An Intelligent System for Endotracheal Tube Monitoring

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Endotracheal intubation is widely used in intensive care units for unconscious and semi-conscious patients who cannot breathe independently. Unplanned extubation and tube migration are alarming threats to the safety of ventilated patients, which occur when a patient or external force inadvertently removes or moves an endotracheal breathing tube from the airway. Annually, unplanned extubation adversely affects an average of 7.3% of intubated patients, resulting in doubled ICU stay lengths, over 33,000 unnecessary deaths, and an excess of $3.9 billion in avoidable health costs. Current ETT placement tracking is achieved through continuous capnography (CO_2 tracking) and pulse oximetry, both of which suffer from false alarms up to 70% of the time, causing alarm fatigue. Capnograms are also sensitive and need frequent replacements, so a simpler, redundant, and more efficient system is needed to replace it. Such system would have to automatically monitor tube position, track the patient's breathing, and identify tube movement or dislodgement. This research project utilizes simple sensors and a microcontroller and does not compromise the airflow through the endotracheal tube. Testing shows that tracking endotracheal tube humidity, temperature, and pressure, combined with breathing sounds, provides redundant detection of endotracheal tube positioning. Humidity tracking mirrors capnography signals while enabling faster and simpler detection. Spectral features that are extracted from the tube audio alone nearly perfectly classify the inhales and exhales using a Random Forest machine learning algorithm. When combined with temperature and pressure, these four detection modes provide increased accuracy and simplification of endotracheal tube positioning.

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