Lung sonography is useful for the initial detection of left-sided double lumen tracheal tube position in both novice and expert; a randomized prospective crossover study

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Abstract

Background Detecting the position of the double lumen tube (DLT), lung sonography, can be an effective technique and may provide more detailed information than chest auscultation. However, the diagnostic efficacy of lung sonography for determining DLT position can differ between novice and expert.

Methods We enrolled and allocated ninety patients into two groups; one group using chest auscultation and the other using lung sonography for the determination of DLT position. In both groups, two repeat-assessments were provided by two independent examiners; first by a novice, and second by an expert. The primary outcome was the overall accuracy, sensitivity, specificity, positive or negative predictive values between novice and expert in confirming the position of the left-sided DLT. In both groups, final position was confirmed by a fiberoptic bronchoscopy.

Results Both using auscultation and sonography, novices and experts showed similar diagnostic efficacy. However, in patients using sonography, both novice and expert showed better outcomes than in patients using chest auscultation. In receiver operating characteristic analysis, lung sonography seemed to show a better predictability in incorrect DLT position than chest auscultation, especially by experts.

Conclusion Lung sonography showed a better diagnostic efficacy for detecting DLT position than chest auscultation. Furthermore, using lung sonography, novice investigator may perform similar assessment for identifying incorrect DLT position to expert.

Background

A double lumen tube (DLT), especially, the left-sided double lumen tube (LDLT), is commonly used for the lung isolation in one-lung ventilation during thoracic surgery. To achieve an effective lung separation, the endobronchial cuff should be located at an appropriate position.[1] A rapid and accurate confirmation of the DLT position is required to decrease the risk of hypoxia and airway trauma.[2] The fiberoptic bronchoscopy (FOB) has been a widely used technique to confirm the optimal position of the tube, there can be a clinical situation which may not be available due to a lack of device.[3, 4] Furthermore, FOB usually requires a specific knowledge and trained clinical skills by an expert.

Although the chest auscultation is an easy and rapid first-line technique for initial detecting DLT position, its findings are subjective and less validated to accurately identify the incorrect DLT position.[5–7] Compared to chest auscultation, lung sonography can be a non-invasive and effective technique for checking the position of the endotracheal tube even under disturbing and emergent situations.[8–12] Even in thoracic surgery, lung sonography can be a superior method for determining DLT position.[13] However, either using chest auscultation or lung sonography, determining an incorrect DLT position may require a clinical experience and show different results between a novice and an expert investigator. Therefore, we compared the diagnostic efficacy of chest auscultation or lung sonography between novices and experts for verifying the appropriate insertion of LDLT.

Methods

Patients

Ninety adults with age 19 years or more, who were scheduled to undergo thoracic surgery with one-lung ventilation, with an American Society of Anesthesiologists physical status classification of 1–3, were enrolled in this study. The exclusion criteria were body mass index $<18.5 \text{ kg/m}^2$ or $>35.0 \text{ kg/m}^2$, significant thoracic cage deformity due to spine disease or other medical conditions, history of tracheostomy, predicted difficulty in the airway requiring strategies other than direct or video laryngoscopy, history of any type of pulmonary resection or pleurodesis, and history of pleural diseases such as pleural effusion, and tuberculous pleurisy. This study was approved by the Kyung Hee University Hospital at Gangdong Institutional Review Board (IRB#: KHNMC 2017–03–017–001), and written informed consent was obtained from all the subjects participating in the trial. The trial was registered prior to patient enrollment at the national clinical research registry (<http://cris.nih.go.kr>, KCT0002858).

Allocation and randomization

The enrolled patients were randomly assigned according to the initial identifying techniques, chest auscultation or lung sonography. In patients using chest auscultation or lung sonography, the position of the DLT was initially identified by corresponding technique. For randomization of participants, a computer-generated, the random 4 and 6 blocks technique was used. An independent third-party kept the random assignment table for 90 participants before surgery, and notified the research team, of the patient allocation, on the day of the surgery.

Procedures

On arrival at the operating room, standard monitoring including electrocardiogram, peripheral oxygen saturation, end-tidal carbon dioxide concentration, bispectral index, and non-invasive blood pressure monitoring was applied. After preoxygenation with 100 % oxygen for 5 minutes, anesthesia was induced with target-controlled infusion of propofol (Schnider model, effect-site concentration: $4.0 \text{ } \mu\text{g/ml}$) and remifentanyl (Minto model, effect-site concentration; 4.0 ng/ml). Rocuronium bromide was administered to facilitate tracheal intubation. The patients were intubated with LDLT, 37 French size for men and 35 for women, respectively, with direct or video laryngoscopy. Following the passage of the endobronchial cuff through the vocal cords, the DLT was rotated 90 degrees counterclockwise, and subsequently, advanced softly for 28 to 30 cm, according to the anesthesiologist's decision, considering each patient's height. Following intubation, both the tracheal and the bronchial cuffs were inflated, and the initial depth of insertion was recorded. Tracheal intubation was confirmed by the presence of appropriate end-tidal carbon dioxide curve in both groups.

In patients using chest auscultation, the assessment to verify the correct placement of LDLT was made in following way: First, the upper and lower chest sounds were auscultated, bilaterally, without lumen clamping. Second, auscultation was repeated after clamping the tracheal lumen. Finally, the upper and

lower chest sounds of the left lung was auscultated. The correct placement of the LDLT was ensured by the presence of bilateral, symmetric lung sounds before tracheal lumen clamping and the subsequent decrease of the entire right lung sound with accompanying symmetric lung sounds in the upper and lower left lung after clamping the tracheal lumen.

The patients using lung sonography were examined for the presence of sliding sign without lung pulse on both sides of the chest on scanning for pleura movement in the craniocaudal direction from the anterior mid-clavicular line to 12th rib. Subsequently, the tracheal lumen was clamped, and the examination was repeated, bilaterally, for the entire chest. The correct placement of the LDLT was confirmed by the observation of sliding sign detected in the whole chest area, before and after clamping the tracheal lumen, followed by the emergence of right lung pulse sign with a loss of sliding sign, whereas the sliding sign in the left lung was continuously observed with an absence of a lung pulse sign.

In both patients using chest auscultation and lung sonography, two independent anesthesiologists confirmed the placement and appropriate depth of LDLT. One was a novice resident with an experience of less than 15 cases of lung sonography despite of familiar with chest auscultation. The other was an expert staff with experience of more than 200 cases of lung sonography and also familiar with chest auscultation. In each case, the novice resident assessed first, and the expert staff performed the second assessment. Because each investigator recorded their result in a separated sheet and left the room immediately, each assessment result was blinded. For final confirmation of LDLT position, FOB was performed by another blinded expert staff who did not participate in any of the previous procedures. A correct LDLT position can be defined as follows: (1) through the tracheal lumen, the bronchial cuff location below the carina and just slightly visible in the main left bronchus (2) through the bronchial lumen, the tip of bronchial tube was above the second carina.

Outcome measurement

The primary outcome was the overall accuracy, sensitivity, specificity, positive or negative predictive values (PPV or NPV) between novice and expert in confirming the position of the LDLT and matching the observation of fiberoptic bronchoscopy in both two groups. To assess each parameter, a contingency table was made as Table 1.

Secondary endpoints in this study were the time from intubation to the first assessment by each anesthesiologist, total intubation attempts, tracheal tube malposition, tracheal or bronchial cuff injury, bronchial cuff leakage following position change, and the incidence of intubation-related complications such as a sore throat or hoarseness.

Sample size calculation and statistical analyses

On the basis of a previous study,[9] we calculated the requirement of 41 patients per group for an experimental design. With a possibility of 10% loss due to unexpected circumstances, we elected to recruit 45 patients per group into the study. Continuous data were analyzed by the Student's t-test or the

Mann-Whitney U test depending on the presence of normality. Categorical data were analyzed using Chi-square analysis or Fisher's exact test when applicable. Receiver operating characteristic curve (ROC) analysis and area under curve (AUC) was used to assess the predictability of incorrect LDLT position. Statistical analyses were performed using a standard statistical program (SPSS 21.0, Chicago, IL, USA). All values are expressed as a mean $\pm$ standard deviation, median (quartiles), or number (percent).

Results

Ninety patients were enrolled, and two patients were excluded as refused participation after the surgery. Finally, eighty-eight patients were allocated and analyzed (Fig 1). Since pleural adhesion which was not detected in preoperative work-up was revealed after surgery in eighteen patients, a second analysis with patients' data after exclusion of undiagnosed pleural adhesion was performed. The patients' demographic data and postoperative outcomes are shown in Table 2. There were no significant differences between the patients using chest auscultation and using lung sonography.

Parameters showing diagnostic efficacy of each technique is provided in Fig 2 and Table 3. Also, patients' data after exclusion of undiagnosed pleural adhesion was provided. Regardless of using auscultation or sonography, both novice and expert showed similar accuracy, sensitivity, specificity, PPV and NPV. However, when using lung sonography, both novice and expert showed higher specificity and PPV, compared with using chest auscultation. After exclusion of patients with undiagnosed pleural adhesion, similar results were shown compared with overall data. However, when using lung sonography, the diagnostic efficacy more improved in both novice and expert than using chest auscultation.

In ROC curve analysis, experts showed higher but statistically insignificant AUC for predicting incorrect LDLT position in using auscultation or sonography (0.671 vs. 0.559, $P = 0.294$ in using chest auscultation; 0.665 vs. 0.699, $P = 0.768$ in using lung sonography, respectively). After exclusion of patients with pleural effusion, experts showed higher but statistically insignificant AUC than novice using lung sonography (0.817 vs. 0.667, 95% confidence interval = -0.055 to 0.355 , $P = 0.155$).

Discussion

In the present study, lung sonography, in both novice and expert, showed more diagnostic efficacy for detecting LDLT position than chest auscultation. Moreover, in using lung sonography, novice showed similar result to expert.

In lung isolation techniques, it is crucial to detect the incorrect position of the LDLT, since incorrect DLT position may cause intraoperative hypoxia or increased airway pressure.[2] In our study, lung sonography showed a higher specificity and a PPV by both novice and expert, that is, an incorrect finding in lung sonography was significantly correlated with true incorrect position of DLT as observed. Clinically, in using DLT, we surmise that the detection of incorrect position is more important than the confirmation of the correct position because incorrect position of DLT may cause more serious problems than correct

position.[2] Chest auscultation showed a high sensitivity in both novice and expert, however, its low specificity and PPV implies that chest auscultation is less useful to detect incorrect DLT position than lung sonography. Furthermore, lung sonography can provide additional information such as lung consolidations, pneumothorax, atelectasis to investigators.[9, 11]

Both chest auscultation technique and lung sonography have their own advantages and disadvantages for detecting the DLT position. Chest auscultation is an easy and rapid technique but can be subjective based on investigator's findings.[5–7] Compared with auscultation, lung sonography can provide a visual, objective findings of the pleural movement with less inter-observer variance. According to our results, the difference of primary outcomes between novice and expert was smaller in using lung sonography than in using chest auscultation. These observations can support that the in even novice investigator, lung sonography can be relatively easy to perform and may achieve a favorable result. However, in our result, the diagnostic efficacy of lung sonography in expert was increased after patients with undiagnosed pleural effusion excluded. It implies that lung sonography can achieve more reliable results in well trained expert than in novice.

Although lung sonography had higher diagnostic efficacy than chest auscultation for detecting incorrect DLT position, it would be challenging to replace FOB as a confirmative technique and exclude chest auscultation. As well as chest auscultation, lung sonography is an indirect technique using pleural movement in ventilating lung. To confirm DLT position, FOB to directly visualizing DLT location is still a gold standard. Although each technique shows high sensitivity, low accuracy, and specificity cannot make it replace for FOB. Thus, as we used it for the initial measurement and confirmed DLT position by FOB, chest auscultation and lung sonography should not exclude FOB in confirming DLT position. Moreover, despite its usefulness, lung sonography may be affected by device availability or investigator's experience. Compared to sonography, chest auscultation requires no time to prepare a device and no need to be trained, thereby being capable of quick assess.

Our study has a few limitations. First, we did not consider the undiagnosed pleural adhesion. Although we excluded patients with pleural disease preoperatively, the presence of pleural adhesion is difficult to be detected by plain radiography or computed tomography of the chest. Because 18 patients were excluded, the decreased number of patients were analyzed, thereby data being less powered. If a similar study would be conducted with all patients with no pleural adhesion, it may provide more significant results for expert superiority. Second, we did not compare the confirmative effect of two techniques in the present study by investigating the parameter of the incidence of ipsilateral lung collapse. Still, FOB remains the gold standard for confirming DLT position and should be applied whenever available, following intubation with DLT. Third, in the case of using the right-sided DLT for one-lung ventilation, our result can be limited. In addition to bronchial limb positioning, a hole for right upper lobe ventilation should be aligned for the correct right-sided DLT position. Thus, special and deliberate consideration for DLT position is required in using right-sided DLT.

Conclusions

Lung sonography has a better diagnostic efficacy than chest auscultation for initial detecting LDLT position both in novice and expert. Furthermore, in novice investigator, lung sonography enables similar assessment to expert for identifying DLT position.

Abbreviations

DLT: Double lumen tube

LDLT: Left-sided double lumen tube

FOB: Fiberoptic bronchoscopy

PPV: Positive predictive value

NPV: Negative predictive values

ROC curve: Receiver operating characteristic curve

AUC: area under curve

Declarations

Ethics approval and consent to participate

Ethics approval from the institutional review board and written informed consent was obtained from the patient. The consent form will be provided upon request.

Consent for publication

Written informed consent was obtained from the participants for publication of this article and any accompanying tables/images. A copy of the written consent is available for review by the Editor of this journal.

Availability of data and material

The datasets of the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Y. G. conducted intraoperative study protocol and was a major contributor in writing the draft of the manuscript; B. J.L also conducted study protocol and provided a critical revision; Y. S.J followed up the patient and collected postoperative data; H. S., as a corresponding author, conducted the entire study and provided critical revision. All authors read and approved the final manuscript.

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Tables

Table 1. Contingency table to assess the accuracy of chest auscultation and lung sonography in confirming the position of left-sided double lumen tube.

		Auscultation or lung sonography	
		Correct	Incorrect
Fiberoptic bronchoscopy	Correct	A	B
	Incorrect	C	D

Fiberoptic bronchoscopy is a gold standard to confirm the position of left-sided double lumen tube.

The accuracy was calculated as follows: Accuracy (%) = $(A+D)/(A+B+C+D) \times 100$

Table 2. Demographics and postoperative outcomes

Variables	Using chest auscultation (n=45)	Using lung sonography (n=43)	P
Age (years)	62 [55–70]	66 [60–75]	0.102
Sex (Male/Female)	17 (38%)/ 28 (62%)	19 (44%)/ 24 (56%)	0.543
Body mass index (kg/m ²)	23.6 [21.4–25.6]	23.0 [22.1–25.4]	0.884
Measurement time (secs)			
By Novice	47 [40–55]	110 [80–161]	<0.0001
By Expert	43 [36–52]	104 [80–125]	<0.0001
Confirmed by fiberoptic bronchoscopy	74 [54–127]	117 [69–180]	0.027
Tidal depth (cm)	29.0 [27.5–29.0]	29.0 [28.0–29.0]	0.972
Alveolar depth (cm)	29.0 [28.0–30.0]	28.5 [27.3–29.4]	0.508
Endotracheal tube position			
Too deep	10 (22%)	6 (14%)	0.318
Too shallow	8 (18%)	7 (16%)	0.853
Anesthesia time (minutes)	265 [160–325]	253 [180–305]	0.582
Crystallloid amount (ml)	1020 [530–1700]	1045 [620–1320]	0.644
Urine output (ml)	325 [170–540]	300 [180–390]	0.559
Postoperative outcomes			
Sore throat incidence	23 (51%)	20 (47%)	0.668
Sore throat score	2.6 [0.9–5.1]	2.0 [0.0–4.0]	0.200
Hoarseness	5 (11%)	10 (23%)	0.132

Data are expressed as median [interquartile range] or number (%).

Sore throat score was measured by a Visual Analogue Scale using a 10-cm-long stick.

Table 3. Primary outcomes for group auscultation and sonography

		Accuracy	Sensitivity	Specificity	PPV	NPV
<i>In all patients (N = 88)</i>						
Group auscultation <i>n</i> = 45	Novice	53.5%	90.0%	21.7%	50.0%	71.4%
	Expert	64.4%	95.2%	37.5%	57.1%	90.0%
Group sonography <i>n</i> = 43	Novice	68.3%	73.1%	60.0%	76.0%	56.3%
	Expert	69.8%	71.4%	66.7%	80.0%	55.6%
<i>In patients after unanticipated pleural adhesion excluded (N = 70)</i>						
Group auscultation <i>n</i> = 37	Novice	54.3%	93.3%	25.0%	48.3%	83.3%
	Expert	62.2%	93.8%	38.1%	53.6%	88.9%
Group sonography <i>n</i> = 33	Novice	68.8%	75.0%	58.3%	75.0%	58.3%
	Expert	81.8%	89.5%	71.4%	81.0%	83.3%

Data are expressed as percent (%).

PPV: positive predictive value, NPV: negative predictive value

Figures

Figure 1

A study flowchart

Figure 2

Detailed accuracy, sensitivity, specificity, positive predictive value and negative predictive value of novices and experts in patients using chest auscultation and lung sonography. Blue markers and lines indicate the result from a novice anesthesiologist. Red markers and lines indicate the result from an expert anesthesiologist.

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