An Impedance-based Algorithm to Detect Ventilations during Cardiopulmonary Resuscitation

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Introduction: High-quality cardiopulmonary resuscitation (CPR) is a core out-of-hospital cardiac arrest (OHCA) treatment. Capnography is advised to monitor ventilations during CPR, but requires advanced airway management and cannot measure air volumes. Ventilations can be measured using thoracic impedance (TI), but during CPR impedance is affected by chest compression artifacts. This study proposes an algorithm for impedance-based ventilation detection during concurrent compressions.

Materials and Methods: Electronic recordings of 152 OHCA patients treated by the Dallas - Fort Worth emergency services were analyzed. Signal segments were extracted with the following criteria: minimum duration of 60 s during manual chest compressions, and good quality capnography and compression-depth synchronous data. True ventilations were annotated using the capnography, and chest compression instants using compression depth.

Ventilations were detected in three stages. First, TI was filtered to obtain ventilation waveforms, including a least-mean-squares filter to remove compression artifacts. Then, a heuristic peak detector was developed to identify and delimit potential ventilations. Ventilation waveforms were characterized using duration, amplitude, coefficients of a least-squares Legendre polynomial fit, and patient-specific local TI excursion measures. Finally, these features were fed to a random forest (RF) classifier to discriminate true ventilations. Patients were randomly split into training (70%) and test (30%) sets, and 100 random splits were generated to statistically characterize the results.

Results: 423 segments were included, comprising 1210 min of TI recordings and 9665 ground truth ventilations. The heuristic peak detector overestimated ventilations with a median patient-wise sensitivity of 94.1% and a positive predictive value (PPV) of 56.0%. After the RF-classifier the median (interquartile range, IQR) sensitivity, PPV and F-score were 83.9 (70.2-91.2) %, 86.1 (75.0-93.3) % and 84.3 (72.1-91.4) %.

Conclusions: An algorithm to detect ventilations during manual CPR was demonstrated. This would allow feedback on ventilation rate and surrogate measures of insufflated air volume during CPR.