High-Resolution Computer Tomography in Assessing Endotracheal Tube Obstruction

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Introduction

The presence of the endotracheal tube (ETT) disrupts the physiological homeostasis of mucus clearance.[1] Over time the ETT becomes covered in a thick layer of mucus, a process not preventable by the use of commercially available suction catheters (Fig. 1).

***Fig. 1**. ETT in mucus layer.*

The reduction in ETT luminal patency leads to increased airflow resistance and patient work of breathing.[2]

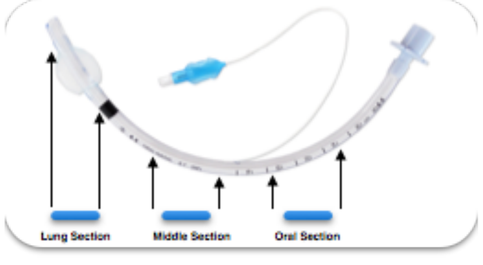
The two parts of this study are A) testing the use of High-Resolution Computer Tomography (HR-CT) in measuring the grade of ETT obstruction and B) determining the relationship between volume loss and increase in airflow resistance in the ETT.

Methods

Part A.

From Nov-Dec 2012, we collected 20 ETTs from the adult intensive care units at MGH. Patients were enrolled in the study group if they required mechanical ventilation for more than 48 hours. Immediately after extubation, these study ETTs were sealed and cut at 24 cm from the Murphy Eye (lung end).

The control group (n=24) consisted of new adult ETTs matched with the study group by size and brand. All the ETTs underwent HR-CT scanning within 48 hours after extubation. HR-CT was performed with an isotopic spatial resolution of 110μm (Siemens Inveon system).



The entire 24cm ETT was scanned. However, three 4.4cm long sections of each tube were used for the analysis (Fig. 2)

***Fig. 2.** Scheme of ETT sections for HR-CT scan analysis*

On the CT images, the luminal space open to ventilation (air) was distinguished from secretions based upon the Hounsfield unit (HU) scale. The threshold of HU -250 to 150 was chosen to optimize the ratio between sensitivity/specificity for mucus visualization on the CT images (Fig. 3).

Voxels were used to determine 1) the volume of air in the ETT free of secretions 2) the cross sectional area (CSA) free of secretions and 3) the ETT internal diameter free of secretions.

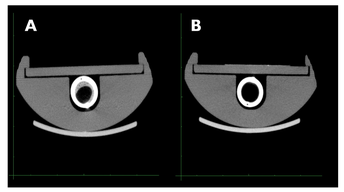


***Fig. 3.** HR-CT images of a used ETT (A) and unused ETT (B).*

Part B.

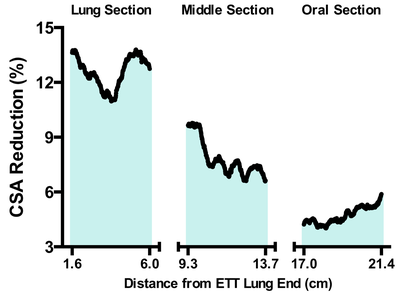
Five additional unused ETTs were internally filled with different amounts of silicone to simulate secretions. The change in pressure to constant airflow across the ETT was measured to evaluate *in-vitro* the correlation between HR-CT imaging data and the resistance to airflow.

Results

Part A.

ETTs from 20 patients (15 males, age 68±14 years, BMI 26±6 kg/m^2) who were intubated for more than 48 hours (average time on ventilator 5.6±4.6 days) were collected.

Study group ETT analysis: HR-CT scan analysis showed an average reduction of 8.2±7.1% of total luminal air volume, ranging from 0.0% to 23.7% (p=0.013 study vs. control group). Minimum CSA reduction was 24.9±3.9% lower than control group.



Cross sectional area was progressively reduced from oral to lung end (oral section 4.7±5.5%, middle section 7.8±8.0% and lung section 12.6±14.4%; p=0.031 for oral vs. lung section) (Fig. 4).

***Fig. 4.** Distribution of CSA reduction of used ETT group along the tube length.*

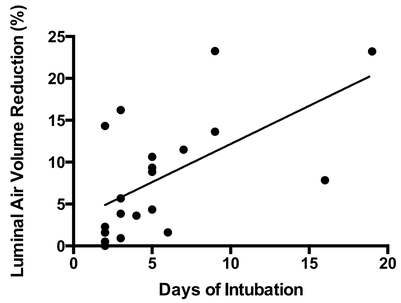


***Fig. 5.** Correlation between grade of ETT occlusion and days of intubation.*

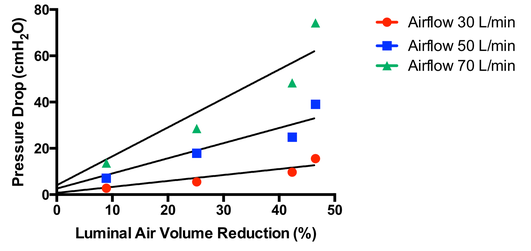
The grade of occlusion was weakly correlated with the length of intubation (R^2=0.352, p=0.006) (Fig. 5).

The mean internal diameters (ID) free of secretions were reduced from initial IDs of 7.0mm to 6.74±0.24mm (p=0.026), of 7.5mm to 7.10±0.52mm (p=0.007), and of 8.0mm to 7.63±0.43mm (p=0.038).

Part B.

Pressure drop (a surrogate of airflow resistance) strongly correlated with an increase in volume loss from the ETT silicone filling. This correlation is maintained at different airflows. (Airflow 30 l/min: R^2= 0.87, p=0.021; 50 l/min: R^2= 0.91, p=0.013; 70 l/min: R^2= 0.90, p=0.015) (Fig. 6).

***Fig. 6.** Correlation between ETT luminal air volume reduction and pressure drop at different airflows.*



Conclusions

Part A. In a group of 20 prolonged mechanically ventilated adult patients, the CSA of the ETT was reduced by about 25%.

Part B. Volume loss determined an increase in airflow resistance.

In summary, standard methods for ETT cleaning are insufficient to prevent ETT narrowing, leading to an increase in patient work of breathing.

References

1. Knowles MR *et al*, J Clin Invest 2002;109:571-9
2. Wilson AM *et al*, Chest 2009;136:1006-13