failure. The pipeline supports signal normalization, automatic vowel segmentation, pitch estimation and stabilization, and the extraction of phonatory and temporal features. By incorporating alternative segmentation strategies and pitch-estimation algorithms, it enables a systematic assessment of how processing choices affect the resulting acoustic descriptors. In a pilot dataset of 12 patients, repeated productions of the vowels /a/, /i/, and /o/ were analyzed. Overall, 46 features were extracted for each vowel across 21 analysis configurations, defined by different segmentation and pitch-estimation methods. Exploratory findings included a consistent decrease in the pause-duration trend for vowel /a/, increases in cepstral peak prominence (CPP) measures for vowels /i/ and /o/, and changes in voicing-continuity and shimmer-related descriptors for vowel /o/. The most robust effects were observed for vowel /o/, where CPP maximum and CPP range increased across all tested configurations. These findings should be interpreted as exploratory and methodological rather than diagnostic. The proposed pipeline provides a reproducible and configurable framework for acoustic analysis in clinically relevant pilot datasets and may support future studies on voice-based monitoring of patients with acute heart failure.**

Keywords—acute heart failure, acoustic voice analysis, repeated vowel phonation, acoustic features, voice biomarkers, paired pre/post-treatment analysis, clinical signal processing

I. INTRODUCTION

Heart failure remains one of the major challenges in contemporary cardiology, associated with frequent hospitalizations, considerable mortality, and a high burden on healthcare systems [1]. Acute heart failure is a particularly important clinical condition because it involves a rapid deterioration of the patient's status, often associated with fluid overload, dyspnea, pulmonary congestion, peripheral edema, fatigue, and reduced exercise capacity. The clinical assessment of patients hospitalized due to heart failure is based on physical examination and medical history, laboratory parameters such as NT-proBNP, imaging studies including echocardiography, and the evaluation of symptoms such as dyspnea, edema, body-weight changes, fatigue, and reduced exercise tolerance [1]. These methods are essential in clinical practice; however, some of them require specialized equipment, blood sampling, direct assessment by medical personnel, or the patient's presence in a medical facility. This motivates the search for additional non-invasive, easily repeatable sources of information that could complement standard clinical assessment.

In recent years, there has been growing interest in digital biomarkers, including voice analysis, as a non-invasive, rapid, and potentially inexpensive source of health-related information. In patients with acute heart failure, fluid overload, pulmonary congestion, tissue edema, respiratory fatigue, and impaired respiratory–phonatory coordination may affect voice production. These effects may be reflected in acoustic parameters related to phonation stability, harmonic structure, perturbation, voicing continuity, and temporal organization of vowel production. However, before voice-derived features can be considered clinically useful, it is necessary to develop repeatable and configurable analysis pipelines and to evaluate whether such pipelines can detect measurable within-patient changes in clinically relevant pilot data.

The literature on voice biomarkers in heart failure has evolved from small exploratory, task-specific acoustic studies toward smartphone-enabled machine-learning approaches that characterize changes between acute decompensation and clinical stabilization and may support longitudinal monitoring [2], [3], [4], [5]. However, the field remains methodologically heterogeneous and requires validation on independent datasets [6], [7], [8]. Early studies reported changes in phonation stability, pitch-related measures, cepstral features, speech phrasing, and glottal-flow measures [2], [4], [9]. More recent work has extended these analyses to larger cohorts, multiple speech tasks, smartphone-based recording, and explainable classification models [3], [4], [5]. Reviews emphasize substantial variability in recording protocols, speech tasks, feature sets, clinical labels, devices, and validation procedures [6], [7]. Longitudinal within-patient designs are particularly relevant because they reduce inter-speaker variability and allow acoustic changes to be assessed in relation to clinical recovery [4], [5]. Harmonized protocols and robust external validation remain necessary before voice-derived features can be considered reliable clinical biomarkers [6], [7], [8].

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