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Review article

A COMPARATIVE STUDY OF TWO LUNG VENTILATION VERSUS ONE LUNG VENTILATION FOR VIDEO-ASSISTED THORACOSCOPIC ESOPHAGECTOMY IN SEMIPRONE POSITION

(AIRWAY MANAGEMENT FOR THORACOSCOPIC ESOPHAGECTOMY)

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Summary

Introduction: *Thoracoscopic esophagectomy is a complex procedure used for the treatment of esophageal cancer in which One Lung Ventilation (OLV) anesthesia is often used with several disadvantages associated mainly with respiratory system. But nowadays, the Two Lung Ventilation (TLV) approach has become popular due to reduction in induction time of anesthesia and better perioperative outcomes. The aim was to compare intraoperative respiratory functions and perioperative surgical parameters between One Lung Ventilation and Two Lung Ventilation anesthesia.* ***Methods:*** *In this randomised, prospective, double-blind study, a total of 80 adult patients (40 patients in each group), posted for video assisted thoracoscopic esophagectomy were included, from January 2021 to August 2022. In the OLV group (40 patients), a double-lumen endotracheal tube was used for One Lung Ventilation, and in the TLV group (40 patients), a single-lumen endotracheal tube was used for Two Lung Ventilation anesthesia. Intraoperative respiratory functions (PaO_2, $PaCO_2$,) and perioperative surgical parameters were observed. Student's t-test and Chi-square tests were applied where appropriate. Statistical significance was defined as $P < 0.05$. (SPSS Version 20, IBM, USA)* ***Results:*** *All 80 patients underwent the thoracoscopic esophagectomy surgery successfully. The Two Lung Ventilation approach had better perioperative lung functions with statistically significant difference in PaO_2 values (P value < 0.0001) at one hour and two hours of thoracoscopy, less preparation time for anesthesia (P value 0.014) and thoracoscopy operative time (P value 0.002) without any perioperative complications.* ***Conclusion:*** *Two Lung Ventilation anesthesia is a convenient and safe approach for thoracoscopic esophagectomy with better perioperative respiratory outcomes.*

Key words: *Esophagectomy; One Lung Ventilation ; Semiprone; Two Lung Ventilation*

Introduction:

Thoracoscopic Esophagectomy is a very complex surgical procedure that has become an alternative to traditional minimally inavasive surgery[1,2]. In 1992, Cuschieri et al. first described thoracoscopic esophagectomy in the prone position, after which it gained rapid popularity with the use of One Lung Ventilation (OLV)[3,4]. However, OLV has several disadvantages associated with the respiratory system, and it presents difficulties in both the induction and maintainance of anesthesia[5,6]. In 2006, Palanivelu reported the use of Two Lung Ventilation (TLV) in thoracoscopic esophagectomy in the prone position[7]. In TLV, shorter anesthesia time and better perioperative outcomes were noted[8,9].

Thus, the goal of this study was to evaluate and compare the outcomes of One Lung Ventilation and Two Lung Ventilation in the semiprone position during video-assisted thoracoscopic oesophagectomy (VATS).

Objectives:

The primary objective was to compare intraoperative respiratory functions (PaO_2, $PaCO_2$) between One Lung Ventilation and Two Lung Ventilation anesthesia.

Secondary objectives inlcude comparing preparation time for induction of anaesthesia, thoracoscopy operating time, blood loss during thoracoscopy, and postoperative hoarseness of voice.

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Methodology:

This is a comparative, prospective, randomised, and double-blind study done from January 2021 to August 2022. After obtaining written, informed consent from all patients and institutional review committtee approval (IRC/2024), a total of 80 patients were included for video-assisted thoracoscopic (VATS) esophagectomy for the study and randomised into two groups (40 patients in each group), named One Lung Ventilation (OLV) and Two Lung Ventilation (TLV) groups. (Figure 1- CONSORT chart). We included patients of either gender with esophageal cancer, ages between 30 and 70 years, and with body mass index (BMI) between 15 and 30 kg/m^2. We excluded patients with predicted difficult intubation, distant metastasis, or those with cardio-respiratory, hepatorenal diseases and neurological disorder.

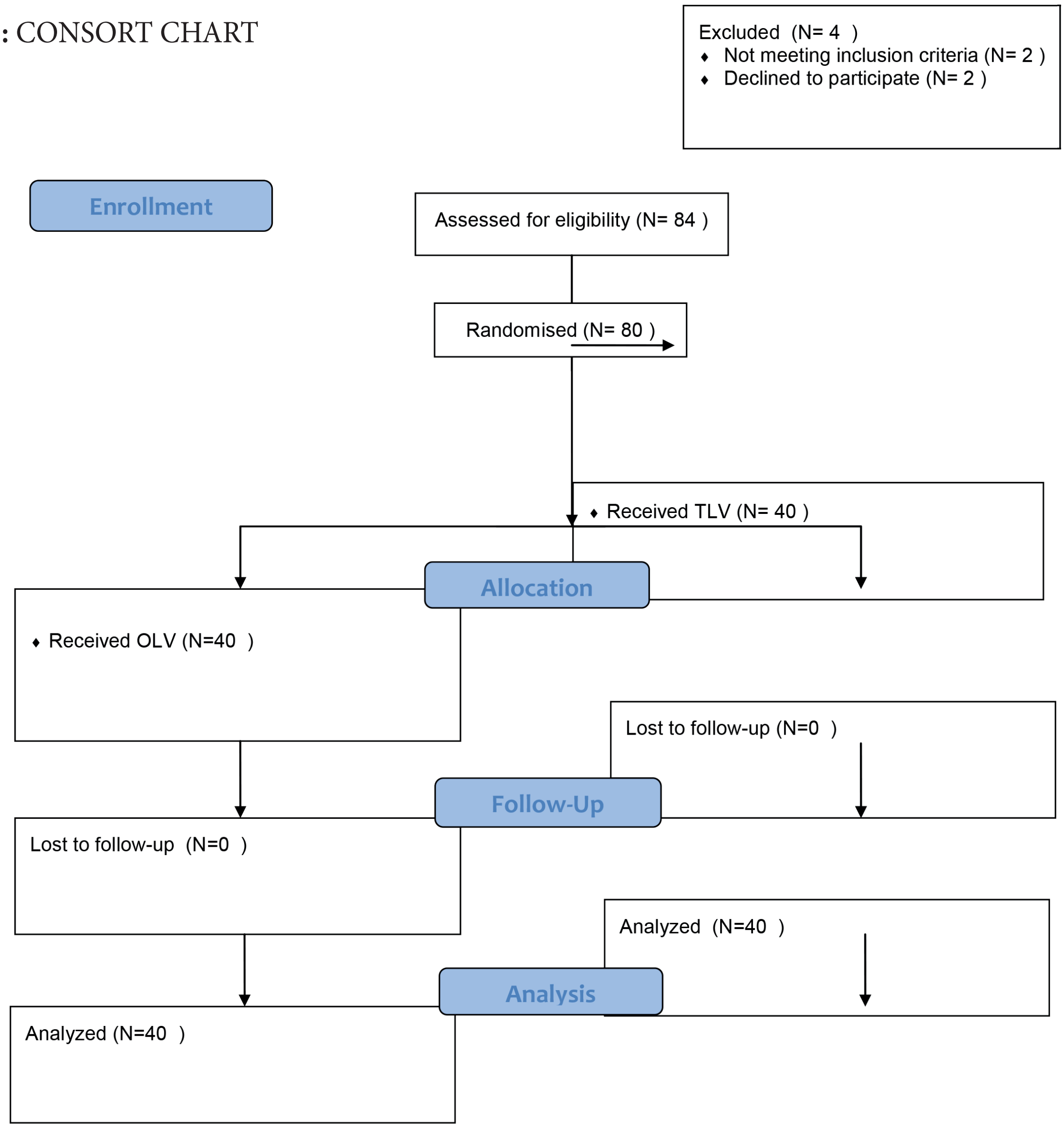
Randomisation was performed using computer-generated numbers. Patients were blinded to their group allocation, and the anesthesiologist involved in data collection was also unaware of the group assignment.

Forty patients underwent surgery with OLV using a double-lumen endotracheal tube (DLET), while remaining forty patients underwent surgery with TLV in which a single-lumen endotracheal (SLET) portex cuffed tube was used.

We evaluated all patients preoperatively and kept them nil by mouth according to standard guidelines. As per our institute protocol, patients were given tablet Ranitidine 150 mg (antacid) orally and tablet Lorazepam 0.5 to 1 mg (anxiolytic) orally night before surgery.

In the operating room, an electrocardiogram, pulse oximeter, noninvasive blood pressure monitors were attached to patients. The patients were

Figure 1: CONSORT CHART



premedicated with inj. Glycopyrolate (0.004 mg/kg), Ranitidine (1 mg/kg), inj. Ondensetron (0.1 mg /kg) intravenouly

In all cases, a central venous catheter was inserted into the right internal jugular vein under ultrasound guidance, and an epidural catheter was placed in the upper lumbar region before operation under local anaesthesia. Patients were induced with Inj. Propofol (2 mg/kg), inj. Fentanyl (2 mcg/kg) and inj. Succinylcholine (2 mg/kg) intravenously. The DLET and SLET were inserted by a senior anaesthesiologist with experience in more than 25 DLET and SLET insertions. Oral intubation was done using double-lumen endotracheal tube in OLV and single-lumen endotracheal tube in TLV. After intubation, the tube placement was confirmed by auscultation and capnography. Additionaly we confirmed proper DLET placement with a fiberoptic bronchoscope as well. Appropriate sized Ryle's tube was used. Anaesthesia was maintained with inj. Vecuronium (0.1 - 0.2 mg/kg iv. bolus, followed by infusion), Sevoflurane (0.6 - 2 %), and a mixture of oxygen and medical air (50:50).

All the patients were positioned in the semi-prone position with right arm abducted, fixed, and resting on an armrest. The head was supported by a head ring and carefully positioned to prevent neck rotation and tube displacement.

The three-port VATS technique was used, with the observation port placed in the right 5th intercostal space in midaxillary line with 10 mm scope. Two working ports, 12 mm each, were placed in the right 4th and right 8th intercostal space in the posterior axillary line for intra-thoracic procedure. Carbon dioxide pneumothorax was created to enhance exposure of the operative field.

The ventilator parameters during VATS were different for both groups. In the TLV group, tidal volume was 6 ml/kg of predicted body weight, positive end expiratory pressure was set to 5 cmH_2O, and respiratory rate was 16-18/min. In the OLV group, tidal volume was 4 ml/kg of predicted body weight, positive end expiratory pressure was set to 5 cmH_2O, and respiratory rate was 20-22/min. The mechanical ventilator settings were adjusted to achieve lower driving pressure with the most satisfactory SpO_2 (94-95%). Two cycling recruitment maneuvers were performed, one at the beginning and one at the end of OLV.

The pressure used for capnothorax was 6 mmHg. Continuous perioperative monitoring of cardio-respiratory conditions included pulse rate, NIBP (systolic, diastolic, and mean arterial pressure), SpO_2, EtCO2, and urine output.

Respiratory parameters (PaO_2 and $PaCO_2$) were recorded at baseline, and one and two hours after the initiation of the thoracoscopic procedure. Perioperative surgical parameters observed and recorded for both groups included preparation time for anesthesia untill DLET/SLET insertion and confirmation, blood loss during thoracoscopy, thoracoscopic operating time, respiratory complications, and postoperative hoarseness of voice.

The artificial pneumothorax was terminated after the completion of thoracoscopic mobilization of the esophagus. Patients were then turned into a supine position. A laparotomy procedure was performed and the lower esophagus was dissected. A gastric tube was made and anastomosis was completed in the left cervical region.

Sample size:

Based on the Hardy-Weinberg principle, the sample size was calculated using the formula $n=4pq/E^2$, where *p* is the prevalence of esophagectimy procedures at our hospital, *q is* 1-p, and *E* is the allowable error. In this study, the prevalence value was 60% and the allowable error was 10% of the prevalence. By applying the formula, at least 34 patients were required for each group. Forty patients were included in each group to compensate for potential dropouts.

Statistical analysis:

The statistical analysis was conducted using SPSS software (version 20, IBM cap. USA). Data were presented as mean ± SD and as numbers. Continuous variables were analysed using unpaired Student's t-test, while categorical variables were analysed using chi-square test with Yate's correction. A P value < 0.05 was considered statistically significant.

Results:

A total of 80 patients underwent surgical treatment, among them 40 patients underwent surgery with OLV and 40 patients with TLV.

The clinical characteristics of two groups are summerized in Table 1. There were no significant differences between two groups in terms of age, gender, smoking and alcohol numbers, tumor staging, or tumour location.

Arterial blood gas (ABG) analysis of PaO2 and PaCO2 was conducted at baseline, and after one and two hours of artificial pneumothorax. Table 2 shows that at baseline (preinduction) phase no differences in these parameters occurred. However, after one and two hours of artificial pneumothorax, PaO2 was significntly better in the TLV group, while PaCO2 levels remained comparable between the two groups.

As shown in Table 3, perioperative parameters such as preparation time of anaesthesia and thoracoscopic operative time were found to be significantly shorter in the TLV group compared to the OLV group. Intraoperative blood loss and post-operative hoarseness of voice were also found to be lower in the TLV group compared to the OLV group, but these differences were not statistically significant.

Table1: Patients and Tumor Characteristics

Characteristics	One Lung Ventilation (N=40)	Two Lung Ventilation (N=40)	P Value
Age (years)	56.73 ± 7.24	57.92 ± 5.41	0.4075
Weigh (kg)	48.22 ± 5.12	46.65 ± 6.33	0.2263
Gender Male : Female (N)	32:8	33:7	0.774
Smoking Yes/No (N)	17/23	16/24	0.82
Alcohol Yes/No (N)	18/22	15/25	0.495
Neoadjuvant Chemotherapy Yes/No (N)	4/36	5/35	0.723
Neoadjuvant Radiotherapy Yes/No (N)	3/39	4/36	0.64
Tumor Staging 1/2/3/4 (N)	4/ 13 / 21 / 2	5 / 10 / 24 / 1	0.479
Tumor location Upper/Middle/ Lower (N)	2 / 30 / 8	4 / 27 / 9	0.480

N-Number; data presented as mean ± standard deviation; Number; kg-kilogram

Table 2: Intraoperative respiratory parameters analysis

Intraoperative respiratory parameters	One Lung Ventilation	Two Lung Ventilation	P Value
Baseline PaO_2	75.60 ± 9.42 (70-86)	74.82 ± 8.25(70 -88)	0.694
1 hour PaO_2	131.35 ± 22.37 (88-145)	204.20 ± 19.46 (172-224)	<0.0001
2 hour PaO_2	291.80 ± 19.62 (192-311)	385.10 ± 11.24 (357-397)	<0.0001
Baseline $PaCO_2$	38.35 ± 4.26 (29- 43)	38.52 ± 4.48 (29-44)	0.862
1 hour $PaCO_2$	49.37 ± 6.74 (41-59)	48.54 ± 8.62 (40-58)	0.632
2 hour $PaCO_2$	42.98 ± 6.28 (37-51)	42.69 ± 6.53 (38- 53)	0.840

Data presented as Mean ± Standard deviation; Range; N – Number;
PaO_2- arterial blood oxygen tension in mmHg;
$PaCO_2$- arterial blood carbon dioxide tension in mmHg

Table 3: Perioperative Parameters and Hoarseness of Voice

Parameter	OLV (N-40)	TLV(N-40)	P Value
Preparation Time (min)	69.03 ±14.59	61.51 ± 12.32	0.014
Thoracoscopy Operative Time (min)	149.06 ± 42.46	120.30 ± 41.39	0.002
Blood loss(Ml)	205.26 ± 121.91	198.78 ± 86.49	0.784
Hoarseness of voice in postoperative period (N)	12	9	0.6113

Min- Minutes; Data presented as Mean ± Standard deviation; N – Number;
Ml-Milliliter

Discussion:

This study found that the Two Lung Ventilation is an easy method of administering anesthesia, while also providing good exposure of the surgery area using the VATS technique. In our study there were no significant differences in patient demographics or tumour characteristics between the two groups. However, a significant difference in PaO_2 was observed after CO_2 insufflation, with comparable differences in $PaCO_2$ between the groups. Notably, all 80 patients underwent VATS surgery without needeing to convert to open thoracotomy, and no perioperative pulmonary complications were reported.

Previously, One Lung Ventilation using a double-lumen endotracheal tube in the prone or semiprone position was the only choice in thoracoscopic esophagectomy since 1992[1]. In this study, intubation of the left main bronchus was performed for left-lung ventilation, allowing the right lung to be collapsed and for the right pneumothorax to be induced using carbon dioxide to enhance visualisation of the surgical field.

One Lung Ventilation with DLET has several disadvantages, including difficulties with intubation, longer anaesthesia adiministration time, risks of intraoperative hypoxemia and tracheobroncheal injury, etc. Additionally, intraoperative translocation of DLET is frequentl, and repositioning is required which interrupts the surgery. One Lung Ventilation in thoracoscopy also requires good preoperative pulmonary functions. Patients having pre-existing poor pulmonary function may not tolerate OLV well. Severe hypoxemia may happen in these patients. Patients may develop postoperative pulmonary atelectasis and infection[5,6].

The preparation time of anesthesia was defined as the duration from the moment the patient was placed on operation table untill the insertion and confirmation of DLET/SLET. It included application of monitors, insertion of intravenous and central line catheters, placement of the epidural catheter, and induction of anesthesia with SLET or DLET. The DLET insertion and it's position confirmation with fibreoptic bronchoscopy require more time as compared to SLET insertion and confirmation. This is the reason for a significant difference in the preparation time of anesthesia between the OLV and TLV groups.

In a study performed in 2006, Two Lung Ventilation anesthesia was performed in 130 patients for thoracoscopic esophagectomy in the prone position, with less incidences of adult respiratory distress syndrome and pneumonia, 0.77% and 1.54% respectively[7]. Partial ventilation of the right lung reduces venous effect to a great extent. In the prone position, functional residual capacity is greater compared to the supine position, leading to better maintenance of the ventilation-perfusion ratio and hypoxia and hypercarbia are avoided. Intermittent right lung ventilation results in opening of the alveoli, which helps in preventing postoperative atelectasis. This is not possible with double-lumen tube in which one lung is completely deflated throughout the procedure[7].

Additionally, hemodynamic changes occured due to carbon dioxide insufflation during thoracoscopy, which created tension in the pneumothorax resulting in a significant decrease in cardiac index, mean arterial pressure (MAP), stroke volume, and increases in central venous pressure [10]. In Japan, 14 patients who underwent surgery which demanded prone position with Two Lung Ventilation while maintaining stable perioperative hemodynamics and oxygenation developped artificial pneumothorax[11]. Luigi Bonavina and colleagues studied 30 patients for thoracoscopic esophagectomy in the prone position with TLV and suggested that the patients in the prone position showed significant improvement of global oxygen delivery and significantly lower mean pulmonary shunt fraction. Perioperative hemodynamic parameters remained stable throughout surgery[12]. In 2014, Lei Cai et al. studied 147 patients who underwent surgery with OLV and TLV in Xijing Digestive Hospital, and have shown that TLV had better intraoperative and postoperative outcomes than OLV[8]. The study conducted by Ibrahim Baloch and colleagues performed on 60 patients in Combined Military Hospital Rawalpindi has shown that TLV has better perioperative outcomes[9]. In Saga University Hospital, Yoshiniri and colleagues evaluated 67 patients undergoing surgery using TLV via a carbon dioxide pneumothorax and found improvements in respiratory mechanics[13].

In our study, the values of PaO2 after artificial pneumothorax are reported higher in the TLV group compared to the OLV group. There is a significant decrease in anesthesia time, operative time as well in the TLV group, while the blood loss was comparable between the groups. SpO_2 was > 94 % in all patients. The benefits of the semi prone position are increase in functional residual capacity and avoidance of inequalities of ventilatory and pulmonary blood flow, which makes hypoxemia less likely[12]. Kim and colleagues observed shorter operative times and less blood loss using single-lumen tube for thoracoscopic bleb resection in 46 patients [14].

Due to a larger diameter and angulated tip, the placement of double-lumen endotracheal tube can lead to tracheobroncheal injury and vocal cord trauma[15]. In our study, postoperative respiratory complications were decreased in the TLV group. Twelve patients in the OLV group had postoperative hoarseness of voice, while this was reported in only nine patients in the TLV group. Heike Knoll and colleagues studied 60 patients for airway injuries after One Lung Ventilation and demonstrated the increased incidence of sore throat and hoarseness of voice in double-lumen tube with OLV[16]. In the series by Cheng and colleagues comparing SLET to DLET, the incidence of postoperative hoarseness of voice dropped from 31.7% to 13.8%[17].

In a systematic review, it is concluded that Two Lung Ventilation may be an alternative to One Lung Ventilation in trans-thoracoscopic esophagectomy, as it has resulted in better oxygenation and a decrease in postoperative inflammatory response[18]. Lung protective ventilation is also recommended to improve oxygenation, decrease inflammatory response, and to decrease pulmonary complications after esophagectomy[19].

Limitations:

This study is a single-centered, hospital-based research work and it might result in selection bias. Long term follow up for cardio-respiratory complications and the duration of hospital stay are not considered in this study.

Conclusion:

In comparison to One Lung Ventilation, Two Lung Ventilation is a feasible and safe approach of administering anesthesia in the semiprone position for video assisted thoracoscopic esophagectomy. It offers better intraoperative respiratory parameters, shorter preparation time for anesthesia, reduced thoracoscopic procedure time, and no perioperative complications.

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