Nationwide Analysis of 90-Day Readmissions and Mortality Following Esophagectomy: Causes, Costs, and Risk Factors

RCOP NRD A24

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## Preamble:

* **Reference Studies:**
  + [Goel et al., 2020](https://doi.org/10.1016/j.athoracsur.2019.08.035)
  + [Yeo et al., 2019](https://doi.org/10.1001/jamanetworkopen.2019.12208)
* **Study Objective:**
* To analyze 90-day readmissions following esophagectomy in a nationally representative cohort using the Nationwide Readmissions Database (NRD). Specific objectives include:
  + Estimating the national 90-day readmission rate after esophagectomy
  + Identifying causes of readmission and associated healthcare utilization
  + Comparing index and readmission mortality and hospital charges
  + Determining patient- and hospital-level predictors of readmission using survey-adjusted survival modeling
* **Data Source:**
* This retrospective cohort study used data from the 2016–2017 Nationwide Readmissions Database (NRD), developed by the Healthcare Cost and Utilization Project (HCUP). The NRD is a nationally representative, all-payer database of U.S. hospitalizations that allows linkage of patients across hospital stays within a calendar year. Survey weights, stratification, and clustering variables support complex sampling design for national estimates.
* **Cohort Definition:**
* Index hospitalizations were defined using the following criteria:
  + Adults aged ≥18 years
  + Esophagectomy procedures identified via ICD-10-PCS codes:
    - Example: 0DB10ZZ, 0DB14ZZ, 0DT10ZZ, etc.
  + Index discharge by the end of September to allow for a complete 90-day follow-up period
  + Complete data on LOS and NRD\_DAYSTOEVENT, required to compute discharge dates
* **Outcomes of Interest:**
  + Primary Outcome:
    - All-cause 90-day readmission (Yes/No), flagged using NRD linkage variables
  + Secondary Outcomes (index admission):
    - In-hospital mortality (DIED)
    - Length of stay (LOS, in days)
    - Total hospitalization charges (TOTCHG), inflation-adjusted to 2017 USD
    - Non-home discharge
  + Readmission Characteristics:
    - In-hospital mortality
    - Length of stay (LOS, in days)
    - Total hospitalization charges (inflation-adjusted to 2017 USD)
    - Top causes of readmission
* **Outcome Definitions:**
  + Readmission:
    - Defined using HCUP NRD’s methodology. Readmissions were identified only among patients with qualifying index events.
    - Trauma-related hospitalizations were excluded only from the readmission pool to avoid unrelated admissions.
  + Mortality:
    - In-hospital death recorded during index or readmission (DIED = 1)
  + LOS:
    - Reported in days; modeled as count outcome
  + Charge:
    - Derived from HCUP’s TOTCHG variable and adjusted to 2017 dollars using Consumer Price Index (CPI) data
  + Non-Home Discharge:
    - Defined as any disposition other than home/self-care, specifically:
      * Transfer to another short-term hospital
      * Transfer to skilled nursing facility (SNF), intermediate, or other facility
      * Left against medical advice
      * Died in hospital
      * Alive, destination unknown
* **Covariates and Variable Construction:**
  + Demographic & Socioeconomic Factors:
    - Age (continuous)
    - Sex (FEMALE; ref = Male)
    - Primary expected payer (Insurance; Medicare, Medicaid, Private, Other)
    - Income quartile based on ZIP code (ZIPINC\_QRTL)
    - Weekend vs weekday admission (AWEEKEND)
    - Elective vs non-elective admission (ELECTIVE)
  + Clinical Variables:
    - Elixhauser Comorbidity Index (elixsum), modeled as a continuous variable
    - Specific comorbidities based on Elixhauser indicators:
      * Diabetes Mellitus
      * Renal Failure
      * Congestive Heart Failure
      * Chronic Pulmonary Disease
      * Liver Disease
      * Weight Loss
      * Hypertension
      * Depression
      * Obesity
      * Coagulopathy
      * Fluid/Electrolyte Disorders
      * Metastatic Cancer
    - In-Hospital/Postoperative complications:
      * Infection
      * Bleeding
      * Acute kidney injury
      * Venous thromboembolism
      * Sepsis
  + Hospital Characteristics:
    - Hospital bed size (Small, Medium, Large)
    - Urban/rural teaching status (Metropolitan, teaching vs non-teaching, etc.)
  + Disposition and Severity:
    - Non-home discharge (e.g., SNF, hospice, other facilities, or death)
    - Length of stay
* **Statistical Methods:**
  + Survey Design and Weighting:
    - All analyses accounted for NRD’s complex survey design using weights (DISCWT), strata (NRD\_STRATUM), and clustering (HOSP\_NRD). Survey-adjusted methods were implemented via survey and srvyr packages.
  + Descriptive Analyses:
    - Baseline characteristics were summarized by 90-day readmission status (“With” vs “Without readmission”).
    - Survey-weighted means and proportions were reported.
    - P-values from design-based statistical tests (Rao–Scott adjusted chi-square for categorical variables; design-based Kruskal–Wallis test for continuous variables).
  + Multivariable Modeling:
    - A survey-weighted Cox proportional hazards model was used to identify predictors of 90-day readmission.
    - The model included demographic, clinical, hospital-level, and index-stay factors.
    - Hazard ratios (HRs) with 95% confidence intervals (CIs) were reported
  + Readmission Characteristics:
  + Among readmitted patients, the following were summarized using survey-weighted statistics:
    - Time to readmission
    - In-hospital mortality during readmission
    - Length of stay and total charges during the readmission
    - Top principal diagnoses at readmission (I10\_DX1)
* **Software:** All analyses were conducted in R Statistical Language (Version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria).

## Baseline Characteristics

| **Characteristic** | **Overall** N = 10,039*1* | **Without Readmission** N = 8,340*1* | **With 90-day readmission** N = 1,699*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 64 (12) | 64 (12) | 64 (12) | 0.9 |
| Sex |  |  |  | 0.4 |
| Male | 7,262 (72%) | 6,014 (72%) | 1,249 (73%) |  |
| Female | 2,777 (28%) | 2,327 (28%) | 450 (27%) |  |
| Primary Expected Payer |  |  |  | 0.2 |
| Private | 3,723 (37%) | 3,098 (37%) | 624 (37%) |  |
| Medicaid | 795 (7.9%) | 635 (7.6%) | 160 (9.4%) |  |
| Medicare | 5,045 (50%) | 4,190 (50%) | 855 (50%) |  |
| Other | 461 (4.6%) | 401 (4.8%) | 60 (3.5%) |  |
| Median Household Income Quartile |  |  |  | 0.9 |
| 0-25th percentile | 2,301 (23%) | 1,910 (23%) | 391 (23%) |  |
| 26th to 50th percentile | 2,762 (28%) | 2,309 (28%) | 453 (27%) |  |
| 51st to 75th percentile | 2,635 (27%) | 2,185 (27%) | 450 (27%) |  |
| 76th to 100th percentile | 2,212 (22%) | 1,821 (22%) | 391 (23%) |  |
| Admission Day |  |  |  | 0.7 |
| Monday-Friday | 9,755 (97%) | 8,107 (97%) | 1,648 (97%) |  |
| Saturday-Sunday | 284 (2.8%) | 233 (2.8%) | 51 (3.0%) |  |
| Admission Type |  |  |  | 0.5 |
| Elective | 8,816 (88%) | 7,336 (88%) | 1,480 (87%) |  |
| Non-elective | 1,190 (12%) | 976 (12%) | 215 (13%) |  |
| Hospital Bed Size |  |  |  | 0.7 |
| Small | 839 (8.4%) | 697 (8.4%) | 142 (8.4%) |  |
| Large | 7,622 (76%) | 6,313 (76%) | 1,309 (77%) |  |
| Medium | 1,578 (16%) | 1,330 (16%) | 248 (15%) |  |
| Hospital Location and Teaching Status |  |  |  | 0.8 |
| Metropolitan, non-teaching | 840 (8.4%) | 692 (8.3%) | 148 (8.7%) |  |
| Metropolitan, teaching | 9,034 (90%) | 7,506 (90%) | 1,528 (90%) |  |
| Non-metropolitan | 165 (1.6%) | 142 (1.7%) | 23 (1.4%) |  |
| Diabetes Mellitus | 2,097 (21%) | 1,675 (20%) | 421 (25%) | 0.004 |
| Renal Failure | 653 (6.5%) | 491 (5.9%) | 162 (9.5%) | <0.001 |
| Congestive Heart Failure | 664 (6.6%) | 519 (6.2%) | 146 (8.6%) | 0.022 |
| Chronic Pulmonary Disease | 2,242 (22%) | 1,815 (22%) | 427 (25%) | 0.024 |
| Liver Disease | 567 (5.6%) | 469 (5.6%) | 98 (5.7%) | >0.9 |
| Weight Loss | 2,460 (25%) | 1,946 (23%) | 514 (30%) | <0.001 |
| Hypertension | 5,801 (58%) | 4,787 (57%) | 1,014 (60%) | 0.2 |
| Depression | 1,167 (12%) | 913 (11%) | 253 (15%) | 0.001 |
| Obesity | 1,443 (14%) | 1,194 (14%) | 250 (15%) | 0.8 |
| Coagulopathy | 797 (7.9%) | 650 (7.8%) | 147 (8.6%) | 0.4 |
| Fluid/Electrolyte Disorders | 3,265 (33%) | 2,572 (31%) | 693 (41%) | <0.001 |
| Metastatic Cancer | 1,654 (16%) | 1,338 (16%) | 316 (19%) | 0.056 |
| Postoperative Infection | 364 (3.6%) | 283 (3.4%) | 81 (4.8%) | 0.059 |
| Postoperative Bleeding | 168 (1.7%) | 144 (1.7%) | 24 (1.4%) | 0.6 |
| Sepsis | 933 (9.3%) | 741 (8.9%) | 192 (11%) | 0.023 |
| Acute Kidney Injury | 942 (9.4%) | 716 (8.6%) | 226 (13%) | <0.001 |
| Venous Thromboembolism | 478 (4.8%) | 383 (4.6%) | 95 (5.6%) | 0.2 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

## Unadjusted Outcomes

### Outcomes of Index Hospitalizations

| **Characteristic** | **Overall** N = 10,039*1* | **Without Readmission** N = 8,340*1* | **With 90-day readmission** N = 1,699*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Length of Stay (days) | 9 (7, 15) | 9 (6, 14) | 11 (8, 20) | <0.001 |
| Inflation-Adjusted Total Charges ($) | 132,055 (80,757, 222,908) | 127,383 (77,394, 212,095) | 158,142 (94,918, 278,034) | <0.001 |
| Discharged to Non-Home Setting | 1,765 (18%) | 1,373 (16%) | 392 (23%) | <0.001 |
| *1*Median (Q1, Q3); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### 90-Day Readmission Timing

The median time to 90-day readmission following index hospitalization was 24 days (IQR: 10–51).

### In-Hospital Mortality by Readmission Status:

Index hospitalizations resulted in:

1. Deaths (n): 312
2. Death Rate (%): 3.12%
3. Death Rate (95% CI): 2.59% to 3.64%

Readmission hospitalizations resulted in:

1. Deaths (n): 68
2. Death Rate (%): 4.05%
3. Death Rate (95% CI): 2.57% to 5.52%

### Resource Utilization for Readmission (LOS, Cost)

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 4 (IQR: 2–8)
2. Median Total Charges (IQR): $32,809 (IQR: $17,968–$64,419)

## Multivariable Analyses

### Multivariable Predictors of 90-Day Readmission

Stratified 1 - level Cluster Sampling design (with replacement)  
With (441) clusters.  
subset(nrd\_design, IndexEvent == 1)  
Sampling variables:  
 - ids: HOSP\_NRD   
 - strata: NRD\_STRATUM   
 - weights: DISCWT

| **Characteristic** | **HR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Age (years) | 1.00 | 1.0, 1.01 | 0.6 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.11 | 0.97, 1.27 | 0.13 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 0.84 | 0.63, 1.11 | 0.2 |
| Medicare | 0.95 | 0.79, 1.15 | 0.6 |
| Other | 0.95 | 0.68, 1.32 | 0.8 |
| Median Household Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.88 | 0.72, 1.07 | 0.2 |
| 51st to 75th percentile | 0.89 | 0.71, 1.10 | 0.3 |
| 76th to 100th percentile | 1.03 | 0.83, 1.27 | 0.8 |
| Admission Day |  |  |  |
| Monday-Friday | — | — |  |
| Saturday-Sunday | 1.05 | 0.67, 1.64 | 0.8 |
| Admission Type |  |  |  |
| Elective | — | — |  |
| Non-elective | 1.10 | 0.90, 1.34 | 0.4 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 1.33 | 1.04, 1.71 | 0.025 |
| Medium | 1.42 | 1.07, 1.89 | 0.015 |
| Hospital Location and Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 1.33 | 1.04, 1.69 | 0.021 |
| Non-metropolitan | 1.89 | 0.99, 3.62 | 0.055 |
| Elixhauser Comorbidity Index | 0.99 | 0.96, 1.03 | 0.6 |
| Discharged to Non-Home Setting |  |  |  |
| No | — | — |  |
| Yes | 0.93 | 0.77, 1.12 | 0.5 |
| Postoperative Infection |  |  |  |
| No | — | — |  |
| Yes | 1.19 | 0.87, 1.63 | 0.3 |
| Postoperative Bleeding |  |  |  |
| No | — | — |  |
| Yes | 1.69 | 1.23, 2.31 | 0.001 |
| Sepsis |  |  |  |
| No | — | — |  |
| Yes | 0.99 | 0.77, 1.27 | >0.9 |
| Acute Kidney Injury |  |  |  |
| No | — | — |  |
| Yes | 1.12 | 0.91, 1.39 | 0.3 |
| Venous Thromboembolism |  |  |  |
| No | — | — |  |
| Yes | 1.40 | 1.01, 1.94 | 0.042 |
| Length of Stay (days) | 0.99 | 0.99, 1.00 | 0.026 |
| Abbreviations: CI = Confidence Interval, HR = Hazard Ratio | | | |

## Top Causes of Readmission

Diagnosis Percentage  
I10\_DX1A419 A419 6.214600  
I10\_DX1K9189 K9189 5.660410  
I10\_DX1J690 J690 5.047350  
I10\_DX1J90 J90 3.428236  
I10\_DX1K222 K222 2.508380  
I10\_DX1J189 J189 2.341791  
I10\_DX1K311 K311 2.290628  
I10\_DX1E860 E860 2.092085  
I10\_DX1R112 R112 2.015964  
I10\_DX1K5660 K5660 1.580224