ORIGINAL ARTICLE

Lung Cancer Treatment Trends During the Coronavirus Disease 2019 (COVID-19) Pandemic: A Claims and Order Data Analysis (2019–2021)

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ABSTRACT

Introduction: Lung cancer is treated using systemic therapy, radiation therapy (RT), and surgery. This study evaluates how utilization of these modalities and cancer stage at initial treatment shifted from 2019 to 2021.

Methods: Claims for lung cancer treatment were extracted from the database of a national health care organization offering Medicare Advantage health plans and paired with enrollment data to determine utilization rates. Seasonally adjusted rates were trended, with monotonicity evaluated using Mann-Kendall tests. Using contemporaneous prior authorization order data, the association between year and the patient's cancer stage at the time of the initial RT or surgery order was evaluated through univariable and multivariable analyses.

Results: The study considered 140.9 million beneficiary-months of data. There were negative and significantly monotonic trends in utilization of RT ($p = 0.033$) and systematic therapy ($p = 0.003$) for initial treatment between January 2020 and December 2021. Analysis of RT and surgery order data revealed that the patients were significantly ($p < 0.001$) more likely to have advanced (stage III or IV) cancer at the time of their surgery order in 2020 and 2021 than in 2019. After adjusting for urbanicity, age, and local income, a significant relationship between year of the initial order and presence of advanced cancer at the time of ordering was found for surgery orders placed in 2020 ($p < 0.001$) and 2021 ($p < 0.01$), but not for RT orders.

Conclusions: There was a per-capita reduction in lung cancer treatment in 2020 and 2021, and patients receiving initial orders for surgery after the onset of the pandemic had more advanced cancer.

Keywords: COVID-19; Radiation therapy; Systemic therapy; Surgery; Wedge resection

Introduction

In response to the coronavirus disease 2019 (COVID-19) pandemic, the Centers for Medicare & Medicaid Services released recommendations that nonessential medical, surgical, and dental procedures be delayed to preserve the availability of hospital capacity and personal protective equipment.[1] This policy caused patients

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to delay or forgo screenings, diagnostic tests, and nonurgent or elective treatments across multiple domains of care unrelated to COVID-19. As delivering treatment became more hazardous to patients and resources were constrained as a consequence of the pandemic, physicians and researchers published several articles advocating for altering the approach to treatment and reconsidering the relative risks and benefits of various treatment options.[2–6] Furthermore, the stage at which patients were diagnosed with lung cancer may itself have changed as a byproduct of the pandemic, as many patients delayed or forwent screening.[7] When patients are not screened for cancer in a timely fashion, diagnoses of cancer may be missed, and when they are made, may be for more advanced disease than would have been found had such delays not occurred.[8–12]

Although prior research has revealed that cancer care changed in response to the pandemic, the impact of that change on stage at initial treatment is unclear. At the South East London Cancer Alliance, there was a decrease in lung cancer diagnoses, although the decrease was less marked than found for prostate, gynecologic, and breast cancers.[13] Data from the University of Cincinnati's lung cancer screening program revealed that mean monthly low-dose computed tomography screenings were significantly ($p < 0.01$) lower from March to July 2020 than they had been in the baseline period (January 2017 to February 2020) and that the percentage of patients with suspicious malignancies was significantly ($p < 0.01$) increased.[7] Nevertheless, data from the UMass Memorial Tumor Registry found that there was no significant change in lung cancer stage at presentation during the pandemic (2020 and 2021) versus what had been observed before the pandemic (2018 and 2019).[14]

The contradictory findings of these single-site studies may be a result of variation in local practices and restrictions on care during the pandemic. Furthermore, none may be generalizable to the United States as a whole. To address these gaps, this study provides a multisite perspective on how lung cancer treatment changed during the pandemic by using claims and prior authorization order data from a national organization offering Medicare Advantage health plans. This study evaluated how the use of systemic therapy, radiation therapy (RT), and surgery for the treatment of lung cancer shifted between 2019 and 2021. By considering these three years, the study evaluated the following three discrete phases: prepandemic, prevaccination, and postvaccination.

Materials and Methods

Study Design

This study was reviewed by the Advarra Institutional Review Board (Pro00064835) and received an exemption from oversight on July 21, 2022, in accordance with the Department of Health and Human Services regulations found at 45 CFR 46.104(d)(4). The study was conducted in accordance with the principles of the Declaration of Helsinki. Two separate but related analyses were conducted: one evaluating claims for systemic therapy, RT, and surgery for the treatment of lung cancer and a second analysis evaluating orders for RT and surgery that went through prior authorization.

Claims data capture all the care that was billed by health care providers to the health plans and contain information on both the procedures performed and the diagnoses used to justify them. They do not, however, capture many clinical details, such as the patient's stage of cancer at the time the claim was billed. Meanwhile, prior authorization order data contain information that the health care provider submitted to the health plans before care was delivered to request that payment be authorized. Orders for RT and surgery for patients with lung cancer contain information on the patient's stage of cancer, unlike claims data. As not all care is required to go through prior authorization, and not all orders go through the same prior authorization vendor, order data are less comprehensive than claims data. This study was not able to consider systemic therapy in the order analysis, as this information was not available. The organization providing prior authorization for RT and surgery did not provide the health plans with prior authorization for systemic therapy.

Data Source and Sample Population

Claims Data. The claims analysis was conducted using retrospective, observational claims data from a national organization offering Medicare Advantage health plans. Claims incurred from January 1, 2019, to December 31, 2021, for systemic therapy, RT, and lung surgery, listing an International Classification of Diseases, tenth revision, diagnosis code related to lung cancer, pertaining to patients between 18 and 89 years of age, were extracted from the claims database. This set of claims was then used to determine the patients who received lung cancer treatment during those years. Claims were excluded from the analysis if the patient was not continuously enrolled in their health plan during the prior 12 months. The national health care organization's enrollment data, pertaining to patients with Medicare Advantage health plans between January 2019 and December 2021, were also extracted so that the characteristics of the health plan beneficiaries—both receiving and not receiving treatment for lung cancer—could be determined.

Order Data. Orders for RT and surgery for the treatment of lung cancer placed between January 1, 2019, and

December 31, 2021, were extracted from the database of a specialty benefit management company providing RT prior authorization services to the national health care organization that supplied the claims database. As the specialty benefit management company did not provide the national health care organization with prior authorization services related to systemic therapy during the time of the analysis, only orders for RT and surgery were considered. Orders were excluded from the analysis if the patient was not continuously enrolled in their health plan during the prior 12 months, if the patient had an order for RT or surgery or a claim for lung cancer treatment in the prior year, or if the order did not pertain to a patient between 18 and 89 years of age. The data associated with each order were reviewed to determine the patient's stage of lung cancer at the time of order entry. The patient's stage of lung cancer was documented by the ordering provider during the prior authorization order entry process and appeared in a standardized field within the order.

Measurement

Claims Data. Each month, the number of patients receiving initial lung cancer treatment was determined. Patients were considered to have received initial treatment if they had not received lung cancer treatment in the prior 12 months. The number of patients who received systemic therapy, RT, surgery, and all potential combinations thereof as their initial lung cancer treatment was determined. Lung cancer was defined using the diagnosis codes indicated in Appendix A1, and claims-based definitions of the treatments are provided in Appendices A2 to A4. Patients were considered to have received a form of treatment if they had one or more claims for that type of treatment in a given month. To assess how the comorbidity profile of patients shifted over time, claims for the patients' initial treatments were evaluated for diagnosis codes related to common lung cancer comorbidities, as defined in Appendix A5. The percentage of patients with initial lung cancer treatment claims experiencing each comorbidity was noted for each year. Percentages were reported for the three most common comorbidities. The same three comorbidities were most frequently observed in all the years included in the analysis.

To determine the number of patients receiving care in general, the number of patients receiving any treatment (initial or not) in each month was also determined. Patients were considered to have received a type of treatment if they had one or more claims for that type of treatment in a given month.

Order Data. Orders for lung RT and surgery were defined by selecting orders with the indication names presented in Appendices A6 and A7. The dependent variable used in the order analysis was the patient's cancer stage at the time of order entry. The independent variable was the timing of the order. Using the date of the order, a categorical variable was generated, indicating the quarter in which the order was placed. A series of control variables were created to capture patient characteristics: the patient's age at the time of the order, the urbanicity of the patient's home ZIP code, the median income of the patient's home ZIP code, and the line of business of the patient's health plan (commercial or Medicare Advantage). ZIP codes were mapped to urbanicity using a table produced by the Centers for Medicare & Medicaid Services and were mapped to median income using the American Community Survey's 2015 to 2019 five-year estimates, which reported income in 2019 inflation-adjusted dollars.[15,16]

Analysis

Claims Data. Utilization rates per capita were determined each month in the observation period by dividing the number of patients with an applicable lung cancer treatment claim (any systemic therapy, any RT, any surgery, or any type of treatment) by the number of people enrolled in the health plan in the month in question. Utilization rates per capita were calculated separately for patients receiving initial treatment and for the totality of patients receiving treatment (both initial and noninitial). Mann-Kendall tests were used to evaluate the monotonicity of the month-by-month trend in utilization of each type of treatment, and both Tau (T) and the level of statistical significance of the trend were reported for each significant trend. To normalize for seasonality in utilization, utilization rates in each month in 2020 and 2021 were divided by utilization rates occurring during the same month in 2019. Rates of utilization, from January 2020 to December 2021, normalized to their same month 2019 levels, were then plotted.

Order Data. A chi-square test was used to determine whether an association was present between the year an order was placed and the patient's lung cancer stage. Chi-square tests were repeated separately for orders for RT versus surgery. A multivariable logit model was run to assess the association between the quarter in which an order was placed and whether the patient receiving the order had advanced lung cancer (stage III or IV) at the time the order was placed, after controlling for the following control variables: the patient's urbanicity, sex, age, and the median income in the patient's home ZIP code. The model considering both RT and surgery orders also controlled for order type (RT versus surgery).

Results

Claims Analysis Results

Data in claims data and order data analyses pertained to 140,857,706 beneficiary-months of health plan enrollment or an average of 3,912,714 beneficiaries per month in a 36-month span.

Initial Treatment Utilization. As found in Figure 1, there was greater utilization of RT and surgery and less utilization of systemic therapy as initial treatment in January 2020 than there had been in January 2019. In April 2020, the first full month of the pandemic, the rate at which patients received surgery was only 74.4% of what it had been in April 2019. Likewise, the RT utilization rate in April 2020 was only 88.9% of the rate observed in April 2019. The rate at which patients used systemic therapy was 83.3% of the April 2019 level in April 2020. Overall, patients were 83.1% as likely to receive treatment in April 2020 as they had been the prior April. The trend lines were evaluated for monotonicity using Mann-Kendall tests, and two of the four trends in Figure 1 were significantly monotonic: RT utilization ($T = -0.316$, $p = 0.033$) and systemic therapy utilization ($T = -0.434$, $p = 0.003$). There was no significant monotonic trend in surgery utilization ($T = -0.203$, $p = 0.172$) or in utilization of any treatment ($T = -0.069$, $p = 0.655$).

The reported prevalence of the most common comorbidity, shortness of breath, declined across the years, from 15.5% in 2019 to 14.4% in 2020 to 12.9% in 2021. The prevalence of pneumonia from an unspecified organism declined from 8.4% in 2019 to 7.7% in 2020 to 6.8% in 2021. Likewise, the prevalence of unspecified chest pain declined from 7.2% in 2019 to 6.1% in 2020 to 6.0% in 2021.

Total Treatment Utilization. As it is possible that initial treatment utilization patterns are different from use patterns overall—considering patients that both initiated treatment and continued treatment in a given month—the rates at which the patient population received RT, surgery, systemic therapy, or any treatment in each month of 2020 and 2021 were compared with the rates at which the patient population received these modes of treatment for lung cancer in 2019 (Fig. 2). In April 2020, the first complete month in which elective care was deferred due to the pandemic, the rate of surgery utilization was 75.1% of what was observed in April 2019, RT utilization was 98.3% of the April 2019 rate, systemic therapy utilization was 99.5% of the April 2019 rate, and utilization of any treatment was 98.1% of the April 2019 rate. Mann-Kendall tests found evidence of monotonicity when total utilization (initial and noninitial) was considered in all the trendlines, except the trendline evaluating surgery utilization ($T = -0.236$, $p = 0.112$). There was a significantly monotonic, negative trend for RT ($T = -0.428$, $p = 0.004$), systemic therapy ($T = -0.64$, $p < 0.001$), and any treatment ($T = -0.606$, $p < 0.001$).

Order Analysis Results

As found in Figure 3, 14,161 orders met the inclusion criteria for the order analysis. After the exclusion criteria were applied, only 9055 orders remained.

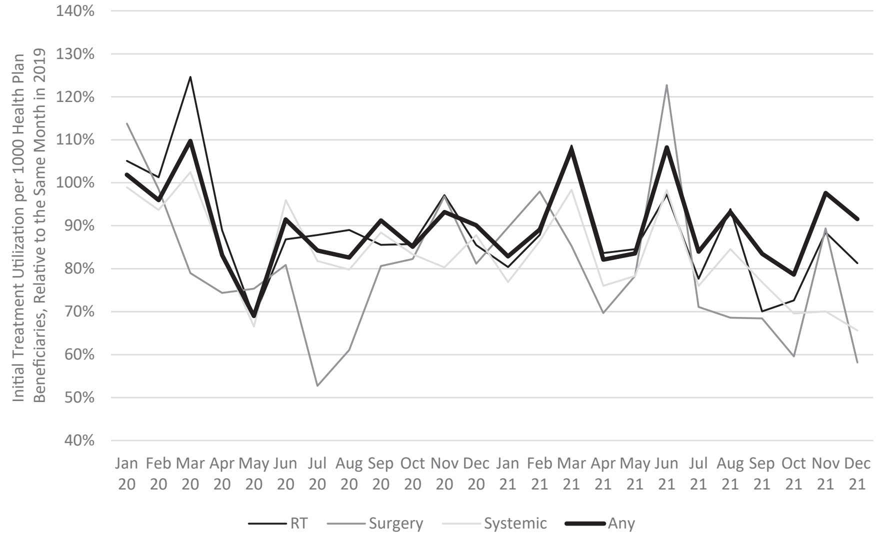

Figure 1. Month-by-month initial treatment utilization in 2020 and 2021, relative to the same month in 2019. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; RT, radiation therapy; Sep, September.

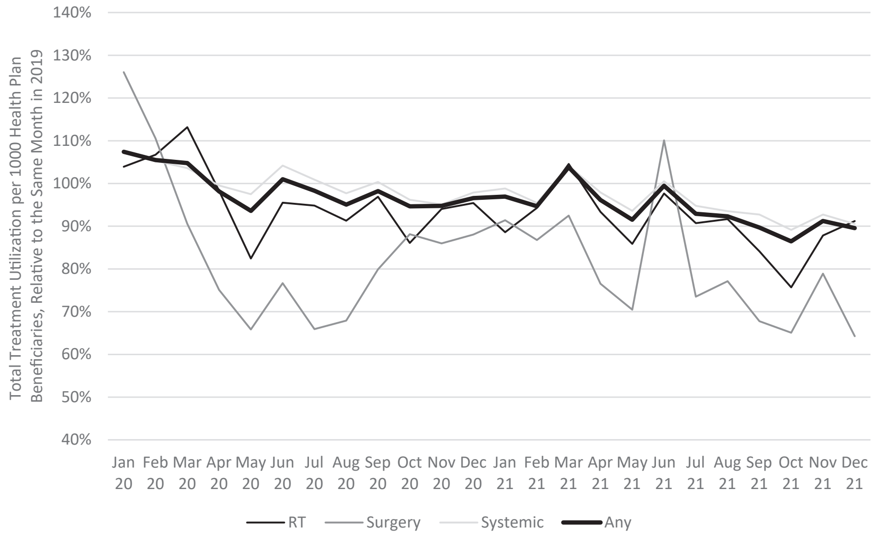

Figure 2. Month-by-month total treatment utilization in 2020 and 2021, relative to the same month in 2019. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; RT, radiation therapy; Sep, September.

The descriptive statistics, presented in Table 1, reveal most of the orders pertained to patients living in urban areas. The percentage of orders pertaining to females ranged from 48.6% in 2019 to 53.3% in 2021. Most of the patients included in the analysis were between 70 and 79 years of age and came from ZIP codes with median incomes between \$40,000 and \$80,000 per year. The percentage of orders that were for surgery ranged from a low of 11.1% in 2021 to a high of 12.6% in 2019.

Univariable Findings. No association was found between the year of the RT order and whether the order was for a patient with stage I or II versus stage III or IV lung cancer ($p = 0.562$). Nevertheless, there was a highly significant relationship between year and cancer stage at the time of surgery orders ($p < 0.001$). As found in Figure 4, the percentage of surgery orders pertaining to patients with advanced lung cancer was 47.2% in 2019, 61.7% in 2020, and 58.7% in 2021. When the two sets of orders were pooled, the relationship between year and stage was not significant ($p = 0.753$).

Multivariable logistic regressions were run to determine the factors associated with whether a patient receiving an initial order for treatment had advanced lung cancer. The analysis was performed by pooling RT and surgery orders, and then controlling for order type, and by evaluating RT and surgery orders separately. As shown in Table 2, the pooled analysis found no association between year and the stage of cancer indicated on the order. Nevertheless, patients living in rural areas ($p < 0.01$) and male ($p < 0.001$) patients were significantly more likely to have advanced cancer at the time of their initial treatment order. Patients aged 70 to 79 years ($p < 0.05$) and 80 to 89 years ($p < 0.001$) were significantly less likely to have advanced cancer at the time of their initial treatment order than were patients aged 18 to 64 years. Given that most of the sample consisted of orders for RT, when the RT orders were evaluated separately, the same variables were significant, in the same directions, as in the pooled analysis. When orders for surgery were evaluated separately, patients receiving orders in 2020 ($p < 0.001$) and 2021 ($p < 0.01$) were significantly more likely to have advanced cancer at the time of their order. None of the other variables considered in the surgery order analysis were associated with patients' likelihood of having advanced cancer at the time of their initial treatment order.

Discussion

Our analysis of claims data revealed that the COVID-19 pandemic reduced all forms of lung cancer treatment utilization, with the impact particularly pronounced for surgery. This was congruent with the findings of a study evaluating lung cancer treatment at a medical center in Japan in March 2020 to May 2020, which found that 9% of patients experienced a treatment delay, with 80% of treatment delays occurring owing to the patient's request due to anxiety regarding the potential for COVID-19 infection.[17] Likewise, an analysis of data on lung surgeries between January 2019 and December 2020 from the Polish National Lung Cancer Registry found a significant ($p < 0.001$) 21% decrease in lung surgeries in 2020, relative to 2019.[18]

The order analysis suggests that patients receiving surgery as initial treatment were at a more advanced

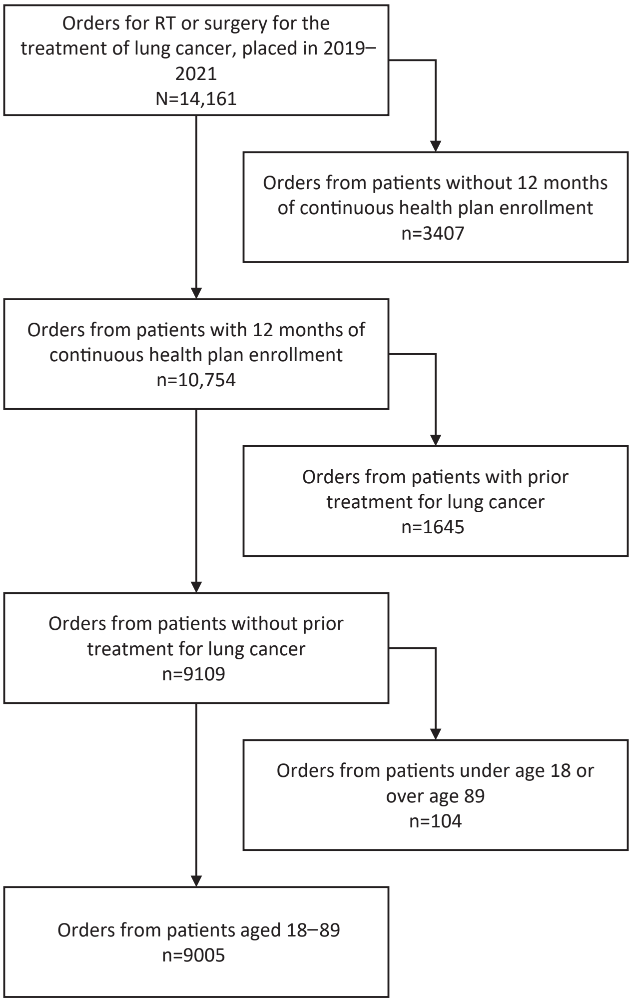

Figure 3. Participant selection diagram. RT, radiation therapy.

stage of lung cancer after the onset of the pandemic. This could have been driven by multiple factors, including patients with less advanced cancer being deprioritized for surgery, or by delays in care. In contrast to this finding, the prevalence of each of the three most common comorbidities listed on claims for initial treatment declined in the three-year period. This could have been an artifact of a decrease in coding quality as a consequence of more abbreviated clinical workups during the pandemic, due to reduced treatment for frailer patients, or the result of a combination of factors.

One driver of the RT findings may be that practice guideline recommendations issued during the pandemic advocated for the delayed and reduced use of RT to conserve health care system resources and to protect patients from potential COVID-19 infection. Reduced use of RT as a treatment modality came in the forms of greater use of hypofractionated approaches, substitution of systemic therapy or immunotherapy for RT, and decreased use of RT for patients nearing the end of life.[3,19] As most of our study focused on the initiation of treatment, increased use of hypofractionation would only be reflected in Figure 2, which reveals how the proportion of patients receiving RT as both initial and noninitial treatment shifted over time. There has been a call for clinicians to risk stratify patients, as there are potential harms resulting from both delay and exposure to infection during treatment.[20,21]

Our analysis of order data, which were available for RT and surgery, but not systemic therapy, found that patients were significantly more likely to have advanced lung cancer if their orders for surgery were placed in 2020 ($p < 0.001$) or 2021 ($p < 0.01$), rather than 2019. Year was not associated with stage for RT orders or for treatment orders overall. As RT orders were several times more numerous than surgery orders, the examination of a combined set of RT and surgery orders predominantly reflects the outcomes observed within the pool of surgery orders. Data reported from Italy have likewise revealed that there was a decrease in the surgical treatment of early stage lung cancers from June to September of 2020, relative to the same period in 2019.[22] These findings, however, are contrary to findings on the basis of data on lung cancer surgeries performed at the Brigham and Women's Hospital in Boston, where there was no difference in the percentage of cases that were for stage III or IV cancer in March to May 2020, relative to cases from 2019.[23]

Table 1. Descriptive Statistics

Variable	2019 (n = 2815)	2020 (n = 2996)	2021 (n = 3194)	All (N = 9005)
Urbanicity: rural; n (%)	693 (24.6)	758 (25.3)	863 (27.0)	2314 (25.7)
Sex: female; n (%)	1369 (48.6)	1523 (50.8)	1702 (53.3)	4594 (51.0)
Age: 65-69 y; n (%)	474 (16.8)	583 (19.5)	641 (20.1)	1698 (18.9)
Age: 70-79 y; n (%)	1490 (52.9)	1541 (51.4)	1555 (48.7)	4586 (50.9)
Age: 80-89 y; n (%)	514 (18.3)	518 (17.3)	612 (19.2)	1644 (18.3)
Income: below \$40k; n (%)	436 (15.5)	464 (15.5)	505 (15.8)	1405 (15.6)
Income: above \$80k; n (%)	305 (10.8)	313 (10.4)	357 (11.2)	975 (10.8)
Order type: surgery; n (%)	356 (12.6)	339 (11.3)	356 (11.1)	1051 (11.7)
Order stage: stage I or II; n (%)	1212 (43.1)	1270 (42.4)	1366 (42.8)	3848 (42.7)

k, thousand.

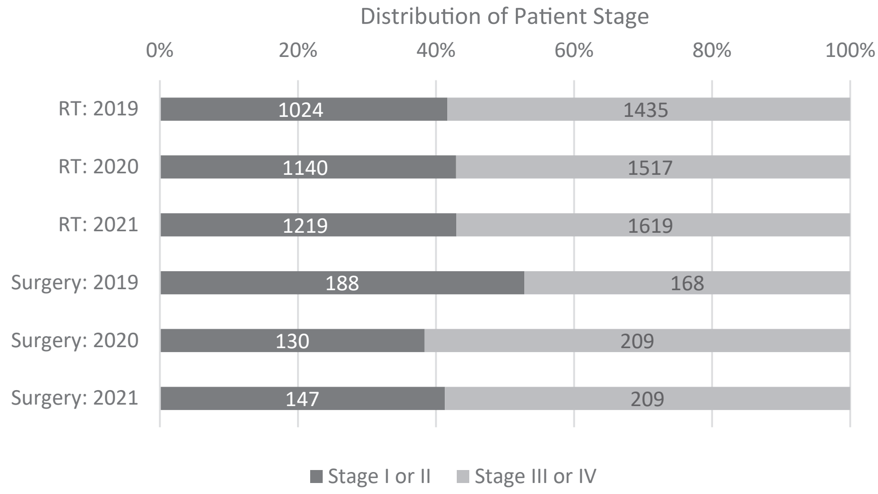

Figure 4. Distribution of patient stage at time of treatment by year and treatment type. RT, radiation therapy.

Patients may have received initial cancer treatment at a more advanced stage of disease owing to decreased early detection. An analysis of data from the low-dose computed tomography lung cancer screening program at the University of Cincinnati found that screening remained reduced, and no-show visits for screening remained increased after screenings resumed. Although only 8% of the patients screened between January 2017 and February 2020 had lung nodules suggestive of malignancy, 29% of the patients screened between March and July 2020 had suspicious nodules.[7] The delays in screening observed were consistent with the recommendations for more conservative approaches to screening that were made during the pandemic.[8]

In the adjusted analyses of the pooled orders and the RT orders, rural patients were significantly ($p < 0.01$) more likely to have advanced lung cancer at the time of initial treatment. Rural patients may have more difficulty accessing care owing to both the reduced availability of treatment facilities in rural areas and longer travel times necessary to receive treatment. Prior research has revealed that among patients with early stage NSCLC, rural residence is associated with not receiving guideline-concordant RT or surgery.[24]

In the pooled analysis and the analysis of RT orders, women were significantly ($p < 0.001$) less likely than men to have advanced cancer at the time of treatment. This was consistent with findings from an analysis of 2005 to 2018 Surveillance, Epidemiology, and End Results program data, which revealed that women were significantly ($p < 0.001$) more likely to have stages 0 to II lung cancer than men.[25] Previous research suggests that when lung cancer is untreated, it may have a different natural history in women than in men.[26]

In the pooled analysis and the analysis of RT orders, patients aged 70 to 79 years ($p < 0.05$) and 80 to 89 years ($p < 0.001$) were significantly less likely than patients aged 18 to 64 years to have advanced cancer at the time of initial treatment. As all the patients included in the analysis had Medicare Advantage health plans,

Table 2. Multivariable Logistic Regressions Evaluating Factors Associated With Advanced (Stage III or IV) Lung Cancer at the Time of Initial Treatment Order

Variable	All, OR (95% CI)	Radiation Therapy, OR (95% CI)	Surgery, OR (95% CI)
Year: 2020 (vs. 2019)	1.02 (0.92-1.13)	0.95 (0.85-1.06)	1.78 (1.32-2.42)
Year: 2021 (vs. 2019)	1.01 (0.91-1.12)	0.95 (0.85-1.06)	1.58 (1.17-2.13)
Urbanicity: rural (vs. urban)	1.15 (1.04-1.28)	1.15 (1.03-1.28)	1.22 (0.90-1.64)
Sex: female (vs. male)	0.78 (0.72-0.85)	0.76 (0.70-0.83)	1.01 (0.79-1.30)
Age: 65-69 y (vs. 18-64 y)	0.97 (0.83-1.13)	0.95 (0.80-1.13)	1.07 (0.71-1.62)
Age: 70-79 y (vs. 18-64 y)	0.77 (0.67-0.88)	0.76 (0.65-0.88)	0.82 (0.57-1.17)
Age: 80-89 y (vs. 18-64 y)	0.51 (0.43-0.59)	0.48 (0.41-0.57)	0.82 (0.50-1.34)
Income: below $40k (vs. $40k-80k or unknown)	1.05 (0.93-1.18)	1.08 (0.95-1.22)	0.87 (0.60-1.27)
Income: above $80k (vs. $40k-80k or unknown)	1.00 (0.87-1.14)	0.98 (0.85-1.14)	1.06 (0.72-1.56)
Order type: surgery (vs. radiation therapy)	0.90 (0.79-1.02)	-	-

CI, confidence interval; k, thousand.

patients aged 18 to 64 years had a permanent disability or an illness that qualified them for Medicare, such as end-stage renal disease or amyotrophic lateral sclerosis.[27] Thus, patients aged 18 to 64 years may both have had more difficulty accessing care than the general Medicare Advantage population due to their qualifying condition and may have potentially been more hesitant to seek care due to overall frailty and concerns over potential exposure to COVID-19 while accessing care.

The Food and Drug Administration issued emergency use authorizations for COVID-19 vaccines from Moderna and Pfizer in mid-December 2020, and their staged rollout began thereafter.[28] Given the five-week period required to complete vaccination at the time, the first vaccine recipients were considered to have achieved full protection in late January 2021 and the months that followed. Although there was state-based variation in the order in which patients were vaccinated, the Centers for Disease Control and Prevention recommended that older people and people at risk for severe COVID-19 for reasons such as cancer receive prioritization in vaccination.[29] Thus, the impact of COVID-19 on lung cancer treatment may have been attenuated in early 2021 as patients with lung cancer achieved full protection.

Limitations

Although this study used two sets of data to provide a window into how lung cancer treatment evolved during a set time period, there are a number of limitations. The claims and order data pertained to the same population of individuals with health plans from a national organization. Thus, the two analyses offer different perspectives on the care used by one population, rather than perspectives on two populations. Relatedly, although the patients lived across the United States, they were not distributed evenly—the patients were predominantly concentrated in the South. Thus, the sample is not representative of the nation at large. Patients from states with age-adjusted lung cancer death rates above the national average were overrepresented in the population, suggesting that the population studied may have used lung cancer treatment more extensively than the overall nation.[30]

Unlike the claims-based analysis, which evaluated utilization of systemic therapy, in addition to RT and surgery, the order-based analysis only considered the stage at which patients received RT and surgery. The analysis relied on the accuracy of the declarations made during the prior authorization process, and it was not possible to observe progression. Data on patients' grade, comorbidities, and smoking status were likewise unavailable and thus could not be included in the models. Systemic therapy order data were also not available, as the specialty benefit management company that supplied the order data was not responsible for managing systemic therapy benefits. Although the omission of systemic therapy orders from the analysis changes the clinical profile of the patients, relative to the more holistic claims-based analysis, it is still possible to make inferences about how the stage at which patients received RT and surgery changed during the three-year period.

Likewise, the claims-based definitions and order-based definitions of RT and surgery are slightly different, as found in the Appendix. Not all cancer-related care is subject to prior authorization. Nonetheless, the prior authorization data provided a snapshot of how patients' stage at initial treatment changed over time and helped provide context to the observations found in the claims data.

In conclusion, these findings collectively suggest that there was a per-capita reduction in lung cancer treatment in both the prevaccination and postvaccination phases of the pandemic. Treatment utilization was depressed in 2020 and 2021, relative to 2019. Furthermore, patients receiving initial orders for surgical treatment were significantly ($p < 0.01$) more likely to have advanced lung cancer after the onset of the pandemic. Future research should investigate whether patients continue to face COVID-19–related barriers in accessing lung cancer screening and treatment.

CRediT Authorship Contribution Statement

Adam C. Powell: Conceptualization, Investigation, Methodology, Project Administration, Visualization, Writing - original draft.

Logan M. Horrall: Conceptualization, Data curation, Formal Analysis, Methodology, Writing - review and editing.

James W. Long: Conceptualization, Resources, Supervision, Validation, Writing - review and editing.

Bryan A. Loy: Conceptualization, Methodology, Validation, Writing - review and editing.

Amin J. Mirhadi: Conceptualization, Methodology, Validation, Writing - review and editing.

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Appendix

Appendix A1. Definition of Lung Cancer

Definition	ICD-10-CM
Malignant neoplasm of upper lobe, unspecified bronchus or lung	C34.10
Malignant neoplasm of upper lobe, right bronchus or lung	C34.11
Malignant neoplasm of upper lobe, left bronchus or lung	C34.12
Malignant neoplasm of middle lobe, bronchus or lung	C34.2
Malignant neoplasm of lower lobe, unspecified bronchus or lung	C34.30
Malignant neoplasm of lower lobe, right bronchus or lung	C34.31
Malignant neoplasm of lower lobe, left bronchus or lung	C34.32
Malignant neoplasm of overlapping sites of unspecified bronchus and lung	C34.80
Malignant neoplasm of overlapping sites of right bronchus and lung	C34.81
Malignant neoplasm of overlapping sites of left bronchus and lung	C34.82
Malignant neoplasm of unspecified part of unspecified bronchus or lung	C34.90
Malignant neoplasm of unspecified part of right bronchus or lung	C34.91
Malignant neoplasm of unspecified part of left bronchus or lung	C34.92
Kaposi's sarcoma of unspecified lung	C46.50
Kaposi's sarcoma of right lung	C46.51
Kaposi's sarcoma of left lung	C46.52
Secondary malignant neoplasm of unspecified lung	C78.00
Secondary malignant neoplasm of right lung	C78.01
Secondary malignant neoplasm of left lung	C78.02
Carcinoma in situ of unspecified bronchus and lung	D02.20
Carcinoma in situ of right bronchus and lung	D02.21
Carcinoma in situ of left bronchus and lung	D02.22
Benign neoplasm of bronchus and lung	D14.3

ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.

Appendix A2. Claims-Based Definition of Radiation Therapy

2D/3D	HCPCS
Radiation treatment delivery, >1 MeV; simple	77402
Radiation treatment delivery, >1 MeV; intermediate	77407
Radiation treatment delivery, >1 MeV; complex	77412
Radiation treatment delivery, single treatment area, single port or parallel opposed ports, simple blocks or no blocks: up to 5 MeV	G6003
Radiation treatment delivery, single treatment area, single port or parallel opposed ports, simple blocks or no blocks: 6–10 MeV	G6004
Radiation treatment delivery, single treatment area, single port or parallel opposed ports, simple blocks or no blocks: 11–19 MeV	G6005
Radiation treatment delivery, single treatment area, single port or parallel opposed ports, simple blocks or no blocks: 20 MeV or greater	G6006
Radiation treatment delivery, 2 separate treatment areas, 3 or more ports on a single treatment area, use of multiple blocks: up to 5 MeV	G6007
Radiation treatment delivery, 2 separate treatment areas, 3 or more ports on a single treatment area, use of multiple blocks: 6–10 MeV	G6008
Radiation treatment delivery, 2 separate treatment areas, 3 or more ports on a single treatment area, use of multiple blocks: 11–19 MeV	G6009
Radiation treatment delivery, 2 separate treatment areas, 3 or more ports on a single treatment area, use of multiple blocks: 20 MeV or greater	G6010
Radiation treatment delivery, 3 or more separate treatment areas, custom blocking, tangential ports, wedges, rotational beam, compensators, electron beam; up to 5 MeV	G6011
Radiation treatment delivery, 3 or more separate treatment areas, custom blocking, tangential ports, wedges, rotational beam, compensators, electron beam; 6–10 MeV	G6012

(continued)

Appendix A2. Continued

2D/3D	HCPCS
Radiation treatment delivery, 3 or more separate treatment areas, custom blocking, tangential ports, wedges, rotational beam, compensators, electron beam; 11–19 MeV	G6013
Radiation treatment delivery, 3 or more separate treatment areas, custom blocking, tangential ports, wedges, rotational beam, compensators, electron beam; 20 MeV or greater	G6014
Brachytherapy	**HCPCS**
Intraoperative radiation treatment delivery, x-ray, single treatment session	77424
Intraoperative radiation treatment delivery, electrons, single treatment session	77425
Infusion or instillation of radioelement solution (includes 3 mo follow-up care)	77750
Intracavitary radiation source application; simple	77761
Intracavitary radiation source application; intermediate	77762
Intracavitary radiation source application; complex	77763
Remote afterloading high-dose rate radionuclide interstitial or intracavitary brachytherapy, includes basic dosimetry, when performed; 1 channel	77770
Remote afterloading high-dose rate radionuclide interstitial or intracavitary brachytherapy, includes basic dosimetry, when performed; 2–12 channels	77771
Remote afterloading high-dose rate radionuclide interstitial or intracavitary brachytherapy, includes basic dosimetry, when performed; over 12 channels	77772
Interstitial radiation source application, complex, includes supervision, handling, loading of radiation source, when performed	77778
High-dose rate electronic brachytherapy, interstitial or intracavitary treatment, per fraction, includes basic dosimetry, when performed	0395T
IMRT	**HCPCS**
Intensity-modulated radiation treatment delivery (IMRT), includes guidance and tracking, when performed; simple	77385
Intensity-modulated radiation treatment delivery (IMRT), includes guidance and tracking, when performed; complex	77386
Intensity-modulated treatment delivery, single or multiple fields/arcs, via narrow spatially and temporally modulated beams, binary, dynamic MLC, per treatment session	G6015
Compensator-based beam modulation treatment delivery of inverse planned treatment using 3 or more high resolution (milled or cast) compensator, convergent beam modulated fields, per treatment session	G6016
Neutron Therapy	**HCPCS**
High energy neutron radiation treatment delivery; 1 or more isocenter(s) with coplanar or non-coplanar geometry with blocking and/or wedge, and/or compensator(s)	77423
Proton Beam	**HCPCS**
Proton treatment delivery; simple, without compensation	77520
Proton treatment delivery; simple, with compensation	77522
Proton treatment delivery; intermediate	77523
Proton treatment delivery; complex	77525
Stereotactic Radiosurgery	**HCPCS**
Thoracic target(s) delineation for stereotactic body radiation therapy (SRS/SBRT), (photon or particle beam), entire course of treatment	32701
Stereotactic body radiation therapy, treatment delivery, per fraction to 1 or more lesions, including image guidance, entire course not to exceed 5 fractions	77373
Image-guided robotic linear accelerator-based stereotactic radiosurgery, complete course of therapy in one session, or first session of fractionated treatment	G0339
Image-guided robotic linear accelerator-based stereotactic radiosurgery, delivery including collimator changes and custom plugging, fractionated treatment, all lesions, per session, second to fifth sessions, maximum five sessions per course of treatment	G0340

2D/3D, two-dimensional/three-dimensional; HCPCS, Healthcare Common Procedure Coding System.

Appendix A3. Claims-Based Definition of Lung Surgery

Definition	HCPCS
Thoracotomy, with diagnostic biopsy(ies) of lung nodule(s) or mass(es) (e.g., wedge, incisional), unilateral	32097
Removal of lung, pneumonectomy	32440
Removal of lung, pneumonectomy; with resection of segment of trachea followed by broncho-tracheal anastomosis (sleeve pneumonectomy)	32442
Removal of lung, pneumonectomy; extrapleural	32445
Removal of lung, other than pneumonectomy; single lobe (lobectomy)	32480
Removal of lung, other than pneumonectomy; 2 lobes (bilobectomy)	32482
Removal of lung, other than pneumonectomy; single segment (segmentectomy)	32484
Removal of lung, other than pneumonectomy; with circumferential resection of segment of bronchus followed by bronchobronchial anastomosis (sleeve lobectomy)	32486
Removal of lung, other than pneumonectomy; with all remaining lung following previous removal of a portion of lung (completion pneumonectomy)	32488
Thoracotomy; with therapeutic wedge resection (e.g., mass, nodule), initial	32505
Thoracoscopy; with diagnostic biopsy(ies) of lung nodule(s) or mass(es) (e.g., wedge, incisional), unilateral	32608
Thoracoscopy, surgical; with lobectomy (single lobe)	32663
Thoracoscopy, surgical; with therapeutic wedge resection (e.g., mass, nodule), initial unilateral	32666
Thoracoscopy, surgical; with removal of two lobes (bilobectomy)	32670
Thoracoscopy, surgical; with removal of lung (pneumonectomy)	32671

HCPCS, Healthcare Common Procedure Coding System.

Appendix A4. Claims-Based Definition of Systemic Therapy

Description	HCPCS
Ado-trastuzumab emtansine	J9354
Afatinib	J8999
Alectinib	J8999
Amivantamab-vmjw	J9061
Atezolizumab	J9022
Bendamustine hydrochloride	J9033, J9034, J9036
Bevacizumab	C9257, J9035
Bevacizumab-awwb	Q5107
Bevacizumab-bvzr	Q5118
Bevacizumab-maly	J9999
Brigatinib	J8999
Cabozantinib	J8999
Capmatinib	J8999
Carboplatin	J9045
Cemiplimab-rwlc	J9119
Ceritinib	J8999
Cetuximab	J9055
Cisplatin	J9060
Crizotinib	J8999
Cyclophosphamide	J8530, J9070, J9071
Dabrafenib	J8999
Dacomitinib	J8999
Denosumab	J0897
Docetaxel	J9171
Doxorubicin hydrochloride	J9000
Durvalumab	J9173
Entrectinib	J8999
Erlotinib hydrochloride	J8999
Etoposide; etoposide phosphate	J8560, J9181

(continued)

Appendix A4. Continued

Description	HCPCS
Fam-trastuzumab deruxtecan-nxki	J9358
Gefitinib	J8565
Gemcitabine	J9198, J9201
Ipilimumab	J9228
Irinotecan hydrochloride	J9205, J9206
Larotrectinib	J8999
Lorlatinib	J8999
Lurbinectedin	J9223
Mobocertinib	J8999
Nivolumab	J9299
Osimertinib	J8999
Paclitaxel	J9267
Paclitaxel, albumin bound	J9264
Pamidronate disodium	J2430
Pembrolizumab	J9271
Pemetrexed	J9304, J9305
Pralsetinib	J8999
Ramucirumab	J9308
Selpercatinib	J8999
Sotorasib	J8999
Temozolomide	J8700, J9328
Tepotinib	J8999
Topotecan; topotecan hydrochloride	J8705, J9351
Trametinib	J8999
Vemurafenib	J8999
Vincristine sulfate	J9370
Vinorelbine tartrate	J9390
Zoledronic acid	J3489

HCPCS, Healthcare Common Procedure Coding System.

Appendix A5. Definitions of Comorbid Diagnoses

Definition	ICD-10-CM
Chest pain on breathing	R07.1
Precordial pain	R07.2
Pleurodynia	R07.81
Intercostal pain	R07.82
Other chest pain	R07.89
Chest pain, unspecified	R07.9
Chronic cough	R05.3
Dyspnea, unspecified	R06.00
Orthopnea	R06.01
Shortness of breath	R06.02
Acute respiratory distress	R06.03
Other forms of dyspnea	R06.09
Hemoptysis	R04.2
Pneumonia, unspecified organism	J18.9
Malignant neoplasm of upper lobe, unspecified bronchus, or lung	C34.10
Malignant neoplasm of upper lobe, right bronchus, or lung	C34.11
Malignant neoplasm of upper lobe, left bronchus, or lung	C34.12
Compression of vein	I87.1

ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.

Appendix A6. Prior Authorization Indication Names Classified as Lung RT

Indication Name
2D/3D: Lung cancer palliative care
2D/3D: Mesothelioma
2D/3D: Non-small cell lung cancer—stage I or II
2D/3D: Non-small cell lung cancer—stage III
2D/3D: Small cell lung cancer—extensive stage
2D/3D: Small cell lung cancer—limited stage
IMRT: Lung cancer—palliative care
IMRT: Mesothelioma
IMRT: Non-small cell lung cancer—stage I or II
IMRT: Non-small cell lung cancer—stage III
IMRT: Small cell lung cancer—extensive stage
IMRT: Small cell lung cancer—limited stage
Proton beam lung: Lung cancer—palliative treatment
Proton beam lung: Mesothelioma
Proton beam lung: Non-small cell lung cancer stage I or II
Proton beam lung: Non-small cell lung cancer stage III
Proton beam lung: Small cell lung cancer—extensive stage
Proton beam lung: Small cell lung cancer—limited stage
SBRT: Lung cancer—palliative care
SBRT: Mesothelioma
SBRT: Non-small cell lung cancer—stage I or II
SBRT: Non-small cell lung cancer—stage III
SBRT: Small cell lung cancer—extensive stage
SBRT: Small cell lung cancer—limited stage

2D/3D, two-dimensional/three-dimensional; IMRT, intensity-modulated radiation treatment delivery; RT, radiation therapy; SBRT, stereotactic body radiation therapy.

Appendix A7. Prior Authorization Indication Names Classified as Lung Surgery

Indication Name
Lung wedge resection
Thoracoscopy: lung wedge resection: pulmonary metastasis (metastasectomy)
Thoracoscopy: lung wedge resection: stage I or II lung cancer
Wedge resection of stage 3 lung cancer
Thoracoscopy: lung wedge resection: interstitial lung disease/ pulmonary fibrosis

References

1. Centers for Medicare & Medicaid Services. CMS releases recommendations on adult elective surgeries, non-essential medical, surgical, and dental procedures during COVID-19 response. https://www.cms.gov/newsroom/press-releases/cms-releases-recommendations-adult-elective-surgeries-non-essential-medical-surgical-and-dental. Accessed October 11, 2022.
2. Dingemans AM, Soo RA, Jazieh AR, et al. Treatment guidance for patients with lung cancer during the coronavirus 2019 pandemic. *J Thorac Oncol*. 2020;15:1119-1136.
3. Bakhribah H, Zeitouni M, Daghistani RA, et al. Implications of COVID-19 pandemic on lung cancer management: a multidisciplinary perspective. *Crit Rev Oncol Hematol*. 2020;156:103120.
4. Banna G, Curioni-Fontecedro A, Friedlaender A, Addeo A. How we treat patients with lung cancer during the SARS-CoV-2 pandemic: *primum non nocere*. *ESMO Open*. 2020;5:e000765.
5. Calabrò L, Peters S, Soria JC, et al. Challenges in lung cancer therapy during the COVID-19 pandemic. *Lancet Respir Med*. 2020;8:542-544.
6. Singh AP, Berman AT, Marmarelis ME, et al. Management of lung cancer during the COVID-19 pandemic. *JCO Oncol Pract*. 2020;16:579-586.
7. Van Haren RM, Delman AM, Turner KM, et al. Impact of the COVID-19 pandemic on lung cancer screening program and subsequent lung cancer. *J Am Coll Surg*. 2021;232:600-605.
8. Mazzone PJ, Gould MK, Arenberg DA, et al. Management of lung nodules and lung cancer screening during the COVID-19 pandemic: CHEST expert panel report. *Chest*. 2020;158:406-415.
9. Chen RC, Haynes K, Du S, Barron J, Katz AJ. Association of cancer screening deficit in the United States with the COVID-19 pandemic. *JAMA Oncol*. 2021;7:878-884.
10. Englum BR, Prasad NK, Lake RE, et al. Impact of the COVID-19 pandemic on diagnosis of new cancers: a national multicenter study of the Veterans Affairs Healthcare System. *Cancer*. 2022;128:1048-1056.
11. Croswell JM, Corley DA, Lafata JE, et al. Cancer screening in the U.S. through the COVID-19 pandemic, recovery, and beyond. *Prev Med*. 2021;151:106595.
12. Fedewa SA, Bandi P, Smith RA, Silvestri GA, Jemal A. Lung cancer screening rates during the COVID-19 pandemic. *Chest*. 2022;161:586-589.

13. Purushotham A, Roberts G, Haire K, et al. The impact of national non-pharmaceutical interventions ('lock-downs') on the presentation of cancer patients. *Ecancermedicalscience*. 2021;15:1180.
14. Mallouh M, Linshaw D, Barton B, et al. Changes in stage at presentation among lung and breast cancer patients during the COVID-19 pandemic. *J Am Coll Surg*. 2023;236:1164–1170.
15. Centers for Medicare & Medicaid Services. DME-rural-zip-and-formats. https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/DMEPOSFeeSched/DMEPOS-Fee-Schedule-Items/DME-Rural-Zip-and-Formats. Accessed February 3, 2022.
16. US Census Bureau. S1903 | Median income in the past 12 months (in 2019 inflation-adjusted dollars). https://data.census.gov/cedsci/table?text=S1903&tid=ACSST5Y2019.S1903&hidePreview=false. Accessed August 11, 2021.
17. Fujita K, Ito T, Saito Z, Kanai O, Nakatani K, Mio T. Impact of COVID-19 pandemic on lung cancer treatment scheduling. *Thorac Cancer*. 2020;11:2983–2986.
18. Piwkowski C, Gabryel P, Orłowski TM, Kowalewski J, Kużdżał J, Rzyman W. The impact of the COVID-19 pandemic on the surgical treatment of lung cancer. *Pol Arch Intern Med*. 2022;132:16191.
19. Guckenberger M, Belka C, Bezjak A, et al. Practice recommendations for lung cancer radiotherapy during the COVID-19 pandemic: an ESTRO-ASTRO consensus statement. *Radiother Oncol*. 2020;146:223–229.
20. Cafarotti S, Patella M. Lung cancer surgical management during the outbreak of coronavirus disease 2019. *J Thorac Oncol*. 2020;15:e81.
21. Zhao Z, Bai H, Duan J, Wang J. Recommendations of individualized medical treatment and common adverse events management for lung cancer patients during the outbreak of COVID-19 epidemic. *Thorac Cancer*. 2020;11:1752–1757.
22. Bertolaccini L, Sedda G, Spaggiari L. Paying another tribute to the COVID-19 pandemic: the decrease of early lung cancers. *Ann Thorac Surg*. 2021;111:745–746.
23. Dolan DP, Lee DN, Polhemus E, et al. Report on lung cancer surgery during COVID-19 pandemic at a high volume US institution. *J Thorac Dis*. 2022;14:2874–2879.
24. Nicoli CD, Sprague BL, Anker CJ, Lester-Coll NH. Association of rurality with survival and guidelines-concordant management in early-stage non-small cell lung cancer. *Am J Clin Oncol*. 2019;42:607–614.
25. Stabellini N, Bruno DS, Dmukauskas M, et al. Sex differences in lung cancer treatment and outcomes at a large hybrid academic-community practice. *JTO Clin Res Rep*. 2022;3:100307.
26. Wisnivesky JP, Halm EA. Sex differences in lung cancer survival: do tumors behave differently in elderly women? *J Clin Oncol*. 2007;25:1705–1712.
27. U.S. Department of Health & Human Services. Who's eligible for Medicare?. https://www.hhs.gov/answers/medicare-and-medicaid/who-is-eligible-for-medicare/index.html. Accessed December 21, 2022.
28. Federal Register. Authorizations of emergency use of two biological products during the COVID-19 pandemic; availability. https://www.federalregister.gov/documents/2021/01/19/2021-01022/authorizations-of-emergency-use-of-two-biological-products-during-the-covid-19-pandemic-availability. Accessed April 20, 2023.
29. Dooling K, Marin M, Wallace M, et al. The Advisory Committee on Immunization Practices' updated interim recommendation for allocation of COVID-19 vaccine-United States. *MMWR Morb Mortal Wkly Rep*. 2021;69:1657–1660.
30. QuickStats: Age-adjusted lung cancer death* rates,† by state—national vital statistics system, United States, 2018. *MMWR Morb Mortal Wkly Rep*. 2020;69:1273.