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Laser detection of oxygen in the lungs

In Europe and United State, around 6 ~ 15% of deliveries are preterm according to statistics. A relatively large part of these infants unfortunately suffer from a common lung disease called Respiratory Distress Syndrome (RDS), caused by insufficiency of the surfactant (alveoli coating protein that prevent the air sac from collapsing) in their immature lung. Although there could be harmful effects, currently X-ray is the most applied diagnostic technique in the clinic to detect the cracked pattern indicating the alveoli. An alternative way to investigate the severity of RDS might be to observe the unstable oxygen concentration in the lung, and thus a monitoring system to do real time surveillance could be a way to complement and decrease the use of X-ray diagnostic. GAs in Scattering Media Absorption Spectroscopy (GASMAS) is the introduced technique that uses diode laser in the near infrared range to probe the oxygen concentration. This technique presents an innovative, non-invasive and harmless detection principle which can dynamically monitor and assist ventilation treatment to the lung.

This technique is based on the Beer Lambert law to detect the oxygen absorption signal, the strength of which is depending on the concentration. Nevertheless, such a detection is quite challenging because the oxygen concentration can be extracted only when the light propagation path in the lung is known. But, unlike straight propagation of light in the air, this is not the case when light is propagating in tissue, where the light is heavily scattered and the scattering events are random. Thus it is difficult to calculate how long distance the light has gone in the lung. One solution is to utilise another laser to sense water vapour by using the advantage that the water vapour concentration can be theoretically calculated given the temperature and relative humidity in the lung. So inversely the corresponding propagation path length for the water vapour laser can be calculated using the Beer Lambert law, and it is considered to be equivalent to that probed by the oxygen laser assuming that the light from these two lasers have the same propagation behaviour. However, this is just an approximate assumption. The light propagation is wavelength dependent because tissues response differently when interacting with light of different wavelengths, including absorption and scattering. Ideally, these two lasers used in GASMAS should be as close as possible in wavelength, meanwhile lying at the peaks of the oxygen and water vapour absorption profiles respectively.

Before any practical clinical trial, sufficient measurements in lab, including signal noise suppression, improvement of the detection geometry and data analysis and so on are strongly required to ensure the diagnosis flexibility and reliability. An experimental sample of a robust physical 1:1 infant model would be desired to test the GASMAS system. In our project we have made it possible by using the 3D printer to print the model. Not only the body structure is similar to an infant, with skin, fat, muscle, lung, heart and bone, but also these printed model are assigned with correct optical properties that could simulate the tissue response to light.

During the thesis work, details about the construction of the infant model, both in computer simulation and physical building, are discussed and GASMAS measurements are implemented to investigate the accuracy of oxygen concentration detection.

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