Review Article

Anaesthesia during oesophagectomy

Denise P. Veelo, Bart F. Geerts

Department of Anaesthesiology, Academic Medical Center, Amsterdam, The Netherlands

Contributions: (I) Conception and design: DP Veelo; (II) Administrative support: None; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: DP Veelo; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Denise P. Veelo, MD, PhD. Department of Anaesthesiology, Academic Medical Center, Amsterdam, Meibergdreef 9, 1105 AZ, The Netherlands. Email: d.p.veelo@amc.uva.nl.

Abstract: In this review, we will provide an overview of the current state of the art of perioperative practices for open and laparoscopic oesophagus surgery from the anaesthetist's perspective. Morbidity and mortality after oesophagectomy is still high despite multidisciplinary and enhanced recovery pathways showing promising results. The anaesthetist has an important role in the complex care of the oesophageal cancer patient. Minimizing unnecessary fluid administration, adequate pain management, hypotension, and protective lung ventilation are examples of proven strategies that can improve outcome after this high-risk surgery.

Keywords: Oesophagectomy; anaesthesia; review

Submitted Nov 29, 2016. Accepted for publication Mar 10, 2017.
doi: 10.21037/jtd.2017.03.153
View this article at: http://dx.doi.org/10.21037/jtd.2017.03.153

Introduction

Oesophageal surgery is high-risk. Despite innovations in surgical techniques (open *vs.* laparo-thoracoscopic) and the addition of neo-adjuvant chemo-radiotherapy, major morbidity still can be up to 65% and 30-day mortality rate as high as 4% (1,2). Pulmonary infections and anastomotic dehiscence make up for the majority of reported complications. To reduce complications minimally invasive techniques were introduced and some studies report a more favourable outcome (1). This especially translates into a reduction in pulmonary complications, which are reported to decrease by 60% (2). However, outcome seems especially related to patient and tumour characteristics, surgical experience and hospital volume (3,4). Over the years, it has become clear that a multimodal, multispecialty and dedicated-team approach is essential for these patients, including strict patient selection, work-up, and enhanced recovery after surgery (ERAS) protocols (5). The anaesthetist is an essential member of the multidisciplinary team. Pain and stress, fluid, hemodynamic, and ventilation management can influence outcome significantly. Best practices may differ depending on the surgical techniques used.

In this review, we will provide an overview of the current state of the art perioperative practices for open and laparoscopic surgery from the anaesthetist's perspective.

Preoperative screening and optimisation

Patients with oesophageal cancer often have comorbidities, suffer from significant weight loss, poor nutritional state and are more fragile (6,7). An overweight patient will have a higher chance of wound infections while an underweight patient has odds of death go up 5-fold (8). Timely screening of the preoperative patient will allow the possibility to improve the health status of the patient and to reduce chances of adverse outcome (9). The anaesthetist should be involved early in a multidisciplinary evaluation that also includes a debate whether or not to proceed to surgery based on expected perioperative morbidity.

To assess the perioperative risk of morbidity and mortality some general and some oesophagectomy specific risk scoring systems exist. Warnell and co-workers reviewed ten of these models that were externally validated (3). The accuracy of these scoring varies widely with overestimation of mortality occurring frequently (5–200% of cases) and a reported area under the curve between 0.58 and 0.78. Common risk factors are age, comorbidities (cardiopulmonary, diabetes, renal insufficiency, liver dysfunction), preoperative treatment (neoadjuvant chemotherapy), tumor staging and hospital characteristics (hospital volume of oesophagectomies) (3).

More elaborate general preoperative risk scores have also recently been developed from large databases of over one million patients. The POSPOM scoring system is such a scoring system (10). Unfortunately, it fails to consider the patient comorbidities completely neither does it reflect the full scope of the oesophagectomy (both abdominal and thoracic surgery). However, this score does provide the patient and all specialists involved in the care with a more reliable (albeit likely underestimation) of what would happen if oesophageal surgery were performed.

A structured preoperative screening in an anaesthesia outpatient clinic has become the standard for anaesthesia care in most countries. During the pre-assessment cardiac function should be evaluated by assessing functional disabilities and the MET score. An EKG can provide information about dysrhythmias, conduction delays, previous myocardial infarction, and hypertrophic development of atrium and/or ventricle. When wall motion or valvular issues are suspected, an echocardiography can provide new insights. Most patients will receive chemoradiation, which may impact cardiac function. Lund *et al.* found that baseline cardiac output can be decreased by as much as 15% due to chemo-radiotherapy during rest (11). Although the impact has been described as mild, anaesthetic drugs, surgery, one lung ventilation (shunting), and laparo-thoracoscopy may further influence heart function.

Additional work-up should include blood testing for renal and liver function, haematology, irregular antibodies and clotting upon indication. When oesophagectomy is to be performed, functional assessment of the lungs needs to be performed. The patients need to be able to undergo one-lung ventilation (OLV). As most patients in this population have been or are smokers, the incidence of significant emphysema is higher. Exact cut-offs to perform one-lung ventilation have not been clearly determined. Acute lung injury after oesophagectomy has been reported in as many as 25% of all cases after surgery (12). Risk factors are low pre-operative body mass index, smoking, the experience of the surgeon, the duration of surgery and OLV, post-operative anastomotic leak, peri-operative hypoxaemia, hemodynamic instability requiring additional fluids or vasoactive support (12).

Weight loss is often pathognomonic for poor outcome after surgery and albumin levels can be a marker of very poor nutritional state (13). A dietician should be consulted to optimize weight, fat and protein status. Sometimes it is warranted to delay surgery to supplement proteins as this might improve wound healing and prevent infections or anastomotic breakdown. Early involvement of physiotherapist to improve physical or cardiopulmonary fitness and a dietician for a good nutritional state seems rational but studies into the effect on outcome are contradictory (14-17).

Best anaesthetic practices

Type of anaesthesia

The discussion of the advantages over the use of one anaesthetic over the other has led to a number of studies to be performed. However, this discussion is complicated by the small number of studies available, small number of patients included and the differences in endpoints and methodology, which makes them difficult to compare.

Some studies have described immune-modulatory benefits and reduced ischemia-reperfusion injury markers of volatile anaesthetics during one lung ventilation. However, after thoracic surgery there seems to be no clear relation between inflammatory markers and pulmonary morbidity as the results of clinical studies are conflicting (18-22).

During one lung ventilation hypoxic pulmonary vasoconstriction (HPV) influences intrapulmonary shunting and oxygenation. Volatile anaesthetics have been shown to impair HPV in a dose dependent matter in contrast to propofol in animal models (23). However, when titrate to effect the influence of volatile anaesthetics on intrapulmonary shunting may be equal to that of propofol (24).

Thoracic epidural analgesia

There seems to be no benefit of using either volatile anaesthetics or propofol on the occurrence and severity of post-operative pain (25). But the evidence on the use of multimodal treatment regimes during oesophagectomy and especially the thoracic epidural analgesia (TEA) seems clear. This benefit has been shown for both open as minimally invasive oesophagectomy. TEA provides superior analgesia, reduces respiratory complications, need for postoperative mechanical ventilation, rehabilitations and hospital length of stay (26-30). Most studies show mainly an effect on pulmonary morbidity although a reduction in the incidence of anastomotic leakage has also been suggested (31). TEA has no clear anti-inflammatory effects (32).

Ventilatory management

Ventilatory management during transthoracic oesophagectomy is usually managed with OLV by means of a double-lumen tube (DLT). This technique enables easy separation of both lungs but has also been associated with complications such as hoarseness and damage to the vocal cords, and tracheo-bronchial lacerations. Conformation of position requires fiber-optic bronchoscopy. Recently the video DLT has been introduced. This DLT has an integrated high-resolution camera, which would remove the need for fiber-optic confirmation (33). Although the first reports with this technique are promising, conclusive studies are needed to confirm added safety, utility and cost-effectiveness of this device. An alternative technique for separated lung ventilation is the use of a bronchus blocker. This device is thought to be similar in terms of performance for patients with normal airways. In patients with airway abnormalities and difficult intubation bronchus blockers may be preferred (34). During minimally invasive transthoracic and trans-hiatal surgery the use of one lung ventilation may not be obligatory. One Chinese group reported the use of single lumen intubation for thoracoscopy as feasible and safe (35). Indeed, the need for OLV might also depend on the position of the anastomosis and the need for optimal surgical views. Challenges for the anaesthesiologist during OLV are deoxygenation and hypercapnia due to shunting and atelectasis. The latter may especially be difficult to manage during thoracoscopy, which may take place in the left lateral or prone position (36,37). Laparoscopic surgery in the prone position is described to be associated with better oxygenation due to lower shunt fractions and better ventilation/perfusion matching (38,39). In addition, it may decrease blood loss and improve surgical ergonomics.

The incidence of acute respiratory distress syndrome (ARDS) or acute lung injury (ALI) after oesophagectomy is high with a reported incidence of 16% up to 33% (40). Important etiologic factors are fluid overload, vascular leakage, damage of lung lymphatics and pulmonary endothelium. These are induced by peripheral and alveolar inflammatory mediator production and cellular infiltration. Patient and procedure related risk factors for ALI have been discussed earlier. The severity of the inflammatory response may be a predictive factor in postoperative pulmonary morbidity (41). The use of OLV may aggravate this process. The use of lung protective ventilation strategies during one lung ventilation such as the use of smaller tidal volumes (5 mL/kg), plateau pressures below 35 cmH_2O and the application of PEEP has been shown to decrease the inflammatory response and improve oxygenation and resulted in shorter times until extubation and pulmonary complications (41,42). Although no large outcome studies have been done for patients after oesophagectomy, the benefits of the use of lung protective ventilation in the prevention and treatment of ARDS/ALI in critically ill patients and the general surgical population are well established (43).

Fluid management

Intravenous fluids and outcome

Both hypervolemia and hypovolemia may be associated with increased morbidity (44). Fluid management in this patient group has until recently focused on restricting fluid administration to prevent pulmonary and cardiac complications (40). The majority of studies focus on patients after lung surgery and only a few small retrospective studies are available on oesophageal surgery showing a reduction in pulmonary complications with fluid restriction (45,46). However, it remains unclear whether a reduction in anastomotic leakage can be achieved by fluid restriction as surgical and anatomical factors may play a more important etiologic role. This can also be concluded from the data of Wei *et al.* (45). A relationship between fluid balance and anastomotic leakage was not found. Indeed, a too restrictive approach may also increase the possibility of post-operative complications, such as cardiac ischemia, and kidney failure (44). A review of Ishikawa *et al.* on the development of acute lung injury after lung surgery highlights this fact (47). They state that although the incidence of renal injury in thoracic surgical patients has been estimated to be 1.4%, outcome was mainly based on incidence of patients requiring renal replacement therapy. If other criteria would be used the incidence of kidney injury may be much higher varying between 6% and 33%.

Goal directed therapy

Perioperative goal-directed fluid therapy (PGDT) aims to optimize fluid administration by using objective parameters predicting fluid responsiveness such as pulse pressure and stroke volume variation, stroke volume or cardiac output. Its application has been shown to improve outcome in high risk surgery patients and may either reduce or increase the amount of infused fluids depending on the population studied, pre-PGDT fluid habits, the hemodynamic algorithm and type of fluid used (48). However, most studies have focused on abdominal and vascular surgery patients and outcome data is lacking on those for thoracic surgery, especially those receiving open and laparo-thoracoscopic oesophagectomy. Minimally invasive technologies currently available to guide goal-directed fluid therapy include oesophageal Doppler, arterial waveform analysis, photoplethysmography, and bioimpedance. Some experiences in thoracic surgery have been made using arterial waveform analysis targeting dynamic markers of preload responsiveness such as stroke volume variation (SVV), pulse pressure variation (PPV) and stroke volume index (SVI) (49-51). The accuracy of SVV and PVV are influenced by the tidal volume given and chest compliance, which is affected during open chest surgery. The use of this marker in these patients remains controversial (40). EVLW has been used as a predictor for the development of acute lung injury in patients after thoracotomy. Recently, Haas *et al.* showed that a GDFT algorithm using SVV did not increase extravascular lung water (EVLW) in patients undergoing thoracotomy for lung resection and oesophagectomy suggesting the safety of use of such protocols (49). Unfortunately no large prospective outcome studies have been done as yet and especially the utility of these markers with surgery by means of thoracoscopy is unknown.

Presently restrictive fluid regimes are most advocated based on the evidence available. However, one can make the argument for goal directed approaches generated from experience in the general surgical population, especially for patients with pre-existent kidney disorders.

Haemodynamics *vs.* integrity of the anastomosis

During oesophagectomy multiple arteries are ligated. The newly formed gastric tube depends only on the right gastro-epiploic artery leaving the fundus (and future anastomosis) dependent on passive diffusion of blood. Poor local perfusion is thought to be the main etiologic factor in development of anastomotic leakage (52). Optimally, local perfusion pressure and flow would be monitored during the operation and during the first postoperative days. However, until now this has only been done in experimental settings (53-58).

Monitoring techniques

Standard intraoperative haemodynamic monitoring includes EKG, (continuous) arterial blood pressure, and central venous pressure. Some experimental perfusion or microcirculation monitor techniques have been described in oesophagus surgery (53-59). Examples are Laser Doppler Flowmetry, Near Infrared Spectroscopy (NIRS), Laser Speckle (Contrast) Imaging (LSI), Fluorescence Imaging (FI), Sidestream Darkfield Microscopy (SDF) and Optical Coherence Tomography (OCT). Although these techniques are very promising most are not yet validated and may be difficult to use and interpret at the bedside. Intraoperatively a real-time widefield overview of the flow of the gastric tube may be preferable, such as LSI (59). The surgeon may then be able to adjust location of the anastomosis based on flow parameters and determining borders between vital and less vital (ischemic) tissue regions. Furthermore anaesthesiologists may adjust hemodynamic and fluid management and titrate on effect. Postoperatively other techniques, measuring oxygenation or flow may be more useful. Previous studies researched by Miyazaki, Ikeda and Pierie *et al.* reported that anastomotic leakage was more common in patients with lower local flow values (52,56,57). However, large prospective clinical studies are needed to show the usefulness of these techniques in influencing outcome.

Pressure and/or flow?

For the anaesthesiologist it is important to consider whether to optimize perfusion pressure, flow or both in order to improve outcome, especially anastomotic dehiscence. The evidence on this topic is scarce. One recent observational study studied the effect of hypotensive episodes (systolic pressure decline of >30% of baseline value for more than 5 minutes) during oesophagectomy and the occurrence of anastomotic leak in 84 patients (60). They found that more anastomotic leakages were seen in patients with hypotensive episodes and high vasopressor use. Interestingly, hypotensive episodes seemed more frequent in patients in prone positioning and with the use of epidural catheters. Although this was a small study the results are in line with recent large studies in the general surgical population showing the correlation between low blood pressures and adverse outcome (61). As discussed above little evidence is available on the influence of flow parameters and outcome. The usefulness of monitoring SVI in relation to outcome has also been suggested in a small study of Sugasawa *et al.* (51). They showed that those patients that had a SVI <35 mL/m^2 at the end of oesophagectomy had a higher chance of developing acute kidney injury.

Some efforts have been made to investigate whether the anaesthesiologist can influence perfusion of the gastric tube directly. Most studies confirm that the presence of systemic hypotension negatively affects flow over the gastric tube (52,54,56,58,62). However, increasing MAP above normal levels likely has no additional benefits. Venous congestion may be an additional factor in decreasing flow over the gastric tube. The local application of nitroglycerin is recommended by some investigators under those circumstances (53,55).

Enhanced recovery

Enhanced recovery programs have gained traction in all areas of surgery. The goal is to achieve independence from medical treatment, decrease complication rates and achieve early discharge. Length of stay has been reduced with the help of ERAS protocols in oesophagectomy patients (63). Although most topics mentioned above are part of the ERAS protocol, other items that should be named are early extubation, preoperative carbohydrate loading up to two hours prior to surgery, and early and adequate postoperative feeding (5).

It is unclear if oesophagectomy patients should be transferred to a post-anaesthesia care unit, intensive care unit or normal recovery after surgery. Patient allocation differs between hospitals and is often based on historical choices. It seems rational to have patients stay in a high-care environment to spot early neo-oesophagus breakdown, sepsis, inadequate pain management, and persistent hemodynamic instability. Experience with the protocols and specificities of post-operative care of oesophagectomy is essential.

Aside from achieving early and adequate feeding, diligent fluid titration in the post-operative setting and ward seems a rational approach. Studies on this topic are lacking. Finally, we would like to point out that for the longest periods of their hospital stay oesophagectomy patients are not monitored for their vital signs. Miniaturisation and wireless techniques now allow heart rate, temperature and respiratory rate monitoring with the application of a small patch (64,65). Data is not yet available on the value in spotting the morbid patient by means of these devices but this may be an important possibility to improve care for these patients. With ICU outreach teams and MEWS on one end and wireless monitoring tools on the other, the gap for failure to rescue seems to be closing.

Conclusions

Morbidity and mortality after oesophagectomy is still high despite multidisciplinary and enhanced recovery pathways showing promising results. The anaesthetist has an important role in the care of the complex care of the oesophageal cancer patient. Minimising unnecessary fluid administration, adequate pain management, hypotension, and protective lung ventilation are examples of proven strategies that can improve outcome after this high-risk surgery. Future possibilities for improvement may especially lie in the early rescue of deteriorating patients in the postoperative surgical wards.

Acknowledgements

None.

Footnote

Conflicts of Interest: DP Veelo and BF Geerts have received travel and research grants from Edwards Lifesciences LLC.

References

1. Biere SS, van Berge Henegouwen MI, Maas KW, et al. Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 2012;379:1887-92.
2. Briez N, Piessen G, Torres F, et al. Effects of hybrid minimally invasive oesophagectomy on major postoperative pulmonary complications. Br J Surg 2012;99:1547-53.
3. Warnell I, Chincholkar M, Eccles M. Predicting perioperative mortality after oesophagectomy: a systematic review of performance and methods of multivariate models. Br J Anaesth 2015;114:32-43.
4. Dikken JL, Dassen AE, Lemmens VE, et al. Effect of hospital volume on postoperative mortality and survival after oesophageal and gastric cancer surgery in the Netherlands between 1989 and 2009. Eur J Cancer 2012;48:1004-13.
5. Ford SJ, Adams D, Dudnikov S, et al. The implementation and effectiveness of an enhanced recovery programme

after oesophago-gastrectomy: a prospective cohort study. Int J Surg 2014;12:320-4.
6. Robinson TN, Wu DS, Pointer L, et al. Simple frailty score predicts postoperative complications across surgical specialties. Am J Surg 2013;206:544-50.
7. Yoshida N, Baba Y, Shigaki H, et al. Preoperative Nutritional Assessment by Controlling Nutritional Status (CONUT) is Useful to estimate Postoperative Morbidity After Esophagectomy for Esophageal Cancer. World J Surg 2016;40:1910-7.
8. Mullen JT, Davenport DL, Hutter MM, et al. Impact of body mass index on perioperative outcomes in patients undergoing major intra-abdominal cancer surgery. Ann Surg Oncol 2008;15:2164-72.
9. Guinan EM, Dowds J, Donohoe C, et al. The physiotherapist and the esophageal cancer patient: from prehabilitation to rehabilitation. Dis Esophagus 2017;30:1-12.
10. Le Manach Y, Collins G, Rodseth R, et al. Preoperative Score to Predict Postoperative Mortality (POSPOM): Derivation and Validation. Anesthesiology 2016;124:570-9.
11. Lund M, Tsai JA, Nilsson M, et al. Effects of neoadjuvant chemo or chemoradiotherapy for oesophageal cancer on perioperative haemodynamics: A prospective cohort study within a randomised clinical trial. Eur J Anaesthesiol 2016;33:653-61.
12. Tandon S, Batchelor A, Bullock R, et al. Peri-operative risk factors for acute lung injury after elective oesophagectomy. Br J Anaesth 2001;86:633-8.
13. Goh SL, De Silva RP, Dhital K, et al. Is low serum albumin associated with postoperative complications in patients undergoing oesophagectomy for oesophageal malignancies? Interact Cardiovasc Thorac Surg 2015;20:107-13.
14. Inoue T, Ito S, Ando M, et al. Changes in exercise capacity, muscle strength, and health-related quality of life in esophageal cancer patients undergoing esophagectomy. BMC Sports Sci Med Rehabil 2016;8:34.
15. Inoue J, Ono R, Makiura D, et al. Prevention of postoperative pulmonary complications through intensive preoperative respiratory rehabilitation in patients with esophageal cancer. Dis Esophagus 2013;26:68-74.
16. van Egmond MA, van der Schaaf M, Klinkenbijl JH, et al. Preoperative functional status is not associated with postoperative surgical complications in low risk patients undergoing esophagectomy. Dis Esophagus 2017;30:1-7.
17. Sakurai Y, Masui T, Yoshida I, et al. Randomized clinical trial of the effects of perioperative use of immune-enhancing enteral formula on metabolic and immunological status in patients undergoing esophagectomy. World J Surg 2007;31:2150-7; discussion 2158-9.
18. Erturk E, Topaloglu S, Dohman D, et al. The comparison of the effects of sevoflurane inhalation anesthesia and intravenous propofol anesthesia on oxidative stress in one lung ventilation. Biomed Res Int 2014;2014:360936.
19. Sugasawa Y, Yamaguchi K, Kumakura S, et al. Effects of sevoflurane and propofol on pulmonary inflammatory responses during lung resection. J Anesth 2012;26:62-9.
20. Schilling T, Kozian A, Senturk M, et al. Effects of volatile and intravenous anesthesia on the alveolar and systemic inflammatory response in thoracic surgical patients. Anesthesiology 2011;115:65-74.
21. Lee JJ, Kim GH, Kim JA, et al. Comparison of pulmonary morbidity using sevoflurane or propofol-remifentanil anesthesia in an Ivor Lewis operation. J Cardiothorac Vasc Anesth 2012;26:857-62.
22. De Conno E, Steurer MP, Wittlinger M, et al. Anesthetic-induced improvement of the inflammatory response to one-lung ventilation. Anesthesiology 2009;110:1316-26.
23. Loer SA, Scheeren TW, Tarnow J. Desflurane inhibits hypoxic pulmonary vasoconstriction in isolated rabbit lungs. Anesthesiology 1995;83:552-6.
24. Schwarzkopf K, Schreiber T, Preussler NP, et al. Lung perfusion, shunt fraction, and oxygenation during one-lung ventilation in pigs: the effects of desflurane, isoflurane, and propofol. J Cardiothorac Vasc Anesth 2003;17:73-5.
25. Peng K, Liu HY, Wu SR, et al. Does Propofol Anesthesia Lead to Less Postoperative Pain Compared With Inhalational Anesthesia?: A Systematic Review and Meta-analysis. Anesth Analg. 2016;123:846-58.
26. Saeki H, Ishimura H, Higashi H, et al. Postoperative management using intensive patient-controlled epidural analgesia and early rehabilitation after an esophagectomy. Surg Today 2009;39:476-80.
27. Buise M, Van Bommel J, Mehra M, et al. Pulmonary morbidity following esophagectomy is decreased after introduction of a multimodal anesthetic regimen. Acta Anaesthesiol Belg 2008;59:257-61.
28. Cense HA, Lagarde SM, de Jong K, et al. Association of no epidural analgesia with postoperative morbidity and mortality after transthoracic esophageal cancer resection. J Am Coll Surg 2006;202:395-400.
29. Neal JM, Wilcox RT, Allen HW, et al. Near-total esophagectomy: the influence of standardized multimodal management and intraoperative fluid restriction. Reg

Anesth Pain Med 2003;28:328-34.
30. Flisberg P, Törnebrandt K, Walther B, et al. Pain relief after esophagectomy: Thoracic epidural analgesia is better than parenteral opioids. J Cardiothorac Vasc Anesth 2001;15:282-7.
31. Michelet P, D'Journo XB, Roch A, et al. Perioperative risk factors for anastomotic leakage after esophagectomy: influence of thoracic epidural analgesia. Chest 2005;128:3461-6.
32. Yokoyama M, Itano Y, Katayama H, et al. The effects of continuous epidural anesthesia and analgesia on stress response and immune function in patients undergoing radical esophagectomy. Anesth Analg 2005;101:1521-7.
33. Koopman EM, Barak M, Weber E, et al. Evaluation of a new double-lumen endobronchial tube with an integrated camera (VivaSight-DL(™)): a prospective multicentre observational study. Anaesthesia 2015;70:962-8.
34. Campos JH. Which device should be considered the best for lung isolation: double-lumen endotracheal tube versus bronchial blockers. Curr Opin Anaesthesiol 2007;20:27-31.
35. Zhang R, Liu S, Sun H, et al. The application of single-lumen endotracheal tube anaesthesia with artificial pneumothorax in thoracolaparoscopic oesophagectomy. Interact Cardiovasc Thorac Surg 2014;19:308-10.
36. Fabian T, Martin J, Katigbak M, et al. Thoracoscopic esophageal mobilization during minimally invasive esophagectomy: a head-to-head comparison of prone versus decubitus positions. Surg Endosc 2008;22:2485-91.
37. Mao QX, Guo W, Huang BQ, et al. Impact of artificial capnothorax on coagulation in patients during video-assisted thoracoscopic esophagectomy for squamous cell carcinoma. Surg Endosc 2016;30:2766-72.
38. Tanaka E, Okabe H, Kinjo Y, et al. Advantages of the prone position for minimally invasive esophagectomy in comparison to the left decubitus position: better oxygenation after minimally invasive esophagectomy. Surg Today 2015;45:819-25.
39. Bonavina L, Laface L, Abate E, et al. Comparison of ventilation and cardiovascular parameters between prone thoracoscopic and Ivor Lewis esophagectomy. Updates Surg 2012;64:81-5.
40. Chau EH, Slinger P. Perioperative fluid management for pulmonary resection surgery and esophagectomy. Semin Cardiothorac Vasc Anesth 2014;18:36-44.
41. Michelet P, D'Journo XB, Roch A, et al. Protective ventilation influences systemic inflammation after esophagectomy: a randomized controlled study. Anesthesiology 2006;105:911-9.
42. Shen Y, Zhong M, Wu W, et al. The impact of tidal volume on pulmonary complications following minimally invasive esophagectomy: a randomized and controlled study. J Thorac Cardiovasc Surg 2013;146:1267-73.
43. Guay J, Ochroch EA. Intraoperative use of low volume ventilation to decrease postoperative mortality, mechanical ventilation, lengths of stay and lung injury in patients without acute lung injury. Cochrane Database Syst Rev 2015;(12):CD011151.
44. Bellamy MC. Wet, dry or something else? Br J Anaesth 2006;97:755-7.
45. Wei S, Tian J, Song X, et al. Association of perioperative fluid balance and adverse surgical outcomes in esophageal cancer and esophagogastric junction cancer. Ann Thorac Surg 2008;86:266-72.
46. Kita T, Mammoto T, Kishi Y. Fluid management and postoperative respiratory disturbances in patients with transthoracic esophagectomy for carcinoma. J Clin Anesth 2002;14:252-6.
47. Ishikawa S, Griesdale DE, Lohser J. Acute kidney injury after lung resection surgery: incidence and perioperative risk factors. Anesth Analg 2012;114:1256-62.
48. Grocott MP, Dushianthan A, Hamilton MA, et al. Perioperative increase in global blood flow to explicit defined goals and outcomes following surgery. Cochrane Database Syst Rev 2012;11:CD004082.
49. Haas S, Eichhorn V, Hasbach T, et al. Goal-directed fluid therapy using stroke volume variation does not result in pulmonary fluid overload in thoracic surgery requiring one-lung ventilation. Crit Care Res Pract 2012;2012:687018.
50. Kobayashi M, Koh M, Irinoda T, et al. Stroke volume variation as a predictor of intravascular volume depression and possible hypotension during the early postoperative period after esophagectomy. Ann Surg Oncol 2009;16:1371-7.
51. Sugasawa Y, Hayashida M, Yamaguchi K, et al. Usefulness of stroke volume index obtained with the FloTrac/ Vigileo system for the prediction of acute kidney injury after radical esophagectomy. Ann Surg Oncol 2013;20:3992-8.
52. Miyazaki T, Kuwano H, Kato H, et al. Predictive value of blood flow in the gastric tube in anastomotic insufficiency after thoracic esophagectomy. World J Surg 2002;26:1319-23.
53. Van Bommel J, De Jonge J, Buise MP, et al. The effects of intravenous nitroglycerine and norepinephrine on gastric microvascular perfusion in an experimental model of gastric tube reconstruction. Surgery 2010;148:71-7.

54. Pathak D, Pennefather SH, Russell GN, et al. Phenylephrine infusion improves blood flow to the stomach during oesophagectomy in the presence of a thoracic epidural analgesia. Eur J Cardiothorac Surg 2013;44:130-3.
55. Buise MP, Ince C, Tilanus HW, et al. The effect of nitroglycerin on microvascular perfusion and oxygenation during gastric tube reconstruction. Anesth Analg 2005;100:1107-11.
56. Ikeda Y, Niimi M, Kan S, et al. Clinical significance of tissue blood flow during esophagectomy by laser Doppler flowmetry. J Thorac Cardiovasc Surg 2001;122:1101-6.
57. Pierie JP, De Graaf PW, Poen H, et al. Impaired healing of cervical oesophagogastrostomies can be predicted by estimation of gastric serosal blood perfusion by laser Doppler flowmetry. Eur J Surg 1994;160:599-603.
58. Klijn E, Niehof S, de Jonge J, et al. The effect of perfusion pressure on gastric tissue blood flow in an experimental gastric tube model. Anesth Analg 2010;110:541-6.
59. Milstein DM, Ince C, Gisbertz SS, et al. Laser speckle contrast imaging identifies ischemic areas on gastric tube reconstructions following esophagectomy. Medicine (Baltimore) 2016;95:e3875.
60. Fumagalli U Melis A, Balazova J, et al. Intra-operative hypotensive episodes may be associated with post-operative esophageal anastomotic leak. Updates Surg 2016;68:185-90.
61. Salmasi V, Maheshwari K, Yang D, et al. Relationship between Intraoperative Hypotension, Defined by Either Reduction from Baseline or Absolute Thresholds, and Acute Kidney and Myocardial Injury after Noncardiac Surgery: A Retrospective Cohort Analysis. Anesthesiology 2017;126:47-65.
62. Al-Rawi OY, Pennefather SH, Page RD, et al. The effect of thoracic epidural bupivacaine and an intravenous adrenaline infusion on gastric tube blood flow during esophagectomy. Anesth Analg 2008;106:884-7.
63. Gemmill EH, Humes DJ, Catton JA. Systematic review of enhanced recovery after gastro-oesophageal cancer surgery. Ann R Coll Surg Engl 2015;97:173-9.
64. Stoelting RK. Continuous Postoperative Electronic Monitoring and the Will to Require It. Anesth Analg 2015;121:579-81.
65. Hernandez-Silveira M, Ahmed K, Ang SS, et al. Assessment of the feasibility of an ultra-low power, wireless digital patch for the continuous ambulatory monitoring of vital signs. BMJ Open 2015;5:e006606.

Cite this article as: Veelo DP, Geerts BF. Anaesthesia during oesophagectomy. J Thorac Dis 2017;9(Suppl 8):S705-S712. doi: 10.21037/jtd.2017.03.153

