

Experimental Study on Sleeve Anastomosis in Relation to Pulmonary Hemodynamics

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The two different sleeve anastomosis procedures, which is composed of the right angle (S-group) and oblique anastomoses (O-group) against the tracheal axis were evaluated in relation to pulmonary oxygenation and circulation.

In the S group, the deleterious results of pulmonary function such as a decrease in PaO₂, an elevation of A-aDO₂, a rise of pulmonary artery pressure and a reduction of cardiac output were obtained in addition to the results of an increased pulmonary extravascular water volume (PEWV) measurement and the structural exacerbation by histologic examination.

In the operative procedure of oblique sleeve anastomosis is preferred over that of right angle one on the basis of a result regarding pulmonary circulation in this study. It, also, was certified that at least 7 mm orifice size in the anastomotic site is required for permitting a long term survival on dogs.

INTRODUCTION

Advance in surgery is made possible to extend a surgical indication for advanced lung cancer by which the contiguous organs and/or the tracheal carina are involved. To preserve as much of the healthy lung tissue as possible, as well as to ensure an operative radicality, a procedure of sleeve anastomosis in the tracheobronchial surgery has become widely accepted. The present study is experimentally to clarify the pulmonary hemodynamics between the two different operative procedures of the right angle and oblique anastomosis against the tracheal axis.

MATERIAL AND METHOD

Fifty-three adult mongrel dogs, weighing between 6.5 and 29kg, were anesthetized

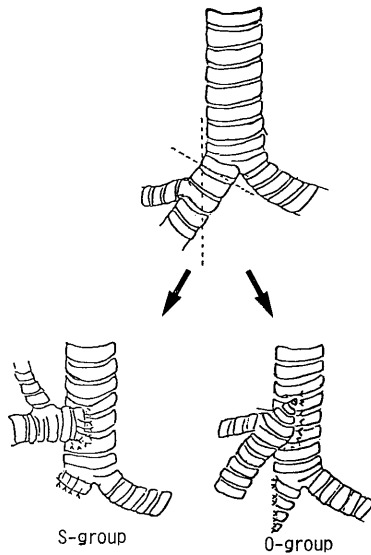


Fig. 1. Schema in sleeve anastomosis

with 20-30mg/kg of sodium pentobarbital, intubated with a cuffed endotracheal tube and ventilated with room air using a respirator (ALKA co.).

Operative procedure: Thoracotomy was carried out via the right posterolateral approach at the Vth intercostal space. After dividing the azygos vein, the right main bronchus was exposed so as to prevent the vagal nerve from surgical damages.

Fig. 1. showed the two different anastomosis types: one is a right angle anastomosis end to side to the trachea (S-group) after dividing the right main bronchus which is cut off at right angle to the tracheal axis, the other is an

oblique anastomosis to the trachea (O-group) after dividing obliquely.

After separating the right main bronchus from the trachea as shown in Fig. 1, the cut edge of the main bronchus was sutured with use of 3-0 nylon of running sutures.

The anastomosis to the trachea was done at the site 1cm proximal to the tracheal bifurcation, making a round hole of at least 5cm in size on the lateral tracheal wall with a fashion of end to side.

Anastomosis was completed by inverted suture on the posterior wall of the trachea and everted one on the anterior wall. Then, the thoracotomized wound was sutured layer to layer, leaving a drainage tube in place.

Blood gas analysis: The blood samples were taken from the femoral artery and blood gas analyses were made, by using IL-Meter (IL 213-a17 PH/blood gas analyzer). The arterial pH, PaCO₂ and PaO₂ values were compared between pre and postoperative periods.

Cardiac output measurement by Swan-Ganz catheter: Two Swan-Ganz catheters (S-G catheter, Kimley Co.) were simultaneously introduced to the right and left main pulmonary arteries to take blood samples via catheter aimed at the measurement of the venous blood pH, PCO₂ and PO₂, and cardiac output by the thermodilution method with 4°C glucose solution cooled by ice slush using a Cardiac Output Meter (Kimley Co.) on the pre and the 3rd, 7th, 10th, 14th, 21th and 28th day of surgery.

The A-aDO₂ value was also calculated by the following equation:

$$P_AO_2 = 149 - (PaCO_2 / 0.75)$$

0.75: constant of respiratory quotient

$$\text{Then } A-aDO_2 = P_AO_2 - PaO_2$$

Pulmonary extravascular water volume (PEWV): To know the degree of the ensuing

lung edema in accordance with the two different operative procedures of sleeve anastomosis, it was measured by the following method.

After intravenous administration of sodium pentobarbital (20-30mg/kg), sacrificed dogs were intubated and ventilated with an animal respirator. Each lobe of the entire lung was separately removed through bilateral thoracotomy and a 10g lung tissue close to the parietal pleura was taken from each lobe. These were put the cutedge downwards for one minute to clear away from the blood by gravity. Thus, each lung specimen separately weighed and again measured after keeping them in the drier at 100°C for 48 hours to permit evaporation. The extravascular water volume of the lung was represented as a disparity in the two values.

Pulmonary hemodynamics: In order to elucidate the pulmonary hemodynamics between two procedures the parameters such as the pulmonary artery pressure(PAP), the pulmonary wedge pressure (PWP), pulmonary vascular resistance (PVR) and cardiac output (CO) were compared.

Histologic examination: Part of peripheral lung tissues taken for estimation of water content of the lung were prepared for histologic examination in 8 dogs with right angle anastomoses and in 7 dogs with oblique anastomoses. The severity of histologic finding of lung edema, atelectasis, the wall thickness, stenosis and degenerative scar of the pulmonary artery, alteration of mucosal membrane, cell infiltration and bleeding and stasis in the lung parenchyma was carefully estimated.

The data were expressed as the mean \pm S.D. Statistical analysis was performed using the Student's t-test. A p-value of less than 0.05 was considered to be significant.

RESULT

Survival times following sleeve anastomoses were compared between O and S groups. Table 1 showed that survivors over 7 days were 12 out of 32 (22.7%) in the S group and 13 out of 21 (24.5%) in the O group. However, there was no significant difference. Death causes within 7 days were respiratory failure in 13 dogs (24.5%) which included 10 dogs in the S group and anastomosis insufficiency in 10 dogs (40.0%) which included 7 dogs in the S group. The other death causes were bleeding and sacrificed. According to elapsing time following surgery as shown in Fig. 2, the arterial pH values did not

Table 1. Survival time after sleeve anastomosis on dogs

Group	survival days	within 7 days	7 days-92 days	total
S-group		20 (37.7%)	12 (22.7%)	32 (60.4%)
O-group		8 (15.1%)	13 (24.5%)	21 (39.6%)
total		28 (52.8%)	25 (47.2%)	53 (100%)

significantly fluctuated on day 3, 7, 10, 14 and 28 between the two groups. These were not statistically significant.

The arterial PaO₂ values were compared on the postoperative courses in both the groups as shown in Fig. 3. The arterial PaO₂ values on day 7, 14 and 28 were statistically significant between both the groups.

The changes in the arterial PaCO₂ values on the postoperative days were assessed in both the groups as shown in Fig. 4. There was no significant difference on the postoperative days.

The A-aDO₂ values were also compared on the postoperative days in both the groups as shown in Fig. 5. On day 14, 21 and 28 after surgery, these were more significantly increased in the S group (P<0.05) whereas no remarkable changes on pre- and postoperative 3rd and 7th day were seen in both the groups. The PEWV value was measured on 10 dogs in the S group and 7 dogs in the O group, including 5 dogs in the S group and 2 dogs in the O group, who died within 7 days after surgery.

Fig. 6. showed the PEWV values which was separately measured in the entire right and left lungs between both the groups.

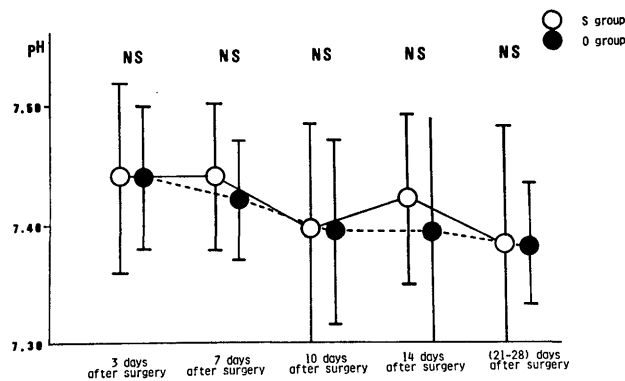


Fig. 2. Changes in the arterial pH values after sleeve anastomosis

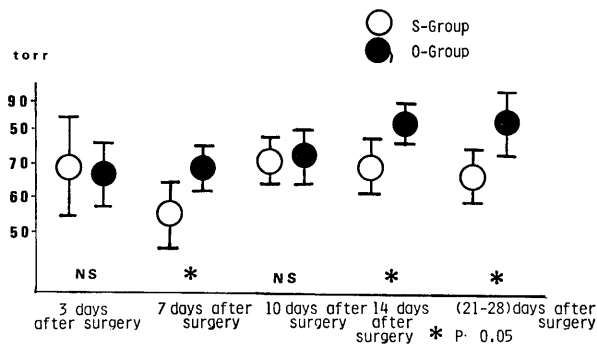


Fig. 3. Changes in the arterial PaO₂ values after sleeve anastomosis

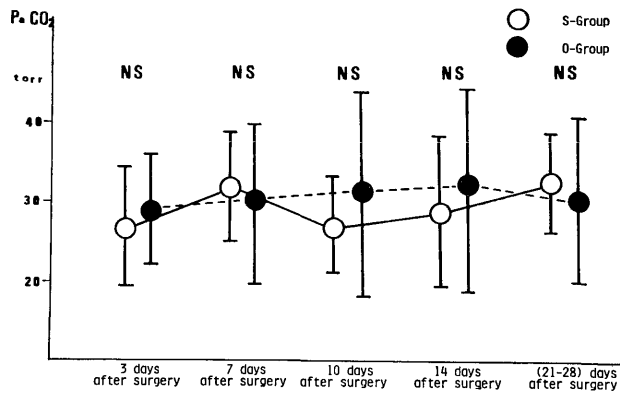


Fig. 4. Changes in the arterial PaCO₂ values after sleeve anastomosis

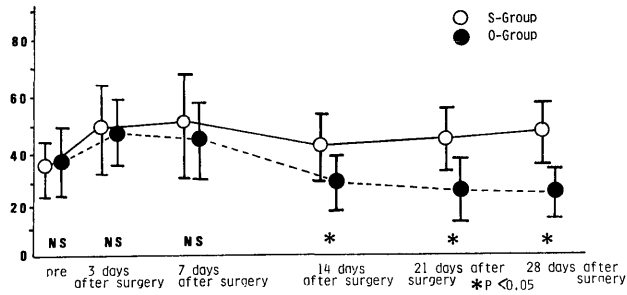


Fig. 5. Changes in the A-aDO₂ values after sleeve anastomosis

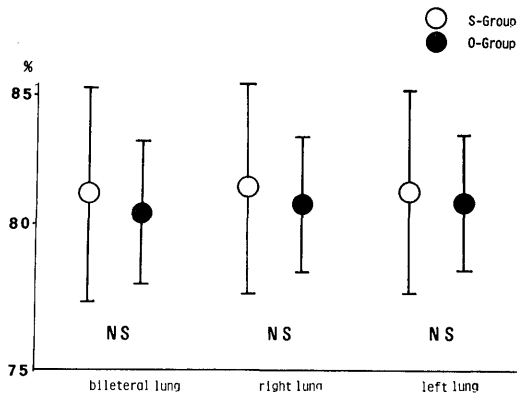


Fig. 6. Changes in the pulmonary extravascular water volume

These were not statistically different in each value. The comparison of the water volume among each lobe on both sides was made in both the groups as indicated in Fig. 7. As for the water volume in the upper and middle lobes, there was no significant

difference in both the groups whereas those in the lower lobes on both sides were significantly high ($P < 0.05$) in the S group.

As for the separated each lobe, the PEWV values were higher in the order of lower, middle and upper lobes in the S group although those were higher in the order of middle, upper and lower lobes in the O group.

Changes in PAP were compared on day 7 and day 14 to 28, following surgery in both the groups. During a period of immediately postoperative day to day 7, the PAP values did not significantly varied in both the groups whereas those in the S group were significantly raised ($P < 0.05$) during a period of the postoperative 14th to 28th days as shown in Fig. 8. The PAP values on the right operated upon were also compared with those on the left as shown in Fig. 9. Those were significantly higher ($P < 0.05$) in the S group rather than in the O group. According to changes in the postoperative periods, the PAP values on the left which was not operated upon were not significantly altered on day 0 to 7 and day 14 to 28 as shown in Fig. 10. The PWP values on the right operated upon were compared between both the groups on day 0 to 7 and on day 14 to 28. There was no significant difference in both the groups as shown in Fig 11 although those on the left did not significantly varied as in Fig 12.

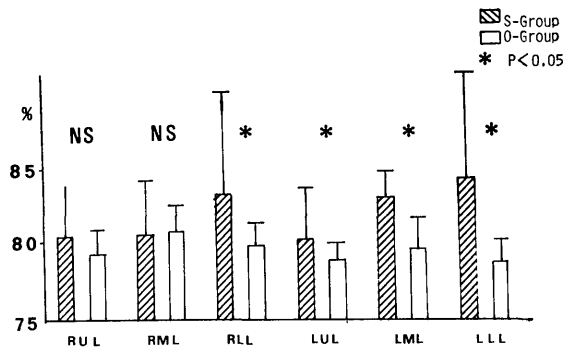


Fig. 7. Changes in the pulmonary extravascular water volume in long survivors more than 1 month after surgery according to each lobe of the entire lung

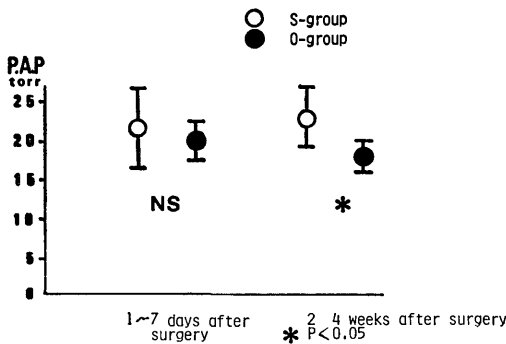


Fig. 8. Changes in the pulmonary arterial pressure on the courses of postoperation

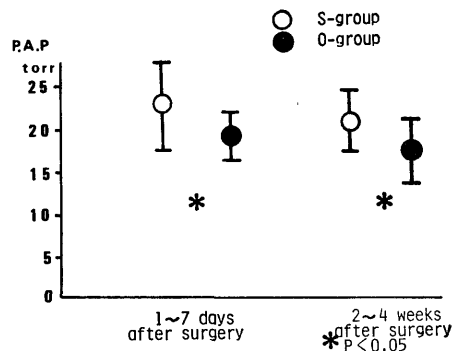


Fig. 9. Changes in the pulmonary arterial pressure on the side operated upon

On the other hand, the PVR values on the right operated upon were significantly different ($P < 0.05$) between S and O groups on day 0 to 7 and also on day 14 to 28 as shown in Fig. 13 although those on the left were not statistically different as shown in Fig. 14. The cardiac output values were also compared between the two groups on day 3, 7 and 14 to 28 as shown in Fig. 15.

On day 3, 7 and 14 to 28, these were not significantly altered whereas on day 28 a significant difference ($P < 0.05$) was shown, indicating the low cardiac output in the S group.

A comparison of the cardiac output values between the both sides of the lungs was made using two S-G catheters introduced to the bilateral main pulmonary arteries. Fig. 16 revealed no significant difference between the both sides of the lungs and the two different operative procedures. Histologic findings on day 7 and on day more than 14 following surgery were summarized in Table 2. Histologic exacerbation was not prominent between both the groups.

The anastomotic opening sizes were compared between longitudinal and transverse diameters in both the groups as shown in Fig. 17. The longitudinal diameters of the orifice in anastomosis in the S group varied although the transverse diameters in the O

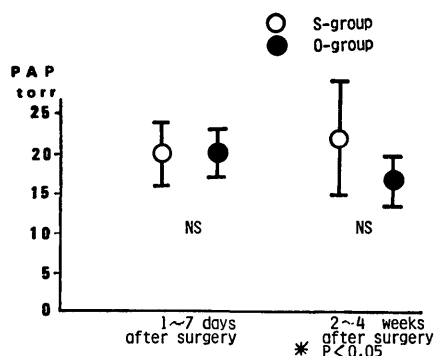


Fig. 10. Changes in the pulmonary arterial pressure on the contralateral lung

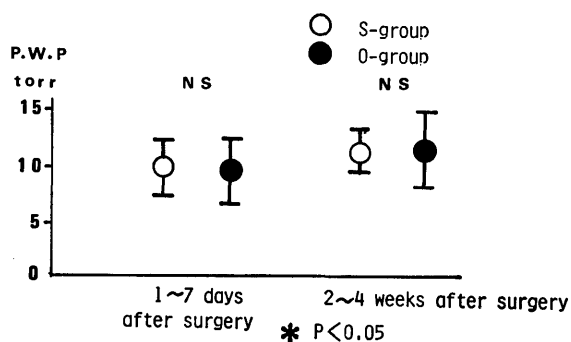


Fig. 11. Changes in pulmonary wedge pressure of the side operated upon during the postoperative period

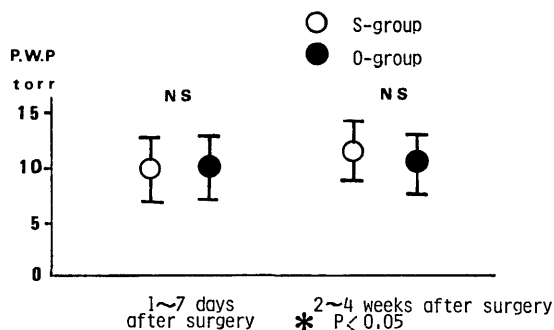


Fig. 12. Changes in pulmonary wedge pressure on the non-operated side during the postoperative period

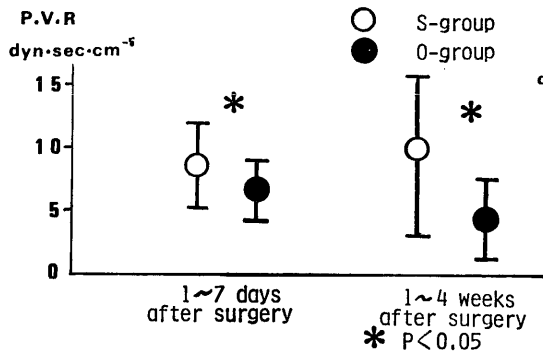


Fig. 13. Changes in PVR on the side operated upon during the postoperative period

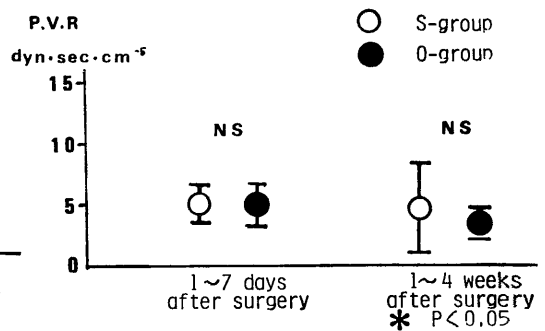


Fig. 14. Changes in PVR on the non-operated side during the postoperative period

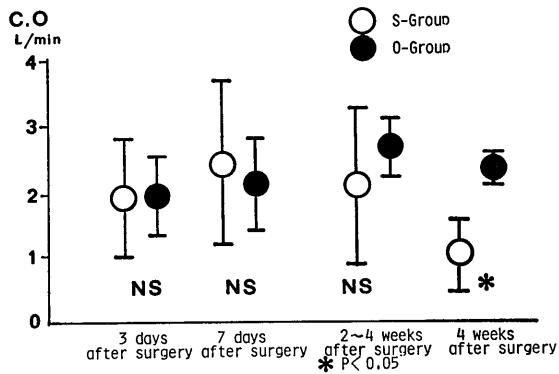


Fig. 15. Changes in CO during the postoperative period

Table 2. Histology findings of the lung at periphery according to two types of sleeve anastomosis

abnormal findings	() %			
	S-Group		O-Group	
	alive within 7 days	alive more than 14 days	alive within 7 days	alive more than 14 days
edema	1/7 (14.2)	0	1/6 (16.7)	0
atelectasis	5/7 (71.4)	1/7 (14.2)	3/6 (50)	2/6 (33)
hypertrophy scar of artery	5/7 (71.4)	2/7 (28.6)		0
degeneration of bronchial mucosa	5/7 (71.4)	0	4/6 (66.7)	0

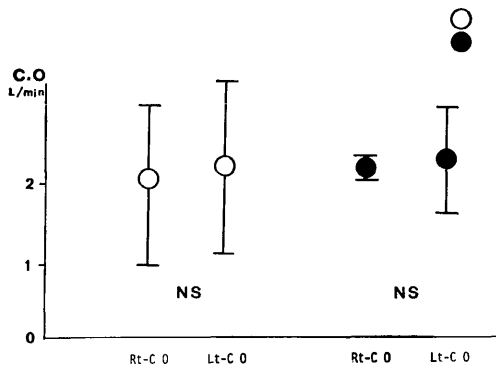


Fig. 16. Changes in CO on bilateral lungs Rt-CO: blood flow in the right lung, which was operated upon Lt-CO: blood flow in the left lung, which was not operated.

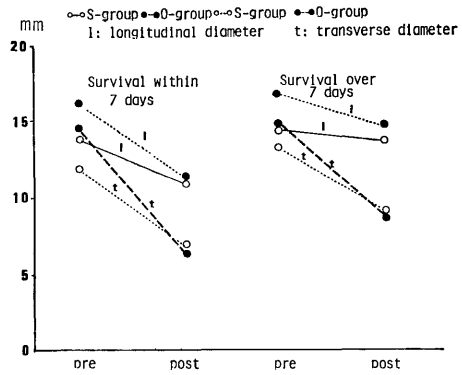


Fig. 17. The average opening orifice diameter in the anastomotic site

group greatly diversified. It is well established that over 7mm of the transverse diameter of the orifice of an anastomosis was necessary for obtaining the survivors of more than 7 days after surgery and also a difference in the longitudinal diameter of more than 2mm in the anastomosis orifices between pre and postoperative periods shortens survival time within 7 days.

DISCUSSION

Important strides in the tracheobronchial surgery toward relief of respiratory distress has been made. The procedures of sleeve anastomoses were widely accepted in the reconstruction of the trachea and its bifurcation.

The present study was to clarify the superiority of right angle (S-group) and oblique (O-group) anastomoses against the tracheal axis with respect to pulmonary hemodynamics. Postoperative pulmonary hemodynamics in the O group is superior to those in the S group in relation to a decrease in PaO₂, an elevation of A-aDO₂, an increase in PAP, an increment of PVR and a reduction of CO

The arterial PaO₂ and PaCO₂ values as well as A-aDO₂ are an important indicator for evaluating the oxygenation of the lung and the supply of oxygen into the peripheral tissues.

In this study the tendency toward a decrease in PaO₂ and an increase in A-aDO₂ in the S group was apparently noticed on day 14 after surgery, showing an influence by the operation type itself. One takes it for granted that bronchoplastic procedure inevitably allows division of the branches of the vagal nerve, bronchial artery and lymphatic channels. However, these affections of the pulmonary hemodynamics on the bronchus-reconstructed lungs were almost the same between the two operative methods of sleeve anastomosis including an influence of denervation.

As reported by HARDY⁴⁾, denervation of the lung may lead to an elevation of PAP and also TOMITA *et al.*⁵⁾ reported the distension of the pulmonary artery in the early phase of the pulmonary angiography, reflecting vasoconstriction of pulmonary capillary beds when performing sleeve anastomoses of the bronchus and pulmonary artery. MINAMI⁶⁾ also noticed that sleeve anastomosis with hilar stripping brings an elevation of A-aDO₂.

In this study, the author confirmed an increase in A-aDO₂ on day 3 to 7, lasting up to on day 48 after surgery. It means that other factors such as hypoventilation except for interruption of the vagal nerve may be contributable. It is apparent that an increase in A-aDO₂ in the S group are, in particular, due to air turbulence in the airway at expiration and inspiration. Of interest is the fact that higher PAP and PVR values in the S group were obtained and also contralateral lung water volume was increasing. It is considered to be a reflection of poor function on an operated lung and of overload on the contralateral one.

BALSEY⁷⁾ also cited that the different sizes of bronchial orifices which are anastomosed could be equal to another by wedge and oblique resections on the membranous portion to elongate a small lumen. However, an approximation of the cartilages at the site of anastomosis is difficult in the loss of supporting ability of the cartilages for the bronchial lumen.

Experimental sleeve anastomosis in this study was satisfactorily feasible to sustain an adequate orifice size in anastomosis regardless of the operative procedures. BARCLEY⁸⁾ also emphasized that the right angle cutting of the bronchial edges at the anastomotic sites is required for obtaining a good adaptation and wound healing. An operative procedure of wrapping of the bronchial anastomotic sites with the pleura and/or pericardium is effective to protect the anastomotic site. This procedure was utilized in this study to prevent sleeve anastomosis from air leak. PEARSON⁹⁾ recommended a wrapping procedure with pedicled pleura which helps develop a good run-off blood flow.

In this study, the superiority between the operative procedure of oblique sleeve anastomosis and right angle one was evaluated in relation to pulmonary hemodynamics. There are few reports with respect to pulmonary hemodynamics following sleeve anastomosis. This study clarified that oblique sleeve anastomosis is superior to right angle one in order to ensure an excellent pulmonary circulation. This is consistent with the fact that the function on the lung operated upon as well as contralateral one can benefit from oblique sleeve anastomosis, which is substantiated by histologic examination and PEWV measurement to some extent. This report also support a relation of the anastomosis orifice size to the survival time. At least 7mm orifice in diameter of sleeve anastomosis is needed for ensuring sustained adequate pulmonary circulation on dogs.

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