Supplementary Online Content

Boffa DJ, Mallin K, Herrin J, et al. Survival after cancer treatment at top-ranked US cancer hospitals vs affiliates of top-ranked cancer hospitals. *JAMA Netw Open*. 2020;3(5):e203942. doi:10.1001/jamanetworkopen.2020.3942

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**eAppendix.** Supplemental Methods

This supplementary material has been provided by the authors to give readers additional information about their work.
eFigure 1. Consort Diagram

Supplemental Figure 1

Top-Ranked Hospitals*  
N = 59

Affiliates of Top Ranked Hospitals  
AHA Annual Survey (2012-15)  
N = 637 “Candidate Affiliates”

Top-Ranked Hospitals  
N = 59

Evidence of Brand Sharing**  
N = 388 “Affiliates”

Accredited by Commission on Cancer***  
N = 56 Top-ranked Hospitals  
(79,981 surgeries)

N = 206 “Affiliates”  
(39,853 surgeries)

12 did not perform complex surgery

* Top ranked by US news and world report at least once between 2013 and 2016
** Brand-sharing was assessed in 2017/18, some hospitals more recently changed how affiliation is communicated
***Hospitals that were accredited for a portion of study period were only considered in the years they were accredited
eFigure 2. Unadjusted 3-Year Survival Curves From Kaplan Meier Analyses for Each Cancer Type With All Stages Combined

Supplemental Figure 2

Figure 2: Survival at top-ranked hospitals is shown in red, and survival at affiliates is shown in blue. 3-year survival was felt to be best supported by the median follow up, but 5-year survival is also provided in Supplemental Table 2.
eFigure 3. Survivorship at Affiliate Hospitals Compared With Top-Ranked Hospitals Landmarked at 90 Days

Survivorship at Affiliate Hospitals, Relative to Top-Ranked Hospitals Landmarked at 90-Days

Figure 3: A forest plot of gamma model results for each procedure is shown, with survivorship at top ranked hospitals serving as reference. The models were adjusted for year, age category, insurance type, Charlson-Deyo group, income category, sex, pathologic stage, grade, receipt and timing of chemotherapy, receipt and timing of radiation therapy, sequence, and, for relevant procedures, whether they involved “extended” resections or not. The “box”
represents the Time Ratio (TR), while the “whiskers” represent the 95% confidence intervals. The light gray at the bottom indicates a sensitivity analysis of patients stratified by age.
Figure 4: A forest plot of logistic regression results for each procedure are shown, with top-ranked hospitals serving as the reference. Mortality was significantly lower at top-ranked hospitals for all procedures excepted proctectomy and cystectomy. The “box” represents the odds ratio, while the “whiskers” represent 95% confidence intervals. The models were adjusted for year, age category, insurance type, Charlson-Deyo group, income category, sex, pathologic stage, grade, receipt of preoperative chemotherapy (within 180 days of surgery), receipt of preoperative radiation therapy (within 180 days of surgery), and, for relevant procedures, whether they were extended or not. In addition, the annual volume for each procedure at each hospital was included in the adjustment.
eFigure 5. Survivorship at Affiliate Hospitals Compared With Top-Ranked Hospitals, Adjusting for Annual Procedural Volume

Figure 5: A forest plot of gamma model results for each procedure is shown, with survivorship at top ranked hospitals serving as reference. The models were adjusted for year, age category, insurance type, Charlson-Deyo group, income category, sex, pathologic stage, grade, receipt and timing of chemotherapy, receipt and timing of radiation therapy, sequence, and, for relevant procedures, whether they involved “extended” resections or not. In addition, the annual volume for each procedure at each hospital was included in the adjustment. The “box” represents the Time Ratio (TR), while the “whiskers” represent the 95% confidence intervals. The light gray at the bottom indicates a sensitivity analysis of patients stratified by age.
**eTable 1. Patient, Tumor, and Treatment Characteristics by Hospital Type**

| Hospital Type                  | Top-Ranked (n=79,981 patients) | Affiliate (n=39,853 patients) |
|--------------------------------|--------------------------------|--------------------------------|
| **Cancer type (%)**            |                                |                                |
| Esophagus                      | 4,899 (6.1)                    | 564 (1.4)                      |
| Gastric                        | 7,465 (9.3)                    | 1,985 (5.0)                    |
| Colon                          | 20,830 (26.0)                  | 22,689 (56.9)                  |
| Rectal                         | 3,632 (4.5)                    | 1,565 (3.9)                    |
| Pancreas                       | 10,088 (12.6)                  | 1,428 (3.6)                    |
| Lung                           | 23,638 (29.6)                  | 9,923 (24.9)                   |
| **Procedure Type**             |                                |                                |
| Esophagectomy                  | 4,899 (6.1)                    | 564 (1.4)                      |
| Partial Gastrectomy            | 5,239 (6.5)                    | 1,510 (3.8)                    |
| Total Gastrectomy              | 2,226 (2.8)                    | 475 (1.2)                      |
| Total Colectomy                | 1,547 (1.9)                    | 720 (1.8)                      |
| Partial Colectomy              | 19,283 (24.1)                  | 21,969 (55.1)                  |
| Lobectomy                      | 22,147 (27.7)                  | 9,528 (23.9)                   |
| Pneumonectomy                  | 1,491 (1.9)                    | 395 (1.0)                      |
| Proctectomy                    | 3,632 (4.5)                    | 1,565 (3.9)                    |
| Whipple                        | 10,088 (12.6)                  | 1,428 (3.6)                    |
| Cystectomy                     | 9,429 (11.8)                   | 1,699 (4.3)                    |
| **Diagnosis Year**             |                                |                                |
| 2012                           | 15,413 (19.3)                  | 5,031 (12.6)                   |
| 2013                           | 16,219 (20.3)                  | 6,379 (16.0)                   |
| 2014                           | 16,662 (20.8)                  | 8,184 (20.5)                   |
| 2015                           | 16,585 (20.7)                  | 10,108 (25.4)                  |
| 2016                           | 15,102 (18.9)                  | 10,151 (25.5)                  |
| **Age in years**               |                                |                                |
| Median (IQR)                   | 66 (58-74)                     | 69 (60-77)                     |
| 18-44                          | 4,136 (5.2)                    | 1,551 (3.9)                    |
| 45-54                          | 9,971 (12.5)                   | 4,299 (10.8)                   |
| 55-64                          | 20,947 (26.2)                  | 8,723 (21.9)                   |
| 65-74                          | 26,934 (33.7)                  | 12,463 (31.3)                  |
| 75-84                          | 15,156 (18.9)                  | 9,564 (24.0)                   |
| >=85                           | 2,837 (3.5)                    | 3,253 (8.2)                    |
| **Sex**                        |                                |                                |
| Male                           | 44,558 (55.7)                  | 20,078 (50.4)                  |
| Female                         | 35,423 (44.3)                  | 19,775 (49.6)                  |
| **Race**                       |                                |                                |
| White                          | 67,329 (84.2)                  | 34,059 (85.5)                  |
| Black                          | 7,297 (9.1)                    | 3,983 (10.0)                   |
| Other, Missing                 | 5,355 (6.7)                    | 1,811 (4.5)                    |
| **Charlson Deyo Score**        |                                |                                |
| Distance to hospital | 0          | 1          | 2          | >=3         |
|----------------------|------------|------------|------------|-------------|
| Median (interquartile range) | 52,442 (65.6) | 25,436 (63.8) | 19,377 (24.2) | 2,573 (3.2) |
| Missing              | 5,589 (7.0)  | 3,177 (8.0)  | 2,589 (7.0)  | 3,177 (8.0)  |

| Insurance            | No insurance | Private insurance | Medicaid | Medicare | Other Government | Missing |
|----------------------|--------------|-------------------|----------|----------|-----------------|---------|
|                     | 1,272 (1.6)  | 31,051 (38.8)     | 4,345 (5.4) | 41,031 (51.3) | 994 (1.2)   | 1,288 (1.6) |
|                     | 749 (1.9)    | 12,290 (30.8)     | 2,282 (5.7) | 23,698 (59.5) | 347 (0.9)   | 487 (1.2)   |

| Median income quintiles² | Lowest 0-20% | 21-40% | 41-60% | 61-80% | Highest 81-100% | Missing |
|--------------------------|--------------|--------|--------|--------|-----------------|---------|
|                         | 9,157 (11.4) | 12,796 (16.0) | 13,420 (16.8) | 15,355 (19.2) | 28,023 (35.0) | 1,230 (1.5) |
|                         | 4,647 (11.7) | 6,292 (15.8)  | 7,386 (18.5)  | 8,511 (21.4)  | 12,570 (31.5) | 447 (1.1)   |

| Urban rural designation of patient county³ | Metro area >= 1 million | Metro area 250,000-1,000,000 | Metro area < 250,000 | Non-metro area < 2,500 adjacent to metro area | Non-Metro area <2,500 not adjacent to metro area | Non-metro 2,500-19,999 adjacent to metro area | Non-metro 2,500-19,999 not adjacent to metro area | Non-metro >=20,000 adjacent to metro area | Non-metro >= 20,000 not adjacent to metro area | Missing |
|-------------------------------------------|-------------------------|-------------------------------|---------------------|----------------------------------|----------------------------------|-----------------------------|-----------------------------|-------------------------------|----------------------------------|---------|
|                                           | 45,628 (57.0)           | 13,201 (16.5)                | 6,776 (8.5)         | 560 (0.7)                        | 651 (0.8)                        | 3,416 (4.3)                  | 1,854 (4.6)                  | 2,004 (2.5)                  | 4,459 (5.6)                        | 2,248 (2.8) |
|                                           | 23,151 (58.1)           | 6,251 (15.7)                 | 4,308 (10.8)        | 188 (0.5)                       | 342 (0.9)                       | 1,854 (4.6)                  | 1,915 (4.8)                  | 685 (1.7)                     | 1,038 (1.3)                        | 735 (1.8)   |

| Distance to hospital⁴ | Median (interquartile range) | Missing |
|----------------------|-------------------------------|---------|
|                      | 26.7 (9.8-67.3)               | 380 (.5) |
|                      | 8.3 (3.8-18.7)                | 78 (0.2) |

| Distance to hospital⁴ | Median (interquartile range) | Missing |
|----------------------|-------------------------------|---------|
|                      | 26.7 (9.8-67.3)               | 380 (.5) |
|                      | 8.3 (3.8-18.7)                | 78 (0.2) |

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< 10 miles & 20,067 (25.1) & 22,482 (56.4) \\
10-24 miles & 18,289 (22.9) & 10,158 (25.5) \\
25-49 miles & 14,782 (18.5) & 4,300 (10.8) \\
50-74 miles & 8,594 (10.7) & 1,357 (3.4) \\
75-99 miles & 4,916 (6.1) & 564 (1.4) \\
100-199 miles & 7,699 (9.6) & 547 (1.4) \\
>=200 miles & 5,254 (6.6) & 367 (0.9) \\
\hline
**Median Days between diagnosis and surgery (IQR)** & 30.0 (10-54) & 17.0 (0-37) \\
\hline
**Clinical Stage Group** & & \\
Missing & 21,584 (27.0) & 18,171 (45.6) \\
0 & 1,453 (1.8) & 799 (2.0) \\
I & 26,496 (33.1) & 10,931 (27.4) \\
II & 19,417 (24.3) & 6,341 (15.9) \\
III & 11,031 (13.8) & 3,611 (9.1) \\
\hline
**Clinical Stage Group Excluding Colon** & & \\
Missing & 8,388 (14.2) & 2,919 (17.0) \\
0 & 739 (1.2) & 179 (1.0) \\
I & 22,862 (38.6) & 7,983 (46.5) \\
II & 17,465 (29.6) & 3,941 (23.0) \\
III & 9,697 (16.4) & 2,142 (12.5) \\
\hline
**Pathologic Stage Group** & & \\
Missing & 5,515 (6.9) & 1,844 (4.6) \\
0 & 2,531 (3.2) & 1,024 (2.6) \\
I & 25,588 (32.0) & 13,118 (32.9) \\
II & 25,928 (32.4) & 12,109 (30.4) \\
III & 16,901 (21.1) & 10,384 (26.1) \\
IV & 3,518 (4.4) & 1,374 (3.4) \\
\hline
**Tumor Grade** & & \\
Well differentiated & 8,240 (10.3) & 5,106 (12.8) \\
Moderately differentiated & 32,990 (41.2) & 21,035 (52.8) \\
Poorly differentiated & 21,496 (26.9) & 8,666 (21.7) \\
Undifferentiated & 6,709 (8.4) & 1,895 (4.7) \\
Missing & 10,546 (13.2) & 3,151 (7.9) \\
\hline
**Cancer Sequence** & & \\
First or only primary & 61,982 (77.5) & 31,548 (79.2) \\
2nd or higher primary & 17,999 (22.5) & 8,305 (20.8) \\
\hline
**Hospital Census Division** & & \\
New England & 5,060 (6.3) & 3,433 (8.6) \\
Middle Atlantic & 21,268 (26.6) & 7,935 (19.9) \\
South Atlantic & 17,019 (21.3) & 9,577 (24.0) \\
East North Central & 15,492 (19.4) & 9,007 (22.6) \\
\hline
| Region                      | Average Annual Surgical Volume<sup>a</sup> | Chemotherapy | Radiation | Surgical Margins |
|----------------------------|--------------------------------------------|--------------|-----------|------------------|
|                            | Median (IQR)                               | No chemotherapy | No radiation | No residual tumor |
| East South Central         | 68.2 (37.8-111.4)                          | 40,501 (50.6)  | 65,530 (81.9) | 73,807 (92.3)    |
| West North Central         | 31.8 (15.0-47.6)                           | 24,957 (62.6)  | 36,115 (90.6) | 37,182 (93.3)    |
| West South Central         | 184 (0.2)                                 | 1,539 (1.9)    | 351 (0.4)   | 1,866 (2.3)      |
| Mountain                   | 2,944 (7.4)                               | 215 (0.5)      | 69 (0.2)    | 1,043 (2.6)      |
| Pacific                    | 1,305 (1.6)                               | 5,253 (6.6)    | 9,840 (12.3)| 3,579 (4.5)      |
|                            | 7,647 (9.6)                               | 7,528 (18.9)   | 2,040 (5.1) | 1,474 (3.7)      |
|                            | 2,131 (2.7)                               | 5,927 (14.9)   | 1,474 (3.7) | 1,043 (2.6)      |
|                            | 2,328 (5.8)                               | 2,984 (7.5)    | 1,474 (3.7) | 1,043 (2.6)      |
|                            | 65,592 (82.0)                             | 2,944 (7.4)    | 2,944 (7.4) | 2,944 (7.4)      |
|                            | 7,972 (20.0)                              | 2,944 (7.4)    | 2,944 (7.4) | 2,944 (7.4)      |

<sup>a</sup> Average annual surgical volume and chemotherapy distribution for the U.S. colorectal cancer patients from 2016 to 2017. The table shows the median (IQR) of surgical volume, categorized by region, and the distribution of chemotherapy and radiation usage. Additionally, it includes the distribution of surgical margins, where no residual tumor is the most common outcome. The data is normalized to percentages for clarity.
| Microscopic residual tumor | 3,242 (4.0) | 1,253 (3.1) |
|---------------------------|------------|------------|
| Macroscopic residual tumor | 236 (0.3)  | 116 (0.3)  |
|Margins not evaluable      | 259 (0.3)  | 95 (0.2)   |
|Missing                    | 571 (0.7)  | 164 (0.4)  |

**Unplanned 30-day readmission**

| Yes | 4,061 (5.1) | 2,028 (5.1) |
|----|-------------|-------------|
|No  | 75,920 (94.9) | 37,825 (94.9) |

**% Compliance w/ CoC Quality Measures (95% CI)**

| Colon cancer, scenario-specific use adjuvant Chemotherapy | 89.0 (88.1-89.8) | 89.9 (89.1-90.6) |
|--------------------------------------------------------|------------------|------------------|
|Colon Cancer, >12 Regional Lymph nodes                  | 95.1 (94.8-95.5) | 91.5 (91.1-91.8) |
|Lung cancer, scenario-specific use adjuvant chemotherapy| 92.5 (91.7-93.2) | 93.2 (92.2-94.2) |
|Lung Cancer, >10 lymph nodes                            | 50.7 (50.0-51.4) | 45.6 (44.7-46.6) |

IQR – Interquartile Range, CoC – Commission on Cancer, CI – Confidence Interval

1. Chi square p-value <.001 for all variables except unplanned readmission. This table contains patients in whom pathologic stage was missing (unlike Table 1 in body of manuscript, in which patients without pathologic stage were excluded).
2. Based on census zip code median income, 2012-2016 American Community Survey data.
3. Based on 2013 patient county and state and United States Department of Agriculture Economic Research Service Urban rural continuum codes at [https://www.ers.usda.gov/data-products/rural-urban-continuum-codes](https://www.ers.usda.gov/data-products/rural-urban-continuum-codes)
4. Crow fly distance between the patient and hospital zip codes.
5. Only includes patients who were known to have gone directly to surgery (i.e. did not have neoadjuvant chemotherapy or radiation. N=56,917 for top-ranked hospital, 34,751 for affiliates.
6. AJCC 7th edition Clinical Stage IV and AJCC 7th edition clinical M+ excluded from the analyses.
7. Census division categories: New England: CT, MA, ME, NH, RI, VT; Middle Atlantic: NJ, NY, PA; South Atlantic: DC, DE, FL, GA, MD, NC, SC, VA, WV; East North Central: IL, IN, MI, OH, WI; East South Central: AL, KY, MS, TN; West North Central: IA, KS, MN, MO, ND, NE, SD; West South Central: AR, LA, OK, TX; Mountain: AZ, CO, ID, MT, NM, NV, UT, WY; Pacific: AK, CA, HI, OR, WA
8. Commission on Cancer Hospital Category types are described at [https://www.facs.org/quality-programs/cancer/coc/apply/categories](https://www.facs.org/quality-programs/cancer/coc/apply/categories)
9. Average annual volume calculated for all procedures included in the analysis, including patients with missing 90-day mortality. Procedure specific volumes are listed in Supplemental Table 3
10. p=0.93
11. Commission on Cancer Quality measures evaluated [https://www.facs.org/quality-programs/cancer/ncdb/qualitymeasures](https://www.facs.org/quality-programs/cancer/ncdb/qualitymeasures) outlined below:
   - Adjuvant chemotherapy is recommended or administered within 4 months (120 days) of diagnosis for patients under the age of 80 with AJCC Stage III (lymph node positive) colon cancer.
   - At least 12 regional lymph nodes are removed and pathologically examined for resected colon cancer.
   - Systemic chemotherapy is administered within 4 months to day preoperatively or day of surgery to 6 months postoperatively, or it is recommended for surgically resected cases with pathologic, lymph node-positive (pN1) and (pN2) NSCLC.
   - At least 10 regional lymph nodes are removed and pathologically examined for AJCC stage IA, IB, IIA, and IIB resected NSCLC
**eTable 2. Annual Procedure Volumes**

| Procedure            | Median | Interquartile range |
|----------------------|--------|---------------------|
| **All procedures**   |        |                     |
| Top-ranked           | 68.2   | 37.8-111.4          |
| Affiliate            | 31.8   | 15.0-47.6           |
| **Esophagectomy**    |        |                     |
| Top-ranked           | 25.0   | 14.6-39.8           |
| Affiliate            | 4.0    | 2.3-5.8             |
| **Gastrectomy**      |        |                     |
| Top-ranked           | 30.8   | 23.0-45.0           |
| Affiliate            | 6.3    | 3.6-10.8            |
| **Colectomy**        |        |                     |
| Top-ranked           | 86.8   | 58.2-127.8          |
| Affiliate            | 39.8   | 27.0-57.4           |
| **Proctectomy**      |        |                     |
| Top-ranked           | 18.8   | 10.2-37.3           |
| Affiliate            | 6.0    | 3.0-13.0            |
| **Whipple**          |        |                     |
| Top-ranked           | 42.6   | 29.4-83.8           |
| Affiliate            | 9.2    | 4.8-19.25           |
| **Lobectomy/Pneumonectomy** | |    |
| Top-ranked           | 103.4  | 72.4-162.0          |
| Affiliate            | 26.4   | 15.0-43.8           |
| **Cystectomy**       |        |                     |
| Top-ranked           | 45.6   | 28.0-71.6           |
| Affiliate            | 8.2    | 3.7-19.4            |

1. Volume based on all complex cancer procedures (as outlined in Methods) 2012-2016, including those missing 30 or 90 day mortality.
2. Two sided Wilcoxon p-values, all significant at <.001
**eTable 3. Time to Treat Across Different Procedures**

| Procedure and facility type | Median days to resection, N, any distance | P-value\(^2\) |
|-----------------------------|------------------------------------------|--------------|
| **Proctectomy**             |                                          |              |
| Top-ranked                  | 42.0 (799) (IQR 23-67)                   | <.001        |
| Affiliate                   | 32.0 (401) (IQR 14-55)                   |              |
| **Total Gastrectomy**       |                                          |              |
| Top-ranked                  | 38.0 (795) (IQR 20-64)                   | 0.02         |
| Affiliate                   | 33.0 (223) (IQR 12-52)                   |              |
| **Partial Gastrectomy**     |                                          |              |
| Top-ranked                  | 40.0 (2,568) (IQR 20-63)                 | <.001        |
| Affiliate                   | 21.0 (968) (IQR 0-42)                    |              |
| **Total Colectomy**         |                                          |              |
| Top-ranked                  | 22.0 (1,300) (IQR 0-46)                  | <.001        |
| Affiliate                   | 6.5 (642) (IQR 0-29)                     |              |
| **Partial Colectomy**       |                                          |              |
| Top-ranked                  | 23.0 (17,165) (IQR 6-40)                 | <.001        |
| Affiliate                   | 11.0 (20,363) (IQR 0-28)                 |              |
| **Esophagectomy**           |                                          |              |
| Top-ranked                  | 58.0 (1,028) (IQR 39-86)                 | 0.01         |
| Affiliate                   | 49.0 (119) (IQR 28-70)                   |              |
| **Lobectomy**               |                                          |              |
| Top-ranked                  | 33.0 (18,806) (IQR 11-56)                | <.001        |
| Affiliate                   | 31.0 (8,607) (IQR 3-52)                  |              |
| **Pneumonectomy**           |                                          |              |
| Top-ranked                  | 39.0 (1,063) (IQR 22-57)                 | 0.19         |
| Affiliate                   | 35.0 (297) (IQR 19-55)                   |              |
| **Whipple**                 |                                          |              |
| Top-ranked                  | 20.0 (6,756) (IQR 3-35)                  | <.001        |
| Affiliate                   | 15.0 (1,159) (IQR 0-29)                  |              |
| **Cystectomy**              |                                          |              |
| Top-ranked                  | 57.0 (4,821) (IQR 37-85)                 | <.001        |
| Affiliate                   | 49.0 (908) (IQR 29-76)                   |              |
| **All Procedures**          |                                          |              |
| Top-ranked                  | 30.0 (55,101) (IQR 10-53)                | <.001        |
| Affiliate                   | 17.0 (33,687) (IQR 0-37)                 |              |

1. Excludes patients with missing 90-day mortality and missing pathologic stage. Excludes patients with neo-adjuvant chemotherapy or radiation or unknown neo-adjuvant radiation and chemotherapy.
2. Two-sided Wilcoxon test.
### eTable 4. Unplanned Readmission Within 30 Days

| Procedure            | Unplanned 30-day readmission percent | Total N  | P-value<sup>2</sup> |
|----------------------|--------------------------------------|----------|----------------------|
| **Proctectomy**      |                                      |          |                      |
| Top-ranked           | 7.3                                  | 2,141    | 0.86                 |
| Affiliate            | 7.5                                  | 1,348    |                      |
| **Total Gastrectomy**|                                      |          |                      |
| Top-ranked           | 5.9                                  | 1,377    | 0.87                 |
| Affiliate            | 6.1                                  | 427      |                      |
| **Partial Gastrectomy|**                                   |          |                      |
| Top-ranked           | 4.6                                  | 3,514    | 0.62                 |
| Affiliate            | 4.9                                  | 1,385    |                      |
| **Total Colectomy**  |                                      |          | 0.16                 |
| Top-ranked           | 6.8                                  | 1,026    |                      |
| Affiliate            | 8.7                                  | 668      |                      |
| **Partial Colectomy**|**                                   |          |                      |
| Top-ranked           | 4.2                                  | 15,011   | <.001                |
| Affiliate            | 5.0                                  | 20,898   |                      |
| **Esophagectomy**    |                                      |          | 0.82                 |
| Top-ranked           | 6.4                                  | 2,556    |                      |
| Affiliate            | 6.6                                  | 466      |                      |
| **Lobectomy**        |                                      |          | 0.03                 |
| Top-ranked           | 3.0                                  | 15,494   |                      |
| Affiliate            | 3.6                                  | 8,731    |                      |
| **Pneumonectomy**    |                                      |          | 0.22                 |
| Top-ranked           | 7.2                                  | 902      |                      |
| Affiliate            | 5.3                                  | 342      |                      |
| **Whipple**          |                                      |          | 0.19                 |
| Top-ranked           | 7.4                                  | 5,863    |                      |
| Affiliate            | 8.6                                  | 1,190    |                      |
| **Cystectomy**       |                                      |          | 0.38                 |
| Top-ranked           | 9.4                                  | 5,273    |                      |
| Affiliate            | 8.7                                  | 1,487    |                      |
| **All procedures**   |                                      |          | 0.78                 |
| Top-ranked           | 5.1                                  | 53,157   |                      |
| Affiliate            | 5.1                                  | 36,942   |                      |

1. 29,735 patients excluded who traveled > 50 miles to resection facility.
2. Chi square p-value, Unplanned readmission vs no unplanned readmission.
eAppendix. Supplemental Methods

General Study Overview

The study was submitted as a proposal to the Commission on Cancer, Quality Integration Committee. After review by members of the NCDB research team and senior members of the CoC, the study was approved as a project that had the potential to address a CoC mission to improve care for patients by studying a potential gap in safety. As is common for NCDB special studies (i.e. those that require additional detail than is provided in the Participant User File), a collaboration was formed between the principal investigator (Boffa), the NCDB research team, the CoC and the American College of Surgeons.

Additional Patient Selection Detail

The selected cancer procedures were chosen because they have been associated with a higher mortality rate, and likely involve multiple different teams of specialists. Furthermore, these procedures have been studied and reported multiple times under the category of “complex cancer surgeries”. While this cohort of procedures does not represent all the complex cancer procedures, we believe this comprises more than 80% of complex cancer surgeries routinely performed in the U.S.

Only cases in which the reporting hospital was also the hospital that performed the procedure were included.

Focus on US News and World Report Rankings

The USNWR rankings were selected for the cohort of hospitals that we anticipated to have better outcomes, that were affiliated with hospitals that have more opportunities to improve in terms of safety and potentially effectiveness. Our prior studies have shown that 1) the public believes that Top Ranking by USNWR is important to their choice, 2) affiliation with a top-ranked hospital increases their preference for care at the affiliate, 3) important differences in safety exist within these networks, and 4) these networks have a large market share of complex cancer surgery (1/3 of cancer surgeries takes place within these networks around the USNWR top 50 hospitals.

We recognize that additional metrics of superior quality could have been chosen (for example, designation as a National Cancer Institute NCI as a comprehensive cancer center). This would be another reasonable approach to take. It is worth noting that there is considerable cross over between the NCI comprehensive cancer centers and the top-ranked hospital cohort.

Additional Hospital Selection Detail

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Hospitals that were both in the top-50 and also affiliated with another top-ranked cancer hospital were all considered in the top-ranked cohort.

For affiliations that developed during the study period, only surgeries that occurred while the affiliation was in place were included in the analyses. The study was not designed to examine specific types of affiliations. However, two hospital mergers were identified during the study period between a top-ranked hospital and another hospital that was not ranked. The merged hospitals are considered together in the top-ranked cohort.

Overall 13 of the top-ranked hospitals had no CoC accredited affiliates. These 13 hospitals were included in the top-ranked cohort. Three of the top-ranked hospitals were not CoC accredited, however, 3 of their affiliate hospitals were. These 3 affiliates (of top-ranked hospitals who were not CoC accredited) were included in the affiliate cohort, though not the corresponding top-ranked hospital. A sensitivity analysis of 90-day mortality demonstrated no difference when the 13 top-ranked hospitals with no CoC accredited affiliates and the affiliates of non-CoC accredited top-ranked hospitals were excluded (OR 1.75 95%CI 1.54-1.99, p<.001).

De-identified Study-Set Creation

The list of top ranked hospitals and their brand-sharing affiliates was provided to the NCDB research team. The NCDB research team then queried the NCDB hospital identifiers for the eligible hospitals (i.e. were CoC accredited). The NCDB then compiled a de-identified database with an indicator for whether the hospital at which the patient underwent surgery was a top-ranked hospital, or the affiliate of a top-ranked hospital at the time surgery took place. This indicator was then used to consider these procedures in aggregate.

Variables

Age is shown as both a continuous and categorical variable. In order to account for the possibility that particularly advanced age strata (i.e. geriatric patients) could have disproportional risk, age was included as categorical variable. The NCDB only captures readmissions to the reporting hospital which performed the surgery. Greater travel distances may reduce the likelihood of patients being readmitted to the hospital that performed the surgery, therefore readmissions were examined exclusively in patients who traveled <50miles (90,099/119,834 patients)

Clinical stage was missing in a substantial proportion of cases, more so in the patients treated at affiliate hospitals. This was primarily due to tumor extension being missing in a proportion of colon cancer clinical staging reports. As a sensitivity analysis, clinical stage was evaluated in all patients excluding colon, and rate of missing data was similar between top-ranked hospitals (Supplemental Table 1).
Chemotherapy was considered as induction if given within 180 days of surgery. For 90-day mortality adjusted analyses, chemotherapy and radiation were considered in the following groupings: yes, none, unknown. Patients that received either chemotherapy more than 180 days prior to surgery, or those that received only adjuvant chemotherapy were considered as none for neoadjuvant.

“Time to treat” was only evaluated in patients that underwent surgery as their first treatment, as the induction strategy can be quite different in terms of number of cycles and duration. This variable is calculated internally by the NCDB. This variable is based off dates which are captured by the NCDB but are not publicly shared.

Extended surgical procedures, which involved removing portions of surrounding organs or tissues, were included in the analyses and adjusted for with an “extended” modifier. The inclusion of extended cases was important, as this could reflect surgical judgement with outcome implications. More specifically, if a patient had an invasive tumor that was growing close to surrounding tissues, the surgeon’s decision to take additional tissue could influence prognosis (i.e. sparing continuous tissue could result in a close or positive margin).

Missing data

For the majority of variables that were included in adjusted models, rate of missing data was less than 5% (range 0 to 13.2%). Missing variables, other than pathologic stage, were imputed using multiple imputation technique. For 90-day mortality and long-term survival, only cases with complete pathologic stage data were considered. A complete case analysis was done for pathologic staging because: 1) the rate of missing data was low, 2) the complexity of imputing across different cancers and procedures while accounting for down-staging with induction therapy types may affect the reliability of imputation.

Statistics

The data were analyzed in aggregate, as opposed to comparing each top-ranked hospital, to each of its affiliates. This was done for multiple reasons. 1) We wished to show an average effect, which was representative of what was taking place across the many types of affiliations, hospital environments and populations in the United States. We recognize there are important nuances that could influence the relative safety and effectiveness of care that we cannot control for. As such, we feel that the aggregate approach best matched with the data that is available. 2) The surgical volumes were not sufficient to compare each hospital to each affiliate. Notably, all models accounted for correlation of outcomes within hospitals. 3) We performed a variance decomposition analysis to assess the proportion of variance in survival.
that was explained by patient, hospital and network levels; this found that 95.3% of the variance was at the patient level, 4.6% was at the hospital level, but only 0.1% was at the network level. This obviated accounting for correlation of outcomes within networks in our models, and also supported the overall design.

Kaplan Meier is shown as 3-year survival, because the median duration of follow-up was felt to be more supportive of a shorter endpoint. 5-year survival statistics are shown as well in supplemental Table 2. Unadjusted survival is shown as this provides several important perspectives for clinicians. First this allows clinicians to view the outcomes of these cohorts in the context of other reported outcomes, including the AJCC staging manual (which describes unadjusted stage-specific survival). Second, this allows clinicians to view the shape of the curves for patterns in survivorship loss. Wide separation could represent surgical complications or health related differences, while cancer specific differences would be expected to impact curves a bit later in the postoperative course.

All analyses were at the patient level, with an indicator for affiliate vs top-ranked used to estimate the main study effect. For 90-day mortality outcomes we used mixed effects logistic regression models, estimating separate models for each procedure and a pooled model which included procedure indicators. To identify the functional form for the survival models, they were first estimated as Cox frailty models, and assessed for violations of the proportional hazards. Schoenfeld residual tests rejected the proportional hazards assumption, therefore, we estimated a set of parametric time to event models, using Akaike Information Criteria (AIC) to identify the gamma distribution as providing the best fit. Mixed effects gamma models for each cancer type included the same risk adjusters as for 90-day mortality, with additional indicators in the lung, colon, and gastric models for procedure type. The pooled model also included indicators for cancer type. For the survival models we report time ratios (TRs) which represent relative decrease in survival time for patients at affiliate hospitals.

Race is a variable that can track with the hospitals in which care is accessed, and can therefore confound the relationship between affiliation and outcomes. As such, race was not included in the primary adjusted models. However, recognizing that race may have some impact on both hospital selection and patient outcome, race/ethnicity were included in our propensity score models outlined below.

To account for potential selection bias, we estimated propensity models where the outcome was treatment at an affiliate hospital. We estimated separate models for the 90-day mortality and survival cohorts, adjusting each for all covariates in the main pooled models (including cancer type or procedure type, respectively), as well as race, area income level, and area educational level; these models were used to predict propensity scores for each patient in each
cohort. Because observation level weighting is problematic for mixed effects models, we incorporated these propensity scores as covariates in all models.

Age was examined for potential interactions. For age, the observed effect was particularly strong at advanced age, but no interactions were noted that undermined the main findings. Prior cancer history was included in the adjustment models (as opposed to simply excluding all patients with prior cancer history), per observations from our prior work\(^5\).

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