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Breathing Detection from Tracheal Sounds in Both Temporal and Frequency Domains in The Context of Phrenic Nerve Stimulation

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Central respiratory paralysis induces a dependence on artificial ventilation if patient’s phrenic nerves and diaphragm remain functional, diaphragm pacing (DP) through electrical stimulation can provide a more natural respiration instead of mechanical ventilation [1]. Different DP technic are illustrated in Fig.1. However, commercialized systems do not embed any respiratory monitoring function and cannot adapt to patients’ electro-ventilation needs. To increase the performance and safety of these systems, in this study, a real-time acoustic respiratory monitoring method based on a microphone is investigated. This method is tested on recordings from 18 healthy individuals.

Equipment:
- An omni-directional microphone was inserted into a 3D-printed support, which was positioned on the neck (at suprasternal notch). (Fig.2)
- Tracheal sounds were first filtered (100Hz - 1200Hz) and amplified (230 times), then sampled at 4600Hz.

Protocol:
Eighteen healthy subjects participated in this observational study. One recording of 30 seconds was performed on each subject. The procedure consisted in 3 succeeding phases : (1) 10s normal respiration ⇒ (2) 10s apnea (holding respiration) ⇒ (3) 10s normal respiration.

Detection algorithm:
Tracheal sounds recordings are processed in real-time with a delay of 0.22s, corresponding to a moving segment of 3×1024 samples. As shown in the detection flow diagram (Fig.3), the segment of recording is first high-pass filtered at 300 Hz to remove cardiac noises, then processed both in temporal and frequency domains. At the end, the detection results of these two domains are combined to get the final result.

Results and discussion

The algorithm is evaluated on its specificity, sensitivity and accuracy, which in this study reached 99.31%, 96.84% and 98.02%, respectively. This result is much higher than the lowest acceptable limit (missing maximum 10s respiration per minute), which corresponds to 82.86% and 90.48% of specificity and accuracy, respectively.

Combination of analysis in two domains can increase detection accuracy because some short noises may be detected as respiration in frequency domain, but could be eliminated in temporal domain like shown in Fig.4. On the contrary, long noises are detected in temporal domain, but eliminated in frequency domain (Fig.5).

Even in the presence of speech and strong background noise (playing video), the detection reached a sensitivity of 92.8% and a specificity of 99.7% (Fig.6).

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