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Pre-and Postoperative Changes in Extravascular Lung Water in Patients with Lung Resection

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ABSTRACT : The availability of measurement of extravascular lung water (EVLW) were clinically evaluated by using double indicator dilution technique and benefit from EVLW measurement was assessed in patients who underwent pulmonary resection.

Thirty-one patients were divided into the three groups. Group I : comprise of five with partial resection or exploratory thoracotomy, Group II : 24 with lobectomy and Group III : two with pneumonectomy.

1) EVLE showed 6.0±2.9/kg six hours after surgery 6.8±3.3ml/kg on day 1, 6.6±3.0ml/kg on day2, 6.5±2.8ml/kg on day 3 with significant decrease ($p<0.05$) as compared with preoperative one.

2) %EVLW, in which pulmonary vascular resistance was corrected, increased on day 1 with significant difference ($p<0.05$), indicating 100.7±3.75 at six hours, 118.1±48.4% on day 1, 117±53.7 on day 2, 107.8±32.3% on day 3.

3) %EVLW in group II was much higher than that in Group I on day 1 ($p<0.05$).

4) %EVLW in patients with massive blood transfusion over 800ml showed significantly high values on day 2 ($p\neq0.05$).

5) %EVLW in patients with the operation time of more than four hours was higher than in those with less than four hours.

In conclusion, EVLW tended to increase in case of prolonged operation time over four hours and large volume blood transfusion over 800ml when wide resection beyond lobectomy would be attempted. Surgeons should be aware of pre-pulmonary edema state in such a patient.

INTRODUCTION

It is well known that grave complication following thoracic surgery is pulmonary edema which has become fatal. Careful postoperative cares focus on prevention of pulmonary edema. For the purpose, meticulous assessment of pulmonary hemodynammics has been attempted with the measurement of central venous pressure and/or the assessment by Swan-Ganz catheter. However, it was insufficient enough to know and prevent occurring pulmonary edema, changes in interstitial composition.

The purpose of this study is to clarify the clinical applicability and validity of EVLW measurement by using thermal dye technique and also to evaluate the influence on the remained lung function.

SUBJECTS

Eligible patients were composed of a total of 36 patients, who are twenty-six patients with primary lung cancer, one with primary lung sarcoma, one with metastatic tumor and three

with inflammatory granuloma-lesion.

The ages ranged from 38 to 75 years old with an average of 63.4±11.8 years old). the sex distribution was in a ratio of 20 : 11 of men to women. The patients were divided into the three groups, according to the resection range. Group I was composed of two with partial resection and three with exploratory thoracotomy, Group II was composed of 24 with lobectory and Group III was composed of two with pneumonectomy.

METHOD

All patients had a flow-directed thermodilution Swan-Ganz catheter inserted percutaneously to the pulmonary artery on the healthy side via the subclavian or femoral vein prior to this study and then EVLW were measured by injecting 10ml of ice saline solution containing 5mg of indocyanine green dye into the central circulation as a bolus using lung Water Computer Model 9310.

The monitorings of hemodynamics were carried out by measuring the mean pulmonary artery pressure(m PAP mmHg), wedge pressure (PCW mmHg) and by calculating cardiac index (CI l/ml/min/M^2).

These measurements were made prior to surgery, six hours 1, 2, 3 days after surgery respectively. Intraoperative fluide transfusion ranged from 3.7 to 13.7ml/kg/hr with an average of 8.3ml/kg/hr.

Student't test was used for statistical analysis and significant difference was regarded as $p<0.05$.

RESULTS

1) EVLW measurement

EVLW prior to surgery showed 7.5±2.4ml/kg and these after surgery altered with time, showing 6.0±2.9ml/kg on day 3 with a significant decrease ($p<0.005$). However, it was significant that re-increase in EVLW was seen on day 1, thereafter gradually decreased.

2) %EVLW

Considering a reduction of pulmonary vascular resistance following pulmonary resection, %EVLW was calculated according to the following equation.

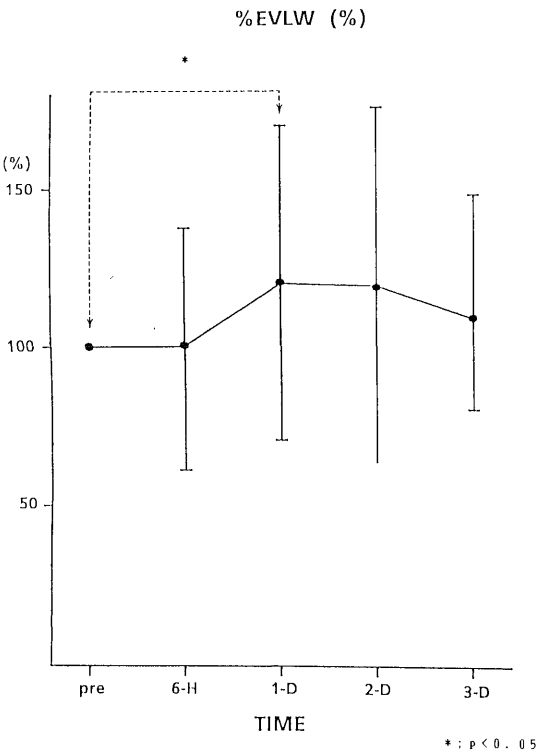

Fig. 1.

$$\%EVLW = \frac{\text{EVLW after surgery}}{\text{EVLW before surgery} \times \frac{\text{the remained pulmonary segments}}{\text{pulmonary segment prior to surgery}}}$$

Fig. 1 showed %EVLW calculated as being 100.7±37.5% immediately after surgery, 118.1±48.4% on day 1, 117.5±53.7% on day 2, 107.8±32.3% on day 3 respectively with a significant increase on day 1 ($p<0.05$).

According to the operation method, %EVLW in Group I showed 79.6±23.6% at six hours 87.4±21.7% on day 1, 101.4±43.0% on day 2 and 98.8±45.1% on day 3 respectively. It indicated a decrease in %EVLW at six hours and on day 1 and recovery of %EVLW on day 2. Meanwhile, %EVLW in Group 2 indicated 103.0±38.7% at six hours 120.2±48.4% on day 1, 119.8±55.5% on day 2, 107.9±28.4% on day 3 with an increase on day 1 and a decrease on day 3. On the other hand, %EVLW in Group III demonstrated 124.0±26.0%, 169.5±44.5%, 129.0±3.5% respectively.

As shown in Fig. 2, %EVLW in Group II was significantly higher ($p<0.05$) than that in Group I. According to the amount of bleeding, in the

eight patients with excessive bleeding of more than 800ml, %EVLW was calculated as being 121.0±37.7% at six hours, 141.9±37.4% on day 1, 161.8±70.0% on day 2 and 136.1±44.8% on day 3 with a significant increase on day 2. In addition, %EVLW in the 23 patients with bleeding of less than 800ml much less fluctuated. On the other hand, %EVLW in patients with massive bleeding remained higher (Fig. 3).

According to the operation time, %EVLW in patients with the operation time of more than four hours showed 110.9±47.5% at six hours after surgery, 147.9±55.5% on day 1, 145.3±68.7% on day 2 and 123.0±12.6% on day 3 with a significant increase on day 1, thereafter a gradual decrease. On the other hand, %EVLW in patients with the operation time of less than four hours indicated 94.3±30.5%, 99.2±34.5%, 99.8±34.7% and 101.9±36.6% respectively without marked variation.

It was significant that %EVLW in patients with the operation time over four hours was higher on day 1 ($p<0.05$) as shown in Fig. 4.

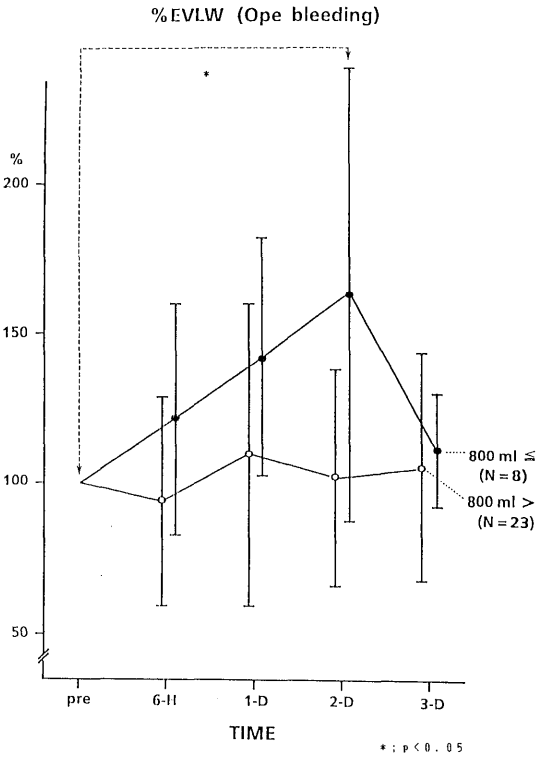

Fig. 3.

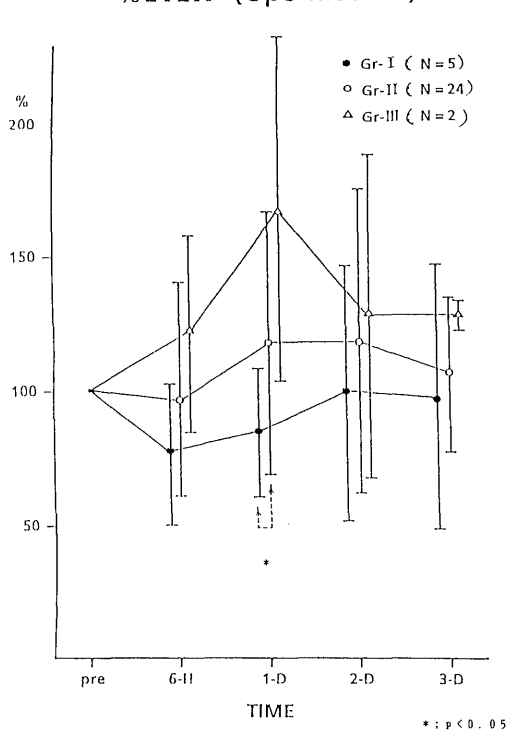

Fig. 2.

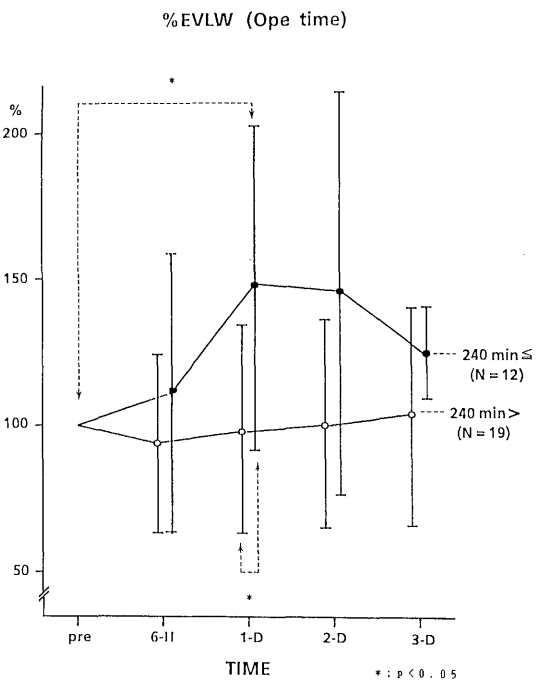

Fig. 4.

3) Hemodynamic changes

mPAP increased from 13.3±3.5mmHg immediately after surgery to 15.6±4.9mmHg on day 3 and then it decreased without significant difference. PCW 4.6±4.0mmHg on day 1. CI varied from 2.88±0.641/min/M^2 prior to surgery to 3.55±0.83 at six hours, 3.19±0.60 on day 1, 3.12±0.46 on day 2 and 3.15±0.53 on day 3 with a significant increase at six hours, thereafter with gradual decrease. PARI ranged from 220±117 dyne. sec. $cm^{-5}M^2$ prior to surgery to 394±127 on day 1 with a significant increase ($p<0.05$) as shown in Fig. 5.

According to the operation method, in Group II, mPAP and PARI increased, on the contrary PCW decreased. On the other hand, in Group I, CI increased as shown in Fig. 6. As compared among patients with increased %EVLW in Group II, increased mPAP, decreased PCW and increased CI present a striking contrast in patients with increased EVLW. On the other hand, increased CI was remarkable in spite of less changes in mPAP and PCW in patients with decreased %EVLW as shown in Fig. 7. According to the amount of bleeding, decreased PCW was seen in patients with bleeding of more than 800ml. On the other hand, increased mPAP at six hours after surgery and on day 1 and increased CI at six hours were recognized although CI decreased on day 2 and 3 as shown in Fig. 8.

With respect to the operation time, it was remarkable that PCW decreased on day 3, CI increased at six hours after surgery in patients with the operation time of more than four hours. On the other hand, it was noted that CI increased at six hours and decreased on day 2 in patients with shortened operation time of less

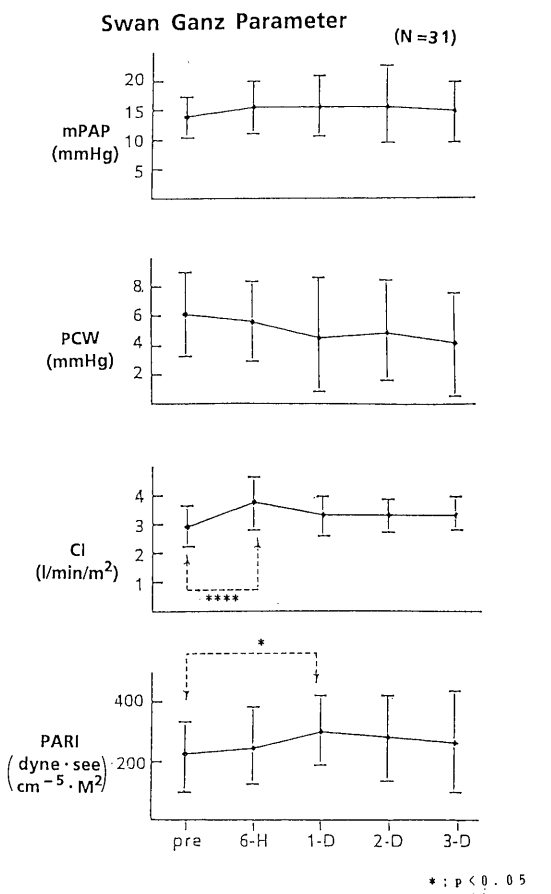

Fig. 5.

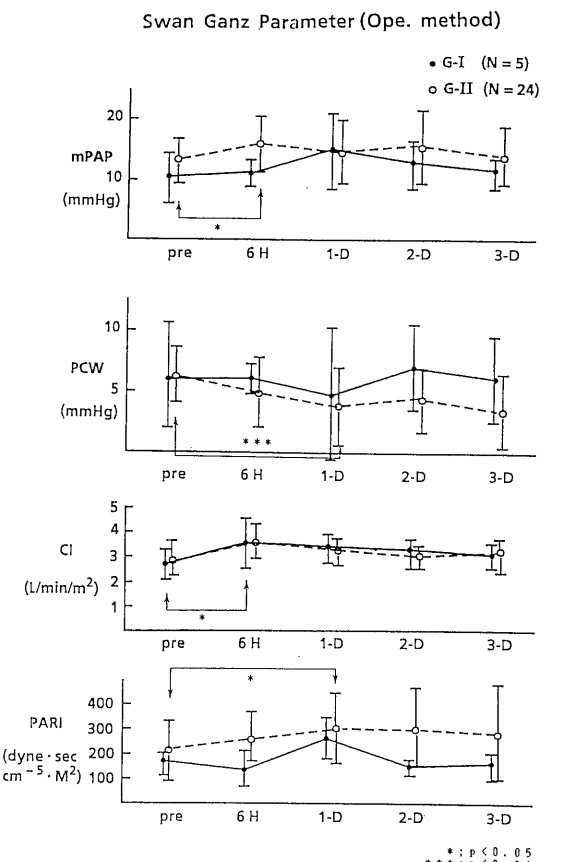

Fig. 6.

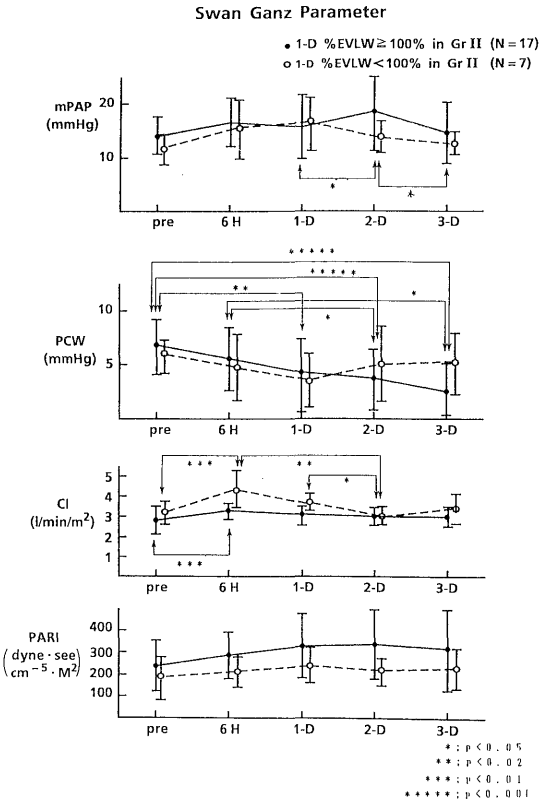

Fig. 7.

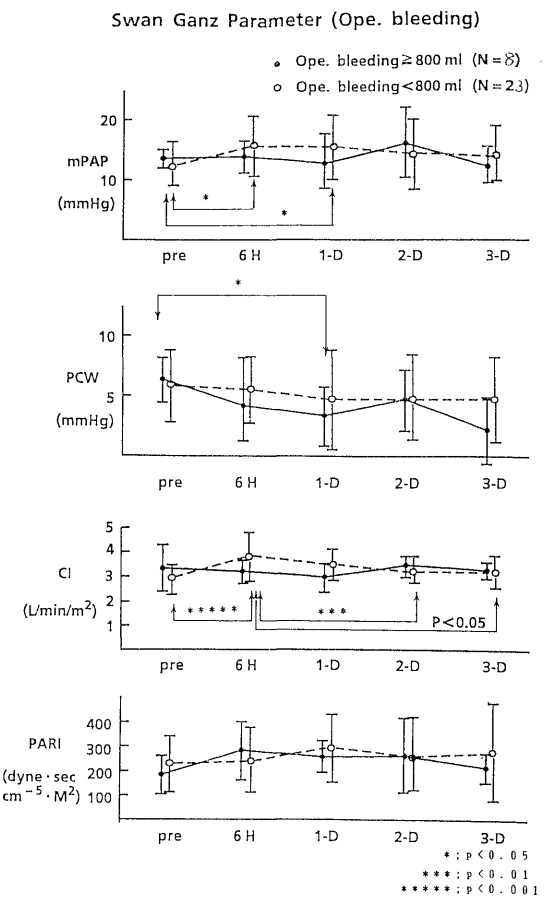

Fig. 8.

Table 1.

(In all cases) (N=31)

TIME	r=0.209 (P<0.02)
BLEED	r=0.210 (P<0.02)
mPAP	r=0.212 (P<0.02)
CI	r=0.169 (P<0.05)

(In GrII) (N<24)

	Day 1 %EVLW<100%	Day 1 %EVLW>=100%
BLEED<800ml	(N=8) BLEED r=0.397 (p<0.02)	(N=10) TIME r=0.307 (p<0.05) BLEED r=0.405 (p<0.01) mPAP r=0.329 (p<0.05)
BLEED>=800ml	(N=0)	(N=6) AGE r=−0.399 (P<0.05)
TIME<240min	(N=5) AGE r=0.420 (p<0.05)	(N=8) mPAP r=0.343 (P<0.05) PARI r=0.361 (p<0.05)
TIME<=240min	(N=3) TIME r=0.573 (p<0.05) BLEED r=0.573 (p<0.05)	(N=8) N. S.

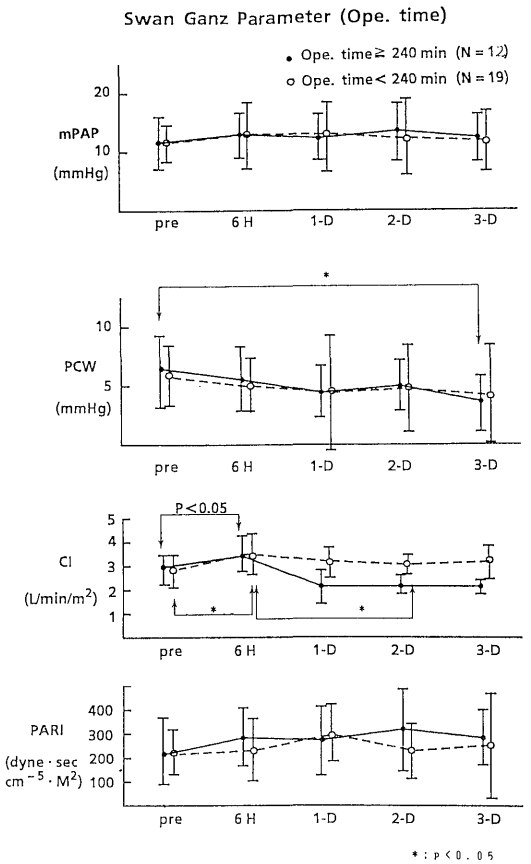

Fig. 9.

than four hours as shown in Fig. 9. There was not close correlation between EVLW and hemodynamic parameters. The coefficient indices between %EVLW and mPAP or CI were 0.212 ($p<0.02$) or -0.169 ($p<0.02$), showing not significant difference.

There was not a definite correlation between %EVLW and bleeding amount or operation time as shown in Table 1.

DISCUSSION

There were large numbers of influential factors on changes in pulmonary hemodynamics such as anesthesia under intratracheal intubation, thoracotomy, lung manipulation, bleeding, hypoxia and hypercapnia and damage to nerve in addition to a decrease in pulmonary parenchym, inflammation, changes in ventilation and perfusion, changes in lymph flow by node dissection and so on. It is accepted that meticulous postoperative care is required for prevention of grave complications with an accurate assessment of changes in pulmonary hemodynamics. Needless to say, one of the most serious complications is pulmonary edema in spite of low incidence. It is explained that pulmonary edema is based on increased pulmonary capillary pressure, decreased interstitial pressure reduced colloid osmotic pressure, elevated permeability of pulmonary capillary and increased pressure between lymphatics due to obstruction. It is well known that water shift is in accordance with a Starling' rule. EVLW represents as an equation: permeability rate X pressure gradient through the walls. Many investigators[4)-7)] reported a detailed pathogenesis although Visscher[2)] defined that abnormal water accumulation of EVLW is included in pulmonary edema. Diagnosis for lung edema used to be clinically made by physical findings, chest x-ray findings and a result of hemodynamic study. However, the assessment of EVLW shed light on early diagnosis for lung edema[8)9)]. Clinical application of measuring EVLW was first reported by Chinard and Enns[20)] in 1954 with double indicator dilution technique using iodine-labelled albumin (RISA) and THO, subsequently reported by Gee[21)] in 1971 with the use of thermo-ICGH double indicator dilution technique.

Lewis[22)] in 1979 designed to measure EVLW by using microcomputer and reported high reproducibility and a linear correlation with Wet/dry weight method. A normal value of EVLW measured by using lung water computer was reported as being 5.7±1.2ml/kg by Lewis[22)] and 5.6±1.8ml/kg by Sibbald[8)]. These approximated each other. Koizumi[9)] reported 8.07±0.16 of EVLW in lung cancer patients in contrast with 7.5±2.4ml/kg of EVLW in this series.

Kuroba[18)] and Otaka[11)] reported high EVLW in patients with heart diseases. It is said that EVLW correlate well with ages. There was not significant difference between 7.04±2.6ml/kg of EVLW in patients under 70 years old and 8.01±2.03 in patients over 70 in this series. Stauf[3)] classified lung edema into the two categories, high pressure edema (HPE) and permeability

edema (PE). Gujton[23] reported that EVLW slightly increased despite increased left atrial pressure of 25mmHg in patients with normal plasma protein concentration although EVLW incrased in proportion to an increased in PCW in patients with low plasma protein concentration. Kackow[24] emphasized that a marked decrease in colloid osmotic pressure-PCW gradient is predictive of lung edema. However, it is difficult to distinguish HPE from PE although HPE is in proportion to an increase in PCW. Shimada[25] explained that EVLW increased in proportion to high mPAP and increased pulmonary blood flow. It is clarified that the severity of lung edema does not correlate with high EVLW and the fact is reported[25] that lung edema in the pathogenesis of DIC results in decreased EVLW by reduced pulmonary vascular beds due to organic obstruction of pulmonary vessels.

Ando[12] reported in patients with esophageal cancer that increased EVLW accompanied an increase in PCW on day 3 and 4 after surgery in reflection of HPE pathogenesis and the mechanism to induce PE might be main on day 1. Kuroda[10] reported high EVLW in patients with impaired cardiopulmonary function. With respect to hemodynamic changes following pulmonary resection, Watanbe[29] also warned of postoperative crisis of high mPAP on day 1 and 2 after surgery. On the contrary, Tomiki[29] pointed out that lobectomy did not influenced on mPAP and PCW. They differ in opinion between EVLW and pulmonary hemodynamics. Shibata[14] clarified that EVLW six to 12 hours after surgery correlated well with PAAAP and PARI and an increase in EVLW in early postoperative period was associated with high permeability of pulmonary vascular beds. There are many influential factors on lung edema such as lung compression maneuver[18], interrupted vagal nerve[19] and reduced pulmonary vascular beds[30-32]. %EVLW is reliable for assessign changes in EVLW as reported by Kaned[32]. It is reasonably contemplated that EVLW is affected by the operation time, bleeding amount. In this series, these factors were taken into consideration by dividing Group I without node dissection and division of vagal nerve and Group II and III with node dissection. As a result, an increase in EVLW in Group II and III was regarded as elevated permeability as reported by Kanemaru[19], who clarified the fact that high EVLW was induced by division of vagal nerve. It is well known that EVLW is influenced by the amount of blood and fluid transfusion[16], electrolyte composition of fluid[18,33], infusion speed. Saldeen[34] reported that microembolism caused lung edem-like lesion. It is reasoned that microcoagulation of blood, which was contained in storaged blood might cause damage to vascular beds and provoke elevated permeability.

Vasoactive substance[35] and thromboxane A_2[36] play an key role in the pathogenesis of lung edema. It is assumed that surgical stress activates complement activity and causes much damage to the walls of vessels, in addition, microatelectasis during surgery causes a decrease in surfactant production. From the results, it is reasoned that prolonged operation time allows an increase in %EVLW.

Grave surgical stress provokes activated complement and an increase in the risk of lung edema. The results of this study warn surgeons of high risk of lung edema concerning prolonged operation time over four hours and increased bleeding amont over 800ml in patients with lobectomy and more exensive resection in terms of EVLW measurement.

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