



## Postoperative intensive care unit stay after minimally invasive esophagectomy shows large hospital variation. Results from the Dutch Upper Gastrointestinal Cancer Audit



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### ABSTRACT

**Introduction:** The value of routine intensive care unit (ICU) admission after minimally invasive esophagectomy (MIE) has been questioned. This study aimed to investigate Dutch hospital variation regarding length of direct postoperative ICU stay, and the impact of this hospital variation on short-term surgical outcomes.

**Materials and methods:** Patients registered in the Dutch Upper Gastrointestinal Cancer Audit (DUCA) undergoing curative MIE were included. Length of direct postoperative ICU stay was dichotomized around the national median into *short ICU stay* ( $\leq 1$  day) and *long ICU stay* ( $> 1$  day). A case-mix corrected funnel plot based on multivariable logistic regression analyses investigated hospital variation. The impact of this hospital variation on short-term surgical outcomes was investigated using multilevel multivariable logistic regression analyses.

**Results:** Between 2017 and 2019, 2110 patients from 16 hospitals were included. Median length of postoperative ICU stay was 1 day [hospital variation: 0–4]. The percentage of *short ICU stay* ranged from 0 to 91% among hospitals. Corrected for case-mix, 7 hospitals had statistically significantly higher *short ICU stay* rates and 6 hospitals had lower rates. ICU readmission, in-hospital/30-day mortality, failure to rescue, postoperative pneumonia, cardiac complications and anastomotic leakage were not associated with hospital variation in length of ICU stay. Total length of hospital stay was significantly shorter in hospitals with relatively short ICU stay.

**Conclusion:** This study showed significant hospital variation in postoperative length of ICU stay after MIE. *Short ICU stay* was associated with shorter overall hospital admission and did not negatively impact short-term surgical outcomes. More selected use of ICU resources could result in a national significant cost reduction.

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### Introduction

**Abbreviations:** Intensive care unit, ICU; Minimally invasive esophagectomy, MIE; Medium care unit, MCU; Dutch Upper Gastrointestinal Cancer Audit, DUCA; Observed, O; Expected, E; Observed/Expected ratio, O/E ratio; Post anesthesia care unit, PACU; Variance inflation factor, VIF; Early recovery after surgery, ERAS.

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Esophageal carcinoma is the seventh most common cancer and the number six cause of cancer-related death globally [1,2]. (Neo) adjuvant chemo (radio)therapy followed by surgical resection is the cornerstone of curative treatment. Esophagectomy is associated with postoperative complication rates of around 65%, severe complications (Clavien-Dindo grade III or higher) occur in 29% of patients [3]. Due to the invasive nature of esophageal cancer surgery,

patients were routinely admitted to the intensive care unit (ICU) for hemodynamic support, pain management or respiratory support [4]. Following the introduction of minimally invasive esophagectomy (MIE) and enhanced recovery after surgery (ERAS), the value of routine ICU admission has been questioned [4,5]. Some studies showed that ICU admission policy after esophageal cancer surgery varied between hospitals, with no impact on short-term mortality rates [4,6]. However, verification of these results in the era of MIE and immediate extubation in the operating room is necessary as prolonged ICU admission of patients without vital ICU indication can be considered a misplaced use of scarce resources and therefore impacts hospital finances and, possibly, ICU capacity [7].

Since 2011, the mandatory nationwide Dutch Upper Gastrointestinal Cancer Audit (DUCA) has registered all surgically treated esophageal or gastric cancer patients [3,8]. The audit aims to improve the quality of Dutch upper gastrointestinal cancer care by identifying and reducing hospital variation in treatment, outcomes and clinical care pathways [9].

Within the scope of value-based health care, this study aimed to 1) gain insight into different hospital policies towards direct postoperative ICU admission, 2) investigate Dutch hospital variation regarding length of direct postoperative ICU stay and 3) investigate the impact of this hospital variation on short-term surgical outcomes after MIE on a hospital level.

## Methods

### Survey questionnaire

This study included an online survey questionnaire among all the 16 hospitals in the Netherlands that currently perform esophageal cancer surgery. The survey needed to be completed by one surgeon on behalf of the hospital and consisted of 14 questions (*online supplements, file 1*) on standard hospital policy regarding length of direct postoperative ICU stay after MIE, reasons for possible protocol deviations, and estimated protocol compliance rates. For each hospital the actual protocol non-compliance rate was calculated using DUCA data (% of patients staying longer on the ICU than the protocol advises) and compared with the estimated protocol compliance rate.

### Analyses of DUCA data

#### Study design

For this retrospective, nationwide cohort study, data was retrieved from the DUCA database. Dutch clinicians are obliged to register all esophageal cancer patients undergoing potentially curative surgery in the DUCA. The DUCA is an opt-out registry. Previous verification of DUCA data estimated completeness at 99.2%. Accuracy of outcome measures ranged from 95.3 to 100% [10]. As patient and hospital data is registered anonymously, informed consent or ethical review was not required under Dutch law. The DUCA scientific committee approved this study's protocol (DUCA201918).

#### Patient selection

All patients undergoing curative MIE for esophageal or gastroesophageal junction cancer between 2017 and 2019 were considered for inclusion. This relatively short timeframe was chosen to minimize the risk of protocol changes in hospitals leading to inconsistent survey and DUCA results. Patients undergoing open surgery were excluded. Hybrid surgery (7.5%) was considered minimally invasive. Patients were excluded in case of non-elective

surgery or invalid registration of length of ICU stay (missing or >365 days). To review the current situation in the Netherlands, all patients undergoing surgery in all hospitals that currently (31-12-2019) still perform esophageal cancer surgery were included.

### Variables for analyses

The DUCA does not distinguish between ICU and medium care unit (MCU) (i.e. MCU is registered as if it were ICU). Total length of ICU stay, including readmission, is recorded in the DUCA. Length of direct postoperative ICU stay is not registered separately. Therefore, in order to ensure fair comparison of direct postoperative ICU stay, patients with ICU readmission were excluded from the hospital variation analyses. These patients were included, however, in the analyses investigating the relationship between hospital variation and short-term surgical outcomes, because the ICU readmission rate was an important outcome measure in this study. Given its skewed distribution, direct postoperative ICU stay was dichotomized around the national median into 'short ICU stay' and 'long ICU stay', with the exact median being added to *short ICU stay*.

### Endpoints

The following endpoints were used for the current study:

- Hospital variation in direct postoperative length of ICU stay after MIE.
- Factors associated with a long direct postoperative ICU stay.
- The impact of hospital variation in direct postoperative ICU stay on clinical outcomes.

### Statistical analyses

#### Hospital variation

Median length of direct postoperative ICU stay with interquartile range and the percentages of *short ICU stay* and *long ICU stay* were determined at hospital level. A funnel plot showed case-mix corrected hospital results [11,12]; multivariable logistic regression, including the case-mix variables described in online supplements, [Table 1](#), estimated the expected (E) number of short ICU stays per hospital. The observed (O) number of short ICU stays per hospital divided by the expected (E) number of short ICU stays produced the observed/expected ratio (O/E ratio). An O/E ratio >1 indicates more observed short ICU stays than was expected based on a hospital's case-mix, whereas an O/E ratio <1 indicates fewer observed short ICU stays than expected. 95% confidence intervals were computed around the benchmark (observed = expected).

#### Sensitivity analyses

To investigate whether hospital variation in postoperative ICU stay was not caused by hospital differences in complication rates, the hospital variation analyses described above were repeated including only patients with neither postoperative/intraoperative complications nor re-interventions.

#### Associated factors

Baseline patient, tumor and treatment characteristics were compared between patients with a short ICU stay and patients with a long ICU stay using either Fisher's exact or  $\chi^2$ -test. Univariable and multivariable logistic regression analyses investigated the impact of patient, tumor, treatment and hospital characteristics on length of ICU-stay. All variables in univariable analyses with one or

**Table 1**  
Baseline characteristics of patients with short ( $\leq 1$  day) and long ( $> 1$  day) direct postoperative ICU stay after minimally invasive esophagectomy in 2017–2019.

		Total	Short ICU stay ( $\leq 1$ day)	Long ICU stay ( $> 1$ day)	P-value ( $\chi^2$ /Fisher)
		No. (%)	No. (%)	No. (%)	
Total		1842	985 (53.5)	857 (46.5)	
Sex					0.085
	Male	1446 (78.5)	788 (80.0)	657 (76.8)	
	Female	395 (21.4)	196 (19.9)	199 (23.2)	
	Missing	1 (0.1)	1 (0.1)	0 (0)	
Age in years					0.223
	<65	701 (38.1)	391 (39.7)	311 (36.3)	
	65–75	920 (49.9)	486 (49.3)	433 (50.6)	
	>75	221 (12.0)	108 (11.0)	112 (13.1)	
Preoperative weight loss in kg					0.524
	None	625 (33.9)	326 (33.1)	298 (34.8)	
	1–5	526 (28.6)	295 (29.9)	230 (26.9)	
	6–10	424 (23.0)	220 (22.3)	204 (23.8)	
	>10	201 (10.9)	106 (10.8)	95 (11.1)	
	Missing	66 (3.6)	38 (3.9)	29 (3.4)	
Body Mass Index					0.519
	<20	108 (5.9)	64 (6.5)	44 (5.1)	
	20–25	850 (46.1)	456 (46.3)	394 (46.0)	
	26–30	656 (35.6)	351 (35.6)	305 (35.6)	
	>30	220 (11.9)	111 (11.3)	108 (12.6)	
	Missing	8 (0.4)	3 (0.3)	5 (0.6)	
ASA score <sup>a</sup>					0.004
	I-II	1360 (73.8)	755 (76.6)	604 (70.6)	
	III+	480 (26.1)	230 (23.4)	250 (29.2)	
	Missing	2 (0.1)	0 (0)	2 (0.2)	
CCI <sup>b</sup>					<0.001
	0	855 (46.4)	494 (50.2)	360 (42.1)	
	1	449 (24.4)	240 (24.4)	209 (24.4)	
	2+	526 (28.6)	247 (25.1)	279 (32.6)	
	Missing	12 (0.7)	4 (0.4)	8 (0.9)	
Previous esophageal, gastric or hiatal surgery					0.610
	No	1805 (98.0)	965 (98.0)	839 (98.0)	
	Yes	31 (1.7)	18 (1.8)	13 (1.5)	
	Unknown/Missing	6 (0.3)	2 (0.2)	4 (0.5)	
Tumor location					0.017
	Intrathoracic	1479 (80.3)	769 (78.1)	708 (82.7)	
	Gastro-esophageal junction	357 (19.4)	212 (21.5)	146 (17.1)	
	Missing	6 (0.3)	4 (0.4)	2 (0.2)	
Histology					0.509
	Adenocarcinoma	1477 (80.2)	793 (80.5)	685 (80.0)	
	Squamous cell	296 (16.1)	149 (15.1)	146 (17.1)	
	Other	32 (1.7)	19 (1.9)	12 (1.4)	
	Unknown/Missing	37 (2.0)	24 (2.4)	13 (1.5)	
Clinical Tumor stage <sup>c</sup>					0.889
	T0-2	398 (21.6)	218 (22.1)	181 (21.1)	
	T3-4	1379 (74.9)	732 (74.3)	645 (75.4)	
	Tx	65 (3.5)	35 (3.6)	30 (3.5)	
Clinical Node stage <sup>c</sup>					0.409
	N0	703 (38.2)	380 (38.6)	322 (37.6)	
	N+	1065 (57.8)	571 (58.0)	494 (57.7)	
	Nx	74 (4.0)	34 (3.5)	40 (4.7)	
Salvage surgery					0.004
	No	1735 (94.2)	928 (94.2)	806 (94.2)	
	Yes	42 (2.3)	13 (1.3)	29 (3.4)	
	Missing	65 (3.5)	44 (4.5)	21 (2.5)	
Neoadjuvant therapy					0.010
	Chemoradiotherapy	1620 (87.9)	880 (89.3)	738 (86.2)	
	None	96 (5.2)	38 (3.9)	59 (6.9)	
	Chemotherapy	125 (6.8)	66 (6.7)	59 (6.9)	
	Other/Missing	1 (0.1)	1 (0.1)	0 (0)	
Hospital volume (esophageal resections per year)					<0.001
	$\leq 40$	466 (25.3)	212 (21.5)	253 (29.6)	
	>40	1376 (74.7)	773 (78.5)	603 (70.4)	
Type of esophagectomy					<0.001
	M1 Transthoracic	1526 (85.7)	844 (85.7)	682 (79.6)	
	M1 Transhiatal	178 (9.7)	87 (8.8)	91 (10.6)	
	Hybrid	138 (7.5)	54 (5.5)	84 (9.8)	
Anastomotic location					<0.001
	Cervical	722 (39.2)	316 (32.1)	406 (47.4)	
	Intrathoracic	1071 (58.1)	639 (64.9)	431 (50.4)	
	None/other/missing	49 (2.7)	30 (3.0)	19 (2.2)	
Intraoperative complications					<0.001

(continued on next page)

Table 1 (continued)

	Total No. (%)	Short ICU stay (≤1 day) No. (%)	Long ICU stay (>1 day) No. (%)	P-value (χ <sup>2</sup> /Fisher)	
Additional organ resection due to tumor ingrowth	No	1758 (95.4)	970 (98.5)	837 (97.8)	0.350
	Yes	83 (4.5)	15 (1.5)	18 (2.1)	
	Missing	1 (0.1)	0 (0)	1 (0.1)	
Additional organ resection due to tumor ingrowth	No	1808 (98.2)	429 (43.6)	258 (30.1)	
	Yes	33 (1.8)	556 (56.4)	597 (69.7)	
	Missing	1 (0.1)	0 (0)	1 (0.1)	

Legend.

<sup>a</sup> American Society of Anesthesiologists Score.

<sup>b</sup> Charlson Comorbidity Index.

<sup>c</sup> In conformity with the 7th edition of the TNM rules for classification.

more subcategories with a p-value <0.1 were added to the multivariable model. Overall p-values for variables were based on ANOVA-analyses. All variables investigated, with reference categories, are presented in online supplements, Table 1.

Impact of hospital variation on short-term surgical outcomes

The following clinical outcomes were investigated: 1) ICU readmission during primary hospital admission, 2) length of hospital stay in days (given its skewed distribution, length of hospital stay was dichotomized around the national median) 3) 30-day/in-hospital mortality (i.e. mortality is registered as long as the primary admission lasts or, in case of discharge, until 30 days post-operatively), 4) failure to rescue [13], 5) postoperative pneumonia [14], 6) cardiac complications [14] and 7) anastomotic leakage [14]. The O/E ratio calculated in the hospital variation analyses embodied a case-mix corrected measure of the length of postoperative ICU stay per hospital. The impact of the O/E ratio (continuous variable) on the seven outcomes was investigated using multilevel multivariable logistic regression analyses including all possible confounders depicted in online supplements, Table 1. In case of insufficient degrees of freedom (<10 events per category in the multivariable model), only statistically relevant confounders were added to the models. A relevant confounder was defined as a variable changing the odds ratio of the O/E ratio on the specific outcome by 10% or more [15,16]. The two-level component accounted for unmeasured hospital differences.

Two-sided p-values <0.05 were considered statistically significant. Missing items were analyzed separately if exceeding 5%. Multicollinearity was assessed in all multivariable analyses by calculating the variance inflation factor (VIF). A VIF ≥2.5 was considered indicative of multicollinearity. All statistical analyses were performed using R-studio version February 1, 5019, The R Foundation for Statistical Computing [17].

Results

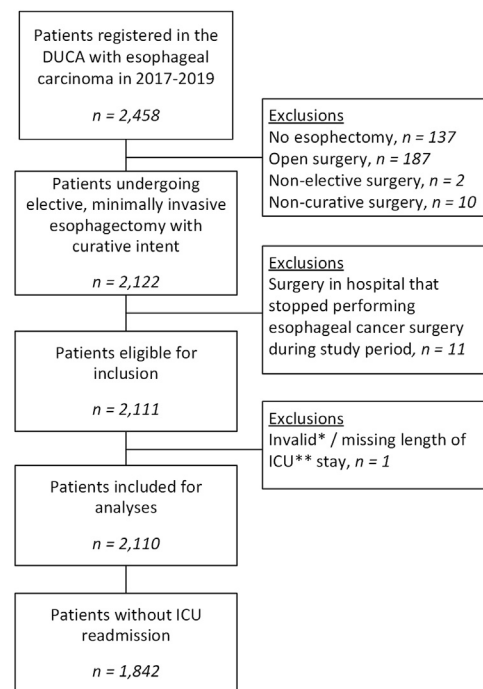
Survey questionnaire

The response rate was 100% (16 out of 16). Every hospital had a protocol regarding postoperative care for patients after esophagectomy. Routine length of postoperative ICU stay was described in the protocol of 14 hospitals (88%). In 3 hospitals, patients were not routinely admitted to the ICU postoperatively; in these hospitals patients stayed the first postoperative night at the post-anesthesia care unit (PACU). Routine ICU stay was 1 day in 12 hospitals, and discharge was generally to the surgical ward, except for 2 hospitals where patients spent an additional day at the MCU. One hospital's protocol advised a routine length of ICU stay of 2 days. All respondents (100%) indicated that patients were

extubated immediately, and 88% mentioned continued hemodynamic or respiratory support as the most important reason for prolonged ICU stay. The estimated protocol compliance rates ranged from 20% to 100%, but were not comparable with actual compliance rates (online supplements, Fig. 1). Reasons for deliberate protocol deviation are presented in online supplements, Fig. 2.

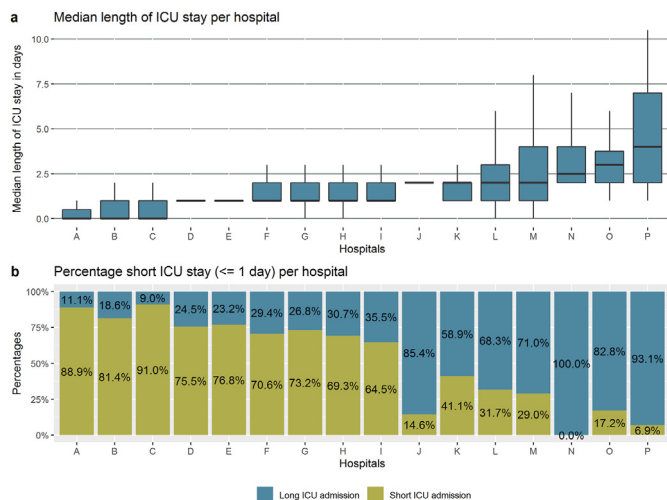
Analyses investigating hospital variation in length of postoperative ICU stay

In total, 1842 patients from 16 hospitals were included (Fig. 1). Median length of direct postoperative ICU stay was 1 day (IQR: 1–2 days). After dichotomization (≤1 day and >1 day), 985 patients (53.5%) had a short ICU stay and 857 (46.5%) had a long ICU stay. Baseline patient, tumor, treatment and hospital characteristics of both groups are presented in Table 1. The median annual esophagectomy hospital volume of the 16 hospitals ranged from 24 to 91.



\* <0 days or >365 days  
\*\* Intensive care unit

Fig. 1. Flowchart of the study.



**Fig. 2.** a. Median length of ICU stay per hospital after minimally invasive esophagectomy. b. Percentage of patients with short ( $\leq 1$  day) and long ICU stay ( $> 1$  day) after minimally invasive esophagectomy per hospital.

In multivariable logistic regression analyses an ASA score of 3 or higher, a Charlson comorbidity index of 2 or higher, salvage surgery, no neoadjuvant therapy, low hospital volume ( $\leq 40$ ), transthoracic or hybrid surgery, cervical anastomosis and intraoperative complications were associated with a long ICU stay (Table 2).

Among the 16 hospitals, median length of direct postoperative ICU stay ranged from 0 (IQR: 0 to 1) to 4 (IQR: 2 to 7) days (Fig. 2a). All hospitals that had access to a PACU, had a median length of ICU stay of 0 days. After dichotomization, the percentage of short ICU stay ranged from 0% to 91% among hospitals (Fig. 2b). Case-mix corrected hospital results are presented in Fig. 3; 7 hospitals had statistically significant higher short ICU stay rates and 6 hospitals had significantly lower rates. O/E ratios of the 16 hospitals ranged from 0.00 to 1.66, which corresponded to corrected percentages of respectively 0% and 88% of patients having a short ICU stay.

### Sensitivity analyses

A total of 657 patients (35.7%) did not have any intra or postoperative complications, nor a re-intervention. Median length of direct postoperative ICU stay ranged from 0 to 4 days among the 16 hospitals. After dichotomization around the national median ( $\leq 1$  day and  $> 1$  day), the percentage of short ICU stays per hospital ranged from 0% to 100% (online supplements, Fig. 3). This variation remained significant after case-mix correction (online supplements, Fig. 4).

### Analyses investigating the impact of hospital variation in length of postoperative ICU stay on short-term surgical outcomes

For these analyses, 2110 patients were included (Fig. 1). In multilevel multivariable logistic regression analyses, the O/E-ratio of short ICU stay per hospital was not statistically significant associated with ICU readmission, in-hospital/30-day mortality, failure to rescue, postoperative pneumonia, cardiac complications or anastomotic leakage (Table 3). This indicates these outcomes did not differ between hospitals with relatively high short ICU stay rates or hospitals with low rates. Length of hospital stay was 9 days after short ICU stay and 13 days after long ICU stay, which was statistically significant in multilevel multivariable logistic regression analyses (Table 3).

## Discussion

This nationwide, population-based cohort study showed a 4-day difference among Dutch hospitals in direct postoperative length of ICU stay after MIE. A survey among all 16 esophageal cancer surgery centers in the Netherlands showed that this variation could not be fully explained by differences in protocols regarding postoperative ICU stay. It was also not explained by hospital differences in complication rates. High ASA score, high Charlson comorbidity index, salvage surgery, no neoadjuvant therapy, cervical anastomosis (associated with high intrathoracic tumor location), transthoracic or hybrid surgery and intraoperative complications were associated with a long ICU stay. In addition, length of ICU stay was significantly shorter in high-volume hospitals ( $> 40$  annual esophagectomies). Hospital variation in length of direct postoperative ICU stay was not associated with ICU readmission, short-term mortality, failure to rescue, postoperative pneumonia, cardiac complications and anastomotic leakage. However, length of hospital admission was significantly shorter in hospitals with relatively short postoperative ICU stay.

To our knowledge, this is the first study using population-based data to investigate routine direct postoperative ICU admission after MIE. In conformity with the current study, a previous study including almost 8000 esophagectomy patients between 2004 and 2008 showed hospital variation in terms of postoperative ICU admission that did not impact short-term mortality rates [4]. This study did not report on the surgical procedure (i.e. minimally invasive or open). A 2015 meta-analysis showed that routine ICU admission varied from 0 to 4 days in protocols [6].

The survey conducted as part of this study showed that hospital variation in length of ICU stay could not be fully explained by differences in hospital protocols. Several other factors might play an important role. It emerged from the survey that all Dutch hospitals that did not routinely admit patients to the ICU had a PACU. Compared to treatment at the ICU, admitting patients to the PACU might lead to a significant cost reduction [18], and might lead to earlier discharge to a step-down unit since patients generally only stay at the PACU for a maximum of 24 h [19]. Hospital differences in ERAS protocol availability might also lead to hospital variation in terms of length of ICU stay. Several studies demonstrated that ERAS protocols after esophagectomy might reduce length of ICU stay [20,21]. Another factor that might explain hospital variation in length of ICU stay is the timing of extubation as studies showed that immediate extubation reduces length of ICU stay [22,23]. However, in the current study's survey all hospitals stated that they intend to immediately extubate patients. As the DUCA does not register timing of extubation, this could not be verified. Another factor that might influence hospital results in terms of length of postoperative ICU stay is the used analgesic modality. The hypotensive effect of epidural anesthesia might require inotropic hemodynamic support at an ICU level of care. Paravertebral analgesia has enjoyed increasing interest in recent years since it may reduce the incidence of hypotensive events and therefore instigate shorter ICU stay [24,25]. Hospital logistics might also play a crucial role in the hospital variation found in the current study. Sensitivity analyses showed, even for uncomplicated patients, a 4-day difference in routine postoperative ICU stay among hospitals. This suggests that some hospitals cannot accomplish early ICU discharge, even in the case of uneventful recovery. This might be caused by bed unavailability at the step-down care unit or other logistical imperfections. The phase of the minimally invasive learning curve of each individual hospital might also partially explain the hospital variation. Introduction of MIE in a non-expert center leads to higher complication rates [26]. Even though the underlying reasons remain speculative, the presence of hospital variation indicates that

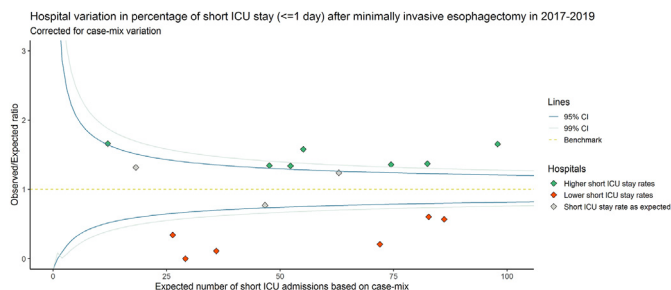
**Table 2**

Univariable and multivariable logistic regression analyses to assess the association of patient, tumor, treatment and hospital characteristics with long ICU stay (&gt;1 day) after minimally invasive esophagectomy in 2017–2019.

Factor		N	Univariable analyses			Multivariable analysis		
			OR	CI (95%)	P-value	aOR	CI (95%)	P-value
Sex	Male	1446	1		0.09			0.32
	Female	395	1.22	0.97–1.52		1	1.13	0.89–1.43
Age in years	<65	701	1		0.22			
	65–75	920	1.12	0.92–1.36	0.26			
	>75	221	1.29	0.95–1.75	0.10			
Preoperative weight loss <sup>a</sup>	None	625	1		0.52			
	1–5	526	0.86	0.68–1.08	0.20			
	6–10	424	1.02	0.79–1.30	0.89			
	>10	201	0.98	0.71–1.35	0.92			
Body Mass Index (BMI)	<20	108	1		0.52			
	20–25	850	1.26	0.84–1.90	0.27			
	26–30	656	1.26	0.84–1.92	0.27			
	>30	220	1.43	0.90–2.29	0.13			
ASA score <sup>b</sup>	I–II	1360	1		<0.01			0.02
	III+	480	1.36	1.10–1.67		1	1.31	1.04–1.65
CCI <sup>c</sup>	0	855	1		<0.01			0.03
	1	449	1.19	0.95–1.50	0.14			0.30
	2 +	526	1.55	1.24–1.93	<0.01	1	1.40	1.10–1.78
Previous esophageal, gastric or hiatal surgery	No	1805	1		0.61			
	Yes	31	0.83	0.40–1.69				
Tumor location	Intrathoracic	1479	1		0.02			0.08
	Gastro-esophageal junction	357	0.75	0.59–0.95		1	0.78	0.59–1.03
Histology	Adenocarcinoma	1477	1		0.51			
	SCC	296	1.13	0.88–1.44	0.35			
	Other	32	0.79	0.40–1.60	0.52			
Clinical Tumor stage <sup>d</sup>	T0–2	398	1		0.89			
	T3–4	1379	1.06	0.84–1.32	0.63			
	Tx	65	1.03	0.60–1.74	0.92			
Clinical Node stage <sup>d</sup>	N0	703	1		0.41			
	N+	1065	1.02	0.84–1.23	0.86			
	Nx	74	1.38	0.86–2.25	0.19			
Salvage Surgery	No	1735	1		<0.01			<0.01
	Yes	42	2.57	1.35–5.13		1	3.24	1.55–7.46
Neoadjuvant therapy	Chemoradio-therapy	1620	1		0.01			<0.01
	None	96	1.90	1.25–2.92	<0.01	1	1.95	1.24–3.11
	Chemotherapy	125	1.07	0.74–1.53	0.73	1	1.32	0.86–2.04
Hospital volume (esophageal resections per year)	≤40	466	1		<0.01			<0.01
	>40	1376	0.66	0.53–0.81		1	0.67	0.52–0.85
Type of esophagectomy	MI Transthoracic	1526	1		<0.01			<0.01
	MI Transhiatal	178	1.29	0.95–1.77	0.10	1	0.66	0.45–0.96
	Hybrid	138	1.93	1.35–2.76	<0.01	2.46	1.68–3.62	<0.01
Anastomotic location	Cervical	722	1		<0.01			<0.01
	Intrathoracic	1071	0.53	0.43–0.64		1	0.52	0.42–0.66
Intraoperative complications	No	1758	1		<0.01			<0.01
	Yes	83	2.22	1.41–3.56		1	1.91	1.18–3.13
Additional organ resection due to tumor ingrowth	No	1808	1		0.35			
	Yes	33	1.39	0.70–2.81				

Legend.

<sup>a</sup> In kilograms.<sup>b</sup> American Society of Anesthesiologists Score.<sup>c</sup> Charlson Comorbidity Index.<sup>d</sup> In conformity with the 7th edition of the TNM rules for classification.



**Fig. 3.** Case-mix corrected funnel plot showing hospital variation in percentage of short ICU stay ( $\leq 1$  day) after minimally invasive esophagectomy.

a significant cost reduction might be achievable at a national level. To put this into perspective, the costs of one day at ICU average €2224 whereas the daily costs at the hospital ward are estimated at €463 [27].

In the Netherlands, upper gastrointestinal surgeons organize yearly expert sessions in which different practices, protocols and hospital logistics are discussed. Discussing protocols, ERAS items and logistics regarding postoperative ICU stay, and starting national improvement programs, might induce nationwide uniformity in terms of postoperative ICU stay. This might in turn positively impact hospital costs, both through shorter ICU stay and subsequent shorter hospital stay.

This study showed that hospital policy in respect of length of ICU stay did not significantly impact short-term mortality or failure to rescue rates, nor did it impact ICU readmission rates. However, this does not justify immediate change in postoperative care. It rather shows room for discussion on what the ideal, and most cost-effective, care unit is for the early postoperative period after MIE in the current era of immediate extubation. The PACU or a surgical ward with well-trained, proactive and specialized medical personnel might be alternatives to the ICU for certain patients. Future research should focus on what type of high-risk patients benefit from routine ICU admission and for what type of ‘low-risk’

patients direct postoperative ICU admission may not be necessary. However, even in these ‘low-risk’ patients, aggressive and timely postoperative ICU admission might be required when these patients are in need of organ support. Even though no evident recommendations can be made based on the current study, the identified hospital variation indicates nationwide improvement is possible.

This study has some limitations. The DUCA does not register when patients are ready for ICU discharge and therefore the role of hospital logistics remains unclear. In addition, the DUCA does not register ERAS items, so the effect of specific ERAS items on length of ICU stay could not be verified. As this study showed very low protocol compliance rates for some hospitals, the accuracy of the survey results can be questioned. As the DUCA does not distinguish between ICU and MCU, the current study had to pool both wards. The survey was conducted to gain more insight into the different hospital protocols and did distinguish between ICU and MCU.

**Conclusions**

This nationwide, retrospective cohort study showed significant hospital variation in terms of direct postoperative length of ICU stay after minimally invasive esophagectomy for cancer. This variation did not impact short-term mortality, failure to rescue, ICU readmission, anastomotic leakage, cardiac complication or pneumonia rates. However, length of hospital stay was shorter in hospitals with relatively short ICU stay. This indicates that quality of care is not inferior in hospitals with a relatively short length of ICU stay compared to hospitals with a longer direct postoperative ICU stay. Therefore, a more selected use of ICU resources rather than routine post-MIE ICU admission could result in a significant cost reduction at a national level, especially in hospitals where a PACU is available for the primary postoperative care.

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There was no funding for this study.

**Table 3**

Multilevel multivariable logistic regression analyses, nested for hospital identification number, of the impact of varying length of postoperative ICU admission among hospitals on short-term surgical outcomes after minimally invasive esophagectomy.

	Outcome incidence	Multivariable multilevel analysis with random effects for each hospital			
		Corrected for	aOR of the Observed/Expected ratio <sup>a</sup> of short ICU stay for each hospital	95% CI	P-value
ICU readmission	231/1873	All <sup>b</sup>	1.01	0.71 –1.43	0.976
Length of hospital stay (>11 days) <sup>c</sup>	824/1873	All <sup>b</sup>	0.58	0.37 –0.90	0.017
In-hospital/30-day mortality	45/1873	Location of anastomosis <sup>d</sup>	1.25	0.63 –2.45	0.524
Failure to rescue <sup>e</sup>	44/555	None <sup>d</sup>	1.45	0.73 –2.88	0.293
Postoperative pneumonia	408/1873	All <sup>b</sup>	0.89	0.53 –1.50	0.658
Cardiac complications	351/1873	All <sup>c</sup>	0.84	0.57 –1.24	0.386
Anastomotic leakage	357/1873	All <sup>c</sup>	1.53	0.97 –2.40	0.066

<sup>a</sup> The observed/expected ratio was calculated for each hospital by dividing the actual number of short ICU stays ( $\leq 1$  day) by the expected number of short ICU stays based on each hospital's case-mix. This continuous variable can be interpreted as a case-mix corrected measure of the length of postoperative ICU admission per hospital. An aOR of the O/E ratio <1 indicates lower chance of the outcome in hospitals with a high O/E ratio (i.e. relatively short postoperative ICU stay).

<sup>b</sup> Corrected for: sex, age, preoperative weight loss, BMI, Charlson Comorbidity Index, ASA-score, previous esophageal, gastric or hiatal surgery, tumor location, histology, clinical Tumor stage, clinical Node stage, neoadjuvant therapy, salvage surgery, hospital volume, type of esophagectomy, location of anastomosis, intraoperative complications, additional organ resection due to tumor ingrowth and hospital identification number as random effect factor.

<sup>c</sup> Given the skewed distribution of length of hospital stay, it was dichotomized around the national median of 11 days.

<sup>d</sup> Given insufficient number of degrees of freedom for correction for all possible confounders, only confounders leading to a 10% change in OR were included for analyses.

<sup>e</sup> Patients with a complicated postoperative course eventually dying in hospital or in first 30 days postoperatively.

## CRediT authorship contribution statement

**Daan M. Voeten:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Leonie R. van der Werf:** Conceptualization, Methodology, Validation, Data curation, Writing - original draft, Writing - review & editing. **Suzanne S. Gisbertz:** Conceptualization, Validation, Writing - review & editing. **Jelle P. Ruurda:** Conceptualization, Validation, Writing - review & editing. **Mark I. van Berge Henegouwen:** Conceptualization, Methodology, Validation, Resources, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration. **Richard van Hillegersberg:** Conceptualization, Methodology, Validation, Resources, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration.

## Declaration of competing interest

MlvBH is consultant for Mylan, Johnson & Johnson, Alesi Surgical and Medtronic, and received research grants from Olympus and Stryker. RvH and JPR are consultants for Medtronic and are proctoring surgeons for Intuitive Surgical Inc. and train other surgeons in robot-assisted minimally invasive esophagectomy. For the remaining authors no conflicts of interest were declared.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejso.2021.01.005>.

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