Ninety-day mortality after resection for lung cancer is nearly double 30-day mortality

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Objective: To evaluate 30-day and 90-day mortality after major pulmonary resection for lung cancer including the relationship to hospital volume.

Methods: Major lung resections from 2007 to 2011 were identified in the National Cancer Data Base. Mortality was compared according to annual volume and demographic and clinical covariates using univariate and multivariable analyses, and included information on comorbidity. Statistical significance ($P < .05$) and 95% confidence intervals were assessed.

Results: There were 124,418 major pulmonary resections identified in 1233 facilities. The 30-day mortality rate was 2.8%. The 90-day mortality rate was 5.4%. Hospital volume was significantly associated with 30-day mortality, with a mortality rate of 3.7% for volumes less than 10, and 1.7% for volumes of 90 or more. Other variables significantly associated with 30-day mortality include older age, male sex, higher stage, pneumonectomy, a previous primary cancer, and multiple comorbidities. Similar results were found for 90-day mortality rates. In the multivariate analysis, hospital volume remained significant with adjusted odds ratios of 2.1 (95% confidence interval [CI], 1.7-2.6) for 30-day mortality and 1.3 (95% CI, 1.1-1.6) for conditional 90-day mortality for the hospitals with the lowest volume (<10) compared with those with the highest volume (>90). Hospitals with a volume less than 30 had an adjusted odds ratio for 30-day mortality of 1.3 (95% CI, 1.2-1.5) compared with those with a volume greater than 30.

Conclusions: Mortality at 30 and 90 days and hospital volume should be monitored by institutions performing major pulmonary resection and benchmarked against hospitals performing at least 30 resections per year. (J Thorac Cardiovasc Surg 2014;148:2269-78)

See related commentary on page 2279.

Hospital volume has been repeatedly associated with the outcome after specific complex surgical resections since first reported by Luft and colleagues in 1979.[1] The purpose of this study was to determine the relationship between hospital volume and outcome and to identify predictors of improved outcome after major pulmonary resection for cancer at 30 days, 90 days, and between 30 days and 90 days (conditional 90-day mortality) postoperatively using the National Cancer Data Base (NCDB). We hypothesized that overall 90-day mortality after a lung resection would be significantly higher than 30-day operative mortality, and that a volume/outcome relationship would persist. Using the NCDB, the American College of Surgeons (ACoS) Commission on Cancer (CoC) has the ability to directly report individual annual volume and mortality data to more than 1500 cancer programs, and to allow programs to compare their data to all CoC-accredited programs in the United States.

METHODS

The NCDB is a joint project of the ACoS CoC and the American Cancer Society and captures data from approximately 70% of all new cancers in the United States treated at approximately 1500 facilities, including 82% of all lung cancers.[2] Institutional review board approval was not required. Lung cancer cases diagnosed from 2007 to 2011 were retrieved from the database. Selection criteria included age 18 years or older and having had a surgical resection in the reporting facility. Lobectomies, bilobectomies, and pneumonectomies were included, but not wedge resections or other resections of less than 1 lobe.

There were 124,418 lung resections identified in 1233 facilities from 2007 to 2011 using the selection criteria. There were 2 hospitals with 40% or more of cases missing 30-day mortality and 4 hospitals with 40% or more of cases missing 90-day mortality. Excluding these hospitals resulted in the exclusion of 17 cases for 30-day mortality and 129 cases for 90-day mortality. An additional 3300 cases missing 30-day mortality regardless of hospital were also excluded, resulting in 121,099 cases available for analysis in 1231 hospitals. Overall, 95% of hospitals were missing 30-day mortality for less than 10% of cases and 86% of hospitals were missing 30-day

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Abbreviations and Acronyms

ACoS = American College of Surgeons
CI = confidence intervals
CoC = Commission on Cancer
NCDB = National Cancer Data Base
NIS = Nationwide Inpatient Sample
SEER = Surveillance, Epidemiology, and End Results

mortality for less than 5% of cases. After excluding 3389 deaths within 30 days and cases missing 90-day mortality, there were 114,905 cases available for analysis to assess conditional 90-day mortality (Figure 1).

Demographic and clinical characteristics of the analytical cases are reported in Table 1. The mean age was 66.6 years; 42% of patients were aged 70 years or older.

Ninety-three percent of resections were lobectomies or bilobectomies and 7% were pneumonectomies. Nine percent of resections were performed in hospitals with an annual surgical volume of less than 10 cases a year, and 11% were performed in hospitals with more than 90 resections a year. The median annual volume for all resections was 33 cases per year. Sixty-two percent of cases were stage 0, I, or occult, and 34% were stage II or III. Twenty-four percent had 1 or more previous primary tumors (sites unknown). Six percent of patients received neoadjuvant chemotherapy and 2% received neoadjuvant radiation.

Mortality within 30 and 90 days of the definitive surgery date was determined, as well as mortality between 31 and 90 days from definitive surgery (conditional 90-day mortality). Annual hospital volume was determined by taking the average number of lung resections performed from 2007 to 2011. Initially, 6 annual volume groups were examined: less than 10, 10 to 19, 20 to 29, 30 to 39, 40 to 89, and more than 90 resections per year. Only currently accredited CoC hospitals were included, and hospitals were required to have reported cancer cases each year between 2007 and 2011. Hospitals with 40% or more of cases missing 30- or 90-day mortality were excluded (because of incomplete follow-up).

Demographic and clinical covariates were used in the univariate and multivariable analyses. Mortality rates were similar for hospital volumes between 10 and 29 and between 30 and 89, so 4 volume groups (0-9, 10-29, 30-89 and $\geq$90) were used in the bivariate and multivariate analyses. NCDB comorbidity information is derived from up to 10 ICD-9-CM codes recorded for each patient. These codes are used to categorize 28 Elixhauser comorbidity groups,[3] which have been found to be a better predictor of outcomes than the Charlson Comorbidity Index.[4,5] Patient income level was not available but was determined from the zip code of residence and the 2000 US Census Bureau median income for that zip code. Patient residence was also categorized by census division.

Statistical Analyses

Overall 30- and 90-day mortality by annual hospital volume was calculated. Because overall 90-day mortality includes deaths that occur in the first 30 days, conditional 90-day mortality was calculated by excluding deaths occurring within the first 30 days from definitive surgery. Factors independently associated with mortality after 30 days can then be evaluated using conditional 90-day mortality.

Thirty-day and conditional 90-day mortality were compared according to annual hospital volume and demographic and clinical characteristics. Statistical significance ($P < .05$) and 95% confidence intervals (CI) were assessed using survey sampling methodology to account for clustering at the hospital level. Multivariate analysis was conducted using a hierarchical regression model that include a random effects model to account for patient clustering within hospitals, using the GLIMMIX procedure in SAS (SAS version 9.4, SAS Institute, Inc, Cary, NC). Variables in the model included all those that were significantly associated with either 30-day or conditional 90-day mortality in the bivariate analyses.

RESULTS

In the first 30 days after definitive surgery, 3389 deaths occurred, resulting in a 30-day mortality rate of 2.8% (95% CI, 2.7-2.9). A total of 6353 deaths occurred within the first 90 days, resulting in an overall 90-day mortality of 5.4% (95% CI, 5.2-5.6). After excluding the deaths in the first 30 days, the conditional 90-day mortality was 2.6% (95% CI, 2.5-2.7) based on 2968 additional deaths between 31 days and 90 days. Figure 2 displays the overall 30-day, conditional 90-day, and 90-day mortality by the 6 hospital volume groups. Figure 3 shows the overall 30-day, conditional 90-day, and 90-day mortality by 4 volume groups.

Thirty-day and conditional 90-day mortality and 95% CIs by annual hospital volume and demographic/clinical variables are displayed in Table 2. Hospital volume is significantly associated with 30-day mortality, with a mortality of 3.7% for volumes less than 10, and 1.7% for volumes of 90 or more. A small but significant decrease in 30-day mortality was found between 2007 and 2011. Other variables significantly associated with 30-day mortality include older age, male sex, lower median income, and living in the southern US regions. Other factors significantly associated with a higher 30-day mortality were higher stage, pneumonectomy, a previous primary cancer, and neoadjuvant radiation. Multiple comorbidities were significantly associated with higher 30-day mortality; lower 30-day mortality was associated with 5 comorbidities (see Table 2).

Similar results were found for conditional 90-day mortality. Annual hospital volume was significantly associated with conditional 90-day mortality although smaller differences were found compared with 30-day mortality. For the lowest hospital volume group, the 90-day conditional mortality rate was 2.9% compared with 2.2% in the highest volume group. Significant associations were also found with diagnosis year, age, sex, race, insurance status, and census division. Clinical variables significantly associated with conditional 90-day mortality include stage, surgery type, having a previous cancer, and having had neoadjuvant radiation and neoadjuvant chemotherapy. Comorbid conditions significantly associated with conditional 90-day mortality were similar to those for 30-day mortality.

Multivariate adjusted odds ratios are displayed in Table 3. Annual hospital volume remained significantly associated with 30-day mortality with an adjusted odds ratio of 2.1 (95% CI, 1.7-2.6), and with conditional 90-day mortality with an adjusted odds ratio of 1.3 (95% CI, 1.1-1.6) for the lowest compared with the highest hospital volume. The adjusted odds ratio for 30-day mortality was 1.3 (95% CI, 1.2-1.5) for hospitals with annual volume less than 30 compared with those with an annual volume greater