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Characterization of Pressure-Volume Dynamics in Cuffed Endotracheal Tubes for Effective Airway Pressure Management: A Benchtop Study

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INTRODUCTION & AIM

Cuffed endotracheal tubes (ETT) play a vital role in enabling mechanical ventilation for patients undergoing surgery or experiencing respiratory distress [1]. However, improper cuff inflation can lead to serious complications such as tracheal mucosal injury and pneumonia, as shown in Fig. 1. This study aims to characterize the pressure-volume characteristics of ETT cuffs to provide data for various cuff behaviours in different test environments and ultimately use that data to find solutions to mitigate these complications.

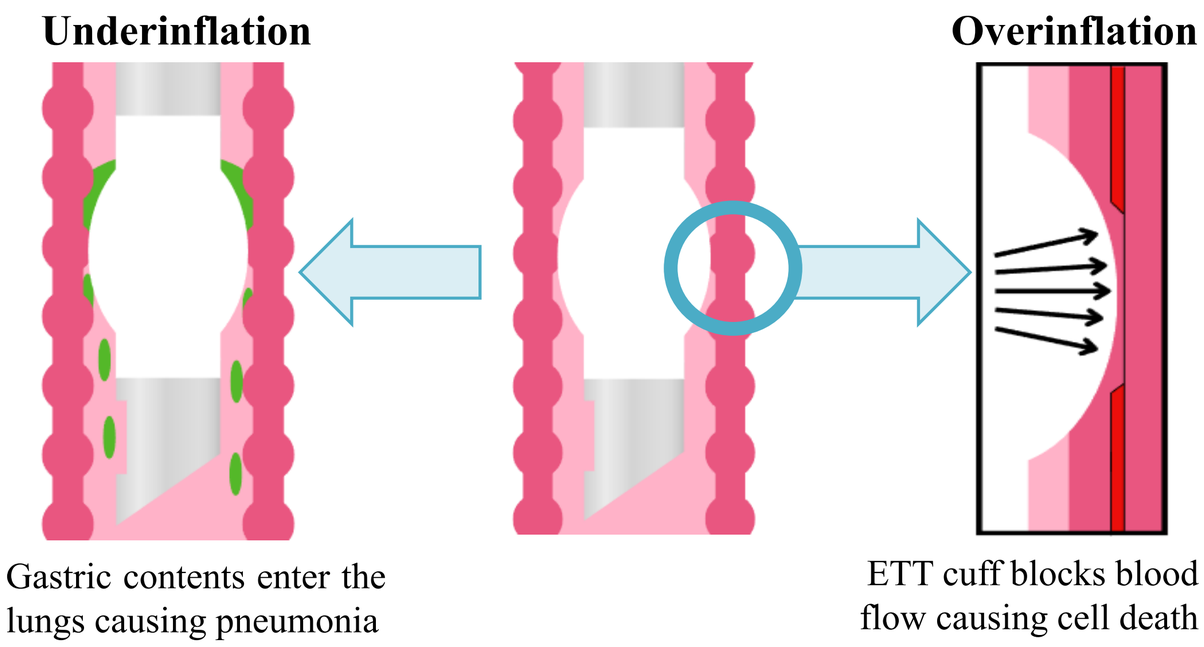


Figure 1: Complications Caused by Improper Cuff Inflation.

METHOD

Two sets of bench tests were performed: a free inflation test and restricted inflation tests using 3D-printed tracheal analogues (*20 mm* and *17.5 mm* diameters) and an elastic trachea model. The free inflation setup included: (**1**) a Posey Cufflator, (**2**) a Patient monitor connected to (**3**) a pressure transducer for cuff pressure measurement, and (**4**) a syringe for input volume measurement. The restricted tests incorporated all components from the free setup, along with (**5**) an additional pressure transducer attached to patient monitor to measure cuff contact pressure on the inner walls of (**6**) tracheal analogue.

Pressure-volume characteristics of the cuffs in free and restricted states were recorded to calculate cuff compliance, which is used to determine the safety of the cuff. Compliance values within the ideal pressure range of 20-30 cmH_2O were then compared between the free and the restricted tests to assess how the cuffs behave in different scenarios.

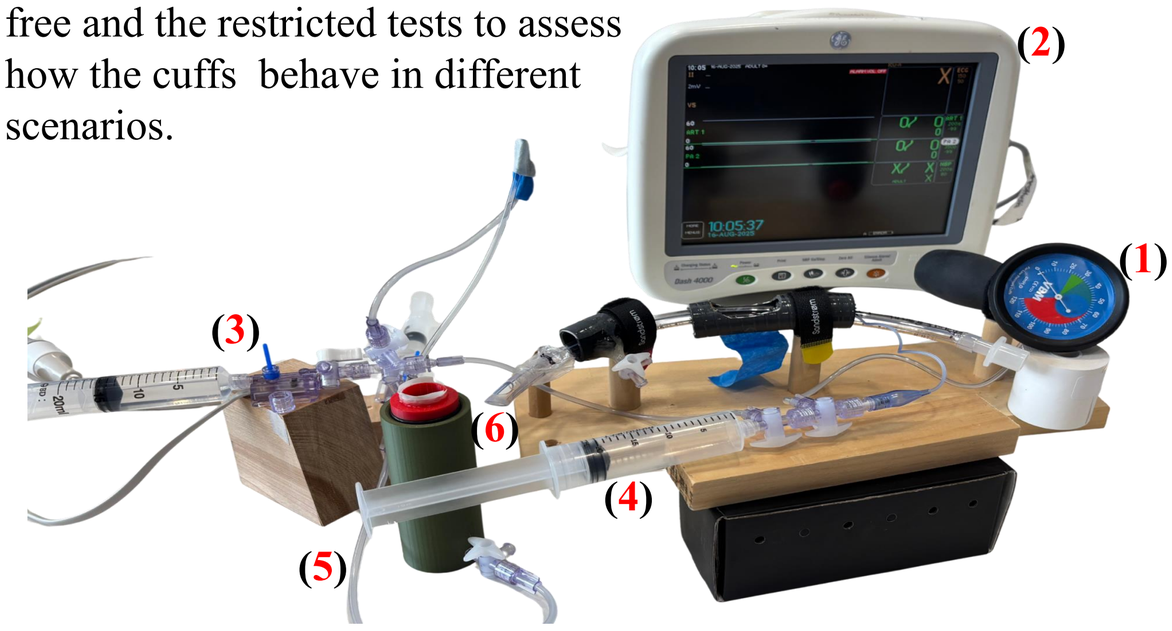
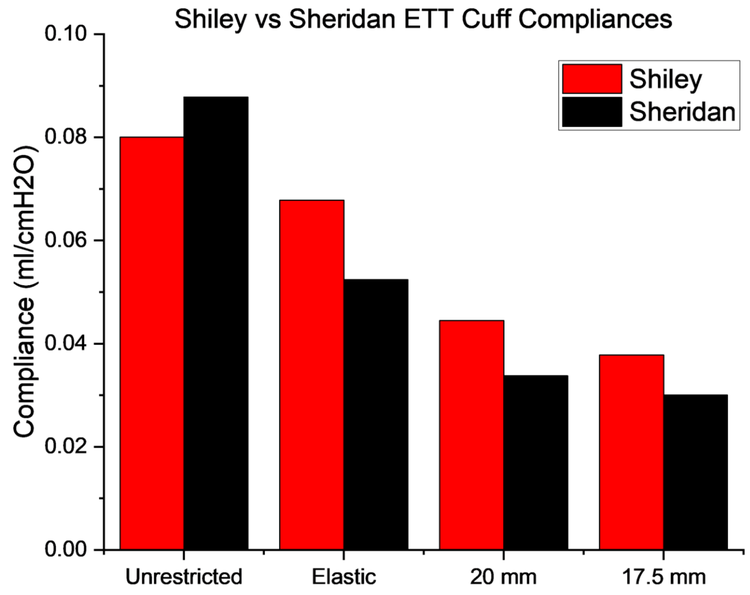
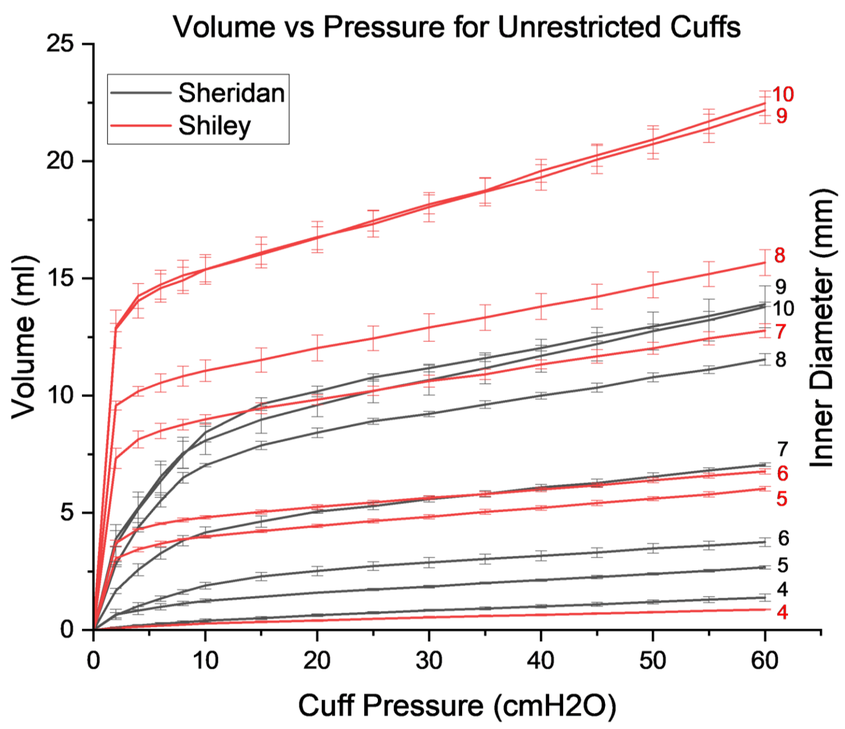


Figure 2: Benchtop Test Setup.

RESULTS & DISCUSSION



- Sheridan cuffs have the highest compliance in unrestricted tests.
- Shiley cuffs have the highest compliance in all restricted tests, regardless of material or diameter.



- Sheridan and Shiley branded cuffs do not follow any patterns when looking at the volume-pressure curves between sizes.

CONCLUSION

- Cuff compliance varies significantly across sizes, brands, and tracheal diameters.
- Thus, ETT cuff behaviour cannot be reliably generalized using a single metric, and clinicians need to take the utmost care in choosing ETT in any scenario.

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REFERENCES

[1] Sultan, P., et al., "Endotracheal Tube Cuff Pressure Monitoring: A Review of the Evidence," *Journal of Perioperative Practice*, 21(11), 379–386, 2011.