Shortage of thoracic surgeons in the United States: Implications for treatment and survival for stage I lung cancer patients

Alexandra L. Potter, BS,[a] Allison L. Rosenstein, BA,[a] Keervani Kandala, BSc,[a] Shivaek Venkateswaran,[a] Mathew V. Kiang, ScD,[b] Olugbenga T. Okusanya, MD,[c] Hugh G. Auchincloss, MD,[a] Linda W. Martin, MD,[d] Yolonda L. Colson, MD, PhD,[a] and Chi-Fu Jeffrey Yang, MD[a]

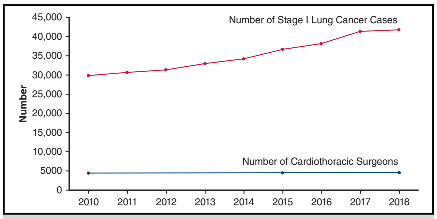
ABSTRACT

Objectives: To evaluate whether there is a shortage of thoracic surgeons in the United States and whether any potential shortage is impacting lung cancer treatment and outcomes.

Design: Using the US Area Health Resources File and Surveillance Epidemiology End Results database, we assessed the number of cardiothoracic surgeons per 100,000 people and the number of stage I non–small cell lung cancer (NSCLC) diagnoses in the US in 2010 versus 2018. Changes in the percentage of patients diagnosed with stage I NSCLC who underwent surgery and stereotactic body radiotherapy and changes in overall survival of patients with stage I NSCLC from 2010 to 2018 in the National Cancer Database were evaluated using multivariable logistic regression and Cox proportional hazards modeling.

Results: From 2010 to 2018, the number of cardiothoracic surgeons per 100,000 people in the US decreased by 12% ($P < .001$), while the number of patients diagnosed with stage I NSCLC increased by 40% ($P < .001$). Over the same period, the percentage of patients who underwent surgery for stage I NSCLC decreased from 81.0% to 72.3% (adjusted odds ratio, 0.59; 95% confidence interval, 0.55-0.63); this decrease was similarly seen in a subgroup of young and otherwise healthy patients. Greater decreases in the percentage of patients who underwent surgery in nonmetropolitan and underserved regions corresponded with worse improvements in survival among patients in these regions from 2010 to 2018.

Conclusions: Recent declines in the US cardiothoracic surgery workforce may have led to significantly fewer patients undergoing surgery for stage I NSCLC and worsening disparities in survival between different patient populations. (J Thorac Cardiovasc Surg 2024;167:1603-14)



Number of stage I non–small cell lung cancer (NSCLC) cases diagnosed in the US versus the number of cardiothoracic surgeons in the US from 2010 to 2018. The *blue line* corresponds to the number of cardiothoracic surgeons practicing in the US; the *red line* corresponds to the number of stage I NSCLC cases diagnosed in the US. Data on the number of cardiothoracic surgeons in the US were available for the years 2010, 2015, and 2018. Data on the number of stage I NSCLC cases diagnosed in the US were available annually from 2010 to 2018.

CENTRAL MESSAGE

Recent declines in the US cardiothoracic surgery workforce may have led to significantly fewer patients undergoing surgery for stage I non-small cell lung cancer and worsening disparities in survival.

PERSPECTIVE

From 2010 to 2018, the number of cardiothoracic surgeons per 100,000 people in the US decreased by 12%, while the number of patients diagnosed with stage I non–small cell lung cancer (NSCLC) increased by 40%. Over the same period, the percentage of patients who underwent surgery for stage I NSCLC decreased from 81.0% to 72.3%. This finding was consistent among a subgroup of young and otherwise healthy patients.

See Commentary on page 1615.

From the [a]Division of Thoracic Surgery, Department of Surgery, Massachusetts General Hospital, Boston, Mass; [b]Department of Epidemiology and Population Health, Stanford University, Stanford, Calif; [c]Division of Esophageal and Thoracic Surgery, Department of Surgery, Thomas Jefferson University Hospital, Philadelphia, Pa; and [d]Department of Surgery, University of Virginia, Charlottesville, Va.

Data Availability Statement: Four datasets were used under license with permission for the current study. These datasets are available from the Surveillance Epidemiology End Results Program database (https://seer.cancer.gov), National Cancer Database (https://www.facs.org/quality-programs/cancer-programs/national-cancer-database/),

THOR

Abbreviations and Acronyms

- aOR = adjusted odds ratio
- ABTS = American Board of Thoracic Surgery
- AHRF = Area Health Resource File
- IRR = incidence rate ratio
- MOC = Maintenance of Certification
- NCDB = National Cancer Database
- NRMP = National Resident Matching Program
- NSCLC = non–small cell lung cancer
- SBRT = stereotactic body radiotherapy
- SEER = Surveillance Epidemiology End Results

Scanning this QR code will take you to the table of contents to access supplementary information. To view the AATS Annual Meeting Webcast, see the URL next to the webcast thumbnail.

The increasing adoption of lung cancer screening in the US,[1-3] coupled with a rapidly aging US population,[4] may lead to an unprecedented number of lung cancer patients requiring thoracic surgery in the US. Indeed, despite presently low adoption rates of lung cancer screening in the US,[5] several studies have already shown that the adoption of lung cancer screening in the US is associated with a significant shift toward earlier stages of lung cancer diagnosed,[6,7] with a 55% increase in the number of stage I lung cancers diagnosed in individuals age 55 to 80 years.[6] It is possible that large increases in the number of patients requiring surgery for lung cancer, without corresponding increases in the number of thoracic surgeons, could lead to delays in care and the receipt of non–guideline-concordant treatment for patients diagnosed with early-stage lung cancer.

Previous studies have forewarned of an impending shortage of thoracic surgeons in the US.[8-13] A study published in 2009 estimated that there would be a shortage of 1994 thoracic surgeons by 2030 in the United States.[11] More recently, a study by Moffatt-Bruce and colleagues[9] estimated that the average caseload per thoracic surgeon would increase by 121% from 2010 to 2035. These studies also reported that the number of cardiothoracic surgery training programs and training positions offered decreased markedly from 2010 to 2014, providing further evidence of an impending shortage of thoracic surgeons.

However, to date no study has examined whether there is a current shortage of thoracic surgeons and whether any potential shortage is impacting the oncologic treatment and survival of patients diagnosed with early-stage lung cancer. The objectives of this study were to first evaluate whether there is a current shortage of thoracic surgeons in the US by examining (1) changes in the size and age of the thoracic surgery workforce from 2010 to 2018, and assessing whether any changes in the thoracic surgery workforce were also observed in the colorectal surgery and radiation oncology workforces; (2) changes in the number of residents matching into thoracic surgery programs from 2010 to 2018; and (3) changes in the demand for thoracic surgery from 2010 to 2018. We then sought to assess whether any potential shortage of thoracic surgeons coincided with changes in lung cancer treatment (ie, surgery vs stereotactic body radiotherapy [SBRT]) and survival.

METHODS

Data Sources

National Cancer Database and Surveillance, Epidemiology, and End Results program. The National Cancer Database (NCDB) is a clinical oncology registry that is jointly administered by the Commission on Cancer of the American College of Surgeons and the American Cancer Society. The NCDB was chosen for this analysis because it is the largest clinical oncology database in the US, capturing approximately 65% of all newly diagnosed cases of lung cancer in the US each year, and because it includes data on the presence of comorbidities.[14,15]

The Surveillance, Epidemiology, and End Results (SEER) program database includes data from 18 population-based US registries that cover approximately 28% of the US population.[16] The SEER program database was selected for this analysis because it is a population-based registry, which allows for the analysis of changes in the incidence of early-stage lung cancer over time. In both the NCDB and SEER program databases, for the years of study inclusion (2010-2018), clinical staging was classified using American Joint Committee on Cancer (8th edition) criteria according to the best available data.[17]

US Area Health Resource File. Data on the number of active physicians by specialty in the US were obtained from the 2020 United States Area Health Resource File (AHRF).[18] The AHRF was chosen for this analysis because it comprises data on the number and age of physicians by specialty (eg, cardiothoracic surgeons, radiation oncologists, colorectal surgeons) in each county in the US. The AHRF also includes data on US counties' metropolitan versus rural classification, defined according to the 2013 Rural-Urban Continuum Codes.[19]

American Board of Thoracic Surgery 10-year specialty-specific Maintenance of Certification exam data. Beginning in 2015, the American Board of Thoracic Surgery[20] (ABTS) required

Area Health Resource File (https://data.hrsa.gov/topics/health-workforce/ahrf), and National Resident Matching Program (https://www.nrmp.org/match-data-analytics/).

Read at the 102nd Annual Meeting of The American Association for Thoracic Surgery, Boston, Massachusetts, May 14-17, 2022.

Received for publication Jan 31, 2023; revisions received Aug 10, 2023; accepted for publication Aug 28, 2023; available ahead of print Sept 15, 2023.

Address for reprints: Chi-Fu Jeffrey Yang, MD, Division of Thoracic Surgery, Department of Surgery, Massachusetts General Hospital, 55 Fruit St, Boston, MA 02114 (E-mail: cjyang@mgh.harvard.edu).

0022-5223/$36.00

https://doi.org/10.1016/j.jtcvs.2023.08.059

all ABTS-certified cardiothoracic surgeons to complete a 10-year Maintenance of Certification (MOC) exam.[21] Cardiothoracic surgeons completing the 10-year MOC III exam select any 1 of 4 specialty-specific exams to complete, depending on their primary practice: cardiac, thoracic, congenital, or a combined cardiothoracic exam (for surgeons with a mixed practice). For the present study, we obtained data on the number of cardiothoracic surgeons completing the cardiac, thoracic, congenital, or combined cardiothoracic exam from 2017 to 2022. These data were obtained for analysis to allow for the assessment of changes in the proportion of cardiothoracic surgeons that completed the thoracic exam (as opposed to the other specialty-specific MOC exams) over time. Of note, data prior to 2017 were not available for analysis.

National Resident Matching Program data. Data on the number of applicants to cardiothoracic surgery fellowship programs, number of cardiothoracic surgery fellowship positions offered, and number of matches to cardiothoracic surgery fellowship programs from 2010 to 2021 were obtained from the National Resident Matching Program data.[22]

Study Design

This retrospective study was approved by the Massachusetts General Hospital Institutional Review Board (2020P004110; approved February 2, 2021). The need for written consent was waived by the Institutional Review Board, given the study's retrospective nature. Patients diagnosed with clinical stage I non–small cell lung cancer (NSCLC) from 2010 to 2018 in the NCDB and patients diagnosed with stage I (the SEER database does not provide clinical versus pathologic staging) NSCLC in the SEER database were identified using *International Classification of Diseases 3rd Edition* histology codes. We chose to evaluate patients diagnosed with stage I NSCLC because surgery is the standard of care for these patients.[23] In our analysis using the NCDB, patients with nonmalignant pathology, unknown clinical staging information, a prior history of cancer, or "indolent" histologic subtypes of NSCLC (eg, typical carcinoid tumors and histologic subtypes formerly classified as bronchioloalveolar carcinoma, such as minimally invasive adenocarcinoma or lepidic adenocarcinoma) were excluded (Table E1). In addition, we excluded patients in the NCDB who were deemed to be at too high risk to undergo surgery (see the Appendix E1 for details). Data on the number of active cardiothoracic surgeons, colorectal surgeons, and radiation oncologists in the US in 2010 and 2018 were obtained from the US AHRF.

We conducted several analyses to evaluate whether there is a shortage of cardiothoracic surgeons in the US and whether any potential shortage coincided with changes in the treatment and outcomes of patients diagnosed with stage I NSCLC. A shortage of thoracic surgeons was defined as an insufficient supply of thoracic surgeons that is unable to provide adequate surgical care for early-stage, operable lung cancer patients.

Changes in the US cardiothoracic surgery workforce: AHRF and ABTS 10-year specialty-specific MOC exam data analyses. Using the AHRF, we examined changes in the number of nonfederal cardiothoracic surgeons (excluding cardiothoracic surgeons employed by the Veterans Affairs or a commissioned corps) per 100,000 people in 2010 versus 2018. Because data on the number of cardiothoracic surgeons who treat patients with lung cancer is unavailable in the AHRF, this analysis of the number of cardiothoracic surgeons in the US includes surgeons practicing both cardiac and thoracic surgery. Subgroup analyses were conducted by age group and by metropolitan versus nonmetropolitan status.

Next, using data from the ABTS 10-year MOC III exam, we evaluated whether the proportions of cardiothoracic surgeons who completed the specialty-specific MOC III thoracic exam and cardiothoracic exam increased from 2017 to 2022. One potential concern is that—even if the overall number of cardiothoracic surgeons did not change in the US from 2010 to 2018—the proportion of cardiothoracic surgeons practicing general thoracic surgery could have still increased, leading to an overall increase in the number of general thoracic surgeons in the US. To address this concern, we performed an analysis using data from the ABTS 10-year specialty-specific MOC III exam. Of note, surgeons who complete the thoracic exam have a predominately general thoracic surgery practice. Surgeons who complete the cardiothoracic exam have a mixed general thoracic and cardiac practice; therefore, assessments of changes in the proportion of cardiothoracic surgeons completing the thoracic exam or cardiothoracic exam (as opposed to the cardiac or congenital exams) can be used to evaluate whether the proportion of cardiothoracic surgeons practicing general thoracic surgery has increased over time.

THOR

Changes in the US colorectal surgery and radiation oncology workforces: AHRF analysis. To assess whether similar changes in the number of surgeons per 100,000 people and changes in the distribution of surgeons by age also occurred in other surgical specialties, we evaluated changes in the number of colorectal surgeons per 100,000 people and changes in the distribution of colorectal surgeons by age in 2010 versus 2018. Colorectal surgeons were chosen for comparison because colorectal surgery requires a similar structure and duration of training as thoracic surgery (ie, general surgery residency followed by fellowship), and because similar numbers of nonmetastatic colon cancers and nonmetastatic lung cancers are diagnosed in the US each year.[24] We also examined changes in the number of radiation oncologists per 100,000 people and changes in the distribution of radiation oncologists by age in 2010 versus 2018, given that SBRT is the most common treatment other than surgery for clinical stage I lung cancer.[23]

Changes in the number of stage I NSCLC diagnoses: SEER analysis. Using the SEER database, we assessed changes in the number of stage I NSCLC cases diagnosed from 2010-2018.

Changes in the number of cardiothoracic surgery fellowship applicants, positions offered, and matches: National Resident Matching Program Data analysis. We examined changes in the number of cardiothoracic surgery fellowship applications, positions offered, and matches to cardiothoracic surgery fellowship programs from 2010 to 2021. Of note, we did not include applicants to integrated cardiothoracic surgery programs, because the large majority (~96%) of applicants to integrated programs focus on cardiac surgery, not general thoracic surgery.[25]

Changes in stage I NSCLC treatment and survival: NCDB analysis. Using the NCDB, we examined changes in the percentage of patients diagnosed with stage I NSCLC who underwent surgery and who received SBRT, without surgery, from 2010 to 2018. To assess whether changes in the use of surgery and SBRT for stage I lung cancer could be explained by an increasing number of patients who were too frail to undergo surgery, we performed sensitivity analyses of patients age <65 years with no comorbidities.

Next, we hypothesized that if there were a shortage of thoracic surgeons in the US, lung cancer patients receiving care in medically underserved regions would be impacted the most by this shortage, whereas those living in regions with greater access to medical care would be less impacted. To test this hypothesis, we conducted subgroup analyses by metropolitan versus nonmetropolitan status, median household income, and hospital type (ie, community vs academic hospital). The method of dichotomization for each subgroup analysis is detailed in Appendix E1.

Finally, we examined whether there were differential changes in the hazard of death from 2010 to 2018 among patients living in metropolitan versus nonmetropolitan regions and higher-income versus lower-income regions and among patients treated at community hospitals versus academic hospitals.

Statistical Analysis

The numbers of cardiothoracic surgeons per 100,000 people in the US in 2010 and 2018 were calculated by dividing the number of cardiothoracic surgeons by the size of the US population in 2010 and 2018. Analyses were conducted at the county level. Changes in the number of cardiothoracic surgeons per 100,000 people in the US in 2010 versus 2018 were assessed using the Wilcoxon signed-rank test. Changes in the proportion of cardiothoracic surgeons aged $\geq$ 55 years in 2010 versus 2018 were evaluated using the Pearson chi-square test. Similar analyses were performed among colorectal surgeons and radiation oncologists.

Changes in the number of stage I NSCLC cases diagnosed in 2010 versus 2018, changes in the number of cardiothoracic surgeons in the US in 2010 versus 2018, and changes in the number of cardiothoracic surgery fellowship applicants, positions offered, and matches in 2010 versus 2021 were examined using univariable Poisson regression. Changes in the proportion of cardiothoracic surgeons completing the ABTS 10-year specialty-specific MOC thoracic and cardiothoracic exams were evaluated using the Cochran–Armitage test.[26,27] The number of stage I NSCLC cases diagnosed in 2010 and 2018 were obtained from the SEER database. To estimate the number of stage I NSCLC cases diagnosed nationally in 2010 and 2018, the number of cases in the SEER database were multiplied by 1/0.278, because the SEER database covers approximately 27.8% of the US population.[16]

Changes in the odds of undergoing surgery and undergoing SBRT for stage I NSCLC each year from 2010 to 2018 were examined using multivariable logistic regression and predicted marginal modeling. The covariates included in these models were year of diagnosis, sex, age, race, facility type (eg, academic vs community cancer program), median household income of individuals living in the patient's area of residence, percentage of individuals without a high school education living in the patient's area of residence, insurance status, distance of the patient's residence from the hospital, metropolitan status, Charlson–Deyo Comorbidity Score, histology, tumor location, tumor size, and clinical T status.

Changes in the hazard of death each year from 2010 to 2018 among patients diagnosed with stage I NSCLC were examined using a Cox proportional hazards model, adjusting for the same covariates listed above. We performed interaction tests between the year of lung cancer diagnosis and metropolitan status, median household income level, and facility type to identify whether there were differential changes in the odds of undergoing surgery and SBRT from 2010 to 2018 and in the hazard of death from 2010 to 2018 among different patient subgroups.

Statistical analysis was performed using STATA/MP software, version 17.0 for Windows (StataCorp).

RESULTS

From 2010 to 2018, the Number of Stage I Lung Cancers Diagnosed in the US Increased Sharply, Whereas the Number of Cardiothoracic Surgeons Per 100,000 People in the US Decreased

The number of stage I lung cancer cases diagnosed in the US increased by 40.0% from 2010 to 2018, from 29,913 to 41,858 (incidence rate ratio [IRR], 1.40; 95% CI, 1.38-1.42; $P < .001$) (Figure 1). In contrast, the number of cardiothoracic surgeons in the US did not change significantly from 2010 to 2018 (from 4461 to 4580; IRR: 1.00; 95% CI, 1.00-1.01; $P = .21$). The number of cardiothoracic surgeons per 100,000 people in the US decreased by 12% from 2010 to 2018 (from 0.50 to 0.44; $P < .001$).

In a subgroup analysis of metropolitan versus nonmetropolitan regions, the number of cardiothoracic surgeons per 100,000 people did not change significantly from 2010 to 2018 in metropolitan regions (from 0.95 to 0.91; $P = .13$), whereas the number of cardiothoracic surgeons per 100,000 people decreased by 32.2% (from 0.21 to 0.14; $P = .003$) in nonmetropolitan regions.

The Percentage of Cardiothoracic Surgeons Who Completed the ABTS MOC III Thoracic Exam Did Not Change Significantly From 2017 to 2022

From 2017 to 2022, a total of 1248 cardiothoracic surgeons completed the ABTS 10-year MOC exam. During this period, the percentage of cardiothoracic surgeons who completed the specialty-specific general thoracic exam (indicating surgeons who had a predominately general thoracic practice) did not change significantly (19.3% in 2017 to 24.8% in 2022; $P = .08$) (Table E2). Additionally, from 2017 to 2022, the percentage of cardiothoracic

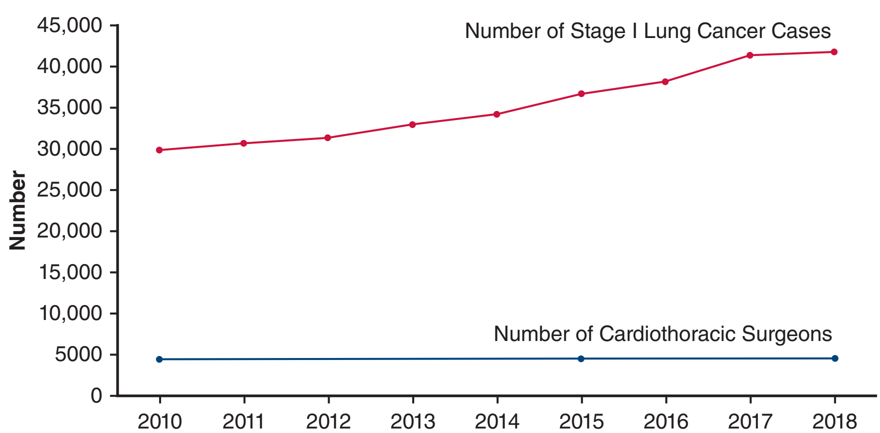


FIGURE 1. Number of stage I NSCLC cases diagnosed in the US versus the number of cardiothoracic surgeons in the US from 2010 to 2018. The *blue line* corresponds to the number of thoracic surgeons practicing in the U.S. The *red line* corresponds to the number of stage I NSCLC cases diagnosed in the US Data on the number of thoracic surgeons in the US were available for the years 2010, 2015, and 2018. Data on the number of stage I NSCLC cases diagnosed in the US were available annually from 2010 to 2018.

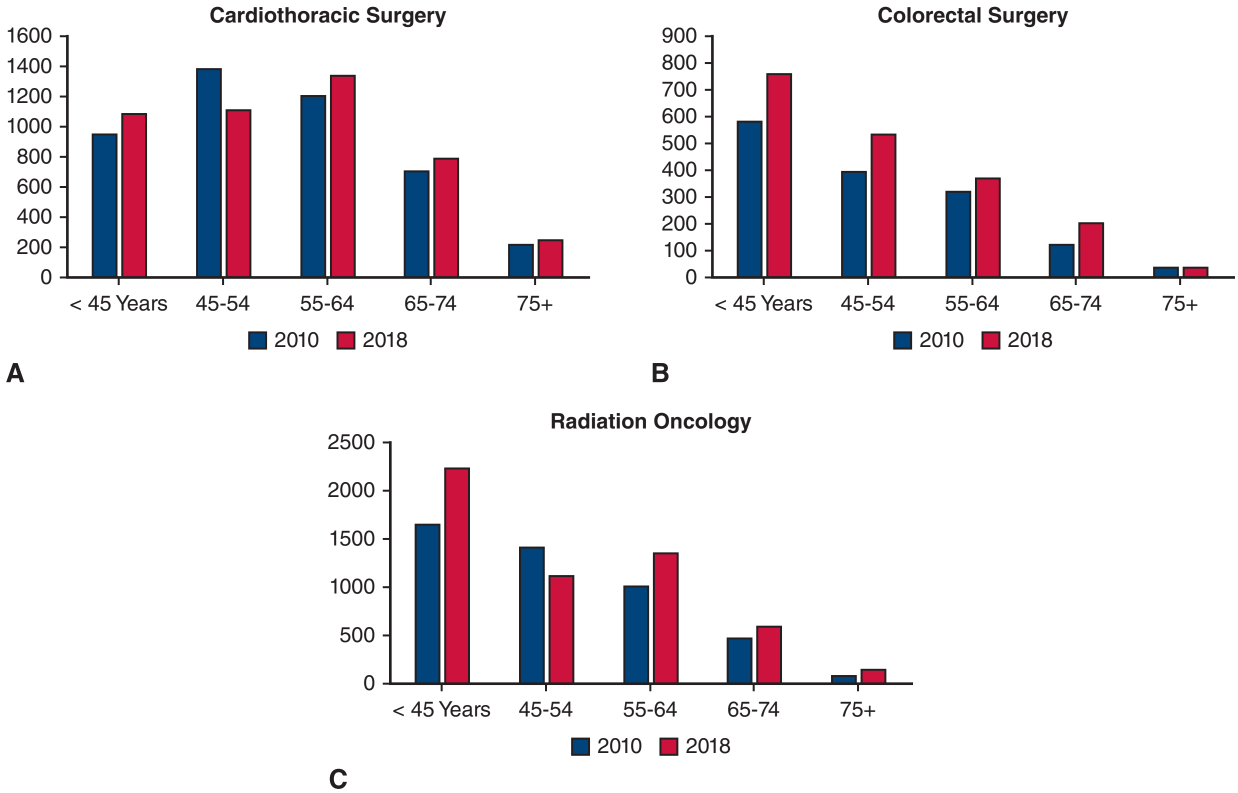


FIGURE 2. Changes in the number of (A) cardiothoracic surgeons, (B) colorectal surgeons, and (C) radiation oncologists in the US by age group in 2010 versus 2018. The *blue bars* correspond to the number of physicians in the US by age group in 2010. The *red bars* correspond to the number of physicians in the US by age group in 2018.

surgeons who completed the specialty-specific cardiothoracic exam (indicating surgeons who had a mixed cardiac and thoracic practice) decreased significantly, from 46.8% in 2017 to 19.0% in 2022 ($P < .001$).

The Cardiothoracic Surgery Workforce Has Aged Significantly Over the Last Decade

Figure 2, *A*, shows changes in the number of cardiothoracic surgeons, stratified by age group, in 2010 versus 2018. Of note, from 2010 to 2018, there were increases in the number of cardiothoracic surgeons age 55 to 64 years, 65 to 74 years, and $\geq$ 75 years. From 2010 to 2018, the percentage of cardiothoracic surgeons age $\geq$ 55 years increased from 47.7% to 51.8% ($P < .001$).

A subgroup analysis by metropolitan versus nonmetropolitan status showed that from 2010 to 2018, the percentage of cardiothoracic surgeons age $\geq$ 55 years in metropolitan regions increased slightly, from 47.4% to 51.3% ($P < .001$) while the percentage of cardiothoracic surgeons age $\geq$ 55 years in nonmetropolitan regions increased from 54.6% to 70.5% ($P = .004$).

The Number of Colorectal Surgeons Per 100,000 People Has Increased

In contrast to the cardiothoracic surgery workforce, the number of colorectal surgeons per 100,000 people in the US increased by 25% from 2010 to 2018 (from 0.12 to 0.15; $P < .001$). In a subgroup analysis of metropolitan versus nonmetropolitan regions, the number of colorectal surgeons per 100,000 people increased significantly in both metropolitan regions (from 0.26 to 0.33; $P < .001$) and nonmetropolitan regions (from 0.03 to 0.05; $P = .02$) from 2010 to 2018. Furthermore, the percentage of colorectal surgeons age $\geq$ 55 years did not change significantly from 2010 to 2018 (30.5% vs 32.0%; $P = .32$) (Figure 2, *B*).

The Number of Radiation Oncologists Per 100,000 People Has Increased

In contrast to the cardiothoracic surgery workforce, the number of radiation oncologists per 100,000 people in the US increased by 9% from 2010 to 2018 (from 0.53 to 0.58; $P = .02$). A subgroup analysis of metropolitan versus

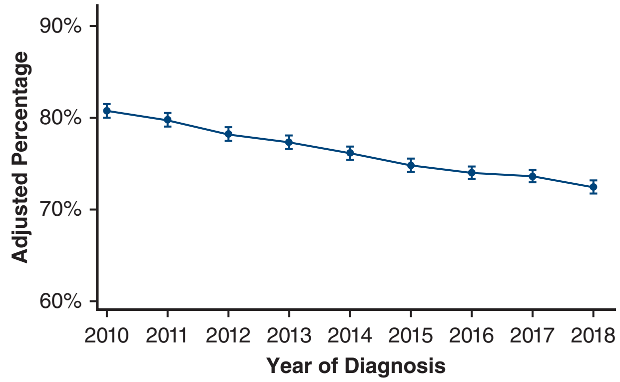


FIGURE 3. Multivariable-adjusted percentage of patients undergoing surgery for stage I non–small cell lung cancer (NSCLC) each year from 2010 to 2018. The x-axis is the year of diagnosis, and the y-axis is the multivariable-adjusted percentage of patients who underwent surgery for stage I NSCLC each year. *Error bars* indicate 95% confidence intervals.

non-metropolitan regions showed that the number of radiation oncologists per 100,000 people in the US increased significantly in metropolitan regions (from 0.96 to 1.04; $P = .001$) and remained constant in nonmetropolitan regions (from 0.26 to 0.29; $P = .36$). The proportion of radiation oncologists age $\geq$ 55 years increased from 33.3% to 38.0% ($P < .001$), driven primarily by a decrease in the proportion of radiation oncologists age 45 to 54 years (30.7% in 2010 vs 20.7% in 2018; $P < .001$) (Figure 2, *C*). Notably, the proportion of radiation oncologists age <45 years increased from 36.0% to 41.3% ($P < .001$) from 2010 to 2018.

The Number of Applicants Matching Into Cardiothoracic Surgery Fellowship Programs Has Not Changed Significantly Over the Last Decade

From 2010 to 2021, the number of cardiothoracic surgery fellowship positions offered (from 116 to 101; IRR, 0.87; 95% CI, 0.67-1.14; $P = .31$) and the number of applicants who matched into cardiothoracic surgery fellowship programs (from 84 to 99; IRR, 1.18; 95% CI, 0.88-1.58; $P = .27$) did not change significantly. However, the number of applicants to cardiothoracic surgery fellowship programs increased by 50.5% (from 93 to 140; IRR, 1.51; 95% CI, 1.16-1.96; $P = .002$) (Figure E1).

The Percentage of Patients in the NCDB Undergoing Surgery For Stage I NSCLC Decreased Significantly Over the Last Decade, Even Among Patients Who Were Young and Otherwise Healthy

From 2010 to 2018, a total of 133,947 patients met the study inclusion criteria in the NCDB. Baseline characteristics of these patients are summarized in Table E3. From 2010 to 2018, the percentage of patients diagnosed with stage I NSCLC who underwent surgery decreased by 8.7 (95% CI, 7.7-9.7) percentage points, from 81.0% (n = 8789) to 72.3% (n = 13,264) ($P < .001$). In multivariable-adjusted analysis, the odds of undergoing surgery for stage I NSCLC were 41% lower in 2018 versus 2010 (adjusted odds ratio [aOR], 0.59; 95% CI, 0.55-0.63) (Figure 3, Table E4). Among a subgroup of patients age <65 years with no comorbidities, the odds of undergoing surgery for stage I NSCLC were 24% lower in 2018 versus 2010 (aOR, 0.76; 95% CI, 0.61-0.93; $P = .009$) (Table E5).

The Percentage of Patients in the NCDB Undergoing Surgery For Stage I NSCLC Decreased Faster Among Patients Living in Medically Underserved Regions

Figure 4 shows the multivariable-adjusted changes in the percentage of patients who underwent surgery for stage I NSCLC stratified by metropolitan versus nonmetropolitan status, median household income, and facility type. From 2010 to 2018, there was a faster decrease in the percentage of patients who underwent surgery for stage I NSCLC in nonmetropolitan regions compared to metropolitan regions (aOR, 0.96; 95% CI, 0.94-0.97; $P < .001$) and in lower-income regions compared to higher-income regions (aOR, 0.99; 95% CI, 0.97-0.998; $P = .02$). Additionally, there were faster decreases in the percentage of patients who underwent surgery for stage I NSCLC at community hospitals compared to academic hospitals (aOR, 0.92; 95% CI, 0.90-0.95; $P < .001$).

The Use of SBRT For Stage I Lung Cancer Patients in the NCBD Increased Significantly, Even Among Young and Otherwise Healthy Patients Who—Under Current Recommendations—Should Undergo Surgery

From 2010 to 2018, the percentage of patients who underwent SBRT for stage I NSCLC increased by 9.1 (95% CI, 8.3-9.8) percentage points, from 6.4% (n = 708) in 2010 to 15.5% (n = 2875) in 2018. In multivariable-adjusted analysis, patients diagnosed with stage I lung cancer had 2.74-fold greater odds (95% CI, 2.49-3.02; $P < .001$) of undergoing SBRT in 2018 compared to 2010 (Table E6). In a subgroup of patients who were younger (<65 years) and otherwise healthy, patients diagnosed with stage I lung cancer had 2.08-fold greater odds (95% CI, 1.47-2.93; $P < .001$) of undergoing SBRT in 2018 compared to 2010 (Table E7).

The Percentage of Patients in the NCDB Undergoing SBRT For Stage I NSCLC Increased Faster Among Patients Living in Medically Underserved Regions

From 2010 to 2018, faster increases in the proportion of patients who underwent SBRT for stage I NSCLC were seen

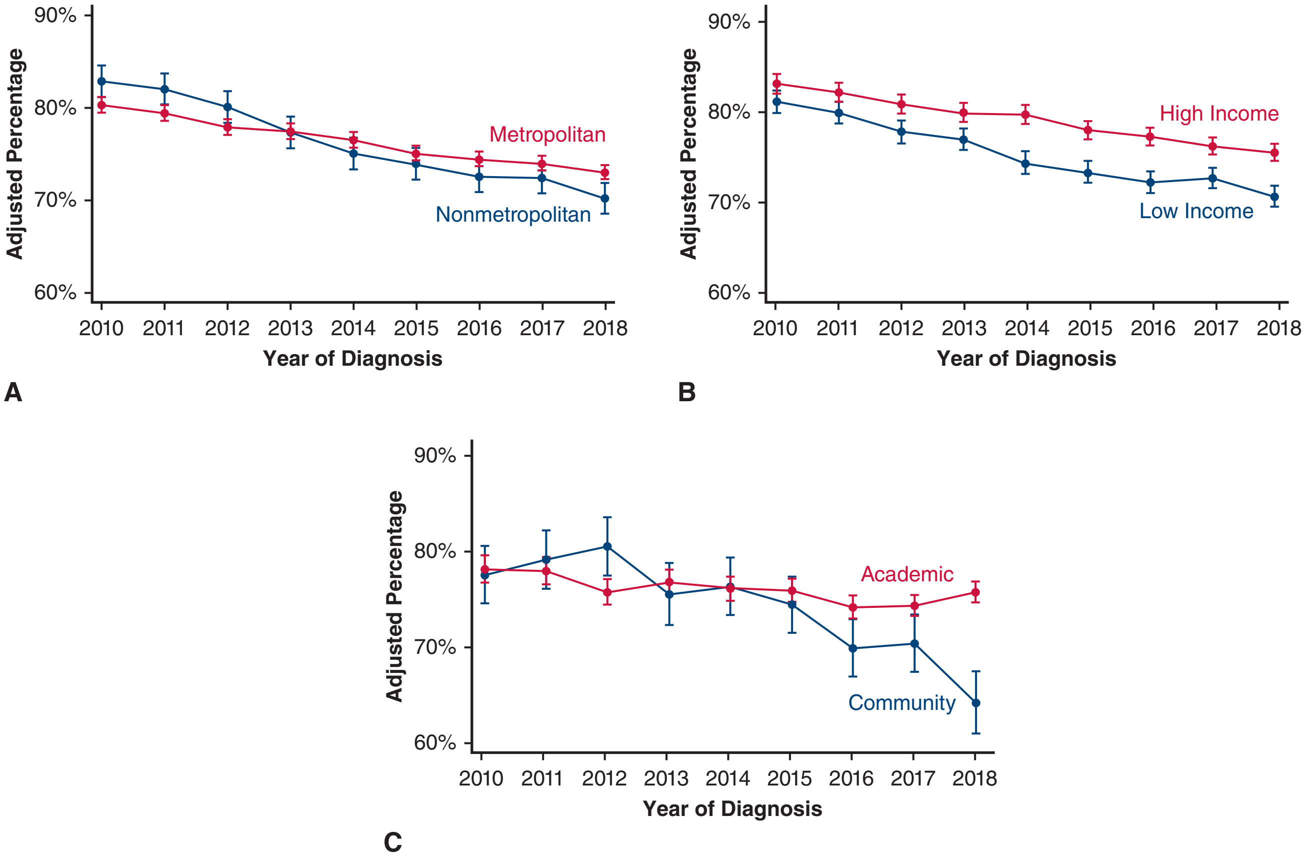


FIGURE 4. Multivariable-adjusted percentage of patients undergoing surgery for stage I non–small cell lung cancer (NSCLC) each year from 2010 to 2018, stratified by (A) metropolitan versus nonmetropolitan status, (B) high-income versus low-income region, and (C) community versus academic institution. The x-axis is the year of diagnosis, and the y-axis is the multivariable-adjusted percentage of patients who underwent surgery for stage I NSCLC each year. *Error bars* indicate 95% confidence intervals.

in patients living in lower-income regions compared to high-income regions (aOR, 1.03; 95% CI, 1.01-1.04; $P = .001$) and in nonmetropolitan regions compared to metropolitan regions (aOR, 1.05; 95% CI, 1.02-1.07; $P < .001$). Additionally, from 2010 to 2018, faster increases in the proportion of patients who underwent SBRT for stage I NSCLC were seen in patients treated at community hospitals compared to academic hospitals (aOR, 1.32; 95% CI, 1.26-1.39; $P < .001$) (Figure 5).

Improvements in the Survival of Patients Diagnosed With Stage I NSCLC Over the Last Decade Did Not Extend to Patients Living in Medically Underserved Regions

From 2010 to 2017, the hazard of death among all patients diagnosed with stage I NSCLC decreased significantly (multivariable-adjusted hazard ratio [aHR], 0.96; 95% CI, 0.96-0.97; $P < .001$) (Figure E2, Table E8). However, from 2010 to 2017, the hazard of death decreased significantly more slowly in patients diagnosed with stage I NSCLC living in nonmetropolitan regions compared to metropolitan regions (aHR, 1.02; 95% CI, 1.01-1.04; $P = .001$) and in those living in lower-income regions compared to higher-income regions (aHR, 1.02; 95% CI, 1.004-1.03; $P = .005$). Additionally, patients diagnosed with stage I NSCLC who were treated at community hospitals had significantly slower decreases in the hazard of death from 2010-2017 compared to those treated at academic hospitals (aHR, 1.03; 95% CI, 1.01-1.05; $P = .02$).

DISCUSSION

In this national analysis from 2010 to 2018, we found that the number of stage I NSCLC cases diagnosed in the US increased sharply, while the number of cardiothoracic surgeons per 100,000 people in the US decreased. During the same period, the proportion of patients diagnosed with stage I NSCLC who underwent surgery decreased significantly, while the proportion of these patients who underwent SBRT increased significantly. From 2010 to 2018, greater decreases in the proportion of patients undergoing surgery, greater increases in the proportion of patients receiving

THOR

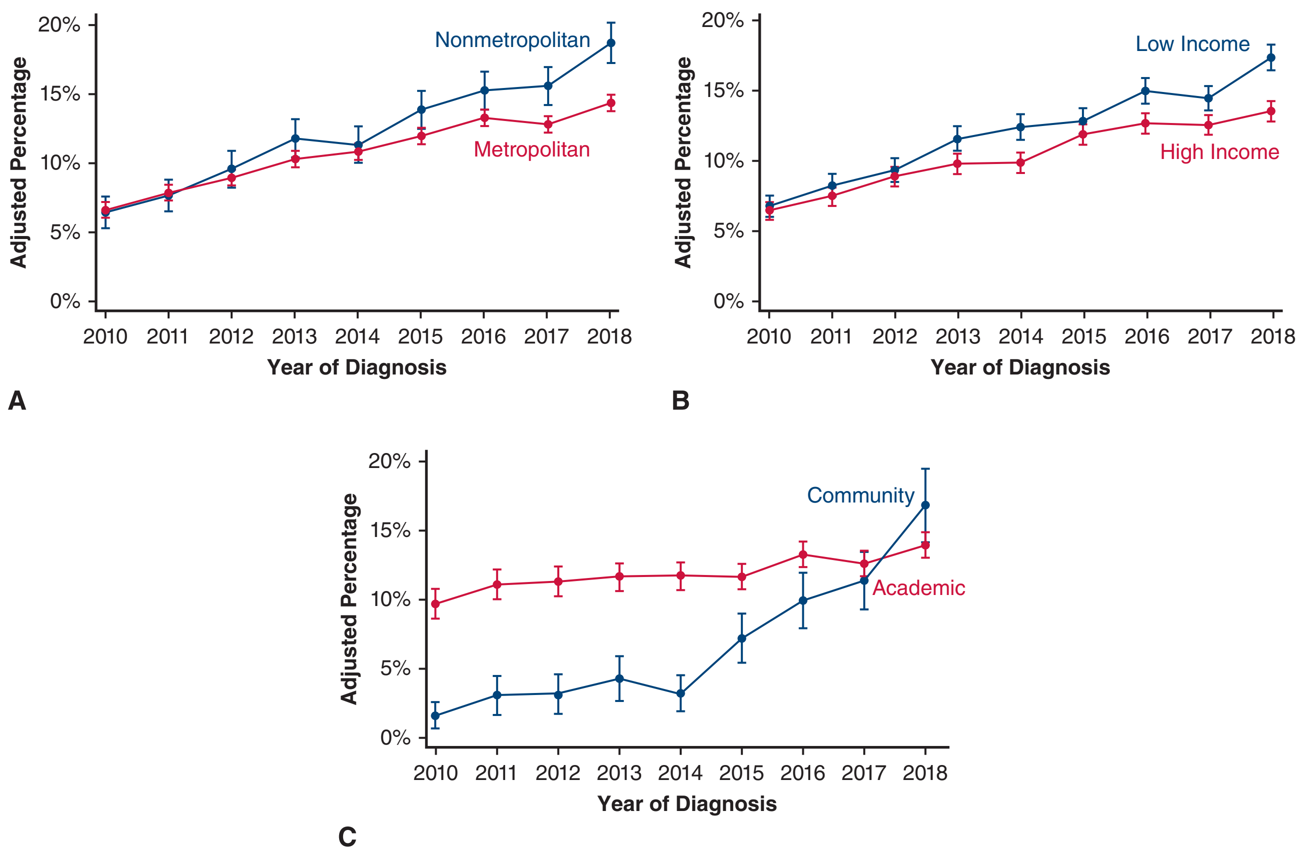


FIGURE 5. Multivariable-adjusted percentage of patients who underwent stereotactic body radiotherapy (SBRT) for stage I non–small cell lung cancer (*NSCLC*) each year from 2010 to 2018, stratified by (A) metropolitan versus nonmetropolitan status, (B) high-income versus low-income region, and (C) community versus academic institution. The x-axis is the year of diagnosis, and the y-axis is the multivariable-adjusted percentage of patients who underwent SBRT for stage I NSCLC each year. *Error bars* indicate 95% confidence intervals.

SBRT, and slower improvements in survival were seen in patients living in medically underserved regions versus those living in more affluent regions.

We also evaluated whether changes in the cardiothoracic surgery workforce were observed in the colorectal surgery workforce (a surgical specialty with a similar training pathway as thoracic surgery) and the radiation oncology workforce (a nonsurgical specialty treating an increasing proportion of early-stage lung cancer patients). Although the number of cardiothoracic surgeons per 100,000 people in the US decreased significantly from 2010 to 2018, the numbers of colorectal surgeons and radiation oncologists per 100,000 people in the US increased significantly from 2010-2018. These data suggest that the observed changes in the cardiothoracic surgery workforce are not generalizable to other surgical and medical specialties.

Our findings build on previous studies that predicted future shortages of thoracic surgeons based on estimated changes in US population size and changes in the number of thoracic surgeons in the US.[8-13] However, those previous studies did not examine whether there is a current shortage of thoracic surgeons in the US and whether any potential shortage coincides with changes in patient care and outcomes. In contrast to those previous studies, the present study analyzed real-world data from a large-scale clinical registry to identify whether a current shortage of thoracic surgeons coincides with changes in cancer treatment and survival for patients diagnosed with stage I NSCLC. Importantly, our findings suggest that we are now facing a shortage of thoracic surgeons that may be contributing to increases in non–guideline-concordant treatment and worse survival for patients diagnosed with stage I NSCLC, particularly in medically underserved US regions.

Although our findings suggest that there is a shortage of thoracic surgeons in the US, we investigated other reasons that could possibly explain our findings. Notably, we found decreases in the use of surgery and increases in the use of SBRT even among younger patients with no major comorbidities, suggesting that these changes cannot be entirely explained by an increasing number of patients who were too frail for surgery. In addition, we found greater decreases in the percentage of patients undergoing surgery, greater increases in the percentage of patients undergoing SBRT, and slower improvements in survival in patients living in medically underserved regions versus more affluent regions. Collectively, these findings suggest that a shortage of thoracic surgeons in the US may be contributing to increases in non–guideline-concordant treatment and worse survival for stage I lung cancer patients.

Of note, we did find that overall survival improved in the entire cohort from 2010 to 2017. Because many stage I lung cancer patients die from causes other than lung cancer, improved management of other diseases (eg, heart disease) and an increase in overall life expectancy may result in an increase in overall survival that is independent of access to lung cancer treatment. These factors likely contributed to the improved overall survival among lung cancer patients during the study period.

The findings of our study illustrate the need to implement strategies to improve the delivery of thoracic surgical care in the US, particularly in medically underserved regions. Immediate solutions to improve the delivery of thoracic surgical care include using telemedicine and virtual tumor boards to extend care to medically underserved regions. Telemedicine and virtual tumor boards can increase access to multidisciplinary lung cancer care for patients with lung cancer living in medically underserved areas. Increasing access to multidisciplinary lung cancer care may allow more patients to receive appropriate oncologic care and follow-up (eg, follow-up with medical oncology if needed, biomarker testing).

Another possible solution is to consider regionalizing lung cancer surgery, such that patients living in medically underserved regions have access to at least one designated center that offers lung cancer surgery. A previous study found that the regionalization of lung cancer surgery from 16 regionwide sites to 5 designated centers in a US health care system was associated with significant reductions in length of stay and morbidity after lung cancer resection.[28] It is possible that, in addition to improving the quality of care, regionalization of lung cancer surgery also may improve access to lung cancer surgery. Of course, any benefits to regionalizing lung cancer surgery should be carefully considered in the context of increased travel burden for patients.[29]

In addition to the aforementioned solutions, other possible solutions include increasing the number of cardiothoracic surgery positions offered while also ensuring that any new positions created are located in regions where thoracic surgeons are needed most. It is worth highlighting that, although the number of cardiothoracic surgery positions offered has not changed during the past decade, interest in cardiothoracic surgery programs has risen sharply during the past decade. From 2010 to 2021, we found that there has been a 50% increase in the number of applicants to cardiothoracic surgery programs. Increasing the number of cardiothoracic surgery positions offered to match this growing interest may therefore be one path forward. Additionally, cardiothoracic surgery fellowship programs should consider implementing designated rural thoracic surgery rotations and other incentives to encourage more thoracic surgery trainees to train and ultimately work long-term in medically underserved regions.

This study has several limitations. First, it is important to note that our findings do not demonstrate a causal relationship between changes in the cardiothoracic surgery workforce and changes in lung cancer treatment and survival. It is worth noting that there likely are several contributing factors to the changes in lung cancer treatment patterns, including changes in patient preferences and an increase in the proportion of patients deemed too high-risk to undergo surgery. We do note, however, that a previous study showed that the majority of early-stage lung cancer patients reported preferring surgery over SBRT.[30] Additionally, we did perform analyses of patients who were younger and otherwise healthy, and still found a declining use of surgery and increasing use of SBRT in this population; these data suggest that changes in treatment patterns cannot be entirely attributed to an increase in the proportion of patients deemed too high risk to undergo surgery. It is also possible that slower increases in life expectancy in the general population among lower-income and rural populations compared to higher-income[31] and nonrural populations[32] might have contributed to the differential changes in overall survival between medically underserved and more affluent patient populations observed in the present study. Nonetheless, our findings do raise the concern that the demand for thoracic surgeons is rising without an increase in the supply of thoracic surgeons to meet this growing demand. Furthermore, our findings suggest that these changes in the supply of and demand for thoracic surgeons coincide with concerning changes in the treatment patterns for and survival of stage I lung cancer. Second, estimates of the number of stage I NSCLC cases diagnosed in the US were obtained by multiplying the number of cases in the SEER database by 3.57; this estimation assumes that the sample of patients included in the SEER database is unbiased and representative. We do note, however, that the SEER database is a robust dataset that represents 28% of the US and includes data from 18 cancer registries from different regions of the US.[16] Third, given that this is a retrospective analysis, there is the possibility of confounding. However, we did try to reduce the possibility of confounding through the use of multivariable modeling and through sensitivity analyses of patients who were younger and otherwise healthy. Fourth, data on the number of general thoracic surgeons in the US were not available, and thus we used the number of cardiothoracic surgeons (including cardiac surgeons, general thoracic surgeons, and surgeons with a mixed thoracic and cardiac practice) in the US as a proxy for the number of general thoracic surgeons. Of note, this is an overestimate of the number of surgeons who perform lung cancer resections, given that <21% of cardiothoracic

THOR

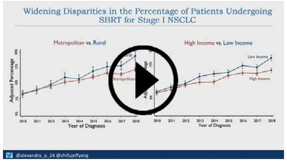
surgeons identify thoracic surgery as their primary practice.[21] Furthermore, the relative numbers of cardiothoracic surgeons in the AHRF who are cardiac surgeons, are general thoracic surgeons, or have a mixed practice are unknown. One theoretical concern is that although the number of cardiothoracic surgeons in the US did not change from 2010 to 2018, the proportion of cardiothoracic surgeons who are general thoracic surgeons may have increased, thereby leading to an increase in the number of general thoracic surgeons in the US. To address this concern, we performed an analysis using data from the ABTS 10-year MOC III exam to assess whether the proportion of cardiothoracic surgeons completing the general thoracic specialty-specific exam (indicating the proportion of cardiothoracic surgeons who predominately practice general thoracic surgery) increased from 2017 to 2022. Importantly, we found that the proportion of cardiothoracic surgeons completing the general thoracic specialty-specific exam did not change significantly from 2017 to 2022, while the proportion of cardiothoracic surgeons completing the cardiothoracic specialty-specific exam (indicating the proportion of cardiothoracic surgeons who have a mixed thoracic and cardiac practice) decreased significantly from 2017 to 2022. These findings, in addition to data from previous studies,[21,33] support that the proportion of cardiothoracic surgeons who practice general thoracic surgery (either as their primary practice or as part of a mixed thoracic and cardiac practice) has remained relatively constant or even decreased over the last decade.

CONCLUSIONS

In this national analysis from 2010 to 2018, we found that the number of stage I NSCLC cases diagnosed in the US increased sharply, while the number of cardiothoracic surgeons per 100,000 people in the US decreased. During the same period, the proportion of patients diagnosed with stage I NSCLC who underwent surgery decreased significantly, while the proportion of these patients who underwent SBRT increased significantly. From 2010 to 2018, greater decreases in the proportion of patients undergoing surgery, greater increases in the proportion of patients receiving SBRT, and slower improvements in survival were seen in patients living in medically underserved regions versus those living in more affluent regions. These findings suggest that recent declines in the US cardiothoracic surgery workforce may have led to significantly fewer patients undergoing surgery for stage I NSCLC and worsening disparities in survival between different patient populations. With the growing adoption of lung cancer screening and corresponding increase in the number of early-stage lung cancers diagnosed in the US, these data show the need to increase access to thoracic surgical care in the US, particularly in medically underserved regions.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/1409.



Conflict of Interest Statement

L.M. has received consulting fees from AstraZeneca, Genentech, Ontarget Laboratories, and Ethicon. C.J.Y. has received honoraria from AstraZeneca. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

We thank the American Board of Thoracic Surgery and Dr Cameron Wright for providing data from the ABTS 10-year MOC III exam for analysis in the present study.

References

1. Narayan AK, Gupta Y, Little BP, Shepard JO, Flores EJ. Lung cancer screening eligibility and use with low-dose computed tomography: results from the 2018 Behavioral Risk Factor Surveillance System cross-sectional survey. *Cancer*. 2021;127:748-56. https://doi.org/10.1002/cncr.33322
2. Tailor TD, Tong BC, Gao J, Henderson LM, Choudhury KR, Rubin GD. Utilization of lung cancer screening in the medicare fee-for-service population. *Chest*. 2020;158:2200-10. https://doi.org/10.1016/j.chest.2020.05.592
3. Richards TB, Soman A, Thomas CC, VanFrank B, Henley SJ, Gallaway MS, et al. Screening for lung cancer—10 states, 2017. *MMWR Morb Mortal Wkly Rep*. 2020;69:201-6.
4. United States Census Bureau, America Counts Staff. By 2030 all baby boomers will be age 65 or older. Accessed December 10, 2019. https://www.census.gov/library/stories/2019/12/by-2030-all-baby-boomers-will-be-age-65-or-older.html
5. American Lung Association. Lung cancer key findings. Accessed March 12, 2023. https://www.lung.org/research/state-of-lung-cancer/key-findings
6. Potter AL, Rosenstein AL, Kiang MV, Shah SA, Gaissert HA, Chang DC, et al. Association of computed tomography screening with lung cancer stage shift and survival in the United States: quasi-experimental study. *BMJ*. 2022;376:e069008. https://doi.org/10.1136/bmj-2021-069008
7. Khouzam MS, Wood DE, Vigneswaran W, Goyal A, Czerlanis C, Blackmon SH, et al. Impact of federal lung cancer screening policy on the incidence of early-stage lung cancer. *Ann Thorac Surg*. 2023;115:827-33. https://doi.org/10.1016/j.athoracsur.2022.11.021
8. Williams TE Jr, Sun B, Ross P Jr, Thomas AM. A formidable task: population analysis predicts a deficit of 2000 cardiothoracic surgeons by 2030. *J Thorac Cardiovasc Surg*. 2010;139:835-40; discussion 840-1. https://doi.org/10.1016/j.jtcvs.2009.12.004
9. Moffatt-Bruce S, Crestanello J, Way DP, Williams TE Jr. Providing cardiothoracic services in 2035: signs of trouble ahead. *J Thorac Cardiovasc Surg*. 2018;155:824-9. https://doi.org/10.1016/j.jtcvs.2017.09.135
10. Grover A, Gorman K, Dall TM, Jonas R, Lytle B, Shemin R, et al. Shortage of cardiothoracic surgeons is likely by 2020. *Circulation*. 2009;120:488-94. https://doi.org/10.1161/circulationaha.108.776278
11. Williams TE Jr, Satiani B, Thomas A, Ellison EC. The impending shortage and the estimated cost of training the future surgical workforce. *Ann Surg*. 2009;250:590-7. https://doi.org/10.1097/SLA.0b013e3181b6c90b

12. Eberth JM, Crouch EL, Josey MJ, Zahnd WE, Adams S, Stiles BM, et al. Rural-urban differences in access to thoracic surgery in the United States, 2010 to 2014. *Ann Thorac Surg*. 2019;108:1087-93. https://doi.org/10.1016/j.athoracsur.2019.04.113
13. Oslock WM, Satiani B, Way DP, Tamer RM, Maurer J, Hawley JD, et al. A contemporary reassessment of the US surgical workforce through 2050 predicts continued shortages and increased productivity demands. *Am J Surg*. 2022;223:28-35. https://doi.org/10.1016/j.amjsurg.2021.07.033
14. Mallin K, Browner A, Palis B, Gay G, McCabe R, Nogueira L, et al. Incident cases captured in the National Cancer Database compared with those in US population based central cancer registries in 2012-2014. *Ann Surg Oncol*. 2019;26:1604-12. https://doi.org/10.1245/s10434-019-07213-1
15. Bilimoria KY, Stewart AK, Winchester DP, Ko CY. The National Cancer Data Base: a powerful initiative to improve cancer care in the United States. *Ann Surg Oncol*. 2008;15:683-90. https://doi.org/10.1245/s10434-007-9747-3
16. National Cancer Institute. Surveillance, Epidemiology, and End Results (SEER) Program. SEER*Stat Database: Incidence - SEER Research Plus Data, 18 Registries, Nov 2020 Sub (2000-2018) - Linked To County Attributes - Total US, 1969-2019 Counties, National Cancer Institute, DCCPS, Surveillance Research Program, released April 2021, based on the November 2020 submission. Accessed April 1, 2022. www.seer.cancer.gov
17. Detterbeck FC, Boffa DJ, Kim AW, Tanoue LT. The eighth edition lung cancer stage classification. *Chest*. 2017;151:193-203. https://doi.org/10.1016/j.chest.2016.10.010
18. US Department of Health and Human Services Health Resources and Services Administration. Area health resources file 2022. Accessed April 1, 2022. https://data.hrsa.gov/topics/health-workforce/ahrf
19. USDA Economic Research Service. Documentation. Accessed April 1, 2022. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation/#referencedate
20. American Board of Thoracic Surgery. Accessed July 24, 2023. https://www.abts.org/ABTS/MOCWebPages/10-year_Milestone.aspx
21. Colson YL, Putnam JB, Yang SC, Fann JI, Vaporciyan AA, Dearani JA, et al. American Board of Thoracic Surgery 10-year Maintenance of Certification exam improves and validates knowledge acquisition. *Ann Thorac Surg*. 2019;108:1895-900. https://doi.org/10.1016/j.athoracsur.2019.05.074
22. National Resident Matching Program. Results and data: specialties matching service 2021 appointment year. Accessed April 1, 2022. https://www.nrmp.org/match-data-analytics/fellowship-data-reports/
23. National Comprehensive Cancer Network. NCCN Guidelines insights: non-small cell lung cancer, version 1.2023. Accessed January 28, 2023. https://jnccn.org/view/journals/jnccn/21/4/article-p340.xml
24. Centers for Disease Control and Prevention, United States Cancer Statistics (USCS). Data visualizations tool. Accessed April 1, 2022. https://www.cdc.gov/cancer/uscs/dataviz/index.htm
25. Davis TA, Yang SC. Unmatched integrated cardiothoracic surgery program applicants: where do they end up? *Ann Thorac Surg*. 2018;106:1556-60.
26. Cochran WG. Some methods for strengthening the common χ^2 tests. *Biometrics*. 1954;10:417-51.
27. Armitage P. Tests for linear trends in proportions and frequencies. *Biometrics*. 1955;11:375-86.
28. Ely S, Jiang SF, Patel AR, Ashiku SK, Velotta JB. Regionalization of lung cancer surgery improves outcomes in an integrated health care system. *Ann Thorac Surg*. 2020;110:276-83. https://doi.org/10.1016/j.athoracsur.2020.02.019
29. Symer MM, Abelson JS, Yeo HL. Barriers to regionalized surgical care: public perspective survey and geospatial analysis. *Ann Surg*. 2019;269:73-8. https://doi.org/10.1097/sla.0000000000002556
30. Sullivan DR, Eden KB, Dieckmann NF, Golden SE, Vranas KC, Nugent SM, Slatore CG. Understanding patients' values and preferences regarding early stage lung cancer treatment decision making. *Lung Cancer*. 2019;131:47-57. https://doi.org/10.1016/j.lungcan.2019.03.009
31. Chetty R, Stepner M, Abraham S, Lin S, Scuderi B, Turner N, et al. The association between income and life expectancy in the United States, 2001-2014. *JAMA*. 2016;315:1750-66. https://doi.org/10.1001/jama.2016.4226
32. Abrams LR, Myrskylä M, Mehta NK. The growing rural–urban divide in US life expectancy: contribution of cardiovascular disease and other major causes of death. *Int J Epidemiol*. 2022;50:1970-8. https://doi.org/10.1093/ije/dyab158
33. Brescia AA, Louis C, Luc JGY, Coyan GN, Han JJ, Blitzer D, et al. The utilization of educational resources published by the Thoracic Surgery Residents Association. *JTCVS Open*. 2022;11:241-64. https://doi.org/10.1016/j.xjon.2022.04.047

Key Words: stage I NSCLC, shortages, thoracic surgery, lung cancer, SBRT, disparities

Discussion

Presenter: Ms Alexandra Potter

Dr Virginia Litle *(Salt Lake City, Utah)*. Thank you, Alexandra, for sharing the manuscript with me. Basically, your project brings up 3 really important topics in thoracic surgery: workforce changes and lung cancer screening. That was more in the manuscript than here. And disparities. They are all hot topics. So I just have three questions for you, and I'll ask them one at a time.

First, since general surgeons do the majority of lung resections for cancer in the US, how are you going to account for this number going forward, and how does that influence your results—how do you know you're not just comparing apples and oranges here?

Ms Alexandra Potter *(Boston, Mass)*. Thank you for your question. There are older data suggesting that at least 50% of lung resections are performed by general surgeons in the US. The important thing to note is that recent studies have also shown that the number of general thoracic surgeons per 100,000 people in the US is decreasing. It's certainly possible that general surgeons are doing fewer lung resections. However, what we are seeing with our data is that even if general surgeons are doing fewer resections, these patients are not undergoing surgery. And that's really the important point that we want to make is that while it's possible that the shortage of general surgeons is contributing to the decreasing resection rates that we see in this study, these patients are still not undergoing surgery. An additional point we want to add is that as lung cancer care is becoming increasingly complex with the growing use of biomarkers and increasing use of segmentectomy, most patients will require more specialized care, and that is an important consideration moving forward as we look at the workforce.

Dr Litle. And so how do you think we can make changes in that area? By being more participatory in the American

THOR

College of Surgeons might be one approach. Do you have any ideas?

Ms Potter. I think that that's a really important question. It really highlights the challenges of this problem because there are a number of potential solutions we could consider. One of which is increasing the number of cardiothoracic surgery fellowship positions offered. I think it's important to acknowledge that in the match last week, the match rate was only 56%, meaning that 44% of people are interested in this workforce but are unable to get into the workforce. And that highlights the importance of considering increasing the number of positions to match the increasing interest in cardiothoracic surgery, as well as the increasing need for cardiothoracic surgeons.

Dr Litle. Great. Okay, question number two. So large database studies have multiple limitations. You identified some of those on your slides, including lack of granularity about pulmonary function and the ability of patients to tolerate resection. And lack of details about any tumor board discussions, whether there were shared decision making with radiation oncology, etc. So large database studies are good for getting preliminary data for future smaller studies. What would you suggest is an appropriate follow-up study to investigate this further?

Ms Potter. Thank you for your question. And I think an important thing to note is that in our study, we did analyses of patients age 64 and younger and with no comorbidities, and we still saw a decreasing resection rate and increasing use of SBRT among these patients. I think that highlights the importance of the issue, and that it is not just potential confounding. With regard to your question about follow-up studies that we propos for a deeper dive into this topic, I think studies aimed at identifying what point in the pathway from diagnosis to treatment that the treatment decision for a patient becomes one that is not thoracic surgery is really important to identify. Right now, it's hard to know the exact reasons for the decreasing resection rate. We don't know if it's access to care, if they're only seeing a radiation oncologist, or if the case is being presented at a tumor board discussion. Additionally, I think that large-scale databases in the future should consider capturing more detailed reasons for why a patient does not undergo surgery. Right now, the National Cancer Database and the SEER database have one data field for why patients don't undergo surgery. But it's very broad, and it's very challenging to know the precise reasons.

Dr Litle. All right, I have one final question for you. In your manuscript discussion, you talk about disparities and also on your slides, too, and resection rates in vulnerable populations. So how would you suggest improving delivery of care to these populations given that first, it will take time to increase the workforce numbers. And second, there's no guarantee that more thoracic surgeons means higher resection rates in rural, low-income populations.

Ms Potter. I think that's a really important question, and again it highlights the challenge of improving delivery of care in these patient populations. As I had mentioned previously, I do think that increasing the number of fellowship positions offered is needed to get more people entering the workforce so that they can eventually work in rural regions and underserved regions. I think what we can also do is look at what surgical societies are currently doing to increase the number of rural surgeons. For example, the American College of Surgeons has implemented rural surgery rotations, dedicated rural surgery tracks, and incentives to encourage surgeons to practice in areas where we know there are not enough surgeons. We can also consider creative ways to use telemedicine, for example, through the use of virtual tumor boards and virtual clinics. And then to your point that it will take time to get surgeons out there in the workforce, I think the main thing is that we need to start now. One thing we can consider while we wait to build up the workforce is loan forgiveness programs. I also think that efforts to increase lung cancer screening information can be paired with efforts to educate primary care providers about knowledgeable management. I think we can also focus on improving patient education in these underserved regions so that they are well-informed about their treatment options. I think that there are a number of possibilities and possible solutions that we can explore, but that the findings of our study really highlight the urgency of starting now, as opposed to waiting.

Dr Litle. Great. Thank you. Excellent job.

APPENDIX E1

Methods

Study exclusion criteria. In our analysis of patients in the NCDB, we excluded patients deemed too high-risk to undergo surgery. The NCDB includes a data field recording the reason why no surgery was performed on the primary site. Patients who were coded as not undergoing surgery "due to patient risk factors (comorbid conditions, advanced age, progression of tumor prior to planned surgery, etc)"[E1] were excluded from our analysis.

Definitions of patient subgroups. The NCDB records median household income based on the zip code where the patient lives. In addition, the NCDB records data on whether the patient lives in a metropolitan, urban, or rural location based on the 2013 rural-urban continuum codes published by the US Department of Agriculture Economic Research Service. The NCDB also includes data on the type of facility in which the patient was treated (eg, community cancer program, academic center) based on the category classification by the Commission on Cancer Accreditation program.

For the subgroup analyses, we dichotomized low income versus high income, nonmetropolitan status versus metropolitan status, and community hospitals versus academic hospitals. With regard to income, in the NCDB, the median household income for each patient's area of residence is categorized in quartiles based on income ranges across all US ZIP codes. We then created a variable in which "low income" included patients in 2 lowest-income quartiles and "high income" included patients in the 2 highest-income quartiles.

With regard to nonmetropolitan status versus metropolitan status, nonmetropolitan status was defined as patients living in ZIP codes coded as 4 to 9 according to the US Department of Agriculture Economic Research Service rural-urban continuum codes, and metropolitan status was defined as patients living in ZIP codes coded as 1 to 3.

Finally, with regard to community hospitals versus academic centers, community hospitals included patients treated at community cancer programs and academic hospitals included patients treated at an academic/research program, which includes National Cancer Institute–designated comprehensive cancer centers.

E-Reference

E1. National Cancer Database Participant User File. 2018 Data Dictionary. Accessed April 1, 2022. https://www.facs.org/media/xxfgndgn/puf_data_dictionary_2018.pdf

THOR

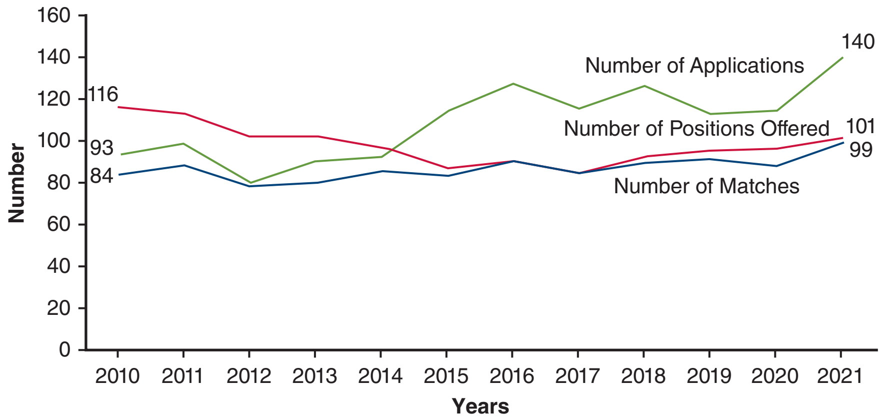


FIGURE E1. Analysis of the National Resident Matching Program data: changes in the number of applicants (either 4/3 or traditional residents) to cardiothoracic surgery fellowship programs, number of cardiothoracic surgery fellowship positions offered, and number of matches to cardiothoracic surgery fellowship programs from 2010 to 2021. Of note, applicants to integrated programs were not included in this analysis.

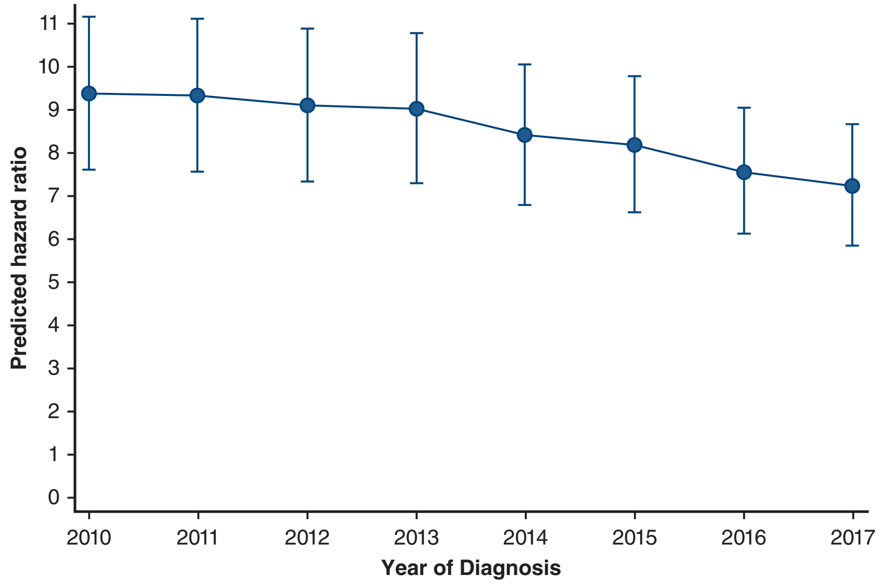


FIGURE E2. Multivariable-adjusted changes in the hazard of death from any cause among patients diagnosed with clinical stage I non–small cell lung cancer from 2010 to 2017. The x-axis is the year of diagnosis, and the y-axis is the predicted hazard ratio.

TABLE E1. ICD-0-3 codes*

Histology	SEER histology ICD-0-3 codes
Adenocarcinoma	8140/3, 8550/3, 8551/3, 8260/3, 8230/3, 8253/3, 8254/3, 8480/3, 8144/3
Squamous cell carcinoma	8070/3, 8071/3, 8072/3, 8073/3, 8074/3, 8075/3, 8076/3, 8078/3, 8083/3
Large cell carcinoma	8012/3, 8013/3, 8014/3
Adenosquamous cell carcinoma	8560/3
Typical carcinoid	8240/3, 8241/3, 8242/3, 8243/3, 8244/3, 8245/3, 8246/3
NSCLC Formerly classified as bronchiolo-alveolar adenocarcinoma	8250/3, 8251/3, 8252/3, 8255/3, 8256/3, 8257/3

*Travis WD, Brambilla E, Nicholson AG, Yatabe Y, Austin JHM, Beasley MB, et al. The 2015 World Health Organization Classification of Lung Tumors: impact of genetic, clinical and radiologic advances since the 2004 classification. *J Thorac Oncol*. 2015;10:1243-60. https://doi.org/10.1097/JTO.0000000000000630.

TABLE E2. Number of cardiothoracic surgeons completing the 10-year maintenance of certification specialty-specific exam from 2017 to 2022

Year	Cardiac, n (%)	General thoracic, n (%)	Cardiothoracic, n (%)	Congenital, n (%)	Total, n
2017	101 (29.0)	67 (19.3)	163 (46.8)	17 (4.9)	348
2018	156 (38.1)	77 (18.8)	129 (31.5)	47 (11.5)	409
2019	181 (45.1)	81 (20.2)	89 (22.2)	50 (12.5)	401
2020	186 (48.9)	78 (20.5)	79 (20.8)	37 (9.7)	380
2021	143 (44.7)	66 (20.6)	91 (28.4)	20 (6.3)	320
2022	149 (51.4)	72 (24.8)	55 (19.0)	14 (4.8)	290
Total	916 (42.6)	441 (20.5)	606 (28.2)	185 (8.6)	2148

Percentages are calculated across rows.

THOR

TABLE E3. Baseline characteristics of the patients meeting study inclusion criteria in the National Cancer Database

Characteristic	Value
Number of patients	133,947
Age at diagnosis, y, median (IQR)	69.0 (63.0-76.0)
Female sex, n (%)	74,570 (55.7)
Race, n (%)	
White	116,164 (86.7)
Black	12,264 (9.2)
Native American	398 (2.6)
Asian	3533 (0.3)
Other/unknown	1588 (1.2)
CDCC, n (%)	
0	66,352 (49.5)
1	41,870 (31.3)
2	16,829 (12.6)
≥3	8896 (6.6)
Insurance status, n (%)	
Not insured	1973 (1.5)
Private insurance/managed care	32,706 (24.4)
Medicaid	7310 (5.5)
Medicare	88,033 (65.7)
Other government	2381 (1.8)
Unknown	1544 (1.2)
Facility type, n (%)	
Community cancer program	6447 (4.8)
Comprehensive community cancer program	54,591 (40.8)
Academic/research program	45,277 (33.8)
Integrated network cancer program	27,258 (20.3)
Other	374 (0.3)
Income,* n (%)	
<$40,227	23,338 (17.4)
$40,227-$50,353	27,470 (20.5)
$50,354-$63,332	27,983 (20.9)
>$63,332	38,411 (28.7)
Unknown	16,745 (12.5)
Education,† n (%)	
≥17.6%	24,064 (18.0)
10.9%-17.5%	33,388 (24.9)
6.3%-10.8%	33,765 (25.2)
<6.3%	26,216 (19.6)
Unknown	16,514 (12.3)
Rurality, n (%)	
Metropolitan	107,751 (80.4)
Nonmetropolitan	22,786 (17.0)
Unknown	3410 (2.5)
Distance from hospital, miles, median (IQR)	11.2 (4.9, 26.6)
Facility location, n (%)	
New England	8068 (6.0)
Middle Atlantic	20,289 (15.1)
South Atlantic	31,214 (23.3)
East North Central	25,153 (18.8)
East South Central	12,226 (9.1)
West North Central	10,620 (7.9)
West South Central	9185 (6.9)
Mountain	4482 (3.3)
Pacific	12,336 (9.2)
Unknown	374 (0.3)
Clinical T status, n (%)	
T1a	10,334 (7.7)
T1b	52,810 (39.4)
T1c	37,886 (28.3)
T2a	32,917 (24.6)
Tumor size, median (IQR)	21.0 (15.0, 28.0)
Histology, n (%)	
Adenocarcinoma	86,854 (64.8)
Squamous cell carcinoma	40,908 (30.5)
Large cell carcinoma	2300 (1.7)
Adenosquamous cell carcinoma	2796 (2.1)
Atypical carcinoid tumor	1089 (0.8)
Grade, n (%)	
Well differentiated	18,864 (14.1)
Moderately differentiated	55,785 (41.6)
Poorly differentiated	33,820 (25.2)
Undifferentiated	872 (0.7)
Unknown	24,606 (18.4)
Year of diagnosis, n (%)	
2010	11,016 (8.2)
2011	11,951 (8.9)
2012	12,549 (9.4)
2013	13,407 (10.0)
2014	14,556 (10.9)
2015	16,045 (12.0)
2016	17,394 (13.0)
2017	18,499 (13.8)
2018	18,530 (13.8)

(Continued)

TABLE E3. Continued

IQR, Interquartile range; *CDCC*, Charlson–Deyo Comorbidity Score. *Median household income of individuals living in the patient's ZIP code. †Percentage of adults age >25 years living in the patient's ZIP code who did not graduate from high school.

TABLE E4. Changes in the odds of undergoing lung cancer resection for clinical stage I NSCLC from 2010 to 2018: multivariable-adjusted analysis

Characteristic	OR	95% CI	P value
Sex (reference: male)	0.98	0.95-1.01	.11
Age	0.93	0.92-0.93	<.001
Race (reference: white)			
Black	0.70	0.67-0.74	<.001
Native American	0.82	0.63-1.08	.15
Asian	1.45	1.31-1.61	<.001
Tumor size	0.97	0.96-0.97	<.001
Clinical T stage (reference: T1a)			
T1b	0.89	0.82-0.95	.001
T1c	0.98	0.90-1.08	.74
T2a	1.55	1.37-1.74	<.001
Facility type (reference: community cancer program)			
Comprehensive community cancer program	1.22	1.14-1.30	<.001
Academic/research program	1.17	1.09-1.26	<.001
Integrated network cancer program	1.36	1.26-1.46	<.001
Income* (reference <$40,227)			
$40,277-$50,353	1.13	1.08-1.19	<.001
$50,354-$63,332	1.25	1.19-1.32	<.001
>$63,333	1.59	1.50-1.68	<.001
CDCC (reference: 0)			
1	1.28	1.24-1.33	<.001
2	1.16	1.11-1.21	<.001
3+	0.87	0.82-0.92	<.001
Education† (reference: >17.6%)			
10.9%-17.5%	1.02	0.97-1.06	.51
6.3%-10.8%	1.00	0.95-1.05	.92
<6.3%	1.03	0.97-1.09	.32
Histology (reference: adenocarcinoma)			
Squamous cell carcinoma	0.65	0.63-0.67	<.001
Large cell carcinoma	2.09	1.80-2.43	<.001
Adenosquamous carcinoma	1.97	1.74-2.24	<.001
Atypical carcinoid	5.24	3.64-7.55	<.001
Tumor location (reference: right upper lobe)			
Right upper lobe	4.70	3.81-5.80	<.001
Right middle lobe	5.42	4.35-6.76	<.001
Right lower lobe	5.03	4.07-6.22	<.001
Left upper lobe	4.46	3.62-5.51	<.001
Left lower lobe	4.65	3.76-5.75	<.001
Bilateral	1.81	0.44-7.42	.41
Overlapping lesion of the lung	18.31	12.64-26.51	<.001
Insurance status (reference: not insured)			
Private insurance/managed care	2.18	1.90-2.49	<.001
Medicaid	1.00	0.86-1.16	.99
Medicare	1.78	1.56-2.04	<.001
Other government	0.57	0.49-0.67	<.001
Distance from hospital	1.00	1.00-1.00	<.001

(Continued)

TABLE E4. Continued

Characteristic	OR	95% CI	P value
Rurality (reference: nonmetropolitan)			
Metropolitan	1.03	0.99-1.07	.21
Year of diagnosis (reference: 2010)			
2011	0.93	0.87-1.00	.07
2012	0.84	0.78-0.90	<.001
2013	0.79	0.74-0.85	<.001
2014	0.73	0.68-0.79	<.001
2015	0.68	0.63-0.73	<.001
2016	0.64	0.60-0.69	<.001
2017	0.63	0.59-0.67	<.001
2018	0.59	0.55-0.63	<.001

NSCLC, Non–small cell lung cancer; *OR*, odds ratio; *CI*, confidence interval; *CDCC*, Charlson–Deyo Comorbidity Score. *Median household income of individuals living in the patient's zip code †Percentage of adults over aged 25 living in the patient's zip code who did not graduate from high school.

THOR

THOR

TABLE E5. Changes in the odds of undergoing lung cancer resection for clinical stage I NSCLC from 2010 to 2018 among a subset of young (<65 years) and otherwise healthy patients: multivariable-adjusted logistic regression analysis

Characteristic	OR	95% CI	*P* value
Sex (reference: male)	1.21	1.10-1.33	<.001
Age	0.95	0.94-0.96	<.001
Race (reference: white)			
Black	0.87	0.76-0.99	.04
Native American	0.64	0.33-1.25	.19
Asian	1.55	1.15-2.10	.004
Tumor size	0.97	0.96-0.98	<.001
Clinical T stage (reference: T1a)			
T1b	0.91	0.74-1.12	.35
T1c	1.08	0.81-1.42	.60
T2a	1.58	1.12-2.25	.01
Facility type (reference: community cancer program)			
Comprehensive community cancer program	0.93	0.75-1.16	.54
Academic/research program	0.87	0.70-1.08	.21
Integrated network cancer program	1.11	0.88-1.41	.37
Income* (reference: <$40,227)			
$40,277-$50,353	1.20	1.05-1.38	.008
$50,354-$63,332	1.36	1.17-1.59	<.001
>$63,333	1.81	1.51-2.16	<.001
Education† (reference: >17.6%)		0.00-0.00	
10.9%-17.5%	1.01	0.89-1.15	.87
6.3%-10.8%	1.01	0.87-1.18	.87
<6.3%	1.25	1.03-1.52	.03
Histology (reference: adenocarcinoma)			
Squamous cell carcinoma	0.60	0.54-0.67	<.001
Large cell carcinoma	1.86	1.21-2.85	.005
Adenosquamous carcinoma	2.67	1.48-4.82	.001
Atypical carcinoid	8.00	2.54-25.22	<.001
Tumor location (reference: right upper lobe)			
Right upper lobe	5.54	3.52-8.73	<.001
Right middle lobe	6.79	4.11-11.19	<.001
Right lower lobe	6.13	3.86-9.74	<.001
Left upper lobe	5.48	3.47-8.65	<.001
Left lower lobe	5.87	3.68-9.36	<.001
Overlapping lesion of the lung	15.26	5.88-39.64	<.001
Insurance status (reference: not insured)			
Private insurance/managed care	2.27	1.83-2.82	<.001
Medicaid	1.02	0.81-1.28	.86
Medicare	0.87	0.70-1.09	.22
Other government	0.55	0.41-0.74	<.001
Distance from hospital	1.00	1.00-1.00	.01
Rurality (reference: nonmetropolitan)		0.00-0.00	
Metropolitan	1.03	0.90-1.18	.69
Year of diagnosis (reference: 2010)			
2011	1.00	0.79-1.28	.97
2012	0.88	0.70-1.11	.27
2013	0.96	0.76-1.21	.71
2014	0.82	0.65-1.02	.07
2015	0.80	0.64-0.99	.04
2016	0.80	0.65-0.98	.04
2017	0.81	0.66-1.01	.06
2018	0.76	0.61-0.93	.009

NSCLC, Non–small cell lung cancer; *OR*, odds ratio; *CI*, confidence interval. *Median household income of individuals living in the patient's ZIP code. †Percentage of adults age >25 years living in the patient's ZIP code who did not graduate from high school.

TABLE E6. Changes in the odds of undergoing SBRT for clinical stage I NSCLC from 2010 to 2018: multivariable-adjusted logistic regression analysis

Characteristic	OR	95% CI	*P* value
Sex (reference: male)	1.07	1.03-1.12	.001
Age	1.07	1.07-1.07	<.001
Race (reference: white)			
Black	1.13	1.05-1.21	.001
Native American	1.19	0.84-1.68	.34
Asian	0.47	0.40-0.55	<.001
Tumor size	1.02	1.01-1.02	<.001
Clinical T stage (reference: T1a)			
T1b	1.41	1.28-1.56	<.001
T1c	1.28	1.13-1.45	<.001
T2a	0.72	0.61-0.84	<.001
Facility type (reference: community cancer program)			
Comprehensive community cancer program	1.55	1.40-1.72	<.001
Academic/research program	1.76	1.58-1.96	<.001
Integrated network cancer program	1.63	1.46-1.81	<.001
Income* (reference: <$40,227)			
$40,277-$50,353	0.87	0.82-0.93	<.001
$50,354-$63,332	0.83	0.78-0.89	<.001
>$63,333	0.64	0.60-0.69	<.001
CDCC (reference: 0)			
1	0.81	0.77-0.84	<.001
2	0.85	0.80-0.90	<.001
3+	1.08	1.00-1.16	.05
Education† (reference >17.6%)			
10.9%-17.5%	1.09	1.03-1.16	.003
6.3%-10.8%	1.16	1.08-1.24	<.001
<6.3%	1.17	1.08-1.27	<.001
Histology (reference: adenocarcinoma)			
Squamous cell carcinoma	1.40	1.34-1.46	<.001
Large cell carcinoma	0.40	0.31-0.50	<.001
Adenosquamous carcinoma	0.53	0.44-0.63	<.001
Atypical carcinoid	0.16	0.09-0.28	<.001
Tumor location (reference: right upper lobe)			
Right upper lobe	2.16	1.41-3.29	<.001
Right middle lobe	1.87	1.21-2.87	.005
Right lower lobe	2.05	1.34-3.13	.001
Left upper lobe	2.26	1.48-3.45	<.001
Left lower lobe	2.22	1.45-3.39	<.001
Overlapping lesion of the lung	0.52	0.27-1.00	.050
Insurance status (reference: not insured)			
Private insurance/managed care	0.71	0.57-0.88	.002
Medicaid	1.31	1.04-1.64	.02
Medicare	0.97	0.78-1.20	.79
Other government	2.56	2.02-3.25	<.001
Distance from hospital	1.00	1.00-1.00	.006
Rurality (reference: nonmetropolitan)			
Metropolitan	0.91	0.87-0.97	.001
Year of diagnosis (reference: 2010)			
2011	1.21	1.08-1.36	.001
2012	1.45	1.31-1.62	<.001
2013	1.74	1.57-1.93	<.001
2014	1.83	1.65-2.03	<.001
2015	2.10	1.90-2.32	<.001
2016	2.39	2.16-2.63	<.001
2017	2.32	2.11-2.56	<.001
2018	2.74	2.49-3.02	<.001

SBRT, Stereotactic body radiotherapy; *NSCLC*, non–small cell lung cancer *OR*, odds ratio; *CI*, confidence interval; *CDCC*, Charlson–Deyo Comorbidity Score. *Median household income of individuals living in the patient's ZIP code. †Percentage of adults age >25 years living in the patient's ZIP code who did not graduate from high school.

THOR

THOR

TABLE E7. Changes in the odds of undergoing SBRT for clinical stage I NSCLC from 2010 to 2018 among a subset of young (<65 years) and otherwise healthy patients: multivariable-adjusted logistic regression analysis

Characteristic	OR	95% CI	*P* value
Sex (reference: male)	0.94	0.82-1.08	.38
Age	1.07	1.06-1.09	<.001
Race (reference: white)			
Black	0.86	0.70-1.06	.16
Native American	2.85	1.33-6.10	.007
Asian	0.22	0.10-0.46	<.001
Tumor size	1.03	1.01-1.05	.004
Clinical T stage (reference: T1a)			
T1b	1.25	0.92-1.70	.15
T1c	0.89	0.58-1.37	.61
T2a	0.43	0.24-0.75	.003
Facility type (reference: community cancer program)			
Comprehensive community cancer program	2.45	1.57-3.82	<.001
Academic/research program	3.10	1.98-4.84	<.001
Integrated network cancer program	2.28	1.44-3.63	<.001
Income* (reference: <$40,227)			
$40,277-$50,353	0.77	0.63-0.94	.01
$50,354-$63,332	0.64	0.51-0.80	<.001
>$63,333	0.42	0.32-0.56	<.001
Education† (reference: >17.6%)		0.00-0.00	
10.9%-17.5%	1.03	0.85-1.24	.80
6.3%-10.8%	1.24	0.99-1.55	.06
<6.3%	1.10	0.82-1.47	.53
Histology (reference: adenocarcinoma)			
Squamous cell carcinoma	1.64	1.40-1.91	<.001
Large cell carcinoma	0.49	0.24-1.00	.05
Adenosquamous carcinoma	0.35	0.13-0.94	.04
Atypical carcinoid	0.11	0.02-0.82	.03
Tumor location (reference: right upper lobe)			
Right upper lobe	1.07	0.42-2.74	.89
Right middle lobe	0.82	0.30-2.23	.70
Right lower lobe	0.91	0.35-2.36	.85
Left upper lobe	1.16	0.45-2.98	.75
Left lower lobe	1.03	0.40-2.67	.95
Overlapping lesion of the lung	0.43	0.08-2.35	.33
Insurance status (reference: not insured)			
Private insurance/managed care	0.46	0.33-0.65	<.001
Medicaid	0.96	0.68-1.38	.84
Medicare	1.35	0.97-1.89	.08
Other government	1.95	1.28-2.99	.002
Distance from hospital	1.00	1.00-1.00	.38
Rurality (reference: nonmetropolitan)			
Metropolitan	1.02	0.84-1.23	.86
Year of diagnosis (reference: 2010)			
2011	1.12	0.74-1.68	.60
2012	1.53	1.04-2.23	.03
2013	1.57	1.08-2.28	.02
2014	1.65	1.15-2.39	.007
2015	1.96	1.38-2.78	<.001
2016	1.77	1.25-2.51	.001
2017	1.59	1.11-2.26	.01
2018	2.08	1.47-2.93	<.001

SBRT, Stereotactic body radiotherapy; *NSCLC*, non–small cell lung cancer *OR*, odds ratio; *CI*, confidence interval. *Median household income of individuals living in the patient's ZIP code. †Percentage of adults age >25 years living in the patient's ZIP code who did not graduate from high school.

TABLE E8. Changes in the hazard of death from any cause in patients diagnosed with clinical stage I NSCLC from 2010 to 2018: multivariable-adjusted Cox proportional hazards analysis

Characteristic	HR	95% CI	*P* value
Sex (reference: male)	0.77	0.75-0.79	<.001
Age	1.04	1.04-1.04	<.001
Race (reference: white)			
Black	0.98	0.94-1.01	.20
Native American	0.98	0.80-1.19	.83
Asian	0.60	0.55-0.65	<.001
Tumor size	1.02	1.01-1.02	<.001
Clinical T stage (reference: T1a)			
T1b	1.08	1.02-1.13	.005
T1c	1.13	1.06-1.20	<.001
T2a	1.14	1.06-1.23	.001
Facility type (reference: community cancer program)			
Comprehensive community cancer program	0.86	0.82-0.90	<.001
Academic/research program	0.78	0.75-0.82	<.001
Integrated network cancer program	0.83	0.79-0.87	<.001
Annual income* (reference <$40,227)			
$40,277-$50,353	0.92	0.89-0.95	<.001
$50,354-$63,332	0.86	0.83-0.89	<.001
>$63,333	0.79	0.76-0.82	<.001
CDCC (reference: 0)			
1	1.12	1.09-1.14	<.001
2	1.32	1.28-1.36	<.001
3+	1.70	1.64-1.77	<.001
Education† (reference >17.6%)			
10.9%-17.5%	1.02	0.99-1.05	.23
6.3%-10.8%	1.05	1.01-1.08	.009
<6.3%	0.95	0.92-0.99	.03
Histology (reference: adenocarcinoma)			
Squamous cell carcinoma	1.30	1.27-1.33	<.001
Large cell carcinoma	1.48	1.38-1.58	<.001
Adenosquamous carcinoma	1.27	1.19-1.36	<.001
Atypical carcinoid	0.66	0.56-0.78	<.001
Tumor location (reference: right upper lobe)			
Right upper lobe	0.66	0.58-0.75	<.001
Right middle lobe	0.70	0.61-0.81	<.001
Right lower lobe	0.68	0.59-0.78	<.001
Left upper lobe	0.69	0.60-0.79	<.001
Left lower lobe	0.67	0.59-0.77	<.001
Bilateral	2.65	0.85-8.30	.09
Overlapping lesion of the lung	0.70	0.58-0.84	<.001
Insurance status (reference: not insured)			
Private insurance/managed care	0.68	0.62-0.74	<.001
Medicaid	1.05	0.95-1.16	.31
Medicare	0.79	0.72-0.86	<.001
Other government	0.91	0.81-1.02	.12
Distance from hospital	1.00	1.00-1.00	.96
Rurality (reference: nonmetropolitan)			
Metropolitan	0.94	0.91-0.97	<.001
Year of diagnosis	0.96	0.96-0.97	<.001

NSCLC, Non–small cell lung cancer; *HR*, hazard ratio; *CI*, confidence interval; *CDCC*, Charlson–Deyo Comorbidity Score. *Median household income of individuals living in the patient's ZIP code. †Percentage of adults age >25 years living in the patient's ZIP code who did not graduate from high school.

THOR