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CME Article

The ASAP project: A first step to an auscultation's school creation

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A B S T R A C T

Objective: This paper describes an ambitious study of in the so-called ASAP project or "*Analyse de Sons Auscultatoires et Pathologiques*".

Results: ASAP is a 3-year-long French collaborative project. It is part of a collaborative telemedicine platform called MERCURE or " *Mobile Et Réseau pour la Clinique, l'Urgence ou la Résidence Externe*". MERCURE deals with projects for remote monitoring or in clinical context thanks to modern tools principally coming from the *News Technologies of Information and Communication*. ASAP aims at making evolve the auscultation technics: by the development objective tools for the analyse of auscultation sounds: electronic stethoscopes paired with computing device; by the creation of an auscultation sounds' database in order to compare and identify the acoustical and visual signatures of the pathologies; and by the capitalisation of these new auscultation techniques around the creation of a teaching unit: « *Ecole de l'Auscultation* ». This auscultation's school will be destined to the initial and continuous formation of the medical attendants.

Conclusion: Previous studies demonstrate the need of performing an exhaustive scientific approach. It is precisely the context of the ASAP project.

Educational aims

- Respiratory sounds include invaluable information concerning the physiologies and pathologies of lungs and airways obstruction.
- To date, respiratory sounds are not well-acoustically characterized (except crackles and wheeze).
- The spectral density and amplitude of sounds can indicate the state of the lungs parenchyma, the dimension of the airways and their pathological modification. Phonopneumogram and spectrogram may give additional objective information.
- The ASAP project develops new objective tools (electronic stethoscope paired with computing device) for the analyse of auscultation sounds.
- This project proposes a worldwide sound database with visual and acoustical signatures, that allow to consult and analyse sounds, realise standard exchange of data. These sounds will, all the more, be a support for learning auscultation.
- Another innovative aspect of the ASAP project is to make diagnosis aid.

1. Introduction

Distinction between normal respiratory sounds and abnormal ones (such as crackles, wheezes...) is important for an accurate medical diagnosis. Respiratory sounds include invaluable information concerning the physiologies and pathologies of lungs and airways obstruction. Thus, the spectral density and amplitude of sounds can indicate the state of the lungs parenchyma, the dimension of the airways and their pathological modification.[1]

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1.1. Limits of human audition

Studies were performed in order to test the human's ear capability to detect crackles in an auscultation signal.[2] The methods used consist in simulated crackles superimposed on real breath sound. The results indicate that the most important detection errors are due to the intensity of the respiratory signal, the type of crackles and the amplitude of crackles. It can be inferred from these studies that the validation of automatic crackles' detection algorithms should not take auscultation as unique reference.

On the contrary, the understanding of mechanisms linked to the creation of breath sounds is, for the moment, imperfect. The recording and analysis of respiratory sounds allow to improve this understanding[3] and an objective relationship between abnormal respiratory sounds with respiratory pathology. Besides, an objective analysis allows to develop classification systems[4] that make it possible to precisely qualify normal and adventitious respiratory sounds. Whilst conventional stethoscope auscultation is subjective and hardly sharable, these systems should provide an objective and early diagnostic help, with a better sensitivity and reproducibility of the results.

Moreover, applications, including diagnosis establishment, monitoring and data exchange through Internet are obviously complementary tools to objective and automatic auscultation sounds analysis. Sensor devices will allow long duration monitoring for patient at home or at hospital. It could also be a useful solution for less-developed countries and remote communities.[5] In addition, this type of system has the great advantage to keep the non-invasive and less expensive characteristics of auscultation.

Finally, studies of Sestini and colleagues[6] indicate that an association between acoustical signal and its image is beneficial to the learning and understanding for students in medical science.

1.2. Definition of common markers

Nowadays, there are several definitions for the typical markers of wheezes and crackles.[8] Thus, a universal semantic has to be created. Several works[9] have attempted to collect definitions of terms relating to respiratory sounds and have arrived at a collection of 162 terms commonly used in the "*Computer Respiratory Sound Analysis*" (CORSA). Nevertheless, it still doesn't allow physician to have a common definition of terms that are used. For example, a wheeze is still currently associated to a "whistling sound", and a crackle to "a sound of rice in a frying pan".

1.3. Definition of semiology

The article of Rossi and colleagues[10] gives recommendations concerning the experimental conditions required for recording respiratory sounds. It describes the optimal experimental conditions (principally concerning background noise, including sounds other than respiratory such as vocal sounds) and the specific procedures according to the type of sounds he wanted to record (breath, cough, snores), information for the recording (diagnosis, evaluation of a therapy, monitoring), the age of subject, and the recording method (free field, endobronchial microphone). Lastly, for short recordings, a sitting position is recommended, but a lay position is preferably for long recordings.

2. Analysis of pulmonary sounds: state of the art

2.1. Definition of terms

The Article of Sovijarvi and colleagues,[9] published in the *European Respiratory Journal*, provides accurate definitions of currently used terms in pulmonary auscultation domain and sound analysis; the more pertinent are recalled here:

2.1.1. Sounds

Adventitious sound: it relates to additional respiratory sounds superimposed on normal breath sounds. It can be continuous (like wheezes) or discontinuous (such as crackles). Some of them (like squawks) have both characteristics. The presence of such sounds usually indicates pulmonary disorders.

Normal breath sound: on the chest wall, respiratory sound is characterized by a low noise during inspiration, and hardly audible during expiration. On trachea, normal respiratory sound is characterized by a broader spectrum of noise, audible both during inspiratory and expiratory phases.

2.1.2. Known trackers

Crackles: these adventitious explosive and discontinuous sounds appear generally during inspiratory phase. They are characterised by their specific waveform, their duration, and their location in the respiratory cycle. A crackle can be characterized by its total duration, as fine (short duration) or coarse (long duration). Occurrences of crackles in lung sounds usually reflect a pathological process in pulmonary tissue or airways.

Rhonchus: rhonchus is a low-pitched wheeze containing rapidly damping periodic waveforms with a duration of $>$100 ms and frequency of $<$300 Hz. Rhonchus can be found, for example, in patients with secretions or narrowing in large airways and with abnormal airway collapsibility.

Wheeze: this adventitious and continuous sound presents a musical character. Acoustically, it is characterized by periodic waveforms with a dominant frequency usually over 100 Hz and with duration of $\geq$100 ms. Wheezes are usually associated with airways' obstruction due to various causes.

2.1.3. Visualisation methods

Phonopneumogram: it is a simultaneous and overlapped display of sound signal and airflow in time domain during breathing:

Spectrogram: it concerns representation in which time is represented in abscises frequency in ordinate, and the intensity of the signal by a palette of colors.

2.1.4. Analysis methods

Artificial neural network (ANN): it is a mathematical model based on biological neural networks that consists in an interconnected group of artificial neurons and processes information using a connectionist approach to computation. Generally, it is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.

Genetic algorithm: it is a search technique used to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. They are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.

Fuzzy logic: it is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought of as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem.

Wavelet: it is a kind of mathematical function used to divide a given function into different frequency components and study each component with a resolution that matches its scale. Wavelet transforms have advantages over traditional Fourier transforms for representing functions that have discontinuities and sharp peaks,