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Does the Murphy’s eye perform its role?

We would like to report the results of a follow-up to our earlier study modelling airflow through a tracheal tube (TT), a limitation of which was the absence of a bevel and a Murphy’s eye (ME) in the simulated TT [1]. Murphy modified the original Magill TT by adding an opening to the side of the tube to provide an air passage should the TT tip become obstructed by mucus [2]. The ME remains a universal features of TTs despite no research on whether it achieves its aim. Measuring gas flow to different lung regions from a TT is impossible *in-vivo*, so we have used computational fluid dynamic (CFD) modelling to simulate flow through a TT and investigate the role of the ME.

A 3-dimensional mathematical model of a human airway provided by ANSYS UK (Milton Park, Abingdon, Oxon) and a commercial CFD package (ANSYS CFX) were used to map air flow through the model, as described elsewhere [1]. The original model geometry was modified to allow simulation of a different TT shape. The following flow parameters were chosen:

- TT of internal diameter 7.5mm.

- A left facing bevel at an angle of 36° to the TT centre and an elliptically shaped ME of area 0.44 cm^2, which conform to European Standards for TT design [3].

- A steady inflow rate of 30 $l.min^{-1}$, representing average inspiratory flow during artificial ventilation [1].

We studied four different TT positions as shown in Fig. 1. In each simulation gas flow to the five lung lobes was calculated as percentage of total flow and streamlines generated to show the flow patterns.

In a normally positioned TT the high gas velocity within the tube leads to the majority of gas flow exiting the TT through the bevel with only a small fraction passing through the ME (Fig. 1A). When the TT is advanced further into the airway and the bevel partially occluded by endobronchial placement flow to the right lung increases further. This is encouraged by the ME now conducting almost a third of the flow and pointing directly at the right main bronchus (Fig. 1B). When the TT is passed further into the right main bronchus and the bevel becomes occluded all flow must now pass via the ME. Again, the high gas velocity results in most flow entering the right lung towards which the ME faces (Fig. 1C). Rotating the TT through 180° so that the bevel faces right and the ME left seems to have no beneficial effect. Again, the high gas velocity means that almost all gas still flows from the TT bevel (Fig. 1D) and so the relative flow to each lung remains determined mostly by the position of the TT in the trachea.

There are limitations to applying our findings to clinical practice: the model represents only a single airway while the anatomy of the carinal region is variable, and we have used an assumed average value for TT flow when flow patterns in patients will be variable. Despite these limitations our simulation has provided information on the pattern of airflow from a TT through the ME which cannot be obtained *in-vivo*. The high velocity of gas through a TT, caused by its narrow diameter relative to the trachea [1], results in no flow through the ME until the tip is almost occluded, when the ME serves its purpose and allows more flow to the right lung (Fig. 1B). When the tip is fully occluded and all flow passes through the ME the high gas velocity again means that most flow passes, at least initially, to the side to which the eye faces. *In vivo*, once the right lung volume reaches a point where compliance decreases, most likely in late inspiration, pendelluft is likely to occur with gas flowing across to the left lung around the TT. In this position the ME therefore provides an alternative flow path which will prevent immediate harm, but cannot be described as ideal pulmonary ventilation.

Our simulation shows that the ME is a useful design feature that has probably saved countless lives but when it is required, due to occlusion of the TT bevel, the flow distribution generated is likely to be abnormal and highly sensitive to the position of the ME. This methodology may be used to determine a better design of TT, for example incorporating more than one ME.

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Figure

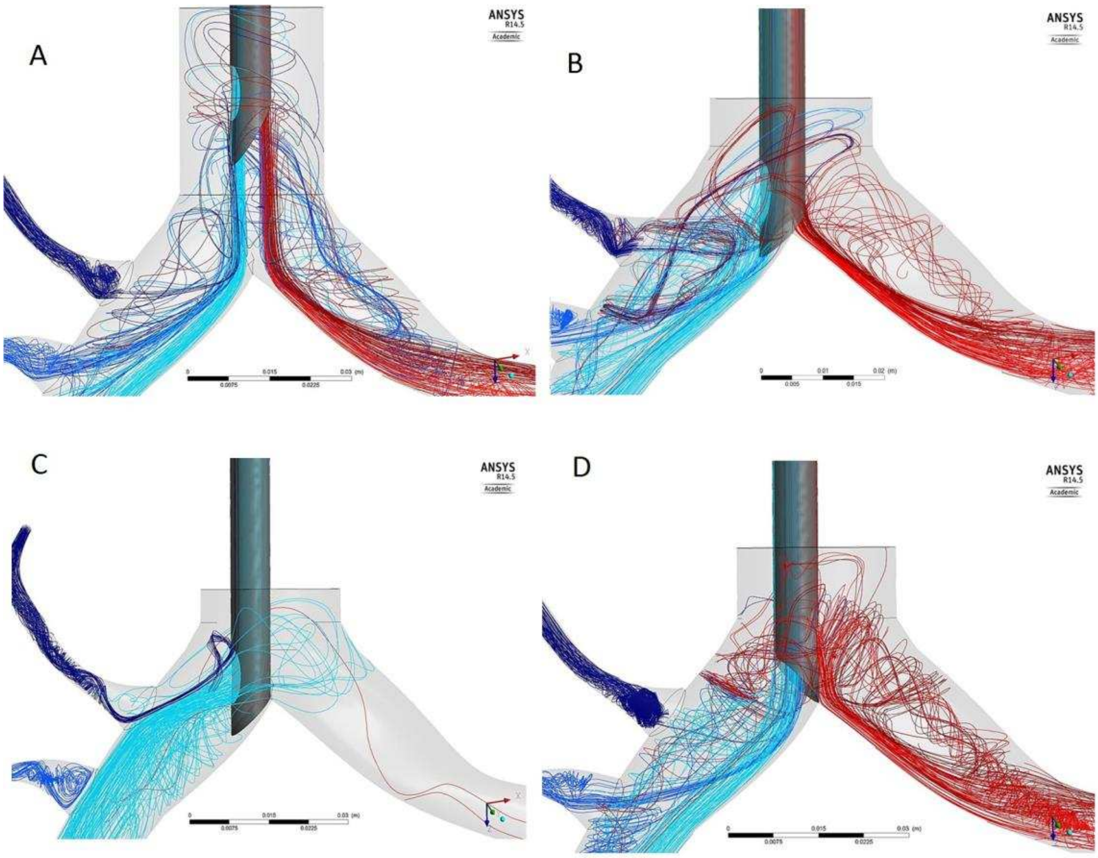

Fig. 1. Flow distribution in the lung, relative flow between the Murphy's eye and tube bevel (%), and streamlines showing flow patterns in the various TT positions studied. In the streamlines the colour of the lines represents the final lobe to which the gas flows: ■ = right upper lobe, ■ = right middle lobe, ■ = right lower lobe, ■ = left upper lobe, ■ = left lower lobe. Position A, TT tip 2 cm from the carina in the centre of the trachea; B, TT tip partially in the right main bronchus with the bevel partially occluded; C, TT further into the right main bronchus with the bevel completely occluded; D, TT rotated 180° and moved towards the right main bronchus with tip touching the carina.

Figure table

	Tube position			
Proportional flow	A	B	C	D
Right upper lobe	1%	1%	4%	1%
Right middle lobe	5%	5%	4%	6%
Right lower lobe	55%	62%	92%	74%
Left upper lobe	9%	8%	0%	5%
Left lower lobe	30%	24%	0%	14%
Murphy's eye	3%	27%	100%	8%
Bevel	97%	73%	0%	92%