Complexities hidden in plain sight: quantifying the impact of tracheal tube pitch, roll and yaw on ability to intubate

Judith Weng Zhu, Robert L. Read, PhD, Senior Member, IEEE, and Erich B. Schulz, MBBS, MBA, FANZCA

***Abstract*— Here we present an experimental sand-box for exploring the three dimensional complexities of tracheal intubations (TI). These complexities have implications for the design of future TI simulations and training mannequins.**

***Clinical relevance*— TI is a time-sensitive, life saving skill, with scarce opportunities for clinical trainees to practice on live patients. Improved simulation based training will enhance the training of first-responders both in hospital and out of hospital.**

I. Introduction

Recent years have seen engineers develop ever more sophisticated real-time simulation techniques to model the life-saving act of tracheal intubation (TI). These advances use accurate three dimensional scans, virtual reality, soft-body and rigid body physics coupled with haptic simulators[1], [2].

Ultimately, the goal of TI is to pass a curved plastic tube through the mouth, down over a curved laryngoscope blade and locate the tube tip such that it arcs anteriorly to pass between the vocal cords. It is well documented that even when clinicians are able to visualize the vocal cords they may fail to achieve this goal. Static geometric analysis reveals that there appear to be little described[3] complexities in the positioning of the tube that may explain these difficulties.

II. Methods

To enable full exploration of this geometry, we developed a simple Typescript program using the Babylon JS library (https://www.babylonjs.com/), augmented to perform accurate mesh-based collision detection rather than the fast but inaccurate collision methods included in the engine. Key anatomical landmarks are parameterized. Using a simple algorithm to constrain the tube within the space bounded by the upper teeth and a simulated endotracheal blade, we can then measure anterior tube tip movement with different combinations of tube roll, yaw and pitch. This code is freely available on-line for others to validate and extend: (https://bitbucket.org/erichbschulz/babairway).

III. Results

Quantitative analysis confirmed that postero-lateral tube movement at the mouth was associated with tube tip location movements in excess of 14mm. At a constant point of contact with the upper teeth, rolling the tube hinders posterior motion of the tube tip.

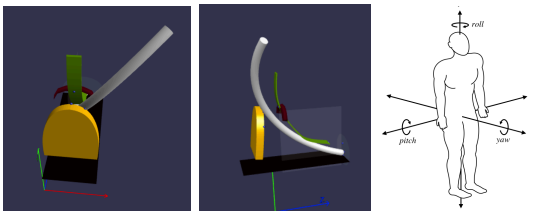

Figure 1. Tracheal tube constrained by the maxillary teeth and a laryngoscope blade illustrating the undesirable posterior deflection of the tube tip towards the esophagus with 40° of roll.

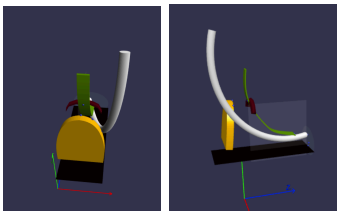

Figure 2: Tube location 15° yaw illustrating redirection of the tube tip anteriorly towards the tracheal as the tube is reoriented.

IV. Conclusion

Although these effects of pitch, roll and yaw are poorly understood by clinicians the geometry speaks for itself. This may be a case where engineers may educate clinicians and provide them with the language and the simulations they require. Those developing simulations should ensure that, at a minimum, their models enable faithful representation of all three axes of tube rotation.

[1] X. Xiao, S. Zhao, Y. Meng, L. Soghier, X. Zhang, and J. Hahn, "A Physics-based Virtual Reality Simulation Framework for Neonatal Endotracheal Intubation," *Proc IEEE Conf Virtual Real 3D User Interfaces*, vol. 2020, pp. 557–565, Mar. 2020, doi: 10.1109/vr46266.2020.1581028031480.

[2] A. Ryason *et al.*, "Validation of a Virtual Simulator With Haptic Feedback for Endotracheal Intubation Training," *Simul. Healthc.*, Jan. 2023, doi: 10.1097/SIH.0000000000000708.

[3] E. Schulz, "Two pathways to intubation," *Twitter*, Mar. 16, 2021. https://twitter.com/ErichSchulz/status/1371758052559482880 (accessed Jul. 23, 2023).