Original Article

Evaluation of Respiratory Status in Patients after Thoracic Esophagectomy Using PiCCO System

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Purpose: Thoracic esophagectomy for esophageal cancer is among the most invasive operations, requiring thoracotomy and laparotomy. With regard to postoperative status, the increment of vascular permeability caused by various inflammatory cytokines might influence the postoperative respiratory condition. The PiCCO (pulse contour cardiac output) system (Pulsion Medical Systems AG, Munich, Germany), a new technique based on an arterial thermodilution technique, allows the measurement of extravascular lung water (EVLW). In this study, we hypothesized that EVLW might be a useful parameter to assess the respiratory condition and evaluated respiratory status using values for EVLW after thoracic esophagectomy.

Patients and Methods: The PiCCO system was established in the intensive care unit (ICU) in 25 patients immediately after thoracic esophagectomy for esophageal cancer. EVLWI (EVLW/body weight, normal range: 3–7 ml/kg) was measured on ICU days (ICUD) 1, 2, and 3. The PaO_2/FiO_2 (P/F ratio), pulmonary compliance, and lung injury score (LIS) were also calculated, and relationships between EVLWI and those parameters were evaluated.

Results: Mean operating time, blood volume, and fluid balance during surgery were 515 ± 16 (395–690) min, 721 ± 91 (167–1,770) ml, and 3,462 ± 292 (1,892–7,300) ml, respectively. The mean ICU stay was 3.4 ± 0.3 (2–10) days, and all patients were discharged from the ICU without complications. EVLWI gradually increased after surgery with values of 8.6 ± 1.9 ml/kg on ICUD 1, 9.7 ± 2.7 ml/kg on ICUD 2, and 10.0 ± 3.0 ml/kg on ICUD 3. EVLWI was well correlated with P/F ratio ($r = -0.358$, $p = 0.0135$), pulmonary compliance ($r = -0.625$, $p = 0.0001$), and LIS ($r = 0.614$, $p = 0.0001$).

Conclusion: EVLWI may be a useful parameter for evaluation of the respiratory condition after thoracic esophagectomy. (Ann Thorac Cardiovasc Surg 2008; 14: 283–288)

Key words: thoracic esophagectomy, respiratory status, pulse contour cardiac output system, extravascular lung water

Introduction

Thoracic esophagectomy for esophageal cancer is among the most invasive operations, requiring thoracotomy and laparotomy. In recent years, experienced centers have reported reduced hospital death rates of less than 10% after transthoracic esophagectomy.[1,2] This reduction has been attributed mainly to improvements in anesthesia, surgical techniques, and postoperative intensive care management. Some investigators postulated that the reduction of postoperative pulmonary complications has led to significant improvements in patients underwent thoracic esophagectomy.[2,3] Therefore the precise evaluation of respiratory status

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Table 1. Preoperative respiratory status

COPD	8% (2/25)
Smoking	72% (18/25)
% VC	103.6% ± 5.6% (73.5%–140.0%)
FEV 1.0%	78.6% ± 2.2% (64.3%–97.6%)
P/F ratio	376 ± 16 (248–454) mmHg
$PaCO_2$	41.8 ± 0.9 (35.9–52.6) mmHg

Mean ± SEM

COPD, chronic obstructive pulmonary disease; VC, vital capacity; FEV, forced expiratory volume; P/F ratio, PaO_2/FiO_2; SEM, standard error of the mean.

Table 2. Intraoperative and postoperative status

Operation time	515 ± 16 (395–690) min
Blood loss (Intraoperative)	721 ± 91 (167–1,770) ml
Fluid balance (Intraoperative)	3,462 ± 292 (1,892–7,300) ml
Extubation	2.4 ± 0.7 (2–4) ICU days
ICU stay	3.4 ± 0.3 (2–10) days

Mean ± SEM

ICU, intensive care unit; SEM, standard error of the mean.

after this operation is necessary.

PiCCO (pulse contour cardiac output) system (Pulsion Medical Systems AG, Munich, Germany), a new technique based on an arterial thermodilution method, allows the measurement of extravascular lung water (EVLW). A recent study showed that the EVLW index (EVLWI, EVLW/body weight) moderately correlated with markers of acute lung injury and was a useful parameter for the evaluation of acute lung injury in human septic shock.[4)]

In this study, using the PiCCO system we evaluated postoperative respiratory status in patients who had undergone thoracic esophagectomy and examined the relationships among EVLWI and other respiratory parameters, such as the PaO_2/FiO_2 (P/F ratio), pulmonary compliance, and lung injury score (LIS).

Patients and Methods

From June 2005 to March 2007, postoperative respiratory status was evaluated in 25 patients (20 men, 5 women; mean age 64.6 ± 1.6 years; range, 44–79) who had undergone thoracic esophagectomy for esophageal cancer and were subsequently admitted to the intensive care unit (ICU) for postoperative management. All patients gave their informed consent for participation in this study.

No patient had preoperative cardiac, pulmonary, liver, or renal dysfunction. All 25 had undergone thoracic esophagectomy, with right thoracotomy and laparotomy, and replacement of the gastric tract. A 3-field lymph node dissection was done in 17 patients and a 2-field lymph node dissection in 8. After admission to the ICU, a 4-Fr thermodilution catheter (PV2014L16, Pulsion Medical Systems AG) was inserted into the femoral artery and connected to a computer for pulse contour analysis. This catheter was used as an arterial line, and systemic blood pressure was continuously monitored. A central venous catheter had been inserted while the patient was still in the operating room. The mean of the infusion volume of acetated Ringer's solution after the operation was 1.0 ± 0.2 ml/kg/h.

Parameters obtained by PiCCO system

EVLW was determined using the PiCCO system. With the PiCCO method, a bolus of iced saline is injected through the central venous catheter, and the change in temperature is measured with a thermistor-tipped femoral arterial catheter. EVLW/weight (EVLWI) was also calculated by the PiCCO system. This parameter was measured daily from admission to the ICU and continuing until discharge, at which point the PiCCO catheter was removed.

Calculation of P/F ratio, pulmonary compliance, and LIS

The P/F ratio, pulmonary compliance, and LIS were calculated daily, beginning with a patient's admission to the ICU and continuing until discharge.

Statistical analysis

Results were expressed as mean ± standard error of the mean (SEM). The relationships among EVLWI, P/F ratio, pulmonary compliance, and LIS were analyzed by linear regression analysis. StatView software version 5.0 (Abacus, Berkeley, CA) was used for the statistical analysis. A statistical significance was assumed at a p value of less than 0.05.

Results

Preoperative respiratory status is shown in Table 1. A high percentage of patients were smokers (72%) (Table 1). However, only 2 (8%) had chronic obstructive pulmonary disease (COPD), and preoperative percent of vital capacity (VC), percent of forced expiratory volume (FEV 1.0), P/F ratio, and $PaCO_2$ were almost within

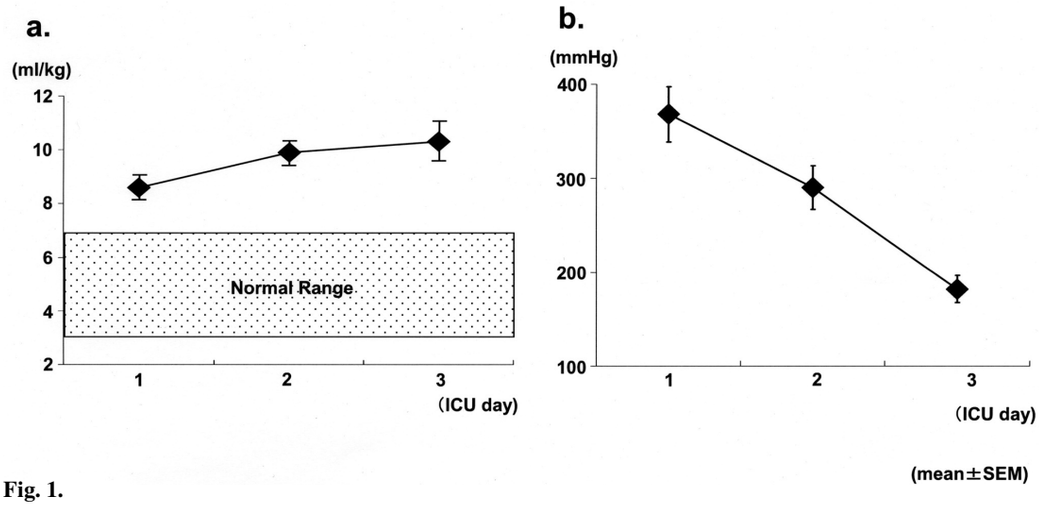

Fig. 1.
a: Changes in EVLWI.
b: Changes in P/F ratio.

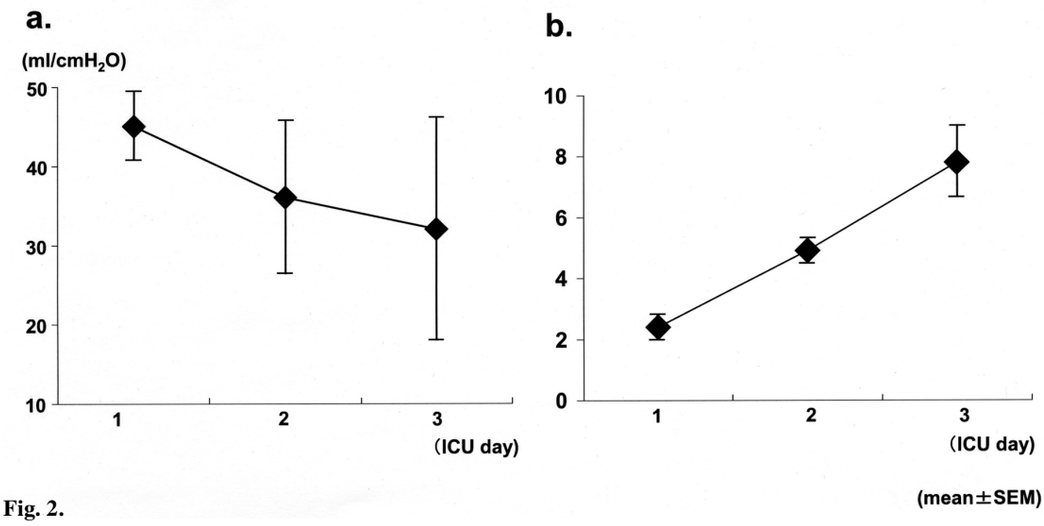

Fig. 2.
a: Changes in pulmonary compliance.
b: Changes in LIS.

normal limits.

The mean of operative time, intraoperative blood loss, and intraoperative fluid balance are shown in Table 2. All patients were extubated until ICU day 4 (that is, POD 3), and the mean ICU stay was 3.4 days (Table 2).

Figure 1a shows the changes in EVLWI. Postoperative EVLWI gradually increased and remained above the normal range during the ICU stay. On the other hand, the postoperative P/F ratio gradually decreased until POD 2 (Fig. 1b). Moreover, postoperative pulmonary compliance gradually lowered until POD 2 (Fig. 2a). As a result, the LIS gradually increased until POD 2 (Fig. 2b). Patients with thoracic esophagectomy were extubated no later than ICU day 4.

Figure 3 shows the relation between EVLWI and the P/F ratio, pulmonary compliance, and LIS. As shown, EVLWI correlated well with the P/F ratio ($r = -0.358$, $p = 0.0135$), pulmonary compliance ($r = -0.625$, $p = 0.0001$), and LIS ($r = 0.614$, $p = 0.0001$).

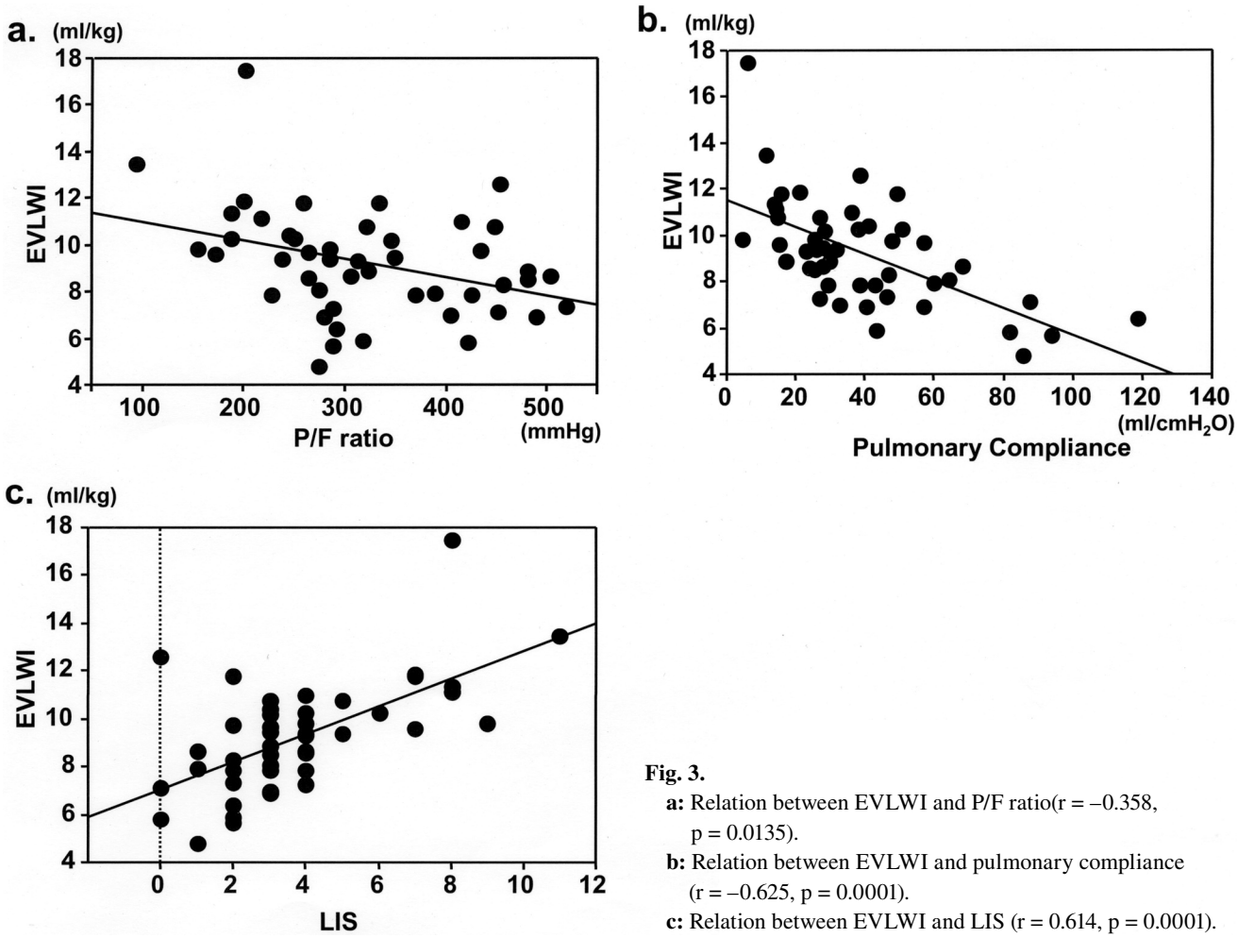

Fig. 3.
a: Relation between EVLWI and P/F ratio($r = -0.358$, $p = 0.0135$).
b: Relation between EVLWI and pulmonary compliance ($r = -0.625$, $p = 0.0001$).
c: Relation between EVLWI and LIS ($r = 0.614$, $p = 0.0001$).

Discussion

Tobacco smoking is strongly associated with the risk of esophageal cancer,[5] and a relatively high percentage of patients with esophageal cancer have COPD. Gillinov and colleague reported that 82 patients were smokers and 26 had COPD among 101 patients who underwent thoracic esophagectomy for esophageal cancer.[6] Moreover, a thoracotomy is required for thoracic esophagectomy, and the lung will be injured during surgery because it is decompressed and/or oppressed by operative materials to maintain operative exposure. Furthermore, the period of one-lung anesthesia required during esophagectomy may also be important. Therefore pulmonary complications such as pneumonia and respiratory insufficiency are among the most frequent complications that develop after esophagectomy.[7] The incidence of pulmonary complications is reported to be within the range of 18%–44%.[8–10] Moreover, acute respiratory distress syndrome is associated with esophagectomy and occurs in 10%–20% of cases.[11,12] Thus an accurate evaluation of postoperative respiratory status is required to reduce pulmonary complications following esophagectomy. In this study, we determined changes in EVLWI, using the PiCCO system, and evaluated the relation between EVLWI and other ordinary pulmonary parameters, such as the P/F ratio, pulmonary compliance, and LIS after esophagectomy.

Our results showed that the postoperative EVLWI was higher than the normal range during the ICU stay. This may be caused by an increase in vascular permeability after thoracic esophagectomy, which, as we mentioned, is among the most invasive of surgeries. Other respiratory parameters such as the P/F ratio, pulmonary compliance, and LIS gradually worsened during the ICU stay, though some patients were extubated on ICU day 2 (that is, POD 1). In this study, only two patients (8%) had COPD, and preoperative respira-

tory function was maintained (preoperative percent of VC and FEV 1.0 were 103.6% ± 5.6% and 78.6% ± 2.2%, respectively). However, the rate of smoking among these patients was high (72%), and there might have been hidden respiratory disorders. Our decisions on extubation are usually based on physiological findings, such as consciousness, cough reflex, and spontaneous thoracic movement, as well as the results of arterial blood gas analysis. Taking our results into consideration, however, we presume that patients who were extubated following thoracic esophagectomy had concealed respiratory dysfunction that could not be shown by physiological findings and/or by the results of blood gas analysis. Therefore the consideration of other respiratory parameters associated with the P/F ratio, pulmonary compliance, and LIS and that precisely reflect the respiratory status should be necessary. In this study, EVLWI was well correlated with the P/F ratio, pulmonary compliance, and LIS. Therefore it is possible to accurately monitor postoperative respiratory status by a continuous evaluation of EVLWI, even after extubation. Kuzkov and co-workers also reported that EVLWI demonstrated moderate correlation with markers of acute lung injury in human septic shock and that EVLWI might be of value as an indicator of prognosis and severity of sepsis-induced acute lung injury.[4)]

There are two methods for *in vivo* quantitative assessment of EVLWI: one is the combined thermo-dye dilution technique, a gold standard, and the other is the single transpulmonary thermodilution method, which can be performed with the PiCCO system. However, the combined thermo-dye dilution technique is cumbersome and time-consuming and has not gained widespread clinical use.[13)] On the other hand, the transpulmonary thermodilution technique is easily applied in a clinical setting, and EVLWI determined by that method correlates with that determined by thermal-dye dilution.[13–15)] We also used a transpulmonary thermodilution technique with the PiCCO system in this study. The intrathoracic blood volume index (ITBVI), which is a useful parameter for the evaluation of preload, also can be measured using the PiCCO system at the same time. It might be possible to establish precise fluid management following thoracic esophagectomy by the combined evaluation of EVLWI and ITBVI.[16)] We are also planning to evaluate the relationship between EVLWI and the prognosis of patients with thoracic esophagectomy.

Limitations of the study

Our study was performed for only a few days when patients with thoracic esophagectomy were in the ICU. A PiCCO system could be used only in the ICU and had to be removed from a patient being moved to an ordinary ward in our hospital. These wards lack the necessary equipment to accommodate a system of this kind.

In conclusion, the postoperative changes of EVLWI in patients with thoracic esophagectomy were evaluated, and EVLWI was well correlated with the P/F ratio, pulmonary compliance, and LIS. Although the present study could not clearly show the superiority of EVLWI assessment with a PiCCO system over these conventional parameters, EVLWI may be a useful parameter of the respiratory condition of these patients because EVLWI assessment can provide additional information for the respiratory management of patients undergoing esophagectomy.

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