Surgery Today (2019) 49:1058–1065
https://doi.org/10.1007/s00595-019-01849-y

ORIGINAL ARTICLE

Risk factors associated with increased drainage volumes of chest tubes after transthoracic esophagectomy for esophageal cancer

Ryo Kato[1] · Tomoki Makino[1] · Makoto Yamasaki[1] · Koji Tanaka[1] · Yasuhiro Miyazaki[2] · Tsuyoshi Takahashi[1] · Yukinori Kurokawa[1] · Masaaki Motoori[2] · Yutaka Kimura[3] · Kiyokazu Nakajima[1] · Masaki Mori[4] · Yuichiro Doki[1]

Received: 20 February 2019 / Accepted: 21 June 2019 / Published online: 24 July 2019

Abstract

Purpose Prolonged chest drain placement can extend the postoperative hospital stay after esophagectomy in esophageal cancer (EC) patients. This study aimed to identify whether or not the risk factors associated with this prolonged chest tube placement are clinically important.

Methods A total of 138 patients who underwent subtotal esophagectomy for thoracic EC were retrospectively analyzed. Using the 75th percentile of the total drainage volume of chest tubes as a cutoff value, the high-output (HO; $n=35$) and low-output (LO; $n=103$) groups were compared in terms of the clinicopathological parameters.

Results The median durations of right and left chest tube placement were 6 and 9 days, respectively, with a median total drainage volume of 2692 ml. When compared with the LO group, the HO group was significantly associated with male gender, a subcutaneous route for reconstruction, blood transfusion, higher morbidity, and prolonged chest drainage and postoperative hospital stays. A multivariable analysis further identified blood loss ($p=0.03$) and the subcutaneous route for reconstruction ($p=0.04$) as independent risk factors for increased chest tube drainage after esophagectomy.

Conclusion Blood loss and the subcutaneous route of reconstruction are risk factors for increased drainage of chest tube after esophagectomy for EC.

Keywords Esophageal cancer · Esophagectomy · Thoracic surgery

Abbreviations

ACF	Adriamycin, CDDP, and 5-FU
DCF	Docetaxel, CDDP, and 5-FU
EC	Esophageal cancer
eGFR	Estimated glomerular filtration rate
ESCC	Esophageal squamous cell carcinoma
HO	High output
LN	Lymph node
LO	Low output
MIE	Minimally invasive esophagectomy

Introduction

Chest tube drainage after esophagectomy for thoracic esophageal cancer (EC) is generally performed to evacuate air and fluid from thoracic cavities and promote re-expansion of the lungs [1]. Although chest tubes are removed when daily drainage is < 150 to 200 ml, the timing of removal is left to the decision of the surgeon, and there is no consensus on the optimal timing after esophagectomy. It has been occasionally argued that a chest drain should be left in place, particularly in cases with posterior mediastinal reconstruction, until a postoperative contrast study shows no evidence of anastomotic leakage. However, chest tubes are sometimes uncomfortable and painful, leading to discouragement of coughing and ambulation, which are necessary to prevent pulmonary complications after esophagectomy. In addition, long-term placement of chest tubes may cause retrograde

✉ Tomoki Makino
tmakino@gesurg.med.osaka-u.ac.jp

1 Department of Gastroenterological Surgery, Graduate School of Medicine, Osaka University, 2-2-E2, Yamada-oka, Suita, Osaka 565-0871, Japan

2 Department of Surgery, Osaka General Medical Center, Osaka, Japan

3 Department of Surgery, Kindai University Faculty of Medicine, Osaka, Japan

4 Department of Surgery and Science, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan

infection of the drain that can also prolong the postoperative hospital stay. Therefore, chest tubes need to be removed as soon as possible to prevent postoperative morbidities and shorten postoperative hospital stays [2].

Although minimally invasive esophagectomy (MIE) with a small incision is widely used for EC and several studies have reported less invasiveness with this approach than with conventional open surgery, whether or not MIE influences chest tube drainage after esophagectomy remains unclear. Other factors, including the age, tumor size, obesity, hypertension, amount of operative blood loss, and number of dissected lymph nodes (LNs), may all also be related to the amount and duration of pleural drainage [3]. However, to our knowledge, few studies have investigated this issue, and there is no evidence available concerning the expected duration and amount of postoperative chest drainage after subtotal esophagectomy for EC. Therefore, it is important to identify factors influencing a prolonged placement of a thoracic drainage tube to encourage early postoperative recovery and introduce clinical pathways.

Accordingly, the present study aimed to assess risk factors associated with the drainage volume of the chest tube after esophagectomy for thoracic EC.

Patients and methods

Clinicopathological information for the eligible patients was retrospectively collected. The daily drainage volume was reviewed from the medical records of patients who underwent esophagectomy procedures in our department of gastroenterological surgery at Osaka University Hospital. The eligibility criteria in this study were as follows: patients who underwent esophagectomy with either a two- or three-field lymphadenectomy for pathologically confirmed thoracic esophageal squamous cell carcinoma (ESCC) between January 2013 and December 2014. The exclusion criteria were as follows: other type of disease such as hypopharynx or lung cancer; two-stage surgery; combined resection with other organs, including the lungs, liver, pharynx, larynx, bronchus, recurrent laryngeal nerve, and major blood vessel; or a diagnosis of synchronous double cancer. A total of 140 consecutive patients met the eligibility criteria. After excluding two patients who postoperatively developed chylothorax leading to the prolonged placement of chest tubes, a total of 138 patients were eventually analyzed in this study.

Using the 75th percentile of the total drainage volume (Fig. 1) of chest tubes as a cutoff value, all patients were classified into two groups: a low-output (LO) group and high-output (HO) group. The clinicopathological parameters were compared between the two groups, and perioperative factors potentially predicting or influencing the drainage volume of the chest tube were also analyzed to evaluate their

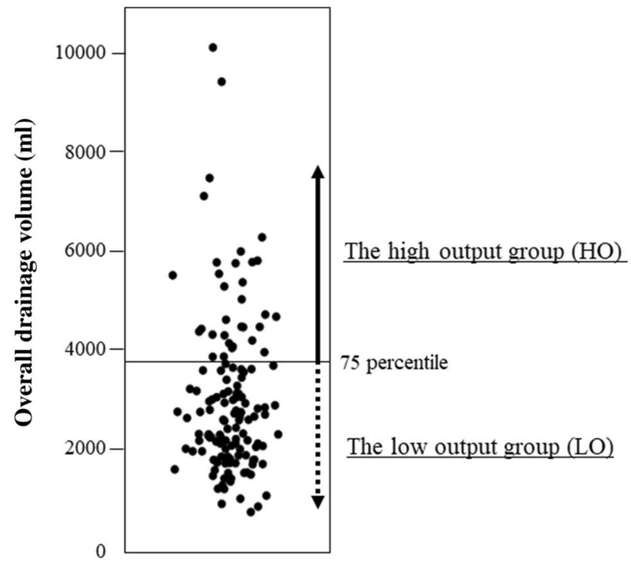

Fig. 1 The overall drainage volume of both chest tubes during their placement and how the two groups were determined

association. Co-morbidities included hypertension requiring anti-hypertensive agents, chronic obstructive pulmonary disease with forced expiratory volume at 1 s of $<70\%$ the predicted normal value, and chronic liver disease. The preoperative serum albumin and estimated glomerular filtration rate (eGFR) were regarded as risk factors and included in the analysis. The original study protocol was approved by the institutional review board of our institution.

Surgical procedure and treatment for EC

Our standard procedures consisted of subtotal esophagectomy with two- or three-field lymphadenectomy via right thoracotomy or video-assisted thoracoscopic surgery, with reconstruction of the gastric tube and anastomosis in the cervical incision [4, 5]. We routinely resect the arch of the azygous vein and preserve both sides of the bronchial arteries as much as possible. The thoracic duct was preserved as much as possible for cT1-2 tumors and resected for cT3-4 tumors [4]. The length of the remnant cervical esophagus was typically 2–4 cm unless the tumor was located in or had spread to the cervical esophagus. The anastomosis was usually established by a mechanical instrument in an end-to-side fashion using a 25-mm circular stapler on the posterior wall of the gastric tube or hand-sewn in an end-to-end fashion with PDS 3-0 sutures if the surgeon deemed the use of a mechanical instrument inappropriate [6]. We tried not to open the left pleura when dissecting along the left side of the descending aorta. Methylprednisolone (250 mg/person, only on the day of operation) was administered intraoperatively to all patients immediately after the thoracotomy incision.

Preoperative chemotherapy comprised cisplatin, 5-FU, and either adriamycin (ACF) or docetaxel (DCF), followed by curative esophagectomy [7]. In the ACF regimen, 700 mg/m^2 5-FU was given by continuous intravenous infusion on days 1–7, while 70 mg/m^2 cisplatin was given by intravenous infusion and 35 mg/m^2 adriamycin by rapid intravenous infusion on day 1. For the DCF regimen, the cisplatin was administered at 70 mg/m^2 and docetaxel at 70 mg/m^2 by rapid intravenous infusion on day 1, and 5-FU was administered at 700 mg/m^2 by continuous intravenous infusion on days 1 through 5. Two courses of ACF or DCF chemotherapy were used over a 3- to 4-week interval [8]. Our indication for preoperative chemotherapy, based on the TNM classification, was cT1–3N1–3 as an absolute indication and either cT2–3N0 or cT4N any without massive infiltration to the bronchus or aorta as a relative indication [9, 10]. Preoperative chemoradiotherapy, consisting of 40 Gy irradiation with a cisplatin and 5-FU regimen, was performed for patients with locally advanced ESCC [4]. Patients who underwent preoperative chemotherapy or chemoradiotherapy had an Eastern Cooperative Oncology Group performance status of 0–1 and a normal bone marrow, kidney, and liver function. Operative treatment was performed 3–5 weeks after the completion of preoperative chemotherapy or chemoradiation.

Management of chest tube

Our policy of chest tube placement is that both right (silicone tube 10 mm) and left (20-Fr trocar) chest tubes are placed in all cases at the end of subtotal esophagectomy. The left chest tube was removed when the daily drainage volume fell below 200 ml with no air leakage. The right chest tube was removed when there was no air leakage, no chylothorax, and no anastomotic leakage after restarting oral intake on or after postoperative day 7.

Statistical analyses

Categorical and continuous variables were compared using the Chi square test and Student *t* test, respectively. Multivariable logistic regression analyses were used to identify independent risk factors influencing the pleural drainage volume after esophagectomy. Factors with a p value < 0.10 in univariate analyses were further analyzed in the multivariable mode. Statistical analyses were performed using the software program JMP ver. 8.0.2 (SAS Institute, Cary, NC, USA), and $p < 0.05$ was considered statistically significant.

Results

Changes in the daily drainage volume of both chest tubes after esophagectomy

The patient characteristics are shown in Table 1. The median overall duration of pleural drainage was 9 days (range 4–39) while those of the right and left chest tubes were 9 (range 4–39) and 6 (range 2–31) days, respectively. The daily total chest tube drainage volumes from postoperative day 0 (POD0) to POD7 are shown in Fig. 2. The 75th percentile and median total drainage volume was 3690 ml and 2692 ml (range 780–10,140), respectively. The median daily volume of both chest tubes increased day by day from POD0 to POD2 and then decreased until tube removal (Fig. 2). The maximum drainage volume in the right chest tube was observed on POD1 as opposed to POD2 for the left chest tube (Fig. 3a, b). Using the 75th percentile (3690 ml) of the total drainage volume of both chest tubes as a cutoff value, patients with a total drainage volume ≥ 3690 ml were classified into the HO group ($n = 35$) while the remaining patients were classified into the LO group ($n = 103$) (Fig. 1). The median duration of pleural drainage placement for either chest tube in the LO and the HO groups were 9 (range 4–15) and 14 (range 4–39) days, respectively, ($p < 0.01$) as shown in Table 1.

Perioperative factors associated with the drainage volume of chest tubes after esophagectomy

Potential perioperative risk factors that significantly influenced the postoperative pleural drainage volume were male gender (LO vs. HO: 76.7% vs. 94.3%, $p = 0.01$), subcutaneous reconstruction route (3.9% vs. 20.0%, $p < 0.01$), and blood transfusion (14.6% vs. 34.3%, $p = 0.01$). The maximum tumor size (39 vs. 32 mm, $p = 0.10$), thoracic duct preservation (5.8% vs. 0%, $p = 0.06$), and blood loss (510 vs. 642 ml, $p = 0.09$) tended to correlate with the total pleural drainage volume, but the differences were not statistically significant. When the postoperative parameters of the LO and HO groups were compared, the HO group was significantly associated with a higher rate of postoperative complications (Clavien–Dindo [C–D] grade ≥ 3: 5.8% vs. 31.4%, $p < 0.01$; grade ≥ 2: 23.3% vs 57.1%, $p < 0.01$), longer duration of pleural drainage (9 vs. 14 days, $p < 0.01$), and longer postoperative hospital stay (28.6 vs. 41.7 days, $p < 0.01$) than the LO group. In addition, when examining each complication type, the rates of recurrent laryngeal nerve paralysis (LO vs. HO: 13.6% vs. 22.9%, $p = 0.20$) and pneumonia (9.7% vs. 11.4%, p = 0.77) were similar between the two groups, although

Table 1 Perioperative factors associated with the drainage volume of chest tubes after esophagectomy

Parameters	Low output ($n = 103$)	High output ($n = 35$)	P value
Age (years) [range]	65 [37–85]	69 [53–82]	0.17
Gender (%)			0.01
Male	79 (76.7%)	33 (94.3%)	
Female	24 (23.3%)	2 (5.7%)	
Body mass index (kg/m^2)	20.9	20.7	0.71
Co-morbidities			
COPD	5 (4.9%)	0 (0%)	0.18
Chronic liver disease	5 (4.9%)	1 (2.9%)	0.61
Hyper tension	16 (15.5%)	5 (14.2%)	0.85
Serum albumin at diagnosis (g/dl)	3.8	3.6	0.12
eGFR	70.1	66.5	0.29
Serum creatinine	0.86	0.90	0.38
Use of anticoagulant	11 (10.7%)	1 (2.9%)	0.16
Tumor location (%)			0.39
Upper thoracic	17 (16.5%)	7 (20.0%)	
Middle thoracic	49 (47.6%)	12 (34.3%)	
Lower thoracic	37 (35.9%)	16 (45.7%)	
Maximum tumor size (mm) [range]	39 [10–120]	32 [9–70]	0.10
Clinical TNM classification			
cT (0/1/2/3/4)	0 (0%)/24 (23.3%)/26 (25.2%)/43 (41.7%)/10 (9.7%)	0 (0%)/5 (14.3%)/8 (22.9%)/20 (57.1%)/2 (5.7%)	0.41
cN (0/1/2/3)	39 (37.9%)/55 (53.4%)/8 (7.8%)/1 (1.0%)	15 (42.9%)/18 (51.4%)/1 (2.9%)/1 (2.8%)	0.69
cM (0/1)	83 (80.6%)/20 (19.4%)	29 (82.9%)/6 (17.1%)	0.76
cStage (0/1/2/3/4)	0 (0%)/29 (28.2%)/22 (21.4%)/33 (32.0%)/19 (18.4%)	0 (0%)/7 (20.0%)/8 (22.9%)/14 (40.0%)/6 (17.1%)	0.75
Preoperative therapy (%)			0.24
Chemotherapy	67 (65.1%)	28 (80.0%)	
Chemoradiotherapy	13 (12.6%)	3 (8.6%)	
None	23 (22.3%)	4 (11.4%)	
Surgical approach (%)			0.56
Thoracotomy	59 (57.3%)	22 (62.9%)	
Thoracoscopic	44 (42.7%)	13 (37.1%)	
Field of lymph node dissection (%)			0.85
Three field	63 (61.2%)	22 (62.9%)	
Two field	40 (38.8%)	13 (37.1%)	
Average number of total dissected lymph nodes (range)	64.5 (9–168)	63.8 (17–115)	0.88
Average number of mediastinal dissected lymph nodes (range)	23.5 (7–72)	23.9 (11–51)	0.85
Thoracic duct preservation (%)			
No	97 (94.2%)	35 (100.0%)	0.06
Yes	6 (5.8%)	0 (0.0%)	
Reconstruction route (%)			< 0.01
Subcutaneous	4 (3.9%)	7 (20.0%)	
Retrosternal	5 (4.9%)	1 (2.9%)	
Posterior mediastinal	94 (91.3%)	27 (77.1)	
Operative time (min)	448 (299–813)	465 (316–686)	0.31
Blood loss (ml)	510 (25–3330)	642 (300–2450)	0.09
Blood transfusion (%)	15 (14.6%)	12 (34.3%)	0.01

Table 1 (continued)

Parameters	Low output ($n = 103$)	High output ($n = 35$)	*P* value
Pathological TNM classification (%)			
pT (0/1/2/3/4)	15 (14.6)/35 (34.0)/15 (14.6)/38 (36.9)/0 (0)	4 (11.4)/11 (31.4)/4 (11.4)/15 (42.9)/1 (2.9)	0.46
pN (0/1/2/3)	46 (44.7)/28 (27.2)/19 (18.5)/10 (9.7)	18 (51.4)/6 (17.1)/6 (17.1)/5 (14.3)	0.60
pStage (0/1/2/3/4)	0 (0%)/41 (39.8)/20 (19.4)/33 (32.0)/9 (8.7)	0 (0%)/11 (31.4)/11 (31.4)/12 (34.3)/1 (2.9)	0.24
Duration of pleural drainage (day) (range)	9 (4–15)	14 (4–39)	< 0.01
Postoperative complication (grade ≥ 3[a]), cases (%)	6 (5.8%)	11 (31.4%)	< 0.01
Length of intensive care unit stay (days) [range]	3.7 [0–12]	4.7 [0–19]	0.06
Length of SIRS (days) [range]	1.9 [0–7]	2.4 [0–10]	0.31
Postoperative hospital stay (days) [range]	28.6 [17–65]	41.7 [21–109]	< 0.01

SIRS systemic inflammatory response syndrome, *COPD* chronic obstructive pulmonary disease, *eGFR* estimated glomerular filtration rate
[a]Clavien–Dindo classification

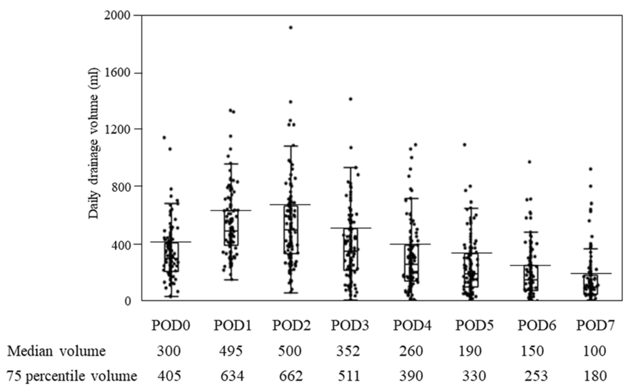

Fig. 2 The change in daily drainage volumes of both chest tubes after esophagectomy

anastomotic leakage occurred less frequently in the LO group than in the HO group (3.9% vs. 20.0%, $p < 0.01$). The length of the stay in the intensive care unit tended to be shorter in the LO group than in the HO group; however, the difference was not statistically significant (3.7 vs. 4.7 days, $p = 0.06$). Other perioperative parameters did not significantly influence the drainage volume of the chest tube, including the age, body mass index, presence of co-morbidities, serum albumin, eGFR, serum creatinine, use of anticoagulant, tumor location, cT, cN, cM, type of preoperative treatment, surgical approach, field of LN dissection, and number of total or mediastinal dissected LNs, reconstruction route, operative time, pT, pN, pStage, or length of systemic inflammatory response syndrome (Table 1).

Of the pre- and intraoperative variables proven to be associated with increased drainage volume in the univariable analysis, the multivariable analysis further identified

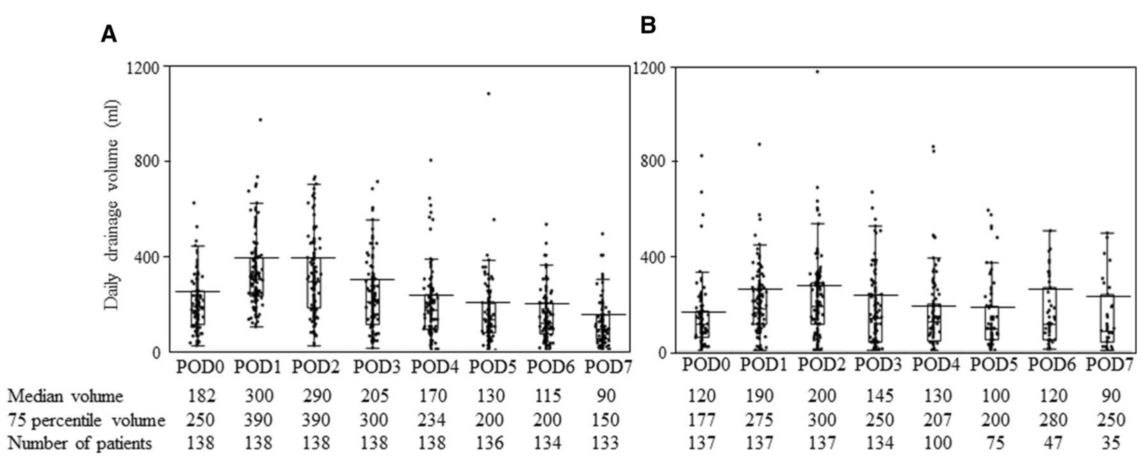

Fig. 3 The change in daily drainage volumes of the right (**a**) and left (**b**) chest tubes after esophagectomy

Table 2 Results of a multivariable analysis of high-output chest tube drainage after esophagectomy

	Univariate			Multivariate		
	HR	95% CI	*p*	HR	95% CI	*p*
Age (> 66/< 66 years)	1.95	0.9–4.3	0.10			
Gender (male/female)	0.20	0.05–0.9	0.02	3.19	0.7–15.1	0.14
Body mass index (> 21/< 21 kg/m^2)	0.92	0.4–2.0	0.85			
Co-morbidities (COPD, chronic liver disease, or hypertension/none)	0.80	0.3–2.2	0.68			
Serum albumin at diagnosis (> 3.8/< 3.8 g/dl)	0.58	0.3–1.3	0.17			
Use of anticoagulant (yes/no)	0.25	0.03–2.0	0.16			
Tumor location (Ut, Mt/Lt)	1.26	0.5–3.4	0.64			
cT (T3-4/1-2)	1.60	0.7–3.5	0.24			
cN (N1-3/0)	0.81	0.4–1.8	0.60			
cM (1/0)	0.86	0.3–2.3	0.77			
cStage (I, II/III, IV)	1.31	0.6–2.8	0.50			
Preoperative therapy (chemo, chemoradiotherapy/none)	0.45	0.1–1.4	0.16			
Surgical approach (thoracotomy/thoracoscopy)	0.79	0.4–1.7	0.56			
Maximum tumor size (≥ 30 mm/< 30 mm)	0.74	0.3–1.6	0.46	1.73	0.7–4.3	0.24
Field of lymph node dissection (three-/two-field)	1.07	0.5–2.4	0.86			
Number of total dissected lymph nodes (> 60/< 60)	1.08	0.5–2.3	0.85			
Number of mediastinal dissected lymph nodes (> 25/< 25)	1.93	0.9–4.2	0.10			
Operative time (> 430 min/< 430 min)	1.41	0.7–3.1	0.38			
Thoracic duct preservation (no/yes)	N/A	N/A	0.14	2.02	N/A	0.99
Reconstruction route (subcutaneous/others)	6.2	1.7–22.7	< 0.01	5.03	1.1–23.1	0.04
Blood loss (≥ 450 ml/< 450 ml)	3.3	1.5–7.5	< 0.01	2.79	1.1–7.0	0.03
Blood transfusion (presence/absence)	3.1	1.3–7.4	0.01	1.73	0.6–5.0	0.31

COPD chronic obstructive pulmonary disease

blood loss (odds ratio 2.79, 95% confidence interval 1.1–7.0, $p = 0.03$) and the subcutaneous route (odds ratio 5.03, 95% confidence interval 1.1–23.1, $p = 0.04$) as independent predictive factors for increased drainage after transthoracic esophagectomy for EC, as shown in Table 2.

Discussion

The median durations for right and left chest tube placements were 6 and 9 days, respectively, with a median total drainage volume of 2692 ml in 138 EC patients who underwent subtotal esophagectomy with or without preoperative treatment. The median durations for drain placement of either chest tube in the LO and HO groups were 9 and 14 days, respectively. When compared with the LO group, the HO group was significantly associated with a male gender, subcutaneous route for reconstruction, and blood transfusion. When comparing the postoperative parameters between the groups, the HO group was significantly associated with a prolonged duration of chest drainage, high rate of postoperative complications (C–D grade ≥ 3), and extended postoperative hospital stay. A multivariable analysis of the pre- and intraoperative factors further identified blood loss and the subcutaneous route for reconstruction as independent risk factors for increased drainage of chest tubes after esophagectomy.

Management of the chest tubes after esophagectomy for EC varies according to the policy of the surgeon and each institution, with no definite consensus or strategy yet established. Although it is desirable to remove chest tubes as early as possible after surgery to facilitate recovery, some patients develop pleural effusion, requiring invasive thoracentesis after removal of chest tubes, leading to a risk of secondary complications. Chest tube placement during esophagectomy is generally necessary to evacuate fluid and/or air from the thoracic cavity and to promote re-expansion of the lungs [1, 11]. In many institutions, surgeons remove chest tubes when the drainage volume becomes < 200 ml/day without bloody, milky, or purulent pleural effusion and no air leaks. Yao et al. reported that a 300 ml/day volume threshold for chest tube removal after thoracoscopic esophagectomy reduced the postoperative chest drainage time without compromising patient safety [12]. Bhandari et al. reported that a 250 ml/day volume threshold for chest tube removal after esophagogastrectomy would not increase the risk of pleural effusion or the total length of stay and cost of hospitalization and would not jeopardize patient safety or clinical outcomes [13]. In addition, because pleural effusion can be reabsorbed in the thoracic cavity, some institutions remove the chest tubes on a fixed postoperative date, regardless of the amount of drainage per day [14]. Prolonged placement of a chest tube is a source of pain; therefore, it discourages coughing and ambulation and can lead to a risk of retrograde infection or extension of the postoperative hospital stay. However, few reports have investigated factors associated with drainage of the chest tubes after esophagectomy. The optimal volume threshold for removal of chest tubes after thoracic surgery has not yet been determined.

Most of the drainage volume is lymph fluid; therefore, reducing lymphorrhea avoids long-term indwelling of the drain tubes. Tsimoyiannis et al. reported that the use of an ultrasonic dissector in gastrectomy reduced the postoperative drainage volume [15]. Sealing of vessels, such as lymph ducts, contributes to the reduction of the drainage volume [14]. Lagarde et al. reported that the transthoracic approach tends to increase the pleural drainage volume after surgery and extend the indwelling period of the drain compared with the transhiatal approach [3]. Using an energy device in esophagectomy might also be effective in terms of reducing the drainage volume and achieving the early removal of the thoracic drain. Since the thoracic duct was resected in most cases in the present study, it cannot be concluded that thoracic duct preservation is not an independent risk factor for increased drainage of chest tube.

In recent years, thoracoscopic surgery for EC has become widely performed and is less invasive to the chest wall than conventional open surgery. Although we hypothesized that thoracoscopic surgery was associated with a lower drainage volume than conventional transthoracic surgery, no significant differences in the chest drainage were identified among the surgical approaches in the present study, with blood loss and the subcutaneous route being found to be the only independent factors. This may be because, in cases with a large amount of intraoperative blood loss, the volume of perioperative fluid replacement often increases in a short period, which can lead to increased transudative pleural effusion, partly caused by adjustments in osmotic pressure. In contrast, patients who undergo reconstruction via a subcutaneous route showed more severe co-morbidities than those who received reconstruction via other routes; this manifested particularly often as liver (subcutaneous route vs. others; 18.2% vs. 3.2%, $p=0.02$) and cardiovascular diseases (36.4% vs. 13.4%, $p=0.04$). This might have led to the increase in postoperative complications and drainage volume of the chest tube.

In terms of the association between postoperative complications and the increased chest drainage volume, subcutaneous anastomotic leakage itself is unlikely to cause intra-mediastinal or thoracic inflammation and infection. However, anastomotic leakage requiring long-term fasting sometime causes deterioration of nutrition, i.e., a low albumin level that can lead to increased transudative pleural effusion. Therefore, it is important to reduce intraoperative blood loss and postoperative complications to reduce the drainage volume from chest tubes, leading to their early removal.

The limitations of the present study include its retrospective design and single-institute setting, which resulted in potential selection bias of patients. However, even after restricting subjects to patients who had undergone preoperative chemotherapy in the present study, a similar result was obtained (data not shown). Regarding the cutoff value of the chest drainage volume used for the categorization, we also tried to use other values, including the median or average value; however, those values failed to identify significant predictors of increased drainage of chest tubes. Although a larger-scale prospective study is necessary to validate the clinical importance of our findings, the present report offers very important information that can help shorten the postoperative hospital stay and ultimately reduce medical costs in surgically treated EC patients.

Conclusion

The increased drainage of chest tubes was associated with an increased incidence of morbidity, and the prolonged placement of a chest tube led to extended postoperative hospital stays after curative esophagectomy for thoracic EC. Increased blood loss and a subcutaneous route of reconstruction were independent risk factors for increased drainage of chest tubes.

Acknowledgements None of the authors have a conflict of interest or financial ties to disclose. All the authors have contributed significantly to this manuscript.

Author contributions All the authors participated in the management of the cases in this original article. TM is a surgeon at our hospital and supervised the study and the writing of this manuscript. YD is the chairperson of our department and supervised the entire process. All the authors read and approved the final manuscript.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Informed consent Written informed consent was obtained from the patients for publication of this manuscript and the accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

References

1. Vyas S, Mitchell I, Smart J, Stoker D, Woolf AK. Routine underwater seal drains are not required after transthoracic oesophagectomy: a pilot study. Eur J Cardiothorac Surg. 2009;35:694–8.
2. Göttgens KW, Siebenga J, Belgers EH, van Huijstee PJ, Bollen EC. Early removal of the chest tube after complete video-assisted thoracoscopic lobectomies. Eur J Cardiothorac Surg. 2011;39:575–8.
3. Lagarde SM, Omloo JM, Ubbink DT, Busch OR, Obertop H, van Lanschot JJ. Predictive factors associated with prolonged chest drain production after esophagectomy. Dis Esophagus. 2007;20(1):24–8.
4. Yamashita K, Makino T, Yamasaki M, Tanaka K, Hara T, Miyazaki Y, et al. Comparison of short-term outcomes between 2- and 3-field lymph node dissection for esophageal cancer. Dis Esophagus. 2017;30(11):1–8.
5. Colvin H, Mizushima T, Eguchi H, Takiguchi S, Doki Y, Mori M. Gastroenterological surgery in Japan: the past, the present and the future. Ann Gastroenterol Surg. 2017;1(1):5–10.
6. Tanaka K, Makino T, Yamasaki M, Nishigaki T, Miyazaki Y, Takahashi T, et al. An analysis of the risk factors of anastomotic stricture after esophagectomy. Surg Today. 2018;48(4):449–54.
7. Makino T, Yamasaki M, Tanaka K, Masuike Y, Tatsumi M, Motoori M, et al. Metabolic tumor volume change predicts long-term survival and histological response to preoperative chemotherapy in locally advanced esophageal cancer. Ann Surg. 2018. https://doi.org/10.1097/sla.0000000000002808.
8. Makino T, Yamasaki M, Tanaka K, Tatsumi M, Takiguchi S, Hatazawa J, et al. Importance of positron emission tomography for assessing the response of primary and metastatic lesions to induction treatments in T4 esophageal cancer. Surgery. 2017;162(4):836–45.
9. Makino T, Miyata H, Yamasaki M, Fujiwara Y, Takiguchi S, Nakajima K, et al. Utility of response evaluation to neo-adjuvant chemotherapy by (18)F-fluorodeoxyglucose-positron emission tomography in locally advanced esophageal squamous cell carcinoma. Surgery. 2010;148(5):908–18.
10. Makino T, Doki Y, Miyata H, Yasuda T, Yamasaki M, Fujiwara Y, et al. Use of (18) F-fluorodeoxyglucose-positron emission tomography to evaluate responses to neo-adjuvant chemotherapy for primary tumor and lymph node metastasis in esophageal squamous cell carcinoma. Surgery. 2008;144(5):793–802.
11. Law S, Boey JP, Kwok KF, Wong KH, Chu KM, Wong J. Pleural drainage after transthoracic esophagectomy: experience with a vacuum system. Dis Esophagus. 2004;17(1):81–6.
12. Yao F, Wang J, Yao J, Hang F, Cao S, Qian J, et al. Early chest tube removal after thoracoscopic esophagectomy with high output. J Laparoendosc Adv Surg Tech A. 2016;26(1):17–22.
13. Bhandari R, Hao YY. Implementation and effectiveness of early chest tube removal during an enhanced recovery programme after oesophago-gastrectomy. JNMA J Nepal Med Assoc. 2015;53(197):24–7.
14. Takebayashi K, Tsubosa Y, Shimada A, Booka E, Niihara M. Evaluation of the volume of chest tube output after esophageal cancer surgery. Nihon Gekakeirengoukaishi. 2016;41(4):553–8.
15. Tsimoyiannis EC, Jabarin M, Tsimoyiannis JC, Betzios JP, Tsilikatis C, Glantzounis G. Ultrasonically activated shears in extended lymphadenectomy for gastric cancer. World J Surg. 2002;26:158–61.