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# University hospital status and surgeon volume and risk of reoperation following surgery for esophageal cancer

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ABSTRACT

*Purpose:* Centralization of surgery improves the survival following esophagectomy for cancer, but whether university hospital setting or surgeon volume influences the reoperation rates is unknown. We aimed to clarify whether hospital status or surgeon volume are associated with a risk of reoperation after esophagectomy.

*Methods:* Patients who underwent esophagectomy for esophageal cancer in 1987–2010 were identified from a population-based, nationwide Swedish cohort study. University hospital status and cumulative surgeon volume were analyzed in relation to risk of reoperation or death (the latter included to avoid competing risk errors) within 30 days of surgery. Multivariable logistic regression provided odds ratios (OR) with 95% confidence intervals (CI), adjusted for calendar period, age, sex, comorbidity, tumor histology, stage, neoadjuvant therapy, resection margin, surgeon volume, and hospital status.

*Results:* Among 1820 participants, 989 (54%) underwent esophagectomy in university hospitals and 271 (15%) died or were reoperated within 30 days of surgery. Non-university hospital status was associated with an increased risk of reoperation or death compared to university hospitals (adjusted OR 1.56, 95% CI 1.13–2.13). Regarding surgeon volume, the ORs were increased in the lower volume categories, but not statistically significant (OR 1.30, 95% CI 0.89–1.89 for surgeon volume <7 and OR 1.10, 95% CI 0.75–1.63 for surgeon volume 7–16, compared to surgeon volume >16).

*Conclusion:* The risk of reoperation or death within 30 days of esophagectomy seems to be lower in university hospitals even after adjustment for surgeon volume and other potential confounders. These results support centralizing esophageal cancer patients to university hospitals.



## Introduction

The curative treatment of esophageal cancer includes surgical resection (esophagectomy) in most patients [1]. One of several potential reasons for the improved 5-year survival of esophageal cancer patients in the last decade is centralization of surgery [1,2]. Surgeon volume is a known long-term prognostic factor in esophageal cancer surgery [3], and higher annual esophagectomy volume may lower early postoperative mortality after esophagectomy regardless of comorbidity [4,5]. However, hospital volume is not prognostic after adjustment for individual surgeon volume [3,6].

University hospital status has not been shown to be associated with long-term survival of esophageal cancer patients [7]. However, university hospitals should be more experienced in the perioperative treatment of patients undergoing major thoracoabdominal surgery due to a higher case load of other procedures, for example cardiac and lung cancer surgery, and have greater staffing and more research activities. Instead of prolonged survival, university hospital status might be associated with lower complication or reoperation rates, which in turn may

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cause poor quality of life also in the long-term perspective [8]. The collection of data concerning complications, as well as reporting of complications, has varied greatly in individual studies [9]. Therefore, reoperation and short-term mortality could be considered a more robust and specific assessment of poor early postoperative outcomes than complications in historical cohorts. Reoperations are also known to decrease the long-term survival after esophagectomy [10]. Yet, the relation between university hospital status, or surgeon volume and risk of reoperations is not known.

The aim of this study was to test the hypotheses that esophagectomy for esophageal cancer in university hospitals and conducted by high-volume surgeons is associated with lower rates of reoperation than in non-university hospitals and lower volume surgeons.

## Methods

### *Study design*

This was a population-based and nationwide cohort study of patients diagnosed with adenocarcinoma or squamous cell carcinoma of the esophagus who had undergone esophagectomy in Sweden between 1987 and 2010, with follow-up until 2016.

### *Exposures*

The study main exposure was university versus non-university hospital status where the esophagectomy was conducted. University hospital was defined as any of the six hospitals affiliated to a university providing education and training for medical students in Sweden, and the remaining 49 hospitals that had conducted esophagectomies during the study period were considered non-university hospitals. The secondary exposure was the cumulative surgeon volume of the individual surgeon during the study period, where <7 was the lowest quartile, 7–16 was the second quartile, and >16 esophagectomies defined the two highest quartiles. Surgeon volume was chosen instead of hospital volume because surgeon volume is more robust predictor of surgeon skill compared to hospital volume, and because hospital volume is not prognostic after adjustment for individual surgeon volume [3]. The algorithm to determine the surgeon volume has been described earlier [3]. Highest two volume quartile surgeons were grouped into one category because there were much more high-volume surgeons operating in university hospitals, and because esophagectomy-associated short-term mortality has been shown to plateau after cumulative surgeon volume of 15 [11].

### *Outcomes*

The primary outcome was the occurrence of reoperation or death within 30 days of primary surgery. The secondary outcome was reoperation alone within 30 days of primary surgery. The primary outcome was chosen to include 30-day all-cause mortality to reduce competing risk errors from mortality before any reoperation was possible. The study was approved by the Regional Ethical Review Board in Stockholm, Sweden.

### *Cohort*

Earlier versions of the cohort of this study have been used for other studies examining esophageal cancer surgery [3,11–13]. In brief, the study cohort included at least 98% of all esophageal cancer patients who underwent curatively intended surgery in Sweden during the study period. The patients with esophageal cancer were identified from the Swedish Cancer Registry, which we have shown to have at least 98% completeness for this cancer [14]. Additionally, the Swedish Patient Registry was used for selecting only patients who had undergone esophagectomy, and this registry has 99.6% positive predictive value for this operation [15]. The Patient Registry also provided information about patient characteristics (age, sex, and comorbidity) and hospital status (university or non-university). Comorbidity data were defined and categorized using the most updated and well-validated Charlson Comorbidity Index [16].

To enable collection of additional and more detailed clinical data, surgery charts and pathology records were retrieved from all hospitals conducting esophageal cancer surgery in Sweden during the study period. The data retrieved from the medical records were assessed and categorized according to a detailed predefined protocol to ensure uniformity. This assessment has been validated for high concordance [12]. The medical records provided information about reoperations, surgeon volume, tumor characteristics (location, stage and histology), as well as details regarding the treatment (type of surgery, radicalness of the resection and neoadjuvant therapy). Tumor stage was classified based on the Union Internationale Contre le Cancer, using the 7th edition of tumor-node-metastasis (TNM) system [17]. Open transthoracic resection with intrathoracic anastomosis was the dominant (>95%) surgical procedure and a gastric tube which was pulled up and anastomosed to the proximal esophagus was the preferred reconstruction.

Mortality data were obtained from the nationwide Swedish Causes of death Registry, which has 100% complete data for date of death.

The information from the registries and medical records was linked for all individual patients using the Swedish personal identity number, a unique 10-digit identifier assigned to each Swedish resident upon birth or immigration, which is a well-validated tool for research purposes [18].

### *Statistical analysis*

All statistical analyses were carried out by an experienced biostatistician (KW), who followed an *a priori* specified study protocol, defining and categorizing the exposures, outcomes and covariates as well as the statistical methods. To estimate the relative risk for the exposures in relation to the outcomes, multivariable logistic regression was used to calculate odds ratios (OR) with 95% confidence intervals (CI). The following covariates were selected and adjusted for as potential confounders: 1) calendar period of surgery (year 1987–1994, 1995–2002, or 2003–2010), 2) age (categorized into <65, 65–75, or >75 years), 3) sex (male or female), 4) comorbidity (Charlson Comorbidity Index score 0, 1, or ≥2), 5) tumor histology (adenocarcinoma or squamous cell carcinoma), 6) tumor stage (0-I, II or III-IV), 7) neoadjuvant therapy (yes or no), 8) resection margin status (radical [R0] or not [R1/2]), 9) surgeon volume (<7, 7–16, or >16, the cumulative number of esophagectomies per surgeon during the study period), and 10) hospital status (university or non-university). Three regression models were created, i.e. a crude model without any adjustments, a Model 1 with adjustment for covariates 1–8 above, and Model 2 which additionally adjusted for surgeon volume for the exposure hospital status and hospital status for the exposure surgeon volume. Subgroup analyses were also conducted stratifying by the covariates 1–8 above, with adjustment for the other covariates. Missing data were handled by carrying out a complete case analysis. The statistical software IBM SPSS v24.0 (IBM Corp., Armonk, NY) was used for all statistical analyses.