Modified right-sided Broncho-Cath™ double lumen tube improves endobronchial positioning: a randomized study

[La sonde double-lumière droite modifiée Broncho-Cath™ améliore le positionnement endobronchique : une étude randomisée]

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Objective: A left-sided double lumen tube is recommended for one-lung ventilation for most thoracic surgeries, but for certain indications, a right-sided double lumen tube (R-DLT) may be mandatory. Frequent malposition of R-DLTs has been reported. We propose an innovative modification of Mallinckrodt's Broncho-Cath™ R-DLT consisting of an enlarged area of the lateral orifice, and studied the impact of this modification on the adequacy of R-DLT positioning.

Methods: Eighty adult patients scheduled for elective thoracic surgery were randomized into two groups: standard Broncho-Cath™ R-DLT, or modified Broncho-Cath™ R-DLT. After induction of anesthesia, the R-DLT was positioned using a fiberoptic bronchoscope. The position of the R-DLT was assessed on three occasions: with the patient supine (T1), then immediately following the patient's transfer to the lateral position (T2), and after repositioning of the tube, when needed, with the patient in lateral position (T3). A score ranging from 1 to 4 was accorded to the relative position of the right upper lobe (RUL) orifice in relation to the origin of the RUL bronchus.

Results: The modified Broncho-Cath™ R-DLT was more frequently in an adequate position at T2: 77% vs 37% of patients ($P = 0.0121$), and easier to reposition at T3: 97% vs 74% of patients ($P = 0.0109$) in comparison to the standard Broncho-Cath™ R-DLT group.

Conclusion: These data suggest the superiority of the modified Broncho-Cath™ R-DLT compared to a standard Broncho-Cath™ R-DLT for optimal R-DLT positioning to facilitate one-lung ventilation during thoracic surgery.

Objectif : Une sonde double-lumre gauche est recommande lors de la ventilation pulmonaire slective pour la majorit des chirurgies thoraciques ; toutefois, dans certaines indications, une sonde double-lumre droite (SDL-D) peut tre requise. Il est fait tat de la malposition frquente des SDL-D. Nous proposons une modification de la SDL-D Broncho-Cath™ de Mallinckrodt qui consiste en une surface largie de l'orifice latral, et avons tudi l'impact de cette modification sur le bon positionnement de la SDL-D.

Mthodes : Quatre-vingts patients adultes devant subir une chirurgie thoracique rgle ont t randomiss en deux groupes : SDL-D Broncho-Cath™ standard, ou SDL-D Broncho-Cath™ modifie. Aprs induction de l'anesthsie, la SDL-D a t positionne l'aide d'un bronchoscope fibres optiques. La position de la SDL-D a t value trois fois : le patient sur le dos (T1), puis immdiatement aprs le transfert du patient en position latrale (T2), et aprs le repositionnement du tube, lorsque requis, le patient toujours en position latrale (T3). Une note de 1 4 a t donne la position relative de l'orifice du lobe suprieur droit (LSD) par rapport l'origine de la bronche lobaire suprieure droite.

Rsultats : La SDL-D Broncho-Cath™ modifie fut plus frquemment dans une position adquate en T2 : 77 % vs 37 % des patients ($P = 0,0121$) et fut plus facile repositionner en T3 : 97 % vs 74 % des patients ($P = 0,0109$) par rapport au groupe SDL-D Broncho-Cath™ standard.

Conclusion : Ces donnes suggrent la supriorit de la SDL-D Broncho-Cath™ modifie par rapport la SDL-D Broncho-Cath™ standard pour un positionnement optimal de la SDL-D afin de faciliter la ventilation pulmonaire slective pendant la chirurgie thoracique.

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ONE lung ventilation (OLV) is a prerequisite for pulmonary surgery, whether the operation is carried out through open techniques or by video-assisted thoracoscopy. One lung ventilation is most commonly facilitated with a double lumen tube (DLT). According to the original recommendations of Benumof,¹ the left-sided version of the tube should be used for most procedures, whether they are performed on the left or the right side.^{2,3} Arguments against the use of the right-sided double lumen tube (R-DLT) include difficulties in properly positioning the tube, as well as risk of misalignment between the lateral orifice of the tube and the origin of the right upper lobe (RUL) bronchus, thus lowering the margin of safety.^{1,4} Benumof's recommendations also mention that the R-DLT should be preferred when one cannot use a left-DLT (L-DLT) in the presence of lesions located in the left main bronchus.¹ Despite these recommendations, the criteria for the regular use of R-DLTs⁵⁻⁹ have never been agreed upon.

In our experience with commercially available R-DLTs, we have observed that it is often necessary to rotate the tube in order to optimally position its lateral orifice anterior to the origin of the RUL bronchus. This finding is observed most frequently following transfer of the patient from the supine to the lateral position. We hypothesized that such difficulties were possibly related to anatomical variations in the origin of the RUL bronchus, which normally arises laterally, a short distance from the trachea, or that such difficulties could be related to the anatomical distortion that might occur during lateral positioning of the patient for thoracotomy.

In order to address this issue, we modified a currently available Broncho-CathTM R-DLT by enlarging the area of its RUL orifice by almost 100%. We hypothesized that this enlargement would facilitate its alignment with the origin of the RUL bronchus and make the R-DLT easier to use. This prospective, randomized, clinical trial was thus designed to assess the impact of this modification on the success rate of adequate Broncho-CathTM R-DLT placement, as determined by fiberoptic bronchoscopy (FOB). The specific objective was to demonstrate by FOB examination that the modified Broncho-CathTM R-DLT more frequently maintained an adequate position after turning the patient into the lateral thoracotomy position (T2), and to assess whether it was easier to reposition the modified tube at (T3) compared to a standard Broncho-CathTM tube.

FIGURE 1 Photographs and schematic representation of the Broncho-CathTM right-sided double lumen tube: standard (1A) and modified (1B)

Note the difference in the angles of the lateral orifice of the tubes. A) lateral orifice and B) bronchial balloon.

Methods

Patient population

The study protocol was approved by the hospital's Research Ethics Board and written informed consent was obtained from all patients. From February to July 2004, ASA class II-IV adult patients between 18 and 85 yr of age, who were scheduled to undergo major left or right thoracic procedures requiring OLV in the lateral decubitus position, were invited to participate in this study. All patients underwent a diagnostic bronchoscopy several days before screening. Excluded was any patient with a history of previous pulmonary resection, and also patients with significant tracheal deviation, tracheal origin of the right superior lobe, proximal right main bronchus lesion, and when a right upper lobectomy was planned with possible sleeve resection for a proximal lesion.

Patients were randomized in a 1:1 ratio for tracheal intubation with a standard Broncho-CathTM R-DLT (control group) or with a modified Broncho-CathTM R-DLT (intervention group). The size of the R-DLT was selected according to Brodsky's chart.^{12,13}

Double lumen tube

The physical characteristics of the right endobronchial DLT used for this study are shown in Figure 1. The standard tube was the commercially available Broncho-CathTM R-DLT from Mallinckrodt Inc. (St-Louis, MO, USA) (Figure 1A). The modified

tube (Figure 1B) was also the commercially available Broncho-Cath™ R-DLT, but the lateral orifice was enlarged by approximately 100%. This was done by increasing the angular width of the lateral orifice from the standard 66° to 180°, so that the RUL orifice occupied 50% of the bronchial lumen circumference (*patent pending*). The length of the orifice was also augmented by a few millimetres distally. After modifying the tube, we verified the integrity of the bronchial cuff to see whether it was possible to cause a leak in the cuff. In order to ensure the reproducibility of these modifications and to minimize the risk of damaging the bronchial cuff, we used a template developed in collaboration with the Laboratory of Biomaterials & Bioengineering at Laval University. All tubes were modified in advance of the scheduled procedure, and their sterility was verified by bacteriological analysis. The only difference between the modified tube and the standard tube was the area of the lateral orifice of the bronchial lumen.

Procedure

Three experienced thoracic anesthesiologists (J.B., M.B., S.S.) performed all tracheal intubations. Following application of routine monitors and after standardized *iv* induction of anesthesia with paralysis, the DLT was positioned using FOB, following the technique used in our institution for more than 15 years (Figure 2). This technique is also similar, in part, to that described by Campos *et al.*^{14,15} After verification of correct positioning, the DLTs were firmly secured with a tracheal cord¹⁶ and the patient was transferred to the lateral decubitus position, while ensuring that his/her head remained immobile.

The exact position of the tube was confirmed by FOB examination on three separate occasions during the intubation maneuvers. We recorded the alignment of the lateral orifice of the tube with the origin of the RUL bronchus according to the following scheme of interpretation. A score ranging from 1 to 4 was attributed (Figure 3): complete visualization of the RUL bronchial origin (P1), partial visualization of the RUL bronchial origin (P2), RUL bronchial origin visible only with minor rotation of the tube (P3), and absence of visualization of the origin of the RUL bronchus with minor rotation of the tube (P4).

These evaluations were first made while the patient was supine following FOB tube positioning (T1). After the patient was turned laterally, the position of the endobronchial tube was verified once again (T2). If the alignment of the tube was not optimal, defined as P2, P3 or P4 at T2, the tube was repositioned (T3). Surgery was allowed to proceed after the third airway

FIGURE 2 Positioning of the right-sided double lumen tube

2.1: After insertion of the right-sided double lumen tube (R-DLT) in the trachea, a fiberoptic bronchoscope is first passed through the endobronchial lumen and the tracheal bifurcation is visualized.

2.2: The fiberoptic bronchoscope is then advanced into the right main stem bronchus (RMB) and the origin of the right upper lobe bronchus (RULB) is identified. The fiberoptic bronchoscope extremity is positioned at the level of the RULB looking through the bronchus intermedius (BI).

2.3: The R-DLT is finally advanced over the fiberoptic bronchoscope while ensuring that the tip of the fiberoptic bronchoscope remains fixed anterior to the RUL orifice. This can be achieved by visual estimation, keeping the carina between the right middle lobe bronchus (RMLB) and the right lower lobe bronchus (RLLB) at a constant distance. The R-DLT is advanced until its extremity is seen through the fiberoptic bronchoscope, after which the bronchoscope is withdrawn (usually < 1 cm), allowing visualization of the right upper lobe bronchus through the lateral orifice of the R-DLT.

examination. All FOB examinations were digitally recorded offline for subsequent reassessment by one anesthesiologist (D.C.) and one respirologist (Y.L.) who were both unaware of the clinical characteristics of the patient. Any disagreement between the two readers was resolved by consensus.

Finally, evaluation was concluded after the third evaluation (T3), before OLV or surgery began, so that there was no influence from lung ventilation or the surgical procedure on endobronchial tube position.

FIGURE 3 Schematic representation of the standard and modified Broncho-Cath™ right-sided double lumen tube (R-DLT) positioned in the proximal tracheobronchial tree. The right side of the illustration shows the Broncho-Cath™ R-DLT correctly positioned according to the relative position of the tube's right upper lobe orifice, in relation to the origin of the right upper lobe bronchus origin:

- P1 = complete visualization of the right upper lobe (RUL) bronchus origin,
- P2 = partial visualization of the RUL bronchus origin,
- P3 = RUL bronchus origin visible only with minor rotation of the tube,
- P4 = absence of visualization of the RUL bronchus origin with minor rotation of the tube.

Statistical and sample size considerations

Data are expressed using means $\pm$ standard deviation for continuous variables or as proportions for categorical data. In the primary analysis, we compared the proportion of patients with each of the four tube positions (P1 to P4) at each of three evaluations (T1, T2, T3) using Fisher's exact test. For continuous data, a Student's *t* test was used to compare groups. In univariate logistic regression analysis, we investigated the

FIGURE 4 Flow diagram.

influence of important clinical characteristics (patient's height, side of surgery and R-DLT size) on the likelihood of P1 at T1, T2 and T3. Then, in a multivariable analysis, the same predictors were incorporated into a regression model. The results were considered significant with *P*-values ≤ 0.05 .

Before performing this study, we undertook a pilot study involving 25 patients (ten patients in a control group and 15 patients who received modified R-DLTs) with a 90% rate of success (P1 at T3) with the modified tube and a 60% rate of success in the control group (unpublished data). Based on these preliminary results, at 80% power and a 0.05 significance level, we calculated that 36 patients were needed in each group to complete the study.

Results

Patients

The trial profile is shown in Figure 4. Eighty-eight were screened (age 19–81 yr); all 80 were randomized and completed the study protocol. The reasons for ineligibility are presented in Figure 4. Baseline clinical characteristics were similar in the two groups (Table I).

Endobronchial tube position

Immediately after moving the patient into the lateral position, the modified Broncho-Cath™ R-DLT remained more frequently in optimal position (P1) compared to the standard Broncho-Cath™ R-DLT (T-2: $P = 0.0121$) (Table II). The difference was also significant when comparisons were made after the tube had been repositioned (T-3: $P < 0.0109$).

Predictors of endobronchial tube position

In logistic regression analyses, neither height, side of surgery, nor R-DLT size predicted P1 at T1, T2 or T3 (Table I). Therefore, we did not proceed with a multivariable analysis.

Discussion

The most important observation from this study is that the modified Broncho-Cath™ R-DLT results in a higher incidence of adequate tube positioning when

compared to the standard Broncho-Cath™ R-DLT for OLV. The modified Broncho-Cath™ R-DLT was associated with a higher frequency of adequate tube position after turning the patient into the lateral position (T2: $P = 0.0121$), and it was also easier to reposition the tube after turning the patient laterally (T-3: $P < 0.0109$), in comparison to a standard Broncho-Cath™ tube.

Although few investigators have specifically evaluated the incidence of R-DLT malpositioning and malfunction during thoracic procedures,^{14,15,17-19} these issues can become very problematic intraoperatively. Malpositioning of the R-DLT is not rigorously defined in most previous studies, many of which refer to inadequate positioning as lack of alignment between the lateral slot of the R-DLT and the origin of the RUL bronchus (as observed during the FOB examination). Most previous studies also fail to identify if lack of alignment is partial or complete, and the effects on

TABLE I Characteristics of the 80 randomized patients

	Standard R-DLT (Control group)	Modified R-DLT (Study group)	P value
Number of patients randomized	(n = 40)	(n = 40)	
Age (mean ± SD)	56.5 ± 14.8	53.7 ± 16.9	0.4324
Sex (M/F)	31/9	26/14	0.3232
Weight (kg)	72.7 ± 14.9	74.6 ± 16.6	0.5887
Height (cm)	167.0 ± 10.3	164.4 ± 27.4	0.5821
<i>Surgery (approach)</i>			
Thoracoscopy/thoracotomy	15/25	16/24	1.0
Side of operation (left/right)	20/20	19/21	1.0
<i>Tube size</i>			
No. 35	6	6	0.8226
No. 37	10	8	
No. 39	20	20	
No. 41	4	7	

R-DLT = right-sided double lumen tube.

TABLE II RESULTS

Time of evaluation	Position score*	Standard tube (Control group) No. patients (%)	Modified tube (Study group) No. patients (%)	P value
T-1	1	33 (86.8)	39 (97.5)	0.1039
Patient supine decubitus	2	5 (13.2)	1 (2.5)	
	3	0	0	
	4	0	0	
T-2	1	14 (36.8)	28 (76.7)	0.0121
Immediately after lateral	2	11 (28.9)	5 (13.2)	
decubitus positioning	3	9 (23.7)	4 (10.5)	
	4	4 (10.5)	1 (2.6)	
T-3	1	28 (73.7)	35 (97.2)	0.0109
After repositioning of the	2	8 (21)	1 (2.8)	
endobronchial tube	3	2 (5.3)	0	
	4	0	0	

*1 = complete visualization; 2 = partial visualization; 3 = visible only with minor rotation; 4 = absence of visualization.

tube position after turning the patient laterally for the thoracotomy are not traditionally documented. McKenna *et al.*,¹⁷ reported an incidence of 89% (8/9 patients) and a study by Klein *et al.*¹⁸ showed 73% (27/37 patients) had right-sided tube malposition, as documented by FOB. The high rates of tube malpositioning were probably related to the fact that R-DLTs were blindly positioned, without using FOB.

In another recent study, Slinger and Triolet¹⁹ examined the adequacy of OLV with different designs of R-DLT from three different manufacturers. All tubes were positioned using FOB, and their results showed a tube misplacement rate of 53% (16/30) after the patient had been turned laterally. These results are similar to those observed in our control group (63%; 24/38), where a standard Broncho-CathTM R-DLT was used.

Two separate studies by Campos and Massa *et al.*,^{14,15} examined the problem of positioning of the R-DLTs. In the first study,¹⁴ a 25% incidence (5/20 patients) of suboptimal alignment was observed, as documented by FOB. In the second study,¹⁵ a 10% incidence (2/20 patients) of suboptimal placement of a R-DLT was observed after turning the patient laterally. While these results are impressive, it must be recognized that airway instrumentation was managed by very experienced anesthesiologists, and that operator dependency is an important factor in the interpretation of the results. Interestingly, Campos and Massa observed in their study¹⁴ that it was necessary to rotate the R-DLT in two of five patients in order to obtain proper alignment of the endobronchial tube with the axis of the RUL bronchus.

Ever since the initially published recommendations of Benumof in 1987,¹ most anesthesiologists have been reluctant to use R-DLTs on a routine basis for thoracic procedures. The difficulty in maintaining proper placement of the standard R-DLT when the patient is repositioned laterally for a thoracotomy remains a limiting factor. As a result of this limitation, there is less reported clinical experience with R-DLTs, and most anesthesiologists remain hesitant to use these airways even when there are specific indications for which they may offer specific advantages in comparison to a L-DLT. It is our view that all thoracic anesthesiologists should have familiarity and experience with R-DLTs for left lung surgery.^{5,7,8,14,17} To reduce the challenges of optimal positioning of the standard Broncho-CathTM R-DLT, and to encourage the use of R-DLTs, we elected to modify the physical characteristics of existing Broncho-CathTM R-DLT, with a goal of improving ease of use, and decreasing the frequency of tube malposition.

Over the years, several improvements in the design of R-DLTs have been proposed. In 1988, Benumof suggested increasing the vertical length of the lateral ventilation orifice to reduce the risk of RUL bronchial obstruction.⁴ In 1989, Trazzi *et al.* introduced a new right-sided endobronchial tube which was inserted through a standard endotracheal tube. It was then engaged into the right main stem bronchus, and acted as a bronchial blocker with an inside ventilating lumen.¹⁰ In 1995, Mercier and Fischler suggested removal of the distal part of the endobronchial extremity of the tube comprising the lateral orifice, retaining only the infero-internal part of this bronchial extremity of the tube, distal to the bronchial balloon.¹¹ Unfortunately, most of these modifications did not resolve the problem of maintaining the lateral orifice in optimal position with respect to the RUL bronchus.

The results of our study show that enlarging the opening of the lateral hole of the endobronchial tube makes it easier to maintain optimal position, and to correctly reposition the DLT, if required, after turning the patient to lateral position. Although we compared optimal tube position (P1) with non-optimal (P2, P3 or P4) or acceptable tube positions (P1, P2) with non-acceptable tube position (P3, P4), the same conclusions can be drawn. The modified tube needs less repositioning after turning the patient to the lateral thoracotomy position. This has the potential to minimize tube manipulations during thoracic anesthesia, which is potentially deleterious with respect to ventilation and gas exchange¹⁴ and may put the patient at risk of contamination or aspiration.

Our study has several limitations. First, we selected ideal positioning of the tube (P1) as the primary outcome. The P2 position probably represents adequate tube placement, but we speculated that a partially aligned tube (P2) can be the precursor of a more significant intraoperative misalignment (P3 or P4), which may lead to obstruction of the RUL bronchus. In the clinical setting, it is not known if partial misalignment of the lateral orifice with the RUL orifice actually increases the risk of hypoventilation or atelectasis of the RUL. Inability to visualize the RUL bronchus is probably more problematic, as the cuff can completely occlude the RUL bronchus. Thus, P1 is probably the best predictor of adequate tube placement. Moreover, our method to describe and score tube positioning is well defined and objective (Figure 3). A second limitation is that the study protocol terminated before OLV was initiated, because the main interest of our protocol was to evaluate the influence of lateral positioning of the modified R-DLT. It will be interesting

in future studies to determine whether the modified Broncho-Cath™ tube can reduce the need for tube manipulation during surgery, and the incidence of RUL atelectasis. A third limitation was our inability to conduct a blinded study, since tube modification was easily recognized during FOB examination. In order to minimize bias, we chose to use post-procedural video evaluation involving two external examiners who reached consensus on each video recording. This is the first time that this method of evaluating DLT positioning has been reported. Finally, we did not observe any adverse events with the use of the modified or the standard R-DLT.

In conclusion, the modified Broncho-Cath™ R-DLT with a widened aperture of the distal orifice on the endobronchial portion of the tube is associated with a higher incidence of adequate tube positioning, when compared to the standard Broncho-Cath™ R-DLT for OLV. Furthermore, the modified Broncho-Cath™ R-DLT requires less manipulation following rotation of the patient to the lateral thoracotomy position. This modification may be particularly beneficial whenever R-DLTs are specifically indicated to facilitate selective lung ventilation during thoracic surgical procedures. Further studies are warranted.

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