

# Survival Impact of an Enhanced Multidisciplinary Thoracic Oncology Conference in a Regional Community Health Care System



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## ABSTRACT

**Introduction:** We compared NSCLC treatment and survival within and outside a multidisciplinary model of care from a large community health care system.

**Methods:** We implemented a rigorously benchmarked “enhanced” Multidisciplinary Thoracic Oncology Conference (eMTOC) and used Tumor Registry data (2011–2017) to evaluate guideline-concordant care. Because eMTOC was located in metropolitan Memphis, we separated non-MTOC patient by metropolitan and regional location. We categorized National Comprehensive Cancer Network guideline-concordant treatment as “preferred,” or “appropriate” (allowable under certain circumstances). We compared demographic and clinical characteristics across cohorts using chi-square tests and survival using Cox regression, adjusted for multiple testing. We also performed propensity-matched and adjusted survival analyses.

**Results:** Of 6259 patients, 14% were in eMTOC, 55% metropolitan non-MTOC, and 31% regional non-MTOC cohorts. eMTOC had the highest rates of African Americans (34% versus 28% versus 22%), stages I to IIIB (63 versus 40 versus 50), urban residents (81 versus 78 versus 20), stage-preferred treatment (66 versus 57 versus 48), guideline-concordant treatment (78 versus 70 versus 63), and lowest percentage of nontreatment (6 versus 21 versus

28); all *p* values were less than 0.001. Compared with eMTOC, hazard for death was higher in metropolitan (1.5, 95% confidence interval: 1.4–1.7) and regional (1.7, 1.5–1.9) non-MTOC; hazards were higher in regional non-MTOC versus metropolitan (1.1, 1.0–1.2); all *p* values were less than 0.05 after adjustment. Results were generally similar

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after propensity analysis with and without adjusting for guideline-concordant treatment.

**Conclusions:** Multidisciplinary NSCLC care planning was associated with significantly higher rates of guideline-concordant care and survival, providing evidence for rigorous implementation of this model of care.

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**Keywords:** Multidisciplinary care; Multidisciplinary Thoracic Oncology Conference; Outcomes; Quality of care; Guideline-concordant treatment; Survival

## Introduction

With a widening array of diagnostic, staging, and treatment options, controlled by clinicians from different specialties, the complexity of lung cancer care suggests a need for structured multidisciplinary interaction.<sup>1</sup> Nevertheless, the multidisciplinary care model is infrequently practiced in the United States, especially in community health care systems where up to 85% of patients with lung cancer receive care.<sup>2</sup> Its usefulness has been questioned in countries where it has been implemented by regulatory fiat.<sup>3</sup> Given that multidisciplinary care delivery disrupts conventional referral processes, requires manpower and infrastructure investments, and demands clinical specialists, the paucity of supportive data is a major barrier to widespread adoption.<sup>4</sup>

In the United States, “multidisciplinary care” is poorly defined and lacks implementation know-how and high-quality evidence to quantify its presumed benefits.<sup>2,5</sup> The published evidence of benefit is mixed, mostly limited to intermediary outcomes, such as more timely care, improved staging, increased surgery referrals, and clinical trial enrollment.<sup>5–9</sup> There is scant, contradictory evidence of survival benefit.<sup>10–13</sup> The combination of implementation barriers and a dearth of evidence accounts for shallow penetration, despite strong advocacy for the model.<sup>14,15</sup> Evidence from community-level care environments might stimulate wider dissemination in the United States and other countries.

We implemented a rigorously benchmarked multidisciplinary thoracic oncology program within a large community-based health care system using team- and implementation-science principles<sup>16</sup> and evaluated its impact by comparing the processes and outcomes of NSCLC care within the greater health care system.

## Materials and Methods

The Baptist Memorial Healthcare Corporation (BMHCC) is a community-based health care system

covering 107 counties in Mississippi, Arkansas, Tennessee, Kentucky, Alabama, and Missouri, states with some of the highest per-capita U.S. lung cancer incidence and mortality.<sup>17</sup> This service area includes approximately 40% of persistent poverty “Delta Regional Authority” counties, congressionally identified as the most socioeconomically challenged region in the United States. In 2011, we started a weekly Multidisciplinary Thoracic Oncology Conference (MTOC) involving all key lung cancer specialists—thoracic surgeons, medical and radiation oncologists, pulmonologists, pathologists, radiologists, nurse navigators, and a palliative care nurse; in 2012, we started a colocated weekly clinic involving thoracic surgeons, medical and radiation oncologists, pulmonologists, nurse navigators, and radiologists.<sup>16</sup>

Colocated clinic patients were discussed in the MTOC, which was “enhanced” by prospective data collection and rigorous benchmarking, on the basis of team science “coordinating mechanisms,” including closed-loop communication, shared mental models, mutual trust, and mutual performance monitoring.<sup>16,18</sup> The key performance benchmarks were the concordance between recommendations and care delivered, timeliness of closed-loop communication with all responsible clinicians (defined as acknowledgment by the recipient of receipt of recommendations within 48 hours of the multidisciplinary clinical encounter), rates of stage confirmation, and timeliness of care delivery.<sup>18</sup> Providers could also refer patients in for enhanced MTOC (eMTOC) review, without clinic evaluation. Patients were re-presented in the eMTOC until a consensus treatment plan was decided.

The multidisciplinary forum was used for decision-making only. All clinical care procedures were performed within the same locations as other health care system patients with NSCLC. With the permission of the Institutional Review Board of the BMHCC (institutional review board #14–15), including a waiver of the informed consent requirement for this low-risk, institutional quality improvement program, we constructed a prospective database of all patients seen in the clinic and discussed in the eMTOC.

To compare the care and outcomes of patients with NSCLC who received or did not receive multidisciplinary case planning, we conducted a retrospective observational study identifying NSCLC cases from the eMTOC within the institutional Tumor Registry from 2011 to 2017. We compared patient demographic, clinical, treatment characteristics, use of guideline-concordant care, and survival between eMTOC and non-MTOC cases.

The eMTOC cohort included all BMHCC Tumor Registry patients with NSCLC who were presented in the eMTOC from 2011 to 2017. The non-MTOC cohort consisted of all other tumor registry patients with NSCLC in

the same time period. Because the eMTOC was based in metropolitan Memphis, we separated the non-MTOC cohort into “metropolitan” and “regional” subcohorts on the basis of the Rural-Urban Commuting Area code of the institution where each patient’s care was registered. Codes 1 to 3 are considered urban, 4 or higher, rural.<sup>19</sup> We also identified patient-level rurality on the basis of each patient’s zip code of residence at the time of lung cancer diagnosis.<sup>20</sup>

Using National Comprehensive Cancer Network guidelines, we categorized treatment as “stage-preferred” when the primary treatment for patients with that clinical stage was administered and “stage-appropriate” to include alternative evidence-based treatment modalities which might be received under certain circumstances (Supplementary Table A.1).<sup>21</sup> Stage was based on the seventh edition of the American Joint Committee on Cancer definitions.

### Statistical Analysis

With three exclusive cohorts, eMTOC, metropolitan non-MTOC, and regional non-MTOC, we summarized demographic characteristics, clinical stage, and guideline-concordant care using appropriate summary statistics. We compared characteristics across groups with chi-square or Kruskal-Wallis tests. We used Kaplan-Meier plots and log-rank tests to compare overall and stage-stratified survival and calculated hazard ratios (HRs) with 95% confidence intervals (CIs) using Cox proportional regression. Proportional hazard assumption was inspected visually. We evaluated the unadjusted univariable association between the hazards of death and our cohorts and then further adjusted for potential confounders or effect modifiers.

Confounding (when a factor not in the causal pathway influences the primary association of interest) was identified when the crude and adjusted bivariable-level HR differed by more than 10%. Effect modification (when a variable not in the causal pathway influences the primary association of interest to varying degrees across its levels) was identified when a significant, bivariable, interaction term existed between the potential effect modifier and primary predictor ( $p < 0.05$ ). The fully adjusted model included all confounders and significant effect modifiers. Variables considered for confounding and effect modification included age, sex, race, insurance, and clinical stage.

Rural patients are more likely to attend rural institutions, metropolitan patients to attend metropolitan institutions, and the eMTOC was located in a metropolitan part of the health care system. Therefore, it was questionable whether patient-level rurality (defined by the Rural-Urban Commuting Area code of the patient’s zip code of residence at the time of cancer diagnosis) is

in the causal pathway or associated with our exposure groups (institution-level rurality). For this reason, we excluded patient-level rurality from the primary analysis. We adjusted for multiple comparisons among the groups using Tukey’s adjustments, or the false discovery rate where indicated.<sup>22</sup>

### Additional Sensitivity Analyses

To minimize the impact of the asymmetric distribution of demographic and clinical characteristics between cohorts, we performed stabilized inverse probability weighting (SIPW) and propensity-matched analysis.<sup>23</sup> Both approaches aim to balance baseline covariates that might bias our primary association. Propensity-matched analyses force balance between exposure groups but can greatly reduce sample size and power. Therefore, we also used the SIPW approach, weighting for age, race, sex, insurance, and clinical stage. We excluded patients with unknown clinical stage in our primary analysis.

After propensity weighting or matching, we stratified by receipt of guideline-concordant treatment and re-evaluated HRs. Because guideline-concordant care can influence survival, stratification enables comparison of patients with similar care. For additional rigor, we repeated both propensity analyses, including patient-level rurality as an adjuster.

The asymmetrical distribution of missing clinical stage raised concern for misclassification bias and the absence of performance status and comorbidity data raised the possibility of differences in the prevalence of competing causes of mortality between cohorts. To evaluate this, we made four independent assumptions to encapsulate the “best case” and “worst case” scenarios: first, we assumed that patients with a reported stage but no treatment received stage-preferred treatment (assuming they were all moribund patients for whom end-of-life care is preferable); second, we assumed that those missing a stage-appropriate indicator (owing to missing clinical stage) all received guideline-concordant care; third, we assumed that these same patients did not receive guideline-concordant care; fourth, we assumed that patients who were missing clinical stage information but received some treatment had received guideline-concordant care and those missing clinical stage who received no treatment had not received guideline-concordant care. For each of these settings, we reran our propensity analyses outlined previously. This allowed us to evaluate the impact of “missingness” and possible misclassification across the groups. We also reconstructed our Kaplan-Meier plots after eliminating those who received no treatment to control missingness.

**Table 1.** Characteristics of Baptist Memorial Healthcare Corporation NSCLC Tumor Registry Cohort

Demographics	Tumor Registry Cohort	eMTOC	Metropolitan <sup>a</sup>	Regional <sup>b</sup>
N (%)	6259	864 (14)	3464 (55)	1931 (31)
Race <sup>c</sup>				
White	4503 (71.9)	564 (65.3)	2446 (70.6)	1493 (77.3)
Black or African American	1688 (27)	291 (33.7)	966 (27.9)	431 (22.3)
Other/unknown	68 (1.1)	9 (1)	52 (1.5)	7 (0.4)
Sex <sup>c</sup>				
Female	2857 (45.7)	435 (50.3)	1613 (46.6)	809 (41.9)
Male	3400 (54.3)	429 (49.7)	1849 (53.4)	1122 (58.1)
Age in y, median (IQR)	68 (61-75)	68 (61-75)	68 (61-75)	69 (61-76)
Insurance <sup>c</sup>				
Medicare	1444 (23.1)	197 (22.8)	872 (25.2)	375 (19.4)
Medicaid	953 (15.2)	119 (13.8)	445 (12.8)	389 (20.1)
Commercial	3157 (50.4)	454 (52.5)	1726 (49.8)	977 (50.6)
Uninsured	705 (11.3)	94 (10.9)	421 (12.2)	190 (9.8)
Clinical stage grouping <sup>c,d</sup>				
Early: I/II/IIIA(T3/N1)	1741 (27.8)	352 (40.7)	823 (23.8)	566 (29.3)
Locally-advanced: IIIA(T4/N2)/IIIB	1128 (18)	189 (21.9)	540 (15.6)	399 (20.7)
Advanced: IV	2745 (43.9)	246 (28.5)	1606 (46.4)	893 (46.2)
Unknown	645 (10.3)	77 (8.9)	495 (14.3)	73 (3.8)
Patient rurality <sup>c</sup>				
Not rural	3760 (60.1)	693 (80.2)	2687 (77.6)	380 (19.7)
Rural	2499 (39.9)	171 (19.8)	777 (22.4)	1551 (80.3)
Treatment				
Stage-preferred treatment rate <sup>c,e</sup>	3087 (55)	520 (66.1)	1675 (56.4)	892 (48)
Guideline-concordant treatment rate <sup>c,e,f</sup>	3839 (68.4)	618 (78.5)	2051 (69.1)	1170 (63)
No treatment rate <sup>c</sup>	1376 (22.0)	58 (6.7)	755 (21.8)	563 (29.2)

<sup>a</sup>Metropolitan: patients without care planning through the eMTOC, who received care within metropolitan Memphis.

<sup>b</sup>Regional: patients without care planning through the eMTOC, who received care within institutions outside greater metropolitan Memphis.

<sup>c</sup>Indicates statistically significant differences across the three cohorts (all  $p < 0.05$ ).

<sup>d</sup>Grouped according to guideline-concordant treatment approach—surgery for early stage, concurrent chemoradiation for locally advanced, palliative systemic therapy for advanced.

<sup>e</sup>According to National Comprehensive Cancer Network guidelines.

<sup>f</sup>Including alternative treatment recommendations acceptable under certain circumstances. eMTOC, enhanced Multidisciplinary Thoracic Oncology Conference; IQR, interquartile range.

## Results

### Distribution of Patient Demographic Characteristics

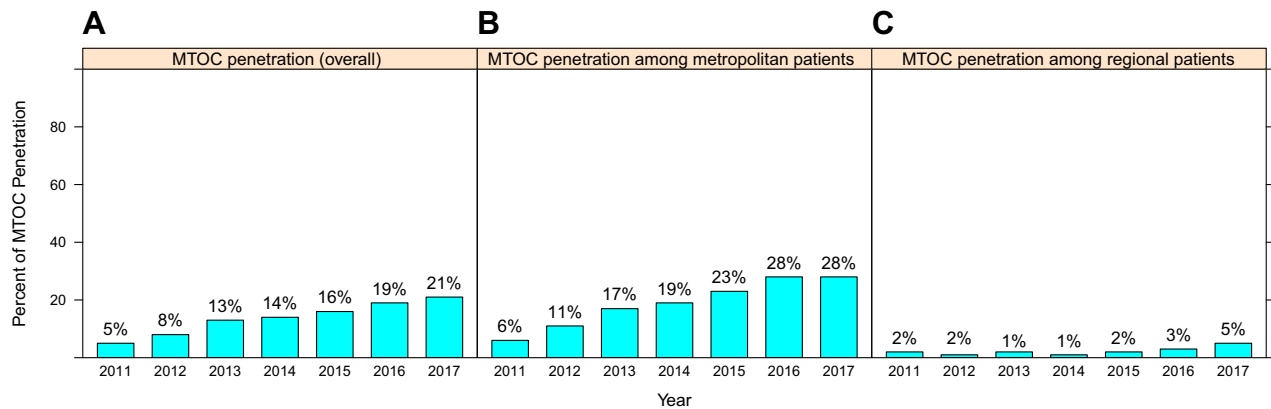
From 2011 to 2017, a total of 6259 patients with NSCLC were registered among the five hospital registries, of which 864 (14%) were discussed in eMTOC, 3464 (55%) received non-MTOC care through metropolitan hospitals, and 1931 (31%) received non-MTOC care in regional hospitals (Table 1). The eMTOC proportion of all patients in the study timespan evolved from 5% in 2011 to 21% in 2017 (Fig. 1A–C). The eMTOC proportion of all metropolitan and regional patients was 19.1% and 2.3%, respectively.

Key demographic and clinical characteristics were unevenly distributed among the three cohorts (Table 1). Notably, eMTOC had the highest proportions of black (34% eMTOC versus 28% metropolitan versus 22% regional), female (50%, 47%, and 42%, respectively), stages I to IIIB (63%, 39%, 50%, respectively),

and urban-residing patients (80%, 78%, and 20%, respectively). The non-MTOC regional cohort had the highest percentage of Medicaid insurance (14%, 13%, and 20%, respectively), and the non-MTOC metropolitan cohort had the highest proportion of Medicare insurance (23%, 25%, 19%, respectively). The frequency of commercial insurance was similar across all groups.

### Treatment Patterns According to Cohort

In the whole cohort, 3087 (55%) received stage-preferred treatment and 752 patients (12%) received stage-appropriate alternative treatment modalities, for a total of 3839 (68%) who received guideline-concordant treatment. eMTOC patients most often received stage-preferred treatment (66% versus 56% versus 48%,  $p < 0.001$ ) and guideline-concordant treatment (79% versus 69% versus 63%,  $p < 0.001$ ). They also had the lowest proportion without treatment (7% versus 22% versus 29%,  $p < 0.001$ ).



**Figure 1.** Enhanced MTOC penetration over time: (A) within the tumor registry overall; (B) among metropolitan patients; (C) among regional patients. MTOC, Multidisciplinary Thoracic Oncology Conference.

### Survival

Among the 6259 patients, 60% had died as of December 31, 2017, with a median survival time of 16.8 months from the date of diagnosis. The aggregate survival probability was 57% (95% CI: 56%–58%) at one year, 38% (37%–40%) at 3 years, and 32% (31%–34%) at 5 years. The median 1-, 3-, and 5-year survival probabilities of the eMTOC, non-MTOC metropolitan, and non-MTOC regional cohorts were as follows: median 36.7 months (95% CI: 30.4–42.8) versus 16.2 months (14.6–17.8) versus 13.3 months (11.8–14.8), log-rank  $p$  value less than 0.001; 1-year survival 72% (69–75) versus 56% (55–58) versus 52% (49–54); 3-year survival 51% (47–54) versus 39% (37–40) versus 32% (30–34); 5-year 40% (36–45) versus 33% (31–35) versus 27% (25–30) (Fig. 2A).

When the cohort was further stratified by stage, there remained significant differences in overall survival among early stage patients, defined as clinical stages I to IIIA (T3N1), for whom primary surgical resection is the preferred treatment (Supplementary Fig. A.1, log-rank  $p < 0.001$ ), and clinical stage IV (Supplementary Fig. A.2,  $p < 0.001$ ). The difference in patients with locally advanced disease, clinical stages IIIA with T4 or N2 and IIIB, was not statistically significant (Supplementary Fig. A.3,  $p = 0.2098$ ). In an analysis restricted to persons who received treatment, there remained significant differences in overall survival (Fig. 2B, log-rank  $p < 0.001$ ).

In a crude Cox proportional hazards model (Table 2), eMTOC patients had significantly lower hazard of death than metropolitan non-MTOC patients (HR = 0.65, 95% CI: 0.58–0.73) and regional non-MTOC patients (0.58 [0.52–0.66]); regional patients had significantly higher hazards than metropolitan patients (1.11 [1.04–1.20]). We identified no confounders. Insurance and clinical stage were the only effect modifiers. We therefore

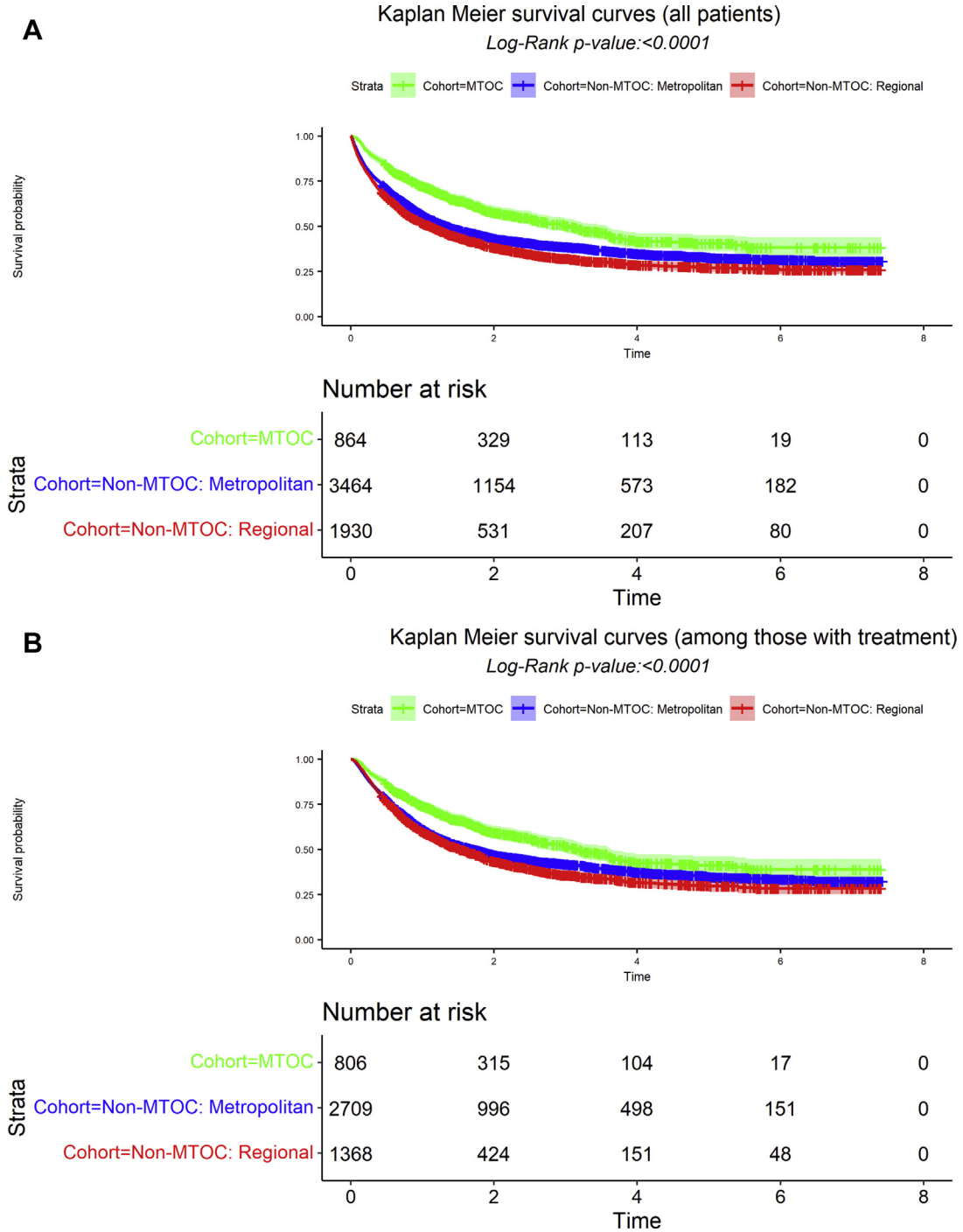
conducted additional analysis stratifying the cohort by insurance and treatment-related stage groupings (early, locally advanced, and advanced) before evaluating the survival impact of the model and location of care delivery.

eMTOC patients had significantly lower hazards of death than metropolitan patients among early or advanced stage patients with commercial insurance, Medicare patients, and patients with no, or unknown, insurance regardless of stage grouping (Fig. 3A). Compared with regional patients, hazards were also significantly lower for commercially insured eMTOC patients with early or late stage and for those with no or unknown insurance who had late or early stage compared (Fig. 3B). There were no subsets of patients in whom non-MTOC care was associated with superior survival. Regional patients had higher hazards than late-stage metropolitan patients with commercial, Medicaid, or patients with no or unknown insurance (Fig. 3C).

### Propensity Analysis

In both propensity analyses, eMTOC patients had significantly lower hazards compared with metropolitan and regional patients (Table 2). The SIPW approach indicated that regional patients had significantly higher hazards than metropolitan patients, but the matched approach revealed no differences.

There was no significant difference in hazard for death between metropolitan patients managed within or outside the eMTOC (HR = 0.95, 95% CI: 0.83–1.09, adjusted  $p = 0.7608$  by SIPW; HR = 0.8 [0.59–1.09], adjusted  $p = 0.3237$  in matched analysis, Table 3) among those with stage-preferred treatment. Care within the eMTOC remained significantly less hazardous for non-recipients of stage-preferred treatment (HR = 0.73 [0.61–0.86], adjusted  $p = 0.0008$  in SIPW



**Figure 2.** Survival of patients with NSCLC receiving care within the Baptist Memorial Healthcare Corporation from 2011 to 2017, stratified by model and location of care delivery. Multidisciplinary case planning (eMTOC) versus nonmultidisciplinary case planning before care within metropolitan Memphis hospitals (non-MTOC: metropolitan) versus nonmultidisciplinary case planning before care within regional hospitals (non-MTOC: regional). (A) Includes patients who received no treatment. (B) Excludes patients who received no treatment. eMTOC, enhanced Multidisciplinary Thoracic Oncology Conference; MTOC, Multidisciplinary Thoracic Oncology Conference.

analysis; HR = 0.48 [0.31–0.73], adjusted  $p = 0.0018$  by propensity matching).

eMTOC patients had lower hazard for death than regional patients, irrespective of receipt of stage-

preferred treatment in the SIPW analysis (HR = 0.81 [0.7–0.93], adjusted  $p = 0.0112$  with stage-preferred treatment; HR = 0.71 [0.59–0.84], adjusted  $p = 0.0003$  without receipt of stage-preferred treatment). In the

**Table 2.** Cox Proportional Hazard Model With Stabilized Inverse Probability Weighting Propensity and Propensity-Matched Analyses

Care Delivery	Hazard Ratio (95% CI)	Unadjusted <i>p</i> Value	Adjusted <i>p</i> Value <sup>a</sup>
Crude (no adjustments)			
eMTOC vs. non-MTOC: metropolitan	0.65 (0.58-0.73)	<0.0001	<0.0001
eMTOC vs. non-MTOC: regional	0.58 (0.52-0.66)	<0.0001	<0.0001
Non-MTOC: regional vs. metropolitan	1.11 (1.04-1.20)	0.0038	0.0106
Stabilized inverse probability weighting <sup>b</sup>			
eMTOC vs. non-MTOC: metropolitan	0.83 (0.74-0.92)	0.0005	0.0014
eMTOC vs. non-MTOC: regional	0.73 (0.65-0.81)	<0.0001	<0.0001
Non-MTOC: regional vs. metropolitan	1.14 (1.06-1.23)	0.0004	0.0012
Propensity-matched <sup>b</sup>			
eMTOC vs. non-MTOC: metropolitan	0.63 (0.5-0.81)	0.0002	0.0007
eMTOC vs. non-MTOC: regional	0.63 (0.49-0.82)	0.0005	0.0016
Non-MTOC: regional vs. metropolitan	1.00 (0.85-1.17)	0.9700	0.9992

Note: Excluding patients with unknown stage. Non-MTOC metropolitan: patients without care planning through the eMTOC, who received care within metropolitan Memphis; non-MTOC regional: patients without care planning through the eMTOC, who received care within institutions outside greater metropolitan Memphis.

<sup>a</sup>Multiple comparisons adjusted using Tukey's correction.

<sup>b</sup>Propensity adjusting for age, race, sex, insurance, and clinical stage.

CI, confidence interval; eMTOC, enhanced Multidisciplinary Thoracic Oncology Conference; MTOC, Multidisciplinary Thoracic Oncology Conference.

propensity-matched analysis, eMTOC patients who received stage-preferred treatment had a HR of 0.76 (0.54–1.06), *p* value equals to 0.2272 compared with regional patients. eMTOC patients who did not receive stage-preferred treatment had a HR of 0.53 (0.34–0.82), adjusted *p* value equals to 0.0117, compared with regional patients. Hazard for death was significantly higher in regional patients who received stage-preferred treatment, compared with metropolitan patients in the SIPW analysis, but not in patients who did not receive stage-preferred treatment, and there was no significant difference in either subset of patients in the propensity-matched analysis (Table 3). Essentially similar results were observed when stratified by stage-appropriate treatment (Table 3).

### Sensitivity Analyses

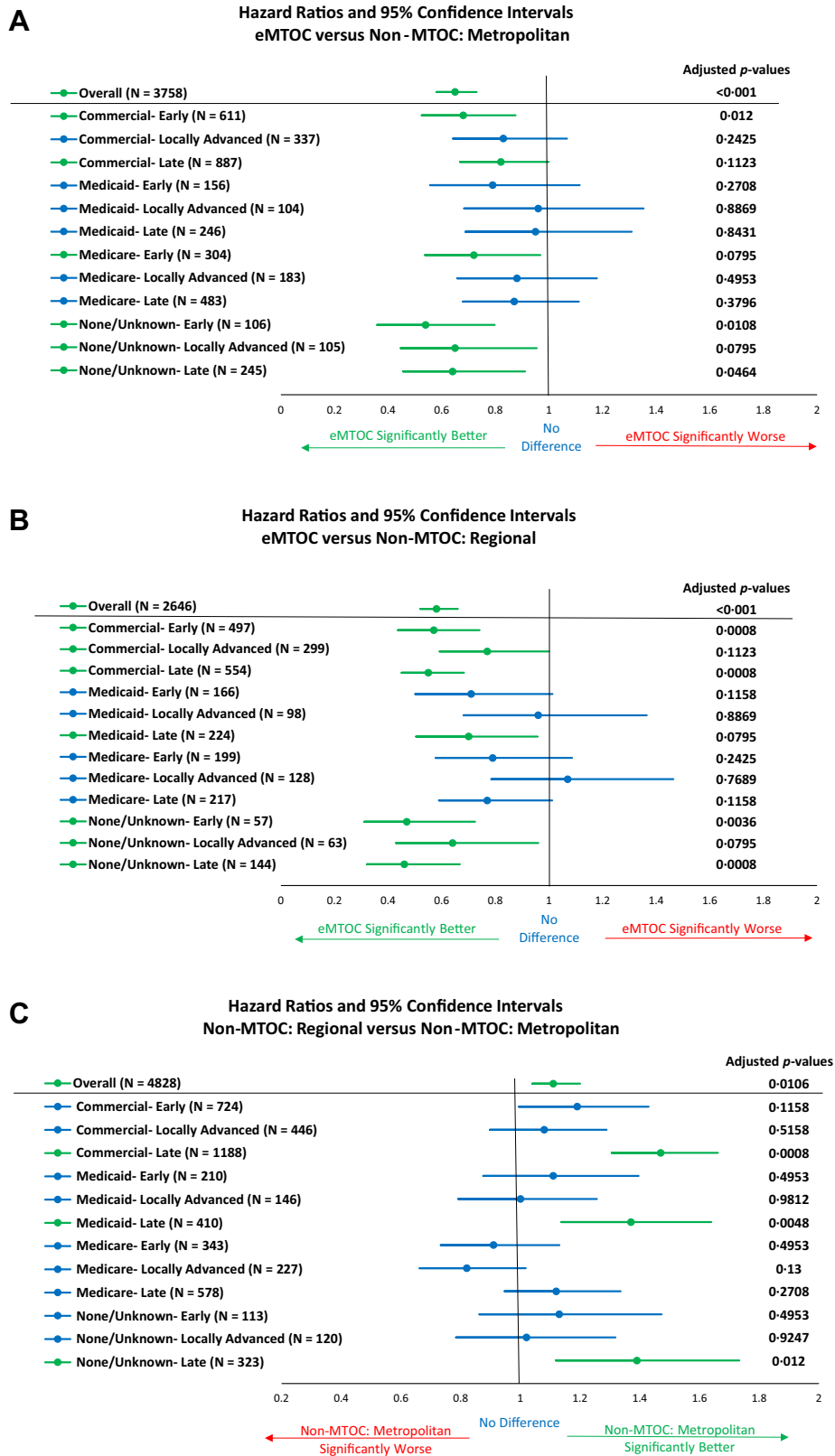
Because we lacked data on patients' performance status, which may influence treatment and to evaluate the impact of asymmetry in the distribution of missing clinical stage data, we repeated the propensity analyses under different hypothetical scenarios. In scenario 1, we assumed that patients with a clinical stage but no treatment had received guideline-concordant treatment, after excluding patients with missing clinical stage (Supplementary Table A.2). Scenario 2 included patients with missing clinical stage and assumed that they had received guideline-concordant treatment (Supplementary Table A.3) or (scenario 3) assumed that they had not received guideline-concordant treatment (Supplementary Table A.4). In scenario 4, we categorized those with a missing stage who received any treatment as having received guideline-concordant treatment

and those who did not receive any treatment as not having received guideline-concordant treatment (Supplementary Table A.5). The hazard of eMTOC recipients was consistently lower (with or without statistical significance) than non-MTOC participants in all scenarios; and the hazard of regional non-MTOC patients was higher in comparison to metropolitan non-MTOC recipients in most scenarios. Adjustment for patient-level rurality did not change these relationships (data not found).

### Discussion

From 2011 to 2017, although only 14% of patients with NSCLC received any form of structured multidisciplinary care planning, this trend increased over time, especially in the metropolitan health care system (Fig. 1). eMTOC patients were significantly more likely to receive any treatment and to receive guideline-concordant treatment. They also had significantly better survival, even after adjusting for potential confounding factors emanating from asymmetric distributions of demographic, clinical, and treatment characteristics. We designed the multidisciplinary program to have open access to indigent and racial minority patients, and through video conferencing, to patients and providers in more rural parts of the health care system. Although we excluded all patients with missing clinical stage information in the primary analysis, we included those who received no treatment, because one of the known attributes of multidisciplinary care is ensuring timely access to specialist treatment.<sup>5,6,24,25</sup>

The eMTOC was solely a decision-making forum. All patients received their diagnostic, staging, and



**Figure 3.** Forest plots illustrating hazard ratios and 95% confidence intervals of cohorts stratified by insurance and treatment-related stage groupings (early, locally advanced, and advanced). (A) Multidisciplinary case planning (eMTOC) versus non-multidisciplinary case planning before care within metropolitan Memphis hospitals (non-MTOC: metropolitan). (B) eMTOC versus nonmultidisciplinary case planning before care within regional hospitals (non-MTOC: regional). (C) Non-MTOC: regional versus non-MTOC: Metropolitan. Because of software limitations, the adjusted p values presented use the false discovery rate for multiple comparison adjustments. eMTOC, enhanced Multidisciplinary Thoracic Oncology Conference; MTOC, Multidisciplinary Thoracic Oncology Conference.



**Table 3.** Cox Proportional Hazard Model With Stabilized Inverse Probability Weighting Propensity and Propensity-Matched Analyses Stratified by Stage-Preferred Treatment Status

Care Delivery	Hazard Ratio (95% CI)	Unadjusted <i>p</i> Value	Adjusted <i>p</i> Value <sup>a</sup>
Stratified by stage-preferred treatment			
Stabilized inverse probability weighting <sup>b</sup>			
Among those with stage-preferred treatment			
eMTOC vs. non-MTOC: metropolitan	0.95 (0.83, 1.09)	0.4811	0.7608
eMTOC vs. non-MTOC: regional	0.81 (0.7-0.93)	0.0040	0.0112
Non-MTOC: regional vs. metropolitan	1.18 (1.06-1.31)	0.0022	0.0064
Among those without stage-preferred treatment			
eMTOC vs. non-MTOC: metropolitan	0.73 (0.61-0.86)	0.0003	0.0008
eMTOC vs. non-MTOC: regional	0.71 (0.59-0.84)	0.0001	0.0003
Non-MTOC: regional vs. metropolitan	1.03 (0.93-1.14)	0.5943	0.8553
Propensity matched <sup>b</sup>			
Among those with stage-preferred treatment			
eMTOC vs. non-MTOC: metropolitan	0.8 (0.59-1.09)	0.1518	0.3237
eMTOC vs. non-MTOC: regional	0.76 (0.54-1.06)	0.1002	0.2272
Non-MTOC: regional vs. metropolitan	1.06 (0.83-1.34)	0.6486	0.8919
Among those without stage-preferred treatment			
eMTOC vs. non-MTOC: metropolitan	0.48 (0.31-0.73)	0.0006	0.0018
eMTOC vs. non-MTOC: regional	0.53 (0.34-0.82)	0.0042	0.0117
Non-MTOC: regional vs. metropolitan	0.9 (0.73-1.13)	0.3705	0.6431
Stratified by stage-appropriate treatment			
Stabilized inverse probability weighting <sup>b</sup>			
Among those with stage-appropriate treatment			
eMTOC vs. non-MTOC: metropolitan	0.91 (0.8-1.03)	0.1244	0.2739
eMTOC vs. non-MTOC: regional	0.83 (0.73-0.95)	0.0061	0.0168
Non-MTOC: regional vs. metropolitan	1.09 (1-1.2)	0.0651	0.1552
Among those without stage-appropriate treatment			
eMTOC vs. non-MTOC: metropolitan	0.69 (0.56-0.86)	0.0007	0.002
eMTOC vs. non-MTOC: regional	0.6 (0.48-0.74)	<0.0001	<0.0001
Non-MTOC: regional vs. metropolitan	1.15 (1.03-1.3)	0.0171	0.045
Propensity matched <sup>b</sup>			
Among those with stage-appropriate treatment			
eMTOC vs. non-MTOC: metropolitan	0.71 (0.54-0.94)	0.0167	0.0440
eMTOC vs. non-MTOC: regional	0.75 (0.55-1.02)	0.0633	0.1514
Non-MTOC: regional vs. metropolitan	0.95 (0.77-1.17)	0.6187	0.8724
Among those without stage-appropriate treatment			
eMTOC vs. non-MTOC: metropolitan	0.48 (0.28-0.8)	0.0049	0.0136
eMTOC vs. non-MTOC: regional	0.46 (0.27-0.78)	0.0041	0.0114
Non-MTOC: regional vs. metropolitan	1.03 (0.8-1.34)	0.7979	0.9645

<sup>a</sup>Multiple comparisons adjusted using Tukey's correction.

<sup>b</sup>Propensity adjusting for age, race, sex, insurance, and clinical stage.

Note: Excluding patients with unknown stage. Non-MTOC metropolitan: patients without care planning through the eMTOC, who received care within metropolitan Memphis; non-MTOC regional: patients without care planning through the eMTOC, who received care within institutions outside greater metropolitan Memphis. CI, confidence interval; eMTOC, enhanced Multidisciplinary Thoracic Oncology Conference; MTOC, Multidisciplinary Thoracic Oncology Conference.

treatment procedures within the same health care system, linking the survival benefit to the decision-making process. The survival benefit may be attributed to the greater likelihood of receiving any treatment, especially, guideline-concordant treatment. This is supported by the finding that metropolitan non-MTOC recipients of stage-preferred treatment had similar survival to the eMTOC patients. This was not the case in the regional non-MTOC patients, for whom rural cancer care delivery might pose additional challenges.<sup>20,26,27</sup>

We provide robust evidence for survival benefit from multidisciplinary decision-making. Reasons for the survival benefit of eMTOC decision-making may include improved staging, higher rates of delivery of guideline-concordant care, in particular, stage-preferred treatment (such as surgical resection for early stage and multimodality therapy for stage III NSCLC). For example, a recent analysis of the U.K.'s National Lung Cancer Audit revealed that fewer than 20% of patients with stage III NSCLC received multimodality treatment, 34% received only palliative treatment, 36% received no treatment,

and aggregate 1-year survival was 32.9%.<sup>28</sup> The proportion of patients who received no treatment was lowest in the eMTOC cohort. Although this might indicate a referral bias toward healthier patients in the eMTOC, it might also indicate the value of more appropriately timely care delivery within the multidisciplinary care structure.

Existing studies of multidisciplinary care have been criticized for being small, noncomparative, noncontemporaneously comparative, or for not clearly defining “multidisciplinary.”<sup>3,5,6,29,30</sup> Most did not attempt, or failed, to reveal a survival benefit.<sup>5,6,10,31,32</sup> A large, multi-institutional retrospective analysis of tumor boards in the U.S. Veterans Affairs Health care system revealed no impact on receipt of guideline-concordant care or survival for lung cancer, among other cancers.<sup>10</sup> Nevertheless, a few studies have revealed an association between multidisciplinary lung cancer care and survival. One was a 117-person, single-institutional, noncontemporaneously controlled, preimplementation versus postimplementation analysis,<sup>33</sup> and another was a single-institutional retrospective analysis spanning 15 years.<sup>11</sup> A retrospective cohort analysis of a Taiwanese national registry data also revealed a survival benefit, but it did not characterize the multidisciplinary structure nor specify how that cohort was identified.<sup>34</sup> A retrospective analysis of 515 patients with stage III NSCLC treated at Taipei Veterans General Hospital identified multidisciplinary decision-making, T-category, performance status, and use of surgery as variables with independent association with survival.<sup>13</sup> Recent analyses of the U.K.’s National Lung Cancer Audit also strongly support the association between the organization of services, receipt of guideline-concordant care, and lung cancer patient outcomes.<sup>12,28</sup>

Our analytical sample is large, within a relatively short time span, involves multiple institutions with different characteristics, includes a contemporaneous control, and involves a prospective multidisciplinary care cohort retrieved from a rigorously implemented, benchmarked, and monitored eMTOC. We used institutional tumor registries to homogenize the data collection and pragmatically evaluate the impact of the eMTOC. Conceptually, we connected Donabedian’s three domains for quality improvement, as follows: structure (eMTOC versus non-MTOC); process (delivery of guideline-concordant treatment); and outcome (survival).<sup>35</sup> We provide real-world evidence of the value of multidisciplinary care within a large, diverse, community-based health care system.

Retrospective analysis of tumor registry data has inherent limitations, including missing information (e.g., performance status, comorbidities, patient-physician interaction, and decision-making), potential

misclassification bias (given the uneven distribution of unstaged and untreated patients), and potential referral bias (e.g., preferential referral of healthier and more resource-replete patients to the eMTOC). Lower rates of non-treatment with eMTOC might indicate preferential referral of patients with better performance status, as might the smaller proportion of patients with advanced clinical stage. We used propensity and multiple sensitivity analyses, including imputation with extreme assumptions on missing data, to account for such biases with generally consistent results.

Using the Tumor Registry structure provides a pragmatic means of measurement, using the same lens to evaluate the eMTOC cohort in comparison to all other patients, without the selection bias that a prospective nonrandomly selected control group might introduce. In addition to a clearly defined and rigorously benchmarked multidisciplinary program, other strengths of our study include a prospectively identified eMTOC cohort and the evaluation of a large, “real-world” multi-institutional cohort. Because 85% of U.S. lung cancer patients receive care in similar community based health care systems, our findings are likely to be generalizable.

In summary, a rigorously implemented eMTOC improved the care and survival of NSCLC patients in one of the first studies to reveal a survival benefit from multidisciplinary planning. This should provide added impetus to promote adoption within diverse care delivery environments. Prospective care planning, evidence-based decision-making, incorporating team science principles to ensure optimal communication, transparent decision-making, and a high level of compliance with multidisciplinary recommendations are feasible in nonacademic health care systems. We are exploring the ability of this approach to overcome rurality associated disparities in lung cancer care.

## CRedit Authorship Contribution Statement

**Meredith Ray:** Methodology, statistical analysis, Writer—review and editing.

**Nicholas R. Faris:** Project administration, Data curation, Writer—review and editing.

**Carrie Fehnel:** Data curation, Writer—review and editing.

**Anna Derrick, Folabi Arigandoye, Alicia Pacheco, Robert Optican, Keith Tonkin, Jeffrey Wright, Roy Fox, Thomas Callahan, Edward T. Robbins, William Walsh, Philip Lammers, Shailesh Satpute:** Writer—review and editing.

**Matthew P. Smeltzer, Meghan Meadows-Taylor:** Statistical consultant, Writer—review and editing.

**Raymond U. Osarogiagbon:** Conceptualization, Investigation, Funding acquisition, Writer—review and editing.

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## Supplementary Data

Note: To access the supplementary material accompanying this article, visit the online version of the *JTO Clinical and Research Reports* at [www.jtocrr.org](http://www.jtocrr.org) and at <https://doi.org/10.1016/j.jtocrr.2021.100203>.

## References

- Osarogiagbon RU. Achieving better quality of lung cancer care. In: Tanoue L, Detterbeck F, eds. *Lung Cancer: A Practical Approach to Evidence-Based Clinical Evaluation and Management*. St. Louis, MO: Elsevier; 2018:167-182.
- Osarogiagbon RU. Overcoming the implementation gap in multidisciplinary oncology care programs. *J Oncol Pract*. 2016;12:888-891.
- Tattersall MH. Multidisciplinary team meetings: where is the value? *Lancet Oncol*. 2006;7:886-888.
- Look Hong NJ, Gagliardi AR, Bronskill SE, Paszat LF, Wright FC. Multidisciplinary cancer conferences: exploring obstacles and facilitators to their implementation. *J Oncol Pract*. 2010;6:61-68.
- Prabhu Das I, Baker M, Altice C, Castro KM, Brandys B, Mitchell SA. Outcomes of multidisciplinary treatment planning in US cancer care settings. *Cancer*. 2018;124:3656-3667.
- Stone CJL, Vaid HM, Selvam R, Ashworth A, Robinson A, Digby GC. Multidisciplinary clinics in lung cancer care: a systematic review. *Clin Lung Cancer*. 2018;19:323-330.e3.
- Beckett P, Woolhouse I, Stanley R, Peake MD. Exploring variations in lung cancer care across the UK—the ‘story so far’ for the National Lung Cancer Audit. *Clin Med (Lond)*. 2012;12:14-18.
- Lau KK, Rathinam S, Waller DA, Peake MD. The effects of increased provision of thoracic surgical specialists on the variation in lung cancer resection rate in England. *J Thorac Oncol*. 2013;8:68-72.
- Khakwani A, Rich AL, Powell HA, et al. The impact of the ‘hub and spoke’ model of care for lung cancer and equitable access to surgery. *Thorax*. 2015;70:146-151.
- Keating NL, Landrum MB, Lamont EB, Bozeman SR, Shulman LN, McNeil BJ. Tumor boards and the quality of cancer care. *J Natl Cancer Inst*. 2013;105:113-121.
- Bilfinger TV, Albano D, Perwaiz M, Keresztes R, Nemesure B. Survival outcomes among lung cancer patients treated using a multidisciplinary team approach. *Clin Lung Cancer*. 2018;19:346-351.
- Adizie JB, Khakwani A, Beckett P, et al. Impact of organisation and specialist service delivery on lung cancer outcomes. *Thorax*. 2019;74:546-550.
- Hung HY, Tseng YH, Chao HS, et al. Multidisciplinary team discussion results in survival benefit for patients with stage III non-small-cell lung cancer. *PLoS One*. 2020;15:e0236503.
- ASCO-ESMO consensus statement on quality cancer care. *J Clin Oncol*. 2006;24:3498-3499.
- Institute of Medicine (IOM). *Delivering High-Quality Cancer Care: Charting a New Course for a System in Crisis*. Washington, DC: The National Academies Press; 2013.
- Smeltzer MP, Rugless FE, Jackson BM, et al. Pragmatic trial of a multidisciplinary lung cancer care model in a community healthcare setting: study design, implementation evaluation, and baseline clinical results. *Transl Lung Cancer Res*. 2018;7:88-102.
- Mokdad AH, Dwyer-Lindgren L, Fitzmaurice C, et al. Trends and patterns of disparities in cancer mortality among US Counties, 1980-2014. *JAMA*. 2017;317:388-406.
- Osarogiagbon RU, Rodriguez HP, Hicks D, et al. Deploying team science principles to optimize interdisciplinary lung cancer care delivery: avoiding the long and winding road to optimal care. *J Oncol Pract*. 2016;12:983-991.
- Economic Research Service, U.S. Department of Agriculture. Rural-urban commuting area codes. <https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes.aspx>. Accessed August 25, 2018.
- Ray MA, Faris NR, Derrick A, Smeltzer MP, Osarogiagbon RU. Rurality, stage-stratified use of treatment modalities and survival of non-small cell lung cancer. *Chest*. 2020;158:787-796.
- National Comprehensive Cancer Network. Non-small cell lung cancer, version 2.2019. [https://www.nccn.org/professionals/physician\\_gls/](https://www.nccn.org/professionals/physician_gls/). Accessed August 14, 2020.
- Kramer CY. Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics*. 1956;12:307-310.
- Robins JM, Hernan MA, Brumback B. Marginal structural models and causal inference in epidemiology. *Epidemiology*. 2000;11:550-560.
- Moghissi K, Connolly CK. Resection rates in lung cancer patients. *Eur Respir J*. 1996;9:5-6.
- BTS recommendations to respiratory physicians for organizing the care of patients with lung cancer. The Lung Cancer Working Party of the British Thoracic Society Standards of Care Committee. *Thorax*. 1998;53(suppl 1):S1-S8.
- Atkins GT, Kim T, Munson J. Residence in rural areas of the United States and lung cancer mortality. Disease incidence, treatment disparities, and stage-specific survival. *Ann Am Thorac Soc*. 2017;14:403-411.
- Johnson AM, Hines RB, Johnson JA 3rd, Bayakly AR. Treatment and survival disparities in lung cancer: the

- effect of social environment and place of residence. *Lung Cancer*. 2014;83:401-407.
28. Adizie JB, Khakwani A, Beckett P, et al. Stage III non-small cell lung cancer management in England. *Clin Oncol (R Coll Radiol)*. 2019;31:688-696.
  29. Osarogiagbon RU. "Like heart valve clinic, it probably saves lives, but... Who has time for that?" The challenge of disseminating multidisciplinary cancer care in the United States. *Cancer*. 2018;124:3634-3637.
  30. Osarogiagbon RU. Making the evidentiary case for universal multidisciplinary thoracic oncologic care. *Clin Lung Cancer*. 2018;19:294-300.
  31. Riedel RF, Wang X, McCormack M, et al. Impact of a multidisciplinary thoracic oncology clinic on the timeliness of care. *J Thorac Oncol*. 2006;1:692-696.
  32. Leo F, Venissac N, Poudenx M, Otto J, Mouroux J, Groupe d'Oncologie Thoracique Azuréen. Multidisciplinary management of lung cancer: how to test its efficacy? *J Thorac Oncol*. 2007;2:69-72.
  33. Forrest LM, McMillan DC, McArdle CS, Dunlop DJ. An evaluation of the impact of a multidisciplinary team, in a single centre, on treatment and survival in patients with inoperable non-small-cell lung cancer. *Br J Cancer*. 2005;93:977-978.
  34. Pan CC, Kung PT, Wang YH, Chang YC, Wang ST, Tsai WC. Effects of multidisciplinary team care on the survival of patients with different stages of non-small cell lung cancer: a national cohort study. *PLoS One*. 2015;10:e0126547.
  35. Donabedian A. The quality of care. How can it be assessed? *JAMA*. 1988;260:1743-1748.