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A comparative study of two- versus one-lung ventilation: for needlescopic bleb resection

Running head: Bleb resection using two-lung ventilation

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ABSTRACT

Background: This prospective study was conducted to evaluate the feasibility of two-lung ventilation with low tidal volume anesthesia compared to one-lung ventilation used for needlescopic bleb resection.

Methods: Patients with spontaneous pneumothorax that underwent bleb resection with a 2 mm thoracoscope were enrolled. During the operation, the tidal volume was set at 4.0 mL/kg in the two-lung group and 8.0 mL/kg in the one-lung group; the respiration rate was set at 23/min and 12/min, respectively, at the same FiO2 (50%).

Results: A total of 108 patients (55 patients in the two-lung group and 53 in the one-lung) were included in this study. The airway pressure was significantly lower in the two-lung group (8.0±3.3 mmHg, 24.0±3.9 in one-lung, $p<0.001$). The time from endotracheal intubation to the incision was 17.1±4.0 minutes in the two-lung group and 35.3±7.6 in the one-lung, significantly different ($p<0.001$). However, the operation time was not different in comparisons between the two groups. Therefore, the total anesthesia time was significantly longer in the one-lung group (77.9±21.6 minutes, 64.9±14.7 in two-lung, $p=0.002$).

Conclusions: Needlescopic bleb resection using two-lung ventilation anesthesia with low tidal volume was technically feasible, cost effective and time saving compared to one-lung ventilation anesthesia.

KEYWORDS: Anesthesia, Pneumothorax, Ventilation, Video-assisted thoracoscopic surgery

INTRODUCTION

The surgical strategy used for the treatment of a spontaneous pneumothorax is resection of the blebs and bullae and obliteration of the pleural space by pleurectomy or pleural abrasion, alone or in combination [1]. The use of video-assisted thoracoscopic surgery (VATS) has become widespread and the traditional open thoracotomy has been replaced with VATS due to its minimal invasiveness and associated low morbidity [2]. As the thoracoscopic surgical techniques continue to improve, the size of the scope has gradually decreased. Recently, a 2-mm thoracoscope (a needlescope) and accompanying instruments have been introduced for bullectomy [3]. Starting in September 2004, we have performed needlescope surgery in all patients that required a lung biopsy [4]. On the basis of this experience, the needlescopic approach to bleb resection for a spontaneous pneumothorax was launched in March 2005 at our hospital.

One-lung (OL) ventilation is a commonly used technique that facilitates surgical visualization during thoracic surgical procedures. In particular, during VATS, one-lung ventilation may play a pivotal role in the successful completion of a planned procedure [5]. However, it has the disadvantages of causing hypoxemia and tracheobronchial trauma [6]. In addition to these complications, it may add additional time and cost to the procedure due to the need to confirm the proper position of the tube by fiberoptic bronchoscopy [7]. Recently, Cerfolio et al. [8] suggested that low tidal ventilation without one lung ventilation is relatively easy to perform in simple VATS procedures such as pleural biopsies and talc pleurodesis. Since April 2007, we have used two-lung (TL) ventilation with low tidal volume ventilation anesthesia for 5 mm thoracoscopic bleb resection in patients with a spontaneous pneumothorax, and have previously reported on its technical safety and feasibility [9].

The goal of this study was to compare the safety and feasibility of two-lung ventilation with low tidal volume anesthesia with one-lung ventilation for needlescopic bleb resection of a spontaneous pneumothorax.

METHODS

Patient population

A consecutive series of 110 patients with primary spontaneous pneumothorax underwent needlescopic bleb resection from April 2007 to May 2008 at the Korea University Guro Hospital. After approval by the Ethics Committee of the Korea University Guro Hospital, written informed consent was obtained from all patients in accordance with the Declaration of Helsinki. All patients were initially managed with chest tube placement; a chest computed tomography (CT) was performed prior to surgery. Surgery was indicated if the first episode of pneumothorax was complicated, if blebs or bullae were observed on the chest CT or in cases with recurrent pneumothorax. Complicated pneumothorax refers to a persistent air leak, hemothorax, or failure of the lung to re-expand, bilaterally, and tension pneumothorax. The patients without blebs or bullae on the chest CT, with their first pneumothorax, and patients with a secondary spontaneous pneumothorax were excluded from this study. In addition, if patients refused the operation, or if moderate to severe pleural adhesions were found on the chest X-ray or chest CT, the patient was excluded. The subjects were assigned to one of the following two procedure arms (55 subjects each) one by one according to the order of hospital admission.

Anesthetic techniques

Soon after general anesthesia was induced, the radial artery was cannulated for intermittent arterial blood gas analysis. In the TL group, the patients were intubated with a

single-lumen endotracheal tube (SHERIDAN/CF® Tracheal Tubes; Hudson RCI, Durham, NC, USA) and ventilated with a tidal volume of 4 mL/kg and a respiratory rate of 23 cycles/min at a FiO_2 of 0.5. In the OL group, the patients were intubated with a double lumen endotracheal tube (Broncho-cath™; Mallinckrodt Medical, Athlone, Ireland) for separate lung ventilation and ventilated with a tidal volume of 8 mL/kg and a respiratory rate of 12/min at an FiO_2 of 0.5 from start to finish. In the OL group, a bronchoscopic examination was performed to confirm the optimal position of the double lumen endotracheal tube. To avoid hypoxia and airway barotrauma, the anesthesiologist controlled the ventilator settings during low tidal volume ventilation or one lung ventilation; when the SpO_2 was too low (<90%) or when the airway peak pressure was too high (>25 mmHg) increasing the FiO_2 or reducing the tidal volume was performed. During the surgery, the arterial blood gas analysis was performed at 10 minutes after establishing low tidal volume settings in the TL group and the one lung ventilation settings in the OL group. The airway pressure, end-tidal CO_2 and the oxygen saturation were recorded. In addition, the time from intubation to the incision, the operation time and total time for anesthesia were measured.

Operative techniques

The patients were placed in the lateral decubitus position. Initially, a 2-mm thoracoscope (needlescope; KARL-STORZ GmbH & Co, Tuttlingen, Germany) was introduced into the thoracic cavity via an 11.5-mm port at the sixth or seventh intercostal space on the anterior axillary line (previous closed thoracostomy site) to examine whether there were any dense adhesions, blebs or bullae. If there were moderate to severe pleural adhesions in the thoracic cavity, two-lung ventilation was converted to one-lung ventilation, or the needlescopic procedure was abandoned. In the cases where the needlescopic procedure was continued, a 2-mm needlescopic port at the fifth or sixth intercostal space along the midaxillary line and

another 2-mm port for the minisite endograsp (Auto Suture; Covidien, Norwalk, CT, USA) at the fifth or sixth intercostal space along the posterior axillary line were made. When there were loose or moderate pleural adhesions, a 5-mm thoracoscope was used that provided better vision; it was introduced through an 11.5-mm port. Then the pleural adhesions were dissected with a 2-mm minisite endograsp or minisite minishears (Auto Suture) through the two 2-mm ports. The bleb resections were performed using 1 or 2 endostaplers via an 11.5-mm port used for securing the pulmonary margins; the resected blebs were removed from the 11.5-mm port (fig. 1). Mechanical and chemical pleurodesis, with iodine soaked cotton, were performed at the apical area of the visceral and parietal pleurae through an 11.5 mm port. Upon completion of the operation, a 28 Fr. chest tube was inserted through the 11.5-mm port.

Statistics

Distribution of the two groups was analyzed using chi-square test, and continuous outcomes with the independent t-test or Mann-Whitney U test depending on the distribution of data. This sample size was determined by using a statistical software program PASS 2008 (NCSS, Kaysville, Utah, USA). A p-value of <0.05 was considered statistically significant. All the other statistical analysis was carried out using statistical software (SPSS for Windows, release 12.0; SPSS Inc., Chicago, IL, USA).

RESULTS

There was no case where two-lung ventilation was converted to one-lung ventilation, or the needlescopic procedure was abandoned; with the exception of two patients in the OL group. In these two cases that were excluded from the study, needlescopic surgery was converted to 5 mm thoracoscopic surgery due to the presence of moderate pleural adhesions. A total of 108 patients were treated for primary spontaneous pneumothorax during the study

period. Fifty five patients and 53 were included in the TL group and the OL group, respectively. The patient age (23.4±10.0 years in TL group, 27.4±14.8 in OL group, p=0.128) and gender (male: female, 52:3 in TL group, 46:6 in OL group, p=0.176*)* were not significantly different in the two study groups.

The most common indications for the needlescopic bleb resection were primary spontaneous pneumothorax with a visible bleb on the chest CT or a recurrent pneumothorax on the same side (table 1). The distribution of the surgical indications was not significantly different between the two groups (p=0.474).

During bleb resection, although the tidal volume and respiratory rate were significantly different between the two groups, the minute volume was not significantly different (table 2). There was no need to decrease the tidal volume more in order to obtain an optimal working field in the TL group. The pH, PCO_2, PO_2, SaO2 and SpO2 were compared between the two groups and were significantly different; however, these differences had no negative impact on the pulmonary status of the patients. In particular, the airway pressure was significantly lower in the TL group than in the OL group (8.0±3.3 mmHg in TL group, 24.0±3.9 mmHg in the OL group, p<0.001); this suggests less airway damage in the TL group. The time from endotracheal intubation to the incision was 17.1±4.0 minutes in TL group and 35.3±7.6 minutes in the OL group; these differences were significant (p<*0*.001) (table 3). However, the operation time was not different in the comparisons between the two groups. Therefore, the total anesthesia time was significantly longer in the OL group (64.9±14.7 minutes in TL group, 77.9±21.6 in OL group, p=0.002).

The thoracoscopic bleb resection with pleurodesis was performed successfully in all patients. The number of endostaplers used was not significantly different in comparisons between the two groups (table 3). Two patients in TL group and three in the OL group had air leakage until the third day postoperatively but the chest tube could be withdrawn by the fifth

or sixth day after surgery by managing this complication with talcum pleurodesis. There were no wound infections, early recurrences or readmissions. The chest tube indwelling duration and length of stay were not significantly different in the comparisons between the two groups. During the follow-up period (15.9±3.5 months, range 5-22), there was no recurrence on the side that underwent surgery.

DISCUSSION

The minimal invasiveness of VATS has changed the treatment strategy for primary spontaneous pneumothorax. Sawada, et al[10] recommended VATS not only for patients with recurrence or prolonged air leakage, but also for the first pneumothorax episode in patients with bullae on the chest CT. Margolis et al[11] suggested that VATS may be an effective first line treatment for primary spontaneous pneumothorax in young adult patients regardless of the chest CT findings. In our hospital the indications for VATS, for the first episode of a primary spontaneous pneumothorax, are similar to those reported by Sawada [10]. For the first episode in patients where blebs or bullae are not detected by CT, a conservative approach is the first-line treatment. However, first episodes with blebs or bullae noted on the CT are treated by VATS.

Needlescopic surgery, using instruments with a diameter of less than 3 mm, has been used mainly in cases requiring a cholecystectomy [12] and sporadically for urology surgery [13]. For thoracic procedures, it has been used for diagnostic thoracoscopy [14], laser ablation or thoracic sympathectomy for palmar hyperhidrosis [15]. Recently, this technique has been used for lung biopsy procedures for diffuse pulmonary disease [16] and bullectomy for patients with a spontaneous pneumothorax [3, 17]. Recently, we reported the first needlescopic resection of a small pulmonary nodule [4].

Compared to conventional thoracoscopic surgery, needlescopy has safety concerns including poor imaging and difficulty with fine motor control [3]; the chest tube 11.5-mm wound is likely the major cause of postoperative discomfort and scarring; even with downsizing of the other two ports. However, it is clear that needlescopic surgery leaves minimal scarring at the other two ports. In addition, especially with narrow posterior interspaces, smaller cameras and instruments that apply less torque likely improve the wound healing effects of intercostal nerve injuries [18]. In addition, as technology advances, low-profile cameras will likely capture high-definition images with less light and supplemental luminescence delivered through separate needle holes; moreover, instruments that angle will also reduce leverage-related rib trauma [18]. We previously reported that there was no significant difference in the operation time, duration of indwelling chest tube and pain according to the size of the thoracoscope [19]. In addition, needlescopic surgery provided an accurate pathological diagnosis for patients with interstitial lung disease and indeterminate pulmonary nodules when compared to the open procedure [4]. Therefore, bleb resection using the needlescope for spontaneous pneumothorax was initiated at our center.

One-lung ventilation is almost always used for VATS. It is usually safe and it provides superb visualization and an excellent working field for procedures involving the pleura, lung and mediastinum, after the appropriate collapse of the lung [8]. However, one-lung ventilation requires additional time and cost. The cost of a single-lumen tube and placing it is $50, compared to the $375 cost of placing a double-lumen endotracheal tube, in the USA [8]. At our hospital, the price is higher for the double-lumen endotracheal tube (US $98) and Univent (US $179) compared to the single-lumen tube (US $3.37). A bronchoscopic examination is mandatory to confirm the positioning of the endotracheal tube for one-lung ventilation; this adds additional time [8]. The complications, high cost and increased time for one-lung ventilation add significant burdens to what is an otherwise very short and simple

procedure. Because 8 ml/kg is the lowest tidal volume that is recommended during one-lung ventilation in most textbooks of anesthesiology, we chose the ventilator setting as 8 ml/kg of tidal volume (based on the ideal body weight) in one-lung ventilation; as long as patients had no problem with gas exchange or airway pressure. However, there have been several studies that have demonstrated acute lung injury after using large tidal volumes, and that lung protective ventilation strategies are associated with small tidal volumes [20]. Therefore, reduction of the tidal volume during one lung ventilation is planned in our next study.

Cerfolio et al. [8] reported that an adequate working field with low tidal volumes could be obtained while both lungs were ventilated during VATS for pleural biopsies and talc pleurodesis. On occasion we would use two-lung ventilation during a VATS for primary spontaneous pneumothorax during a one-lung ventilation procedure to find an air leak, collapsed bleb or bullae. At first, we partially clamped the bronchial lumen of the double-lumen endotracheal tube, on the side undergoing surgery, with normally set tidal volumes to continue ventilating the lung undergoing surgery. Partial clamping resulted in a substantial decrease in the tidal volume delivered to the operative lung and provided a better working field than the complete two-lung ventilation. After several cases with no problems, we placed the double-lumen endotracheal tube, but inflated both lungs and used a low tidal volume. Next, we started to place a single-lumen tube in all cases during the VATS for a primary spontaneous pneumothorax [1]. During this study, we prepared the wire-guided endobronchial blocker for one-lung ventilation in case we failed to obtain adequate surgical visualization with low tidal volumes under two-lung ventilation. Under bronchoscopic guidance, the wire-guided endobronchial blocker can be inserted through the endotracheal tube with the patient in any position, even the lateral position. This procedure can be performed within 10 minutes at our hospital.

The results of a previous study showed that a tidal volume of 4 mL/kg was sufficient to obtain an adequate surgical field (fig. 2); this tidal volume maintained optimal pulmonary function without hypoxia or hypercapnea. Cerfolio et al. [8] routinely decreased the tidal volume to 150 to 250 mL in their study. Although these differences had no negative impact on the pulmonary status of the patients, the airway pressure was significantly lower in the TL group than in the OL group; this suggests that airway damage might be reduced in the TL group.

The most important benefit of this anesthetic procedure was that the total anesthesia time was reduced by decreasing the time from intubation to the incision because bronchoscopic examination was not needed. As a matter of fact, the time for verifying double lumen tube placement is an institutional variable. In experienced hands, it takes a few minutes to confirm the proper position of the double-lumen tube. However, because our center is a training hospital, the anesthesiologist often must teach their trainee how to perform one-lung ventilation. This is a major cause of increase of the total anesthesia time. In addition, the bleb resection using the needlescope for the two-lung ventilation did not require more surgical time compared to surgery using a 5 mm thoracoscope, as reported previously [9].

Awake VATS has been tried under local anesthesia and sedation or thoracic epidural anesthesia in spontaneous pneumothorax [21, 22]. This procedure has several potential advantages including avoidance of airway trauma associated with endotracheal intubation, general anesthesia, and single lung ventilation [23]. In addition, it is associated with minimal hospitalization and cost-saving treatment [24]. Therefore, awake VATS may be considered to be more ideal surgery than our procedure, although there was concern that operating on a ventilating lung would render surgical maneuvers more difficult because of the lung movements and lack of a sufficient operating space [24].

Some investigators have reported thoracoscopic talc peurodesis without bullectomy as initial treatment for recurrence or persistent air leak in patients with spontaneous pneumothorax and small blebs (less than 2cm) [21, 25, 26]. This procedure could be performed via a single port medical thoracoscopy under local anesthesia with sedation and had a good success rate in long-term follow-up. In this study, small blebs/bullae <2cm (Vanderschueren's classification type III or less) were found in 28 patients out of 108 (25.9%) that could be candidates for thoracoscopic talc peurodesis as an alternative treatment.

The results of this study suggest that needlescopic surgery using two-lung ventilation with low tidal volume was safe and effective and could provide an alternative option for a relatively short and simple procedure such as bleb resection for spontaneous pneumothorax. In conclusion, needlescopic bleb resection using two-lung ventilation anesthesia with low tidal volume was safe, technically feasible, cost effective and time saving compared to one-lung ventilation anesthesia.

STATEMENT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

All authors participated in study conception. The data and final manuscript were reviewed by all authors.

Dr. Heezoo Kim : contributed to anesthetic procedure, and correcting data and drafting the article.

Dr. Hyun Koo Kim : contributed to surgical procedure, and analyzing data and drafting the article.

Dr. Du-Young Kang : contributed to surgical procedure.

Dr. Dong-Kyu Lee : contributed to anesthetic procedure.

Dr. Young Ho Choi : contributed to surgical procedure.

Dr. Sang Ho Lim : contributed to anesthetic procedure.

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TABLE 1. Indications for surgery in patients with primary spontaneous pneumothorax

Causes		Patient No. (%)	
		Two-lung group (n=55)	One-lung group (n=53)
First episode	Bleb on CT	21 (38.2)	22 (41.5)
	Prolonged air leak	7 (12.7)	6 (11.3)
	Tension	5 (9.1)	4 (7.5)
	Non re-expansion	3 (5.5)	5 (9.4)
	Bilaterality	2 (3.6)	2 (3.8)
Recurrence	Ipsilateral	12 (21.8)	10 (18.9)
	Contralateral	5 (9.1)	4 (7.5)

TABLE 2. Ventilator settings and arterial blood gas analysis

	Two-lung group	One-lung group	p-value
Tidal volume (mL)	240.5±35.9	498.8±79.0	<0.001
Minute volume (mL)	5.2±1.1	5.4±1.1	0.461
Respiratory rate	22.7±1.9	12.6±1.9	<0.001
Maximum airway Pressure (mmHg)	8.0±3.3	24.0±3.9	<0.001
PH	7.40±0.04	7.43±0.04	<0.001
PCO_2 (mmHg)	41.2±4.5	43.3±3.7	0.020
PO_2 (mmHg)	235.1±45.2	108.1±27.5	<0.001
SaO_2 (%)	99.8±0.6	97.8±1.6	<0.001
End-tidal CO_2 (mmHg)	35.7±5.9	34.6±4.1	0.305
SpO2	99.6±0.7	97.5±1.640	<0.001

TABLE 3. Procedure time and operative results

	Two-lung group	One-lung group	p-value
Time from anesthesia induction to incision (min)	17.1±4.0	35.3±7.6	<0.001
Operation time (min)	31.5±14.2	31.7±19.3	0.956
Total anesthesia time (min)	64.9±14.7	77.9±21.6	0.002
Endostapler used (No.)	2.1±0.7	1.9±0.8	0.434
Chest tube indwelling duration (days)	3.4±1.3	3.7±1.3	0.270
Length of stay (days)	4.4±1.3	4.7±1.3	0.195

FIGURE LEGENDS

FIGURE 1. Intraoperative needlescopic image of a bleb resection.

FIGURE 2. Operative field for the two-lung ventilation with low tidal volume (A) and one-lung ventilation (B) during needlescopic bleb resection for primary spontaneous pneumothorax.