The effect of bronchoscope rotation on tracheal tube orientation at the glottic level in a mannequin

Effet de la rotation du bronchoscope sur l'orientation de la sonde trachéale au niveau de la glotte chez un mannequin

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Abstract

Purpose This study examined the effect of external fiberoptic bronchoscope (FOB) rotations on endotracheal tube (ETT) orientations at the glottic level.

Methods Using a mannequin, a nasal FOB was inserted for image capture. A second FOB with a preloaded ETT taped to its top was inserted orally into mid-trachea. The FOB with the taped ETT was rotated as a unit in the axial plane to five different external angles (-90° , -45° , 0° , $+45^\circ$, $+90^\circ$). At each external rotation, the ETT was advanced into the trachea. The image of the ETT at the glottic level was captured. Endotracheal tube orientation was quantified according to the glottic zone faced by the ETT. The ETT orientations were compared amongst the five external FOB rotations using the Kruskal-Wallis Test, while the ETT orientations at -90° , -45° , $+45^\circ$, and $+90^\circ$ FOB rotations were compared with 0° rotation using the Mann-Whitney U test.

Results There was a significant difference in the ETT orientations amongst the five FOB rotations ($P < 0.001$). The ETT orientations at -90° , -45° , $+45^\circ$, and $+90^\circ$ FOB rotations were different from the 0° rotation ($P < 0.001$ for all comparisons). A -90° FOB rotation was most effective

in turning the ETT tip away from the right laryngeal structures and the interarytenoid tissue.

Conclusion With the ETT loaded on a FOB, rotation of the FOB prior to advancing the ETT is effective in changing the ETT orientation at the glottis. A -90° FOB rotation is most effective in turning the ETT tip away from the right laryngeal structures and interarytenoid tissue.

Résumé

Objectif Cette étude a examiné l'effet de rotations externes d'un bronchoscope à fibres optiques (FOB) sur les orientations d'une sonde endotrachéale (SET) au niveau glottique.

Méthode Un FOB nasal a été inséré pour une saisie d'image sur un mannequin. Un deuxième FOB muni d'une SET préchargée attachée à son extrémité a été inséré oralement jusqu'au milieu de la trachée. Le FOB avec la SET attachée a été tourné, en tant qu'unité sur la coupe axiale, à cinq différents angles externes (-90° , -45° , 0° , $+45^\circ$, $+90^\circ$). Lors de chaque rotation externe, la SET a été poussée vers la trachée. L'image de la SET a été capturée au niveau glottique. L'orientation de la sonde endotrachéale a été quantifiée selon la zone glottique à laquelle la SET faisait face. Les orientations de la SET ont été comparées entre les cinq rotations externes du FOB à l'aide du test de Kruskal-Wallis, et les orientations de la SET lorsque le FOB était à -90° , -45° , $+45^\circ$, et $+90^\circ$ ont été comparées à la rotation à 0° à l'aide du test U de Mann-Whitney.

Résultats Une différence significative a été observée dans les orientations de la SET entre les cinq rotations du FOB ($P < 0,001$). Les orientations de la SET lors des rotations du FOB à -90° , -45° , $+45^\circ$, et $+90^\circ$ étaient différentes de celles pour une rotation de 0° ($P < 0,001$ pour toutes les comparaisons). Une rotation du FOB à

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−90° était la plus efficace pour détourner la pointe de la SET des structures laryngées droites et du tissu interaryténoïdien.

Conclusion *Lorsqu'une SET est attachée à un FOB, une rotation externe du FOB avant d'avancer la SET est efficace pour changer l'orientation de la SET au niveau de la glotte. Une rotation du FOB à −90° est la plus efficace pour détourner la pointe de la SET des structures laryngées droites et du tissu interaryténoïdien.*

Fibreoptic bronchoscope (FOB)-guided intubation is a useful well-recognized and commonly employed tracheal intubating technique in patients with or without difficult airways.^{1,2} However, after insertion of the FOB in the trachea, there is difficulty in advancing the endotracheal tube (ETT) over the FOB in 40–90% of the patients.^{3–5} Johnson *et al.* observed this difficulty endoscopically and found that the ETT's tip impinged on the right arytenoid and interarytenoid soft tissue in 53% of the first intubation attempts.⁶ Asai *et al.* suggested that the degree of FOB and ETT rotation and use of a laryngoscope may improve ETT advancement over the FOB. Several studies have shown that a 90° anticlockwise rotation of the ETT is effective at increasing the success of ETT advancement over the FOB.^{3,6–8} A 90° anticlockwise rotation places the ETT tip away from the right vocal cords and arytenoid, which are common points of impingement, and towards the anterior commissure of the vocal cords.³ A Parker Flex-Tip™ ETT (Parker Medical, Englewood, CO, USA) is specifically designed with a beaklike tip and a posterior-facing bevel, thereby achieving the same effect as the 90° anticlockwise rotation of a conventional ETT.³ This tube has been shown to have a higher success rate than the conventional ETT in FOB-guided intubation.³

Studies have stated the increased success of a 90° anticlockwise rotation on ETT advancement; however, there is no pictorial evidence showing the effect of various external FOB rotations on FOB and ETT orientations at the glottic level. Therefore, the purpose of this study was to describe the effect of five different degrees of external rotation of the FOB with a preloaded ETT as a unit on the orientation of the FOB and ETT at the glottic level.

Methods

Following approval by the institutional Research Ethics Board, two anesthesiologists experienced with bronchoscopy performed the study. A mannequin (Laerdal® Airway Trainer, Laerdal Medical Corporation, Wappingers Falls,

NY, USA) and two FOBs were used for the study. The first bronchoscope (Olympus Optical Co Ltd, model BF 160, Tokyo, Japan) was inserted nasally, operated by one research anesthesiologist (D.T.W.), and used for observational and image capturing purposes. The bronchoscope was positioned approximately 5 cm above the glottis of the mannequin where a full view of the laryngeal structures was acquired.

For intubation, a second bronchoscope with a 5.2 mm outer diameter (Olympus Optical Co Ltd, model LF-TP, Tokyo, Japan) was operated by a second research anesthesiologist (S.D.A.). The second bronchoscope loaded with a 7.5 mm internal diameter (ID) ETT (Mallinckrodt Inc, Hazelwood, MO, USA) taped onto its top (FOB-ETT unit) was inserted orally. The lesser curvature of the tube was facing anteriorly and the bevel was facing leftwards. This bronchoscope position was identified as 0° rotation. The bronchoscope was then advanced through the glottic opening under visualization using the eyepiece until it was approximately 3 cm above the carina. An image of the oral bronchoscope at the glottic opening was captured by the nasal bronchoscope. While holding the 0° position, the ETT was then advanced through the glottic opening until the cuff of the ETT was just beyond the glottic opening. An image of the ETT at the glottic opening was also captured. This procedure was performed three consecutive times at 0° rotation.

The same sequence of FOB insertion into the trachea followed by advancement of a 7.5 mm ID ETT beyond the glottis was repeated for four other external FOB-ETT unit rotations in the following order (−90°, −45°, +45°, and +90°). A negative sign indicates an anticlockwise rotation and a positive sign indicates a clockwise rotation of the bronchoscope. With −90° and +90° rotations, the FOB-ETT unit was rotated in the axial plane to a position near the left and right ear, respectively (Fig. 1). The −45° and +45° rotations involved rotating the bronchoscope to halfway between −90° and 0° and halfway between +90° and 0°, respectively (Fig. 1). Therefore, three consecutive ETT insertions were performed for each of these four external FOB rotation angles.

The same procedure was repeated using two other ETT sizes, 6.5 mm and 7.0 mm ID. Thus, at each external FOB rotation, three consecutive intubation attempts were made using each of the three ETT sizes, and nine images (three insertion attempts x three ETT sizes) were obtained of the FOB and the ETT at the glottic opening.

Endotracheal tube and FOB reference points

The FOB and ETT orientation at the level of the glottic opening was quantified by the glottic zone it faced. The FOB reference point was the 1 mm gap in a built-in circumferential white line that was located at the 6 o'clock

Fig. 1 The five angles of external fiberoptic bronchoscope rotation, -90° , -45° , 0° , $+45^\circ$, and $+90^\circ$, in the axial plane are demonstrated on a mannequin

position when the FOB was held with its control lever facing the operator (Fig. 3). The circumferential lines and gaps were positioned 10 to 40 cm from the FOB tip at 5 cm intervals. The ETT reference point was a 2 mm-wide blue vertical line (white line in hardcopy printouts) along the greater curvature of the ETT that ended at the ETT tip. At the 0° FOB rotation, the blue line faced the FOB operator and the ETT bevel faced left. Therefore, anticlockwise rotation of the ETT would turn the bevel to face a posterior direction and vice versa.

Definition of glottic zones

A total of nine glottic zones were defined (Fig. 2). Zone 0 was demarcated by the medial margins of the corniculate cartilages. Minus zones were located in an anticlockwise direction from zone 0, while positive zones were located in a clockwise direction. Zone +1 was the region between zone 0 and a line drawn along the lateral margin of the corniculate cartilage. Zone +2 was demarcated by the lateral margin of zone +1 and a line drawn along the lateral margin of the cuneiform cartilage. Zones +3 and +4 referred to the medial and lateral halves of the aryepiglottic fold, respectively. The following method was used to separate the aryepiglottic fold into two zones: First, two

Fig. 2 The definition of glottic zones -4 to $+4$ is shown, including zone 0

lines were drawn, one from the inner-medial corner to the inner-lateral corner of the aryepiglottic fold and one from the outer-medial corner to the outer-lateral corner. Second, the midpoints of both lines were connected, thus forming the bisecting line splitting the aryepiglottic fold into zones +3 and +4. The negative zones -1 to -4 were mirror images of the positive zones +1 to +4.

Fiberoptic bronchoscope and ETT orientation measurements

Using hardcopy printouts of the captured images, a horizontal line was drawn on the FOB from the superior margin of the circumferential white line adjacent to the gap across the gap to the superior margin on the opposite side (Fig. 3). One centimetre above this line, a second horizontal line was drawn such that the two angles created by this second line and the edges of the FOB were within 2° of each other as measured by a standard protractor. The midpoints of both lines were connected by a third line that extended into

Fig. 3 Fiberoptic bronchoscope (FOB) orientation. A horizontal line is drawn across the gap from the superior margin of the circumferential white line adjacent to the gap to the superior margin on the opposite side. One centimetre above this line, a second horizontal line is drawn such that angles 1 and 2 created by this second line and the edges of the FOB are within 2° of each other. The midpoints of both lines are connected by a third line that extends into a glottic zone that is then considered as the FOB orientation

a glottic zone. The point that the third line intersected the glottic zone was considered as the FOB orientation.

For ETT orientation, three horizontal lines were drawn across the white stripe at a distance of 1 cm from each other such that the angles created by these lines and the edges of the white stripe were within 2° of each other (Fig. 4). The lowest of the three lines was drawn 1 cm above the glottic level. The midpoints of the three lines were connected by a vertical line and extrapolated until the vertical line intersected a glottic zone. That zone was considered to be the ETT orientation.

Statistical analysis

All data were analyzed using the SPSS statistical program version 13.0 for Windows (SPSS Inc., Chicago, IL, USA). Fibreoptic bronchoscope and ETT orientations at the glottic level were ordinal variables and results were presented as the median and interquartile range (25th to 75th percentile). Fibreoptic bronchoscope orientations amongst the five external rotation angles were compared using the Kruskal-Wallis test, while the FOB orientations at -90° , -45° , $+45^\circ$, and $+90^\circ$ were compared with the 0° orientation using the Mann-Whitney U test with Bonferroni correction. The same tests were used to compare the corresponding ETT orientations. The external FOB orientations were compared with the corresponding ETT orientations at specific rotations using the Mann-Whitney U test with

Bonferroni correction. Significance was assumed when $P < 0.05$.

Results

At each of the five external FOB rotations, three consecutive intubation attempts were made with each of the three ETT sizes. Therefore, at each external rotation, nine images (three insertion attempts $\times$ three ETT sizes) were obtained of the FOB and the ETT at the glottic opening.

Results are presented in Fig. 5, including the median, interquartile range, and representative pictures of the FOB and ETT at each external rotation. There was a significant difference in both the FOB and ETT orientations amongst the five external rotations ($P < 0.001$, $P < 0.001$). There were significant differences in FOB orientation at -90° , -45° , $+45^\circ$, and $+90^\circ$ of rotation compared with 0° ($P < 0.001$ in all comparisons). Likewise, there were significant differences in ETT orientation at -90° , -45° , $+45^\circ$, and $+90^\circ$ compared with the 0° orientation ($P < 0.001$ in all comparisons). There were no instances of ETT or FOB placement in either the $+4$ or -4 zones.

At the level of the glottis, the ETT did not rotate to the same extent as the FOB at the various degrees of external FOB rotation. For three of the five external rotations, -90° , -45° , and $+45^\circ$, the orientation of the ETT was significantly different from the FOB orientation ($P = 0.02$, $P = 0.04$, and $P = 0.02$, respectively).

Fig. 4 Endotracheal tube (ETT) orientation. Three horizontal lines are drawn 1 cm from each other across the white stripe such that the angles created by these lines and the edges of the white stripe (angles 1 and 2, angles 3 and 4, angles 5 and 6) are within 2° of each other. The midpoints of the three lines are connected by a vertical line and extrapolated until it intersects a glottic zone. That zone is considered to be the ETT orientation

Discussion

Effect of external rotation of the FOB on the FOB orientation at the glottic level

We found that the five FOB external rotations resulted in significantly different FOB orientations at the glottic level, which thereby provided evidence that indeed there is translation of rotation. A correctly rotated FOB is important for providing a guide for the ETT to follow, thus reducing the risk of the ETT being impeded by laryngeal structures

Effect of external rotation of the FOB on the ETT orientation at the glottic level

With an ETT fixed on the FOB, our study showed that external rotation of the FOB indeed changed the ETT orientation at the glottic level. We found that each external FOB rotation resulted in a significantly different ETT orientation at the glottic level. An implication of this result is that movement of the ETT bevel into a more favourable

Fig. 5 Images captured by placing the fiberoptic bronchoscope (FOB) nasotracheally showing representative FOB and endotracheal tube (ETT) orientations at the five angles of external FOB rotation. Fiberoptic bronchoscope and ETT orientation medians and interquartile range (IQR) are shown. * $P < 0.001$ FOB or ETT orientation at 4 angles of external rotation compared with 0° FOB external rotation. # $P < 0.05$ comparison of ETT and FOB orientations at the same degree of FOB external rotation

FOB EXTERNAL ROTATION		+90	+45	0	-45	-90
FOB orientation
	Median IQR	-3.0** -3.0, -2.5	-2.0** -2.0, -2.0	0.0 -1.0, 0.0	2.0** 1.0, 2.0	2.0* 2.0, 3.0
ETT orientation
	Median IQR	-2.0* -2.5, -2.0	-1.0* -2.0, -1.0	0.0 0.0, 0.0	2.0* 2.0, 2.5	2.0* 2.0, 3.0

position for intubation can be accomplished by external rotation of the FOB. Literature shows that a 90° anticlockwise ETT rotation results in a higher success of ETT advancement compared with intubation with 0° FOB external rotation.^{3,6-8} Johnson *et al.* revealed that the right laryngeal structures most commonly impede ETT advancement.⁶ The 90° anticlockwise rotation of the ETT places the tip away from the right laryngeal structures to lessen the incidence of impingement. Although they showed that a 90° anticlockwise rotation increased the success of ETT passage in 27% of their patients after failure to advance at 0° of rotation, they did not measure the effect of external rotation on the ETT tip at the glottic level.

We demonstrated that a 90° clockwise rotation causes the ETT tip to be positioned posteriorly with the bevel facing anteriorly. Clockwise rotations also turn the tip away from the right laryngeal structures; however, the posteriorly positioned ETT tip increases the chance of esophageal intubation or impingement of the interarytenoid soft tissue.³ Thus, the logical goal of rotation is to position the ETT tip away from these commonly impinged sites and towards the anterior commissure with the bevel facing posteriorly. We have shown that a 90° anticlockwise FOB rotation is the best means to achieve this goal, with the 45° anticlockwise rotation being a good alternative.

While we observed no difference in success of ETT passage amongst the 6.5, 7.0, and 7.5 mm tube sizes at the different external rotations, an intubation attempt with a size 8.0 mm ID ETT showed the superiority of the 90° anticlockwise rotation over the other external rotations in decreasing chances of ETT impingement. Fig. 6 shows ETT impingement at 90° and 45° clockwise rotations during ETT advancement compared with successful passage of the

Fig. 6 Advancement of an 8.0 mm internal diameter endotracheal tube (ETT) impeded by laryngeal structures using +90° and +45° external fiberoptic bronchoscope rotations is compared with the lack of ETT impediment when using a -90° external rotation

8.0 mm ETT using a 90° anticlockwise rotation. Thus, when using an ETT of larger diameter, it is advisable to use the 90° anticlockwise rotation vs the other external rotations.

Relationship between FOB and ETT orientation at the glottic level

There is a good correlation between FOB and ETT rotation; however, the ETT did not rotate to the same extent as the FOB at various degrees of external FOB rotation. External rotations of -90°, -45°, and +45° showed a significant difference between the FOB and ETT orientation at each external rotation. Therefore, in order to optimize the ETT orientation at the glottic level, one may need to externally rotate the FOB > 90° in order to achieve a 90° rotation of the ETT at the glottic level. The use of a large diameter bronchoscope and a small size ETT decreases the difficulty in railroading and helps to keep the ETT from deviating from the course set by the FOB.^{3,4} A larger gap between them may hinder them from moving together simultaneously, causing the ETT to lag behind the

FOB and therefore resulting in incomplete translation of rotation from the FOB to the ETT at the level of the glottis.

Our study has several limitations. First, the methods used to delineate the glottic zones and to measure the orientations of the FOB and ETT were created arbitrarily to allow semi-quantification, and they were not used previously or validated. Second, the study was performed on a mannequin, thus the implications from these results may not extrapolate to patient situations. Third, the findings of this study pertain specifically to FOB-guided oral intubation and may not be applicable to nasal intubation. Fourth, the study was performed using a single make of ETTs, and the results may not extrapolate to other makes of ETTs. Fifth, the order in which the external rotations were performed was not randomized.

In summary, using a double bronchoscope setup, we have provided pictorial evidence showing changes in FOB and ETT orientation at five different external FOB rotations in a mannequin. The findings of this study indicate that external rotation of a FOB can produce a significant change in the FOB and ETT orientation at the glottic level. A 90° anticlockwise external rotation of the FOB was found to achieve the most significant rotation of the ETT tip away from the right laryngeal structures and towards the anterior commissure where, theoretically, the chances of impingement are minimized. Further clinical studies need to be performed to determine the effect of external FOB rotation on the ETT tip at the glottic level and to evaluate the success rate of ETT passage in clinical settings.

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Conflicts of interest None declared.

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