Using Artificial Intelligence to Assist with Intubation of Pediatric Patients – Development and Evaluation of Smartscope, a Novel Machine Learning Algorithm

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Background/Introduction: Successful first-pass endotracheal intubation rates vary dramatically depending on the patient, personnel involved and the environment in which the procedure occurs [1]. Current methods for endotracheal intubation rely on skilled operators to plan appropriately, identify relevant airway anatomy and perform the procedure. If unrecognized, unsuccessful intubation can lead to significant patient harm [2].

Advances in machine learning programming have led to a variety of applications in medicine. We developed a novel machine-learning based algorithm that can be used to automatically identify vocal cords and airway anatomy to assist with confirmation of intubation using video-laryngoscopy and bronchoscopy.

Methods: Following institutional ethics approval, we accessed bronchoscope videos of patients (ages 0 days to 12 years old); extracting and labelling 204 images. These were augmented to 1632 images with an 80:20 split for training and validation. Using ground truth, two connected convolutional networks (modules) were developed to allow:

1- Automatic real-time identification and labeling of vocal cords, tracheal and trachea-bronchial anatomy using semantic segmentation and image classification
2- Automatic localization of a bronchoscope within the upper airway, trachea and detection of successful endotracheal intubation

Accuracy of the convolutional networks was assessed using Cross Entropy loss. The probability for certainty that a given pixel corresponds to a particular class was determined as 0 = no confidence and 1 = 100% confidence. We also determined to run feasibility tests where the ML algorithm could run on a laptop real-time using a C-MAC, Glidescope and fibreoptic intubation equipment. Feasibility testing was performed on a high-fidelity pediatric intubation manikin.

Results: The semantic segmentation module achieved state-of-the-art segmentation of vocal cords, tracheal rings, bifurcation and “other tissue” classes with mean pixel-wise accuracy of 96.6% and inference time of 6.4ms. Using the semantic segmentation module output, a new algorithm was developed to track key features of the airway. The localization module is able to track the camera position to the nearest tracheal ring, acting as a “tracheal GPS” with a mean iteration time of 5.5 frames per second. The ML algorithms were able to run real-time on a laptop connected to the C-MAC.

Conclusion: We have developed two machine learning algorithms that function as one application, SmartScope and can be used to assist with intubation via video-laryngosopy or bronchoscopy through real-time identification of vocal cords and intubation success. Furthermore, the SmartScope is able to identify tracheal anatomy. Future applications to explore include its utility in assisting intubating among novices and also in difficult intubation scenarios.

References:

[1] Hubble MW, Brown L, Wilfong DA, Hertelendy A, Benner RW, Richards ME. A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rates. Prehosp Emerg Care. 2010;14:337–362.

[2] T. M. Cook, S. R. MacDougall-Davis. Complications and failure of airway management, *BJA: British Journal of Anaesthesia*, Volume 109, Issue suppl_1, December 2012, Pages i68–i85, https://doi.org/10.1093/bja/aes393

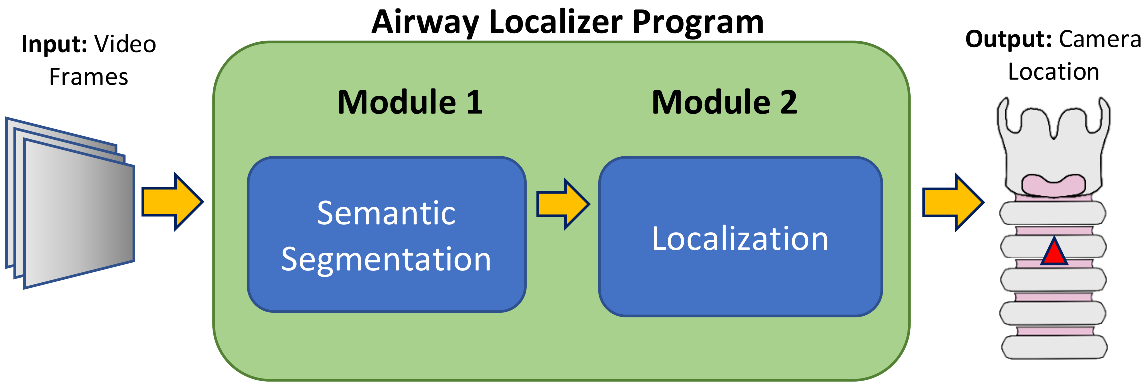

Figure 1 - Flowchart of the program highlighting the interactions between individual modules