Feasibility of Optical Coherence Tomography in the Paediatric Airway – a Proof of Concept Study

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Introduction:

Currently the sole way to obtain cross-sectional diagnostic images of the airway is by a CT scan. However, due to the high dosage of radiation, it is a problematic procedure in paediatric patients. Furthermore, there are no quantifiable imaging-modalities which can be used during endoscopy. Optical coherence tomography (OCT) and optical frequency domain imaging (OFDI) are based on light reflections and is high speed cross-sectional diagnostic imaging modalities with near histology resolution. The aim of the present study is to investigate the feasibility of OCT/OFDI as a diagnostic tool in the paediatric airway regarding the accessibility, feasibility, accuracy of quantifiable measurements and ability to define anatomical and histological structures.

Methods:

OCT/OFDI of the airway was performed on four paediatric subjects in relation to diagnostic dynamic bronchoscopies (DDB) due to respiratory diseases/symptoms to assess feasibility and accessibility. The obtained data was subsequently qualitatively analysed for anatomical abnormalities and divergences in the tracheal and bronchial histology using the analysis tool QCU-CMS. Both normal and pathologic anatomy was detected.

Furthermore, validation of quantifiable measurements was performed in a porcine model where four pigs were OCT- and CT-scanned. Templates of the porcine airways were 3D-printed based on the initial CT-scans, and thereafter OCT-scanned both in air and a contrast medium containing iodine. Paired analysis of the in-vivo OCT and CT scans are compared to in-vitro scans with and without contrast to assess precision and correction factor.

Results:

OCT scans were done on all four patients without any procedural complications. OCT/OFDI imaging is useful in determining branching, stenoses, collapsing, inflammation and the luminal diameter of the paediatric airway.

When comparing the individual OCT-scans to the clinical descriptions based on the diagnostic bronchoscopies, the results are a match.

In the first three cases, the DDBs showed tracheomalacia and bronchomalacia in different grades and severities throughout the respiratory system.

In the OCT scans this is presented as constrictions or stenosis of the respiratory lumen, expressed as a reduction in the luminal diameter. This is detectable in the longitudinal shot as well as the cross-sectional pictures as presented in the attached figure 1.

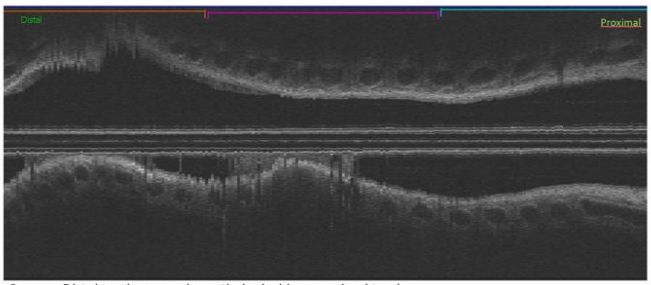
The fourth case is a girl diagnosed with both severe abnormal lung structure in combination with cystic fibrosis. The DDB shows broncho-, trachea- and additionally laryngomalacia and other structural abnormalities. However, the OCT scans in this case are more difficult to analyse due to excessive amounts of mucus throughout the entire airway – in some areas even resulting in a complete obstruction, as seen in figure 2.

More precise and individual case descriptions will be presented at the DSPAP meeting.

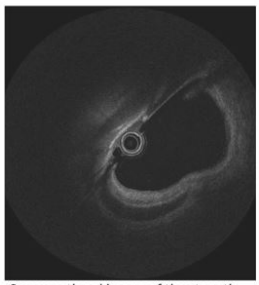
All experiments in the porcine study are performed and quantitative analysis of the data is ongoing. A precise comparison of OCT and CT scans and the correction factor between OCT performed in air and contrast fluid are being presented at the DSPAP meeting. Pre-liminary results show a correction factor in the range of 1.35 to 1.39 for stiff plastic phantoms ranging 4mm to 10mm in diameter.

Discussion:

OCT/OFDI as a diagnostic tool in the paediatric airway shows promising feasibility, however imaging-artifacts occur often in the images when using a short pullback time, which together with the time-consuming analysis needs optimization. Larger airways > 12 mm in diameter are difficult to image due to limited field of view, which is also an issue. Images with similar qualities to histological images of the airway might be used to evaluate pathoanatomy. Precision and accuracy of the measurements is to be further discussed when data is fully analysed.

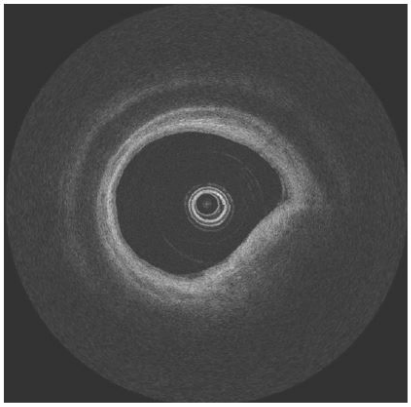


Orange: Distal trachea, purple: pathologic, blue: proximal trachea



Cross-sectional image of the stenotic area of the trachea

Bronchoscopy

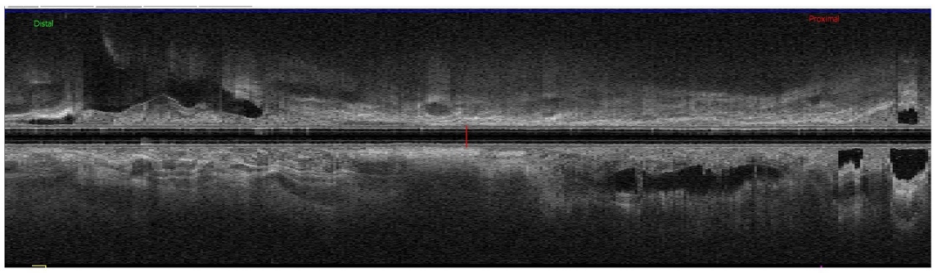


Cross-sectional image of the normal, healthy trachea proximally from the stenosis.

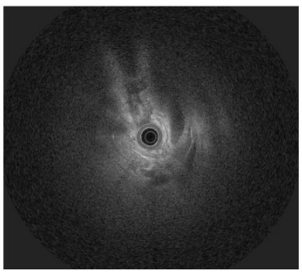
The lumen is dilated and the different layers in the tracheal wall is clearly visible.

The cartilage ring is seen as a hypodense horseshoe-shaped area surrounding the tracheal lumen

Figure 1: *OCT- and brochoschopy pictures from case 1*



Longitudinal shot showing severe contriction and obstruction



Cross-sectional image of the stenotic and obstructed area of the distal airway

Figure 2: *OCT-picture showing complete obstruction of the airway due to severe amount of mucus and bronchomalacia in case 4, a patient diagnosed with cystic fibrosis*