Near Infrared Light Propagation Modeling of Infant Lung with Light Source Placed Inside Intubated Airway

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Abstract: We simulate light propagation in 3D numerical model of infant thorax at 761 nm with light source placed inside the trachea and detectors over the skin between axilla and sternum.
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1. Introduction

The clinical techniques such as X-ray and ultrasound imaging provide information about pulmonary function and gas filling in the lungs of infants but not about the alveolar composition. Gas in scattering media absorption spectroscopy (GASMAS) is a non-invasive method used to measure absolute lung oxygen volume and concentration. The feasibility of GASMAS has already been demonstrated by assessing lung gas content in infants [1, 2] The Biophotonics group at Tyndall is working on the clinical translation of GASMAS to improve the diagnosis accuracy and treatment monitoring of lung disease in new born.

Respiratory distress syndrome (RDS) is a common lung disease present in preterm infants [3]. A typical treatment of RDS involves surfactant administration via intubation [4]. The aim of this work is to study the improvement in lung function assessment that could arise of localizing a light source inside the trachea of an intubated infant and compare this results with previous modeling of light propagation with GASMAS technique where light source and detectors are placed over the skin [5].

2. Method

NIRFAST software [6] is used to construct a 3D numerical model of an infant's thorax and simulate light propagation with 761 nm wavelength in an specific set up where the light source is placed inside the infant's airway and detectors are allocated over the skin between the axilla and sternum (see Fig. 1).

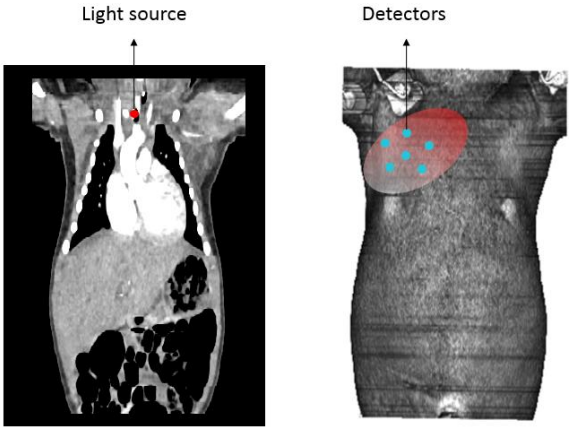

Fig. 1. Coronal slice and volume render from a full CT scan of thorax and abdomen area of a 3.7 kg infant with light source and detectors distribution illustrated.

After segmentation of each organ a set of meshes is created using Finite Element Method (FEM) to assign homogenous tissue optical properties of skin, bone, muscle, heart, arteries/veins and lung relevant for 761 nm wavelength. Once every organ has its respective absorption and scattering coefficients (μ_a and μ_s') the numerical model of the thorax is

used to measure the intensity reached by the detectors allocated over the skin in an array where different lung sections are sampled.

3. Simulation and preliminary results

The full thorax and abdomen CT of a 3.7 kg infant consist of 174 individual slices with a separation of 0.75 mm and a dimension of 512 x 512 pixels. The segmentation process used intensity thresholding in gray scale for each organ in the CT. A unique intensity for each volume is assigned. The segmented lungs can be seen in Fig. 2.c.

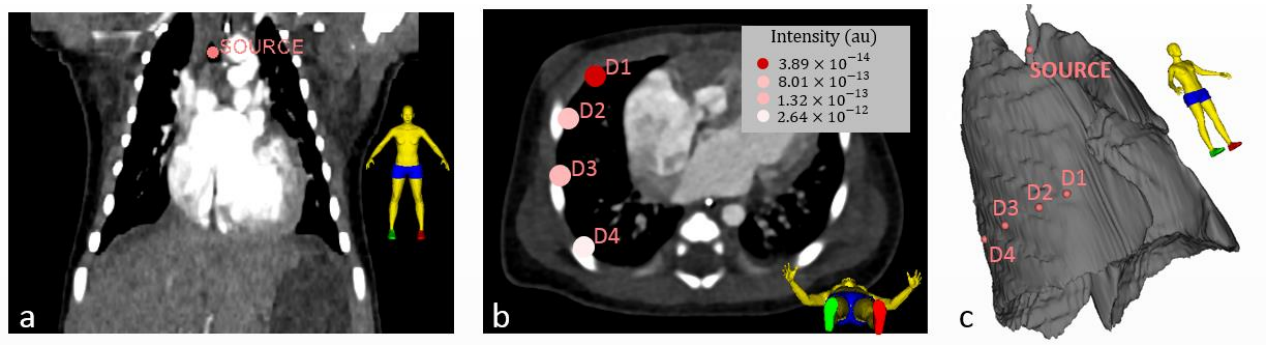

Fig. 2. Coronal and sagittal slices (a, b) and 3D lung model (c) from a CT scan of a 3.7 kg infant with light source placed inside the trachea and detectors (D2, D2, D3 and D4) over the external surface of the lung in the same sagittal plane.

The 3D numerical model of lungs was created with optical properties μ_a= 0.2 cm^{-1} and μ_s'=10 cm^{-1}, a 761 nm light source was placed into the trachea (see Fig. 2) and a set of 4 detectors were placed in the external border of the right lung of a chosen sagittal plane.

In this case, scattering interactions are stronger than absorption and light propagation is executed with the forward model in NIRFAST. The strongest signal is detected in D4 (Fig. 2.b) which is closest to the light source. The detected intensity attenuates as long as light travels longer distances within the lung.

Currently we are working in arteries/veins, skin, bone, muscle and heart numerical models to have a realistic thorax geometry where light at 761 nm is scattered and absorbed by different kinds of tissue and to identify if there is an improvement in signal placing the light source inside the trachea compared to a set up where both light source and detectors are placed over the skin.

We will explore the optimal detector placement positions for accurate oxygen measurements for the clinical translation of GASMAS technique and model the novel idea of placing a light source inside the endotracheal tube to assess RDS treatment when the infant is intubated.

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4. References

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