We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Pulmonary Edema Induced by Esophagectomy

Yusuke Sato, Satoru Motoyama and Junichi Ogawa
*Department of Surgery, Akita University School of Medicine,
 Japan*

1. Introduction

Esophageal cancer is the seventh leading cause of cancer deaths worldwide (410,000 new cases annually)(1). Asian, Middle Eastern, and East African countries have a markedly higher incidence of esophageal cancer than other areas. In the United States, the incidence of adenocarcinoma of the distal esophagus and gastroesophageal junction has progressively increased to approximately 70% of all esophageal cancers over the last two decades. It affects mostly Caucasian men, and its pathogenesis is linked to gastroesophageal reflux disease (GERD) and the development of Barrett's esophagus. On the other hand, squamous cell carcinoma is responsible for 95% of all esophageal cancers worldwide. It arises from whole esophagus, from the cervical esophagus to the gastroesophageal junction, and spreads to the cervical, thoracic, and abdominal lymph nodes with relative ease because of the abundant and complex lymphatic network (2). Therefore, esophagectomy with extensive neck, thoracic, and abdominal lymph node dissection, the so-called "3-field lymph node dissection," is needed for curative surgery for esophageal squamous cell carcinoma (3). Though chemotherapy, radiotherapy, and combination therapy of both have been substantially developed as treatments for esophageal squamous cell carcinoma in recent years, these treatments are still inferior in survival rate and late toxicity compared to surgery (4).

Esophagectomy with 3-field lymph node dissection is one of the most invasive surgical procedures. This highly invasive surgery is currently still associated with high morbidity, despite improvements in surgical techniques and perioperative managements. A "cytokine storm" during and after esophagectomy induces severe hemodynamic changes involving loss of circulating blood volume and filling of the third space. Furthermore, extensive lymph node dissection and ligation or excision of the thoracic duct have a causal influence on mediastinal lymphostasis, which disturbs drainage of extravascular lung water (EVLW) from the lungs and causes pulmonary edema. Pulmonary edema may form the base of pulmonary complications such as atelectasis and pneumonia, the most common complications after esophagectomy.

Monitoring of EVLW in cases of critically ill patients with acute lung injury (ALI) or acute respiratory distress syndrome (ARDS) has proved to be very informative and useful for predicting outcome (5,6).

Based on these findings, we monitored perioperative changes in EVLW using the recently developed single transpulmonary thermodilution technique to determine whether EVLW

correlates with respiratory function and predicts pulmonary complications. In this chapter, we expound on the importance of recognizing and monitoring EVLW during perioperative managements of esophagectomy for thoracic esophageal squamous cell carcinoma.

2. Extravascular Lung Water (EVLW)

EVLW is the amount of water that is present in the lungs outside of the pulmonary vasculature, put simply, the alveoli and interstitium of the lungs. Thus, EVLW is a quantitative term describing pulmonary edema. EVLW is expressed using the formulas described in Fig.1. Intrathoracic thermal volume (ITTV) is computed by multiplying cardiac output (CO) by mean transit time (MTt), which is the time when half of the indicator has passed the point of detection of the artery. Pulmonary thermal volume (PTV) is computed by multiplying CO by downslope time (DSt), which is the exponential downslope time of the thermodilution curve. Global end diastolic volume (GEDV) is calculated by subtracting PTV from ITTV. Intrathoracic blood volume (ITBV) is expressed as GEDV x 1.25. Finally, EVLW is calculated by subtracting ITBV from ITTV. Extravascular lung water index (EVLWI, EVLW/body surface area, ml/m²) is a more precise parameter than EVLW and provides more accurate results, particularly in overweight patients.

Fig. 1. EVLW and other parameters such as intrathoracic thermal volume (ITTV), pulmonary thermal volume (PTV), global end diastolic volume (GEDV), and intrathoracic blood volume (ITBV) are described with these formulas.

3. PiCCO

PiCCO (Pulsion Medical Systems, Munich, Germany, <http://www.pulsion.com>) is a less invasive advanced hemodynamic monitoring system employing the single transpulmonary thermodilution technique (**Fig.2**). It requires only a standard central venous catheter and a femoral, axillary, brachial, or radial artery catheter (but not a pulmonary artery catheter). This system enables monitoring of cardiac function, vascular tone, and fluid distribution, including EVLW. EVLW and EVLWI are automatically calculated after a bolus infusion of cold saline via the central venous catheter. As mentioned above, monitoring EVLW using this system in critically ill patients with ALI/ARDS has proved to be very informative and useful for predicting outcome. The current PiCCO2 system is employed for management of patients not only with ALI / ARDS but also septic shock, burns, major surgery, and cardiac surgery, among others.

Fig. 2. General outline of the PiCCO system, which requires only a standard central venous catheter and a femoral, axillary, brachial, or radial artery catheter, but not a pulmonary artery catheter.

4. EVLW monitoring predicts pulmonary complications after esophagectomy

To determine whether EVLW correlates with respiratory function and predicts pulmonary complications after esophagectomy, we enrolled 23 patients with thoracic esophageal cancer in a prospective observational clinical trial (8). Informed consent was obtained from all patients.

All of these patients underwent esophagectomy with extensive lymph node dissection and reconstruction involving insertion of a gastric tube via the posterior mediastinal route. They were also monitored perioperatively using PiCCO from the day prior to surgery through

postoperative day (POD) two. Our standard operative procedure is right transthoracic esophagectomy and resection of the lesser curvature with dissection of the mediastinal (involving the periesophageal region and areas around trachea and bilateral main bronchus), the abdominal (involving the perigastric region and areas around the celiac axis), and the bilateral neck lymph nodes (areas around common carotid artery, internal jugular vein and transverse cervical artery), the so-called “three-field lymph node dissection”. Following surgery, the extubation criteria for the intratracheal tube were $\text{PaO}_2 > 100$ Torr with a $< 40\%$ inspired fraction of oxygen (FiO_2), forced vital capacity > 800 ml, and no pulmonary complications. Based on these extubation criteria, the tracheal tubes were removed from 11 patients on the morning of POD one (extubation group); the remaining 12 patients remained intubated (intubation group). The respiratory Index was calculated using the following equation: $\text{respiratory index} = (\text{PAO}_2 - \text{PaO}_2) / \text{PaO}_2$, where $\text{PAO}_2 = [(760 - 47 (\text{atmospheric pressure})) \times \text{FiO}_2 - \text{PaCO}_2 / 0.8]$. The respiratory index essentially reflects the ability to oxygenate the lung.

In all patients, EVLW correlated significantly with the respiratory index ($r = 0.638$, $p < 0.0001$) at all measurement points after surgery (**Fig. 3**). The changes in EVLW and respiratory index during the perioperative period in the extubation and intubation groups are shown separately in **Fig. 4**. In the extubation group, EVLW was clearly reduced immediately after surgery ($p = 0.0068$), but it recovered to preoperative levels within 12 h after surgery and remained at that

Fig. 3. EVLW correlated significantly with the respiratory index (RI) ($r = 0.638$, $p < 0.0001$) at all measurement points after esophagectomy.

level through POD two. By contrast, in the intubation group, both EVLW and respiratory index were elevated 12 h after surgery and were even higher 24 h after surgery. All of the patients in the extubation group recovered with no pulmonary complications, whereas four patients (33%) in the intubation group developed pneumonia or atelectasis that required artificial respiration managements. In all four patients that developed pulmonary complications, an increase in EVLW preceded their onset.

Fig. 4. The changes in EVLW and the respiratory index (RI) during the perioperative period in the extubation and intubation groups. In the intubation group, both EVLW and respiratory index were elevated 12 h after surgery and were even higher 24 h after surgery.

5. Conclusion

We have shown that EVLW measured using the PiCCO system reflects the level of postoperative pulmonary edema induced by esophagectomy with extended lymph node dissection. Patients who showed no significant postoperative changes in EVLW or respiratory index recovered without pulmonary complications. By contrast, those patients who showed an increase in EVLW on POD one showed a substantial increase in their respiratory index, and some developed pulmonary complications. Measurement of the EVLW using the PiCCO system thus proved to be a useful method for monitoring the pulmonary edema and was predictive of the pulmonary complications that subsequently occurred. This PiCCO system enables us to begin early managements of patients who develop pulmonary edema following esophagectomy with extensive lymph node dissection.

6. References

[1] "WHO Disease and injury country estimates". World Health Organization. 2009. Retrieved Nov. 11, 2009.

- [2] Motoyama S, Maruyama K, Sato Y et al. Status of involved lymph nodes and direction of metastatic lymphatic flow between submucosal and t2-4 thoracic squamous cell esophageal cancers. *World J Surg.* 2009 Mar;33(3):512-7.
- [3] Akiyama H, Tsurumaru M, Udagawa H et al. Radical lymph node dissection for cancer of the thoracic esophagus. *Ann Surg.* 1994 September; 220(3): 364-373.
- [4] Kato K, Muro K, Minashi K et al. Phase II Study of Chemoradiotherapy with 5-Fluorouracil and Cisplatin for Stage II-III Esophageal Squamous Cell Carcinoma: JCOG Trial (JCOG 9906). *Int J Radiat Oncol Biol Phys.* 2010 Oct 5.
- [5] Martin GS, Eaton S, Mealer M et al. Extravascular lung water in patients with severe sepsis: a prospective cohort study. *Crit Care* 2005;9:R74-R82.
- [6] Michard F, Schachtrupp A, Toens C. Factors influencing the estimation of extravascular lung water by transpulmonary thermodilution in critically ill patients. *Crit Care Med* 2005;33:1243-1247.
- [7] Abo S, Kitamura M, Hashimoto M et al. Analysis of results of surgery performed over a 20-year period on 500 patients with cancer of the thoracic esophagus. *Surg Today* 1996;26:77-82.
- [8] Sato Y, Motoyama S, Maruyama K et al. Extravascular Lung Water Measured Using Single Transpulmonary Thermodilution Reflects Perioperative Pulmonary Edema Induced by Esophagectomy. *Eur Surg Res* 2007;39:7-13.

IntechOpen

Esophageal Cancer - Cell and Molecular Biology, Biomarkers, Nutrition and Treatment

Edited by Prof. Ferdous Rastgar Jazii

ISBN 978-953-51-0223-6

Hard cover, 244 pages

Publisher InTech

Published online 07, March, 2012

Published in print edition March, 2012

Esophageal Cancer illustrates recent achievements and investigations in the esophageal tumorigenesis from different perspectives. Readers find mechanisms involved in esophageal tumorigenesis, cellular, molecular, genetic, epigenetics, and proteomics, their relevance as the novel biomarkers and application in esophageal cancer diagnosis and therapy. The book covers detailed effect of nutritional factors in addition to ethanol metabolic pathway in the inhibition of retinoic acid metabolism and supply. Diagnosis, classification, and treatment of esophageal cancer, application of both surgical and non surgical methods as well as follow up of the disease are described in detail. Moreover readers are endowed with especial features of esophageal cancer such as multiple early stage malignant melanoma and pulmonary edema induced by esophagectomy, the two features that received less attention elsewhere in literature.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Yusuke Sato, Satoru Motoyama and Junichi Ogawa (2012). Pulmonary Edema Induced by Esophagectomy, Esophageal Cancer - Cell and Molecular Biology, Biomarkers, Nutrition and Treatment, Prof. Ferdous Rastgar Jazii (Ed.), ISBN: 978-953-51-0223-6, InTech, Available from: <http://www.intechopen.com/books/esophageal-cancer-cell-and-molecular-biology-biomarkers-nutrition-and-treatment/pulmonary-edema-induced-by-esophagectomy>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen