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## APPENDIX A.

To further mitigate the potential for unobserved confounding, we explored two alternative specifications for our primary analysis.

*Mixed-effects regression models:* First we used a mixed-effects model, adding year fixed effects as well as a random intercept for each hospital to the primary regression model described in the main text.[37] Year fixed effects were added to account for any macroeconomic changes across all hospitals that could be correlated with outcome variables. A random intercept allows outcomes to vary by hospital due to unobserved factors not included in the model's observed covariates. The estimates from a mixed-effects model are based on an inverse-weighted average of variation "within" and "between" hospitals. Intra-hospital correlations (rho) were less than 0.10 (roughly 90% of the variation is between hospitals), leading to a model that puts more weight on the component of "within" hospital variation. Consequently, inferences based on the association of EOL quintile are conservative: they minimize the influence of unobserved variation between hospitals. As with the primary analysis, inferences across the EOL quintiles were reported relative to the first quintile (lowest spending regions) with significance set at an alpha level of 0.05.

The mixed-effects regression model (Appendix Table) was consistent with the primary analysis shown in Table 5. As expected, because the mixed-effects model weighted more heavily to the component of "within" hospital variation, the magnitude of the difference in spine-specific spending across EOL quintile was not as great as those from the previous models. Inference from the mixed-effects largely ignores the potential contribution of unobserved variation between hospitals. Nevertheless, even under this constraint, the mean spine-specific spending among regions in the highest EOL quintile was significantly greater than those in the low EOL quintile. For example, spine-specific spending in the highest EOL quintile for the "fusion, except cervical" cohort was ($4,752; 95%CI $3,834 - $5,670; p<0.001) greater than in the low EOL quintile.

In the mixed-effects models, the association between higher EOL quintile and higher rates of adverse safety events were generally greater than those from the primary models. For example, relative to regions in the low EOL quintile within the "fusion, except cervical" cohort, those in the high EOL quintile had significantly higher likelihood for DVT (OR 1.09; 95%CI 1.01 - 1.19; p=0.036) and readmission at 90 days (OR 1.10; 95%CI 1.04 - 1.16; p<0.001.)

*Instrumental Variable Analysis:* The second alternative specification was to use EOL as a continuous instrumental variable (IV) for spine-specific regional spending, an approach which strengthens the causal inference in observational data.[38] A valid IV has two key characteristics: it is predictive of the exposure (regional spending), but does not have any direct effect on the dependent variable (safety indicators).[39] That is, it only influences the outcomes through its association with the exposure. Using the IV to estimate the effect of regional spine spending on safety measures allows us to isolate the exogenous contributions of spending – the component of spending related to care intensity as opposed to illness severity – and create an unbiased causal inference of the association between spending and quality. Unlike the multivariable regression models which only control for measured (observed) bias, IV approaches

minimize the effect of unmeasured (or unobserved) bias. Because we used regional EOL spending from each region's preceding year, we mechanistically break any direct link between EOL and spine safety indicators. We used the IV approach to model the association between regional spine spending per $1000 with each safety indicator. As with the previous models, we included covariates for age, sex, race, Charlson Comorbidity Index, calendar year, hospital procedure volume, bed count and teaching status.

With F-statistics greater than 10.0, we found no evidence that EOL served as a weak IV. Applying EOL as an IV for spine-specific spending resulted in mixed findings. Specifically, every $1000 increase in regional spending was generally associated with higher rates of readmission, but lower rates of PE (Appendix Table 1.)

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*TABLE A1: Difference in spine-spending and safety indicators as measured through a 90-day episode of care as a function of EOL, for five CMMI-defined inpatient spine surgery cohorts, by modelling approach.*

| Cohort | Multivariable regression<br>Relative risk of outcome as measures of coefficient for linear regression of spending or odds-ratio for dichotomous safety indicators. | | | | | Mixed-effects model<br>Relative risk of outcome as measures of coefficient for linear regression of spending or odds-ratio for dichotomous safety indicators. | | | | | Instrumental Variable Model<br>Relative risk of outcome per $1000 spent during 90-day episode of care, with EOL as IV to remove difference in effect due to age, illness, and pricing. Coefficients and (% difference relative to mean.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spine-specific spending | Died | Readmit | PE | DVT | Spine-specific spending | Died | Readmit | PE | DVT | Died | Readmit | PE | DVT |
| Fusion, except cervical | $18,802 *** | 0.90 | 1.10 ** | 0.94 | 1.08 | $4,752 *** | 0.90 | 1.10 *** | 0.93 | 1.09 * | -0.003<br>-0.26% | 0.051<br>0.36% ** | -0.017<br>-0.78 * | 0.002<br>0.05 |
| Complex fusion | $35,533 *** | 1.09 | 1.15 * | 1.06 | 1.37 *** | $21,845 *** | 1.11 | 1.14 * | 1.04 | 1.38 *** | 0.001<br>0.01% | 0.048<br>0.17% | -0.002<br>-0.05% | 0.042<br>0.54% * |
| Anterior-posterior fusion | $31,733 *** | 1.02 | 1.03 | 0.92 | 1.00 | $21,281 *** | 1.04 | 1.02 | 0.93 | 0.98 | -0.004<br>-0.14% | 0.007<br>0.04% | -0.008<br>-0.29% | -0.008<br>-0.15% |
| Cervical fusion | $17,306 *** | 0.98 | 1.12 *** | 1.02 | 1.21 *** | $10,945 *** | 1.00 | 1.10 ** | 1.00 | 1.17 ** | -0.021<br>-0.90% * | 0.648<br>0.44% ** | -0.021<br>-1.13% * | 0.013<br>0.35% |
| Back & neck surgery, except fusion | $10,378 *** | 0.79 * | 1.09* | 0.88 | 1.08 | $9,209 *** | 0.80 | 1.07 | 0.88 | 1.06 | -0.019<br>-0.84% | 0.040<br>0.25% | -0.037<br>-1.67% * | -0.033<br>-0.67% |

*p<0.05, ** p<0.01, ***p<0.001. Multivariable and mixed-effects regression present regression estimates comparing the highest EOL quintile relative to the lowest EOL quintile. Regression estimates are presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous safety indicators. The IV model includes EOL as an instrument for 90 days episode of care costs. In these models, the beta coefficients and (% change from mean) reflect the magnitude of change per every $1,000 of spine-specific spending. All models control for age, sex, race, comorbidity, calendar year, hospital procedure volume, bed count and teaching status. Died, Readmit, PE, and DVT represent 90-day rate of: mortality, Re-admission, pulmonary embolism, and deep vein thrombosis respectively.

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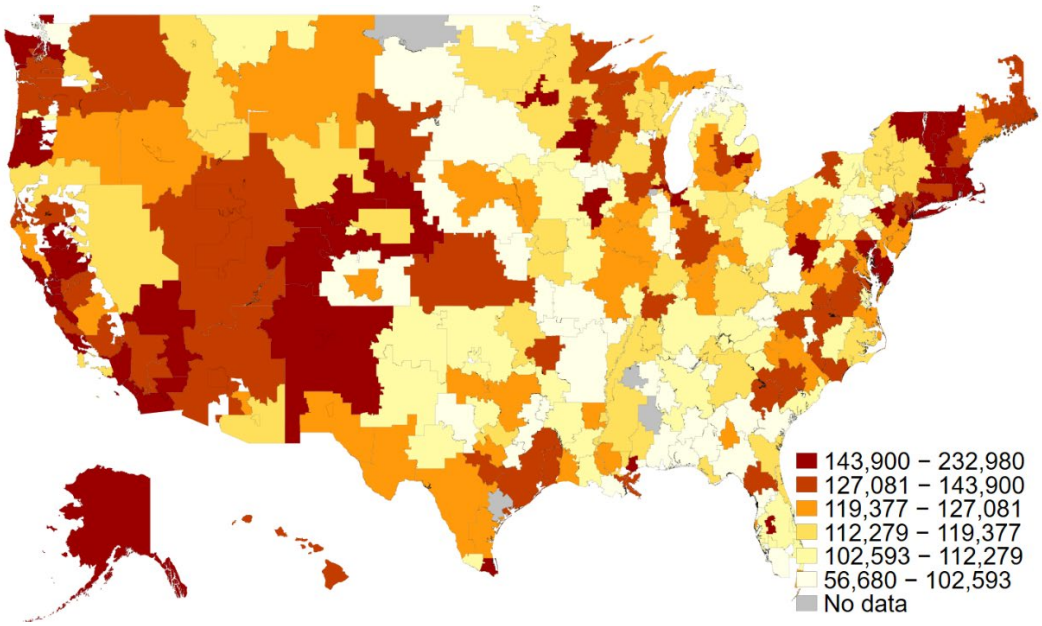
**APPENDIX B.**

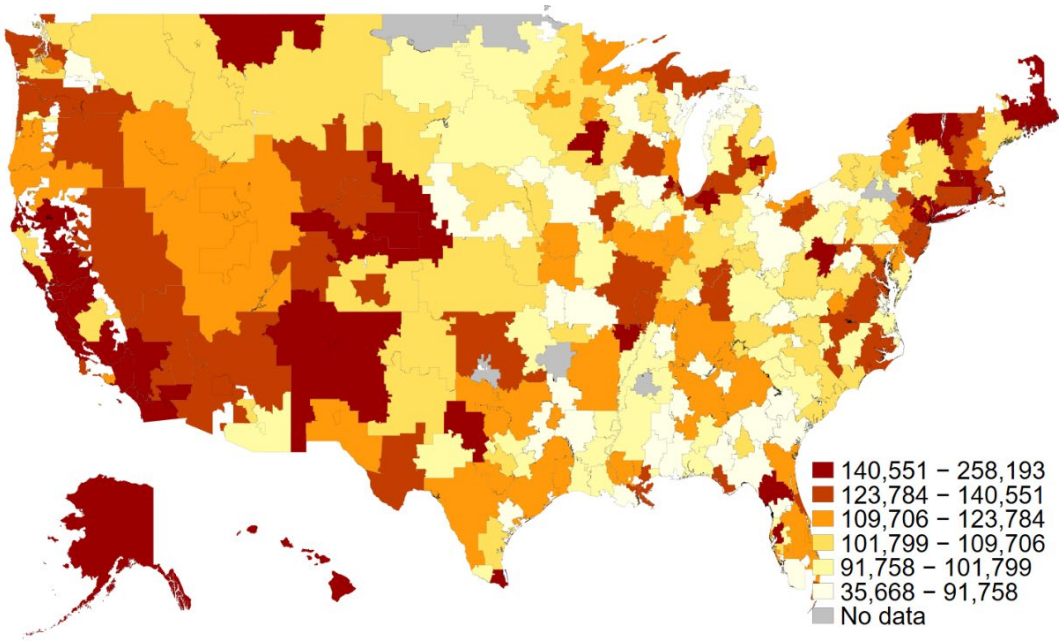
FIGURE B1: Variation across Hospital Referral Regions in the mean 90-day episode-of-care costs ($USD) for the "Complex fusion", "Anterior-posterior fusion", and "Back & neck surgery, except fusion" cohort defined by CMMI's Bundled Payment for Care Improvement Program.

(a) Complex fusion



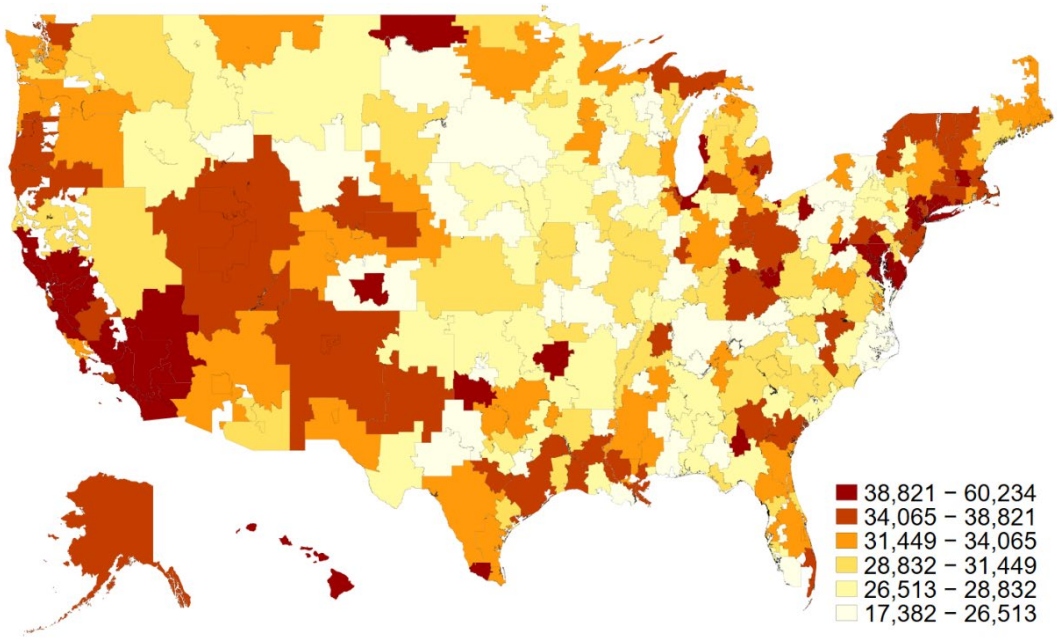
http://dx.doi.org/10.2106/JBJS.21.00389


(b) Anterior-posterior fusion



http://dx.doi.org/10.2106/JBJS.21.00389


(c) Back & neck surgery, except fusion



http://dx.doi.org/10.2106/JBJS.21.00389


*TABLE B1: Spine-specific spending and health care utilization across regional End-of-Life Care Index for five CMMI-defined inpatient spine surgery cohorts*

| Cohort | EOL quintile | Total 90-day spine-specific episode Spending | IP USER % (OR) | OP USER % (OR) | Part B USER % (OR) | SNF USER % (OR) | HHA USER % (OR) | DME USER % (OR) |
|---|---|---|---|---|---|---|---|---|
| Fusion, except cervical | 1 (low) | $63,634 (ref) | 15.1 (ref) | 74.6 (ref) | 97.4 (ref) | 23.7 (ref) | 35.4 (ref) | 47.5 (ref) |
| | 2 | $64,171 | 15.7 (1.05) | 72.4 (0.89) | 96.9 (0.83) | 21.0 (0.84)** | 39.3 (1.19)** | 48.8 (1.05) |
| | 3 | $65,412** | 16.3 (1.09)** | 72.0 (0.87)* | 97.1 (0.90) | 22.2 (0.91) | 41.2 (1.29)*** | 48.8 (1.05) |
| | 4 | $68,875*** | 17.2 (1.16)*** | 69.5 (0.77)*** | 97.8 (1.18) | 24.1 (1.02) | 43.9 (1.44)*** | 50.6 (1.13)** |
| | 5 (high) | $82,435*** | 17.8 (1.21)*** | 63.9 (0.60)*** | 98.1 (1.39)* | 27.7 (1.25)*** | 56.0 (2.39)*** | 51.6 (1.19)*** |
| Complex fusion | 1(low) | $123,959 (ref) | 27.0 (ref) | 79.6 (ref) | 97.7 (ref) | 39.8 (ref) | 48.7 (ref) | 52.3 (ref) |
| | 2 | $125,190 | 27.7 (1.04) | 78.1 (0.91) | 96.1 (0.58)** | 38.6 (0.95) | 48.7 (1.00) | 50.0 (0.91) |
| | 3 | $126,829 | 30.0 (1.16)* | 76.8 (0.84) | 97.9 (1.11) | 37.0 (0.88) | 52.6 (1.17)* | 51.6 (0.97) |
| | 4 | $134,024** | 30.1 (1.17)** | 72.3 (0.66)*** | 97.9 (1.10) | 41.8 (1.09) | 56.3 (1.36)*** | 51.7 (0.98) |
| | 5 (high) | $159,493*** | 30.9 (1.22)** | 72.6 (0.67)*** | 98.0 (1.13) | 40.0 (1.01) | 64.3 (1.91)*** | 53.3 (1.04) |
| Anterior-posterior fusion | 1(low) | $116,660 (ref) | 23.7 (ref) | 74.6 (ref) | 97.9 (ref) | 29.4 (ref) | 41.9 (ref) | 52.8 (ref) |
| | 2 | $110,981* | 26.0 (1.13) | 71.0 (0.83)** | 97.2 (0.72)* | 27.8 (0.92) | 44.6 (1.12) | 52.0 (0.97) |
| | 3 | $114,846 | 27.5 (1.22)* | 71.5 (0.85) | 97.4 (0.78) | 26.3 (0.85)* | 48.8 (1.33)* | 54.5 (1.07) |
| | 4 | $125,040* | 26.0 (1.13) | 67.9 (0.71)** | 97.8 (0.91) | 26.6 (0.86) | 48.1 (1.29)* | 54.9 (1.09) |
| | 5 (high) | $148,393*** | 25.6 (1.11) | 64.7 (0.62)*** | 98.2 (1.17) | 28.1 (0.94) | 59.3 (2.05)*** | 58.5 (1.26)* |
| Cervical fusion | 1(low) | $44,521 (ref) | 15.6 (ref) | 74.8 (ref) | 97.6 (ref) | 13.1 (ref) | 21.0 (ref) | 43.8 (ref) |
| | 2 | $44,962 | 15.5 (0.99) | 73.7 (0.94) | 97.4 (0.90) | 12.5 (0.94) | 23.4 (1.16)** | 44.7 (1.04) |
| | 3 | $45,914* | 17.5 (1.16)*** | 73.7 (0.95) | 97.3 (0.86) | 12.8 (0.97) | 26.2 (1.36)*** | 46.6 (1.12)* |
| | 4 | $49,812*** | 18.4 (1.23)*** | 71.2 (0.83)** | 97.6 (0.97) | 14.7 (1.16)** | 28.8 (1.57)*** | 49.2 (1.25)*** |
| | 5 (high) | $61,827*** | 19.1 (1.29)*** | 65.8 (0.65)*** | 97.7 (1.01) | 17.2 (1.44)*** | 36.9 (2.32)*** | 47.8 (1.18)** |
| Back & neck surgery, except fusion | 1(low) | $29,480 (ref) | 17.4 (ref) | 70.9 (ref) | 96.0 (ref) | 20.9 (ref) | 29.8 (ref) | 36.6 (ref) |
| | 2 | $30,562* | 18.8 (1.10)* | 68.4 (0.89)* | 94.5 (0.72)* | 20.6 (0.99) | 34.4 (1.25)*** | 35.5 (0.96) |
| | 3 | $30,860** | 19.6 (1.16)*** | 69.1 (0.92) | 96.6 (1.17) | 20.6 (0.98) | 35.6 (1.32)*** | 36.6 (1.00) |
| | 4 | $33,495*** | 20.0 (1.19)*** | 64.7 (0.75)*** | 96.7 (1.21) | 22.2 (1.09) | 38.2 (1.49)*** | 36.0 (0.97) |
| | 5 (high) | $39,858*** | 20.6 (1.24)*** | 61.3 (0.65)*** | 97.8 (1.86)*** | 22.7 (1.12) | 47.9 (2.26)*** | 38.9 (1.11)* |

*p<0.05, ** p<0.01, ***p<0.001. Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous utilizations. All models control for age, sex, race, comorbidity, calendar year, hospital procedure volume, bed count and teaching status.

EOL_EI, End-of-Life Inpatient Care index; IP, Inpatient; OP, Outpatient; Part B, Medicare Part B (office-based and provider); SNF, Skilled Nursing Facilities; HHA, Home Health Agency; DME, Durable Medical Equipment; OR, Odd Ratio.

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*TABLE B2: Spine specific spending and variation in spine surgery safety measures across regional End-of-Life Care Index quintile*

| Cohort | EOL quintile | Total 90-day spine-specific episode Spending | Died within 90-days % (OR) | 90-day readmit % (OR) | PE within 90 days % (OR) | DVT within 90 days % (OR) |
|---|---|---|---|---|---|---|
| Fusion, except cervical | 1 (low) | $63,634 | 1.0 (ref) | 13.1 (ref) | 2.5 (ref) | 4.5 (ref) |
| | 2 | $64,171 | 1.1 (1.06) | 13.3 (1.02) | 2.2 (0.87)** | 4.7 (1.04) |
| | 3 | $65,412 | 1.0 (0.99) | 13.2 (1.02) | 2.3 (0.93) | 4.7 (1.05) |
| | 4 | $68,875 | 1.0 (1.01) | 13.9 (1.07)** | 2.3 (0.91) | 4.5 (1.01) |
| | 5 (high) | $82,435 | 0.9 (0.90) | 14.2 (1.10)*** | 2.3 (0.94) | 4.8 (1.08) |
| Complex fusion | 1 (low) | $123,959 | 6.6 (ref) | 25.4 (ref) | 4.9 (ref) | 7.3 (ref) |
| | 2 | $125,190 | 7.0 (1.08) | 25.7 (1.02) | 4.0 (0.82)* | 7.4 (1.02) |
| | 3 | $126,829 | 7.2 (1.12) | 27.3 (1.11) | 3.8 (0.77)* | 7.8 (1.08) |
| | 4 | $134,024 | 7.7 (1.21)* | 27.2 (1.10) | 4.4 (0.90) | 8.9 (1.25)** |
| | 5 (high) | $159,493 | 7.0 (1.09) | 28.0 (1.15)* | 5.1 (1.06) | 9.6 (1.37)*** |
| Anterior-posterior fusion | 1 (low) | $116,660 | 1.9 (ref) | 15.8 (ref) | 2.9 (ref) | 5.6 (ref) |
| | 2 | $110,981 | 2.0 (1.05) | 15.1 (0.94) | 2.3 (0.80)* | 5.3 (0.95) |
| | 3 | $114,846 | 1.6 (0.81) | 16.2 (1.03) | 2.6 (0.90) | 6.1 (1.10) |
| | 4 | $125,040 | 1.9 (0.97) | 16.4 (1.04) | 2.4 (0.83) | 5.6 (1.00) |
| | 5 (high) | $148,393 | 2.0 (1.02) | 16.2 (1.03) | 2.7 (0.92) | 5.6 (1.00) |
| Cervical fusion | 1 (low) | $44,521 | 2.1 (ref) | 13.6 (ref) | 2.0 (ref) | 3.8 (ref) |
| | 2 | $44,962 | 2.1 (1.04) | 13.1 (0.96) | 1.8 (0.88) | 3.7 (0.97) |
| | 3 | $45,914 | 2.1 (1.00) | 14.2 (1.05) | 2.1 (1.06) | 4.2 (1.13)* |
| | 4 | $49,812 | 2.0 (0.98) | 15.0 (1.12)*** | 2.0 (1.01) | 4.3 (1.16)* |
| | 5 (high) | $61,827 | 2.0 (0.98) | 15.0 (1.12)*** | 2.0 (1.02) | 4.5 (1.21)** |
| Back & neck surgery, except fusion | 1 (low) | $29,480 | 1.9 (ref) | 14.5 (ref) | 2.4 (ref) | 4.7 (ref) |
| | 2 | $30,562 | 1.9 (0.99) | 15.3 (1.06) | 2.2 (0.89) | 4.4 (0.94) |
| | 3 | $30,860 | 1.8 (0.93) | 15.4 (1.07) | 2.5 (1.04) | 5.2 (1.12) |
| | 4 | $33,495 | 1.9 (1.00) | 14.9 (1.03) | 2.4 (0.99) | 5.1 (1.11) |
| | 5 (high) | $39,858 | 1.5 (0.79)* | 15.6 (1.09) | 2.1 (0.88) | 5.0 (1.08) |

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*p<0.05, ** p<0.01, ***p<0.001. Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous safety indicators. All models control for age, sex, race, comorbidity, calendar year, hospital procedure volume, bed count and teaching status.

EOL, End-of-Life Care Inpatient index; readmit, Readmission for any reasons; PE, Pulmonary embolism; DVT, Deep Vein Thrombosis; OR, Odd Ratio.

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## APPENDIX C.

## Tables with Fully-specified coefficients for all the covariates in our models

*TABLE C1. Spine-specific spending and health care utilization for Back & neck surgery, except fusion utilization*

| Outcome Variables | Total 90-day spine-specific episode Spending | IP USER OR | OP USER OR | Part B USER OR | SNF USER OR | HHA USER OR | DME USER OR |
|---|---|---|---|---|---|---|---|
| EOL (ref =Q1) | | | | | | | |
| EOL Q2 | $1,082* | 1.10* | 0.89* | 0.72* | 0.99 | 1.25*** | 0.96 |
| EOL Q3 | $1,380** | 1.16*** | 0.92 | 1.17 | 0.98 | 1.32*** | 1.00 |
| EOL Q4 | $4,015*** | 1.19*** | 0.75*** | 1.21 | 1.09 | 1.49*** | 0.97 |
| EOL Q5 (high) | $10,378*** | 1.24*** | 0.65*** | 1.86*** | 1.12 | 2.26*** | 1.11* |
| Beds count (ref = <100) | | | | | | | |
| Beds 100-199 | $1,700** | 1.09 | 1.19* | 0.83 | 1.66*** | 1.52*** | 1.12 |
| Beds 200-299 | $3,206*** | 1.15** | 1.06 | 0.82 | 1.64*** | 1.64*** | 1.11 |
| Beds 300-399 | $3,721*** | 1.18** | 1.16 | 0.74 | 1.61*** | 1.74*** | 1.12 |
| Beds 400-499 | $3,794*** | 1.14** | 1.14 | 0.73 | 1.67*** | 1.54*** | 1.17* |
| Beds 500-599 | $5,094*** | 1.29** | 1.00 | 1.32 | 1.72*** | 1.45*** | 1.18* |
| Beds 600-699 | $5,059*** | 1.29*** | 1.15 | 0.73 | 2.10*** | 1.64*** | 1.12 |
| Beds >=700 | $5,712*** | 1.30*** | 1.06 | 1.32 | 1.77*** | 1.91*** | 1.25* |
| Female (ref =Male) | $1,237*** | 0.97 | 1.14*** | 1.47*** | 1.61*** | 1.50*** | 1.01 |
| Volume (mean) | -$16*** | 1.00*** | 1.00 | 1.00 | 1.00*** | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | | | | |
| Age group 70-74 | $1,532*** | 1.11*** | 1.09*** | 1.31*** | 1.43*** | 1.31*** | 1.10*** |
| Age group 75-79 | $3,177*** | 1.19*** | 1.19*** | 1.61*** | 2.08*** | 1.77*** | 1.16*** |
| Age group 80-84 | $6,086*** | 1.36*** | 1.23*** | 1.80*** | 3.46*** | 2.47*** | 1.01 |
| Age group 85+ | $10,632*** | 1.57*** | 1.17*** | 2.12*** | 6.10*** | 3.09*** | 0.90** |
| Race (ref=white) | | | | | | | |
| Race Black | $6,956*** | 1.16** | 0.92 | 0.89 | 1.59*** | 1.72*** | 1.32*** |
| Race Other | $4,016*** | 0.96 | 0.94 | 0.90 | 1.11 | 1.19*** | 1.16*** |
| CCI (ref =0) | | | | | | | |
| CCI of 1 | $3,334*** | 1.22*** | 1.16*** | 1.18** | 1.48*** | 1.31*** | 1.79*** |
| CCI of 2 or above | $13,277*** | 1.91*** | 1.45*** | 1.15** | 2.62*** | 1.69*** | 2.14*** |
| Teaching status | $4,283*** | 0.94 | 1.73*** | 0.62** | 1.16* | 0.99 | 0.92 |
| Year (ref=2014) | | | | | | | |
| Year 2015 | $1,148*** | 0.98 | 1.04 | 1.15* | 1.09** | 1.08** | 1.03 |
| Year 2016 | $3,036*** | 0.99 | 1.05 | 1.07 | 1.10** | 1.09** | 1.01 |
| Year 2017 | -$3,453*** | 3.09*** | 1.09** | 1.39*** | 1.09** | 1.05 | 0.95 |
| Constant | $17,007*** | 0.10*** | 1.47*** | 20.23*** | 0.04*** | 0.10*** | 0.33*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous utilizations.
EOL Q, End-of-Life Inpatient Care Index Quintile; IP, Inpatient; OP, Outpatient; Part B, Medicare Part B (office-based and provider); SNF, Skilled Nursing Facilities; HHA, Home Health Agency; DME, Durable Medical Equipment; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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***TABLE C2. Variation in spine surgery safety measures for Back & neck surgery, except fusion safety***

| Outcome Variables | Died within 90-days OR | 90-day readmit OR | PE within 90 days OR | DVT within 90 days OR |
|---|---|---|---|---|
| EOL (ref =Q1) | | | | |
| EOL Q2 | 0.99 | 1.06 | 0.89 | 0.94 |
| EOL Q3 | 0.93 | 1.07 | 1.04 | 1.12 |
| EOL Q4 | 1.00 | 1.03 | 0.99 | 1.11 |
| EOL Q5 (high) | 0.79* | 1.09 | 0.88 | 1.08 |
| Beds (ref = <100) | | | | |
| Beds 100-199 | 1.47* | 1.09 | 1.06 | 0.93 |
| Beds 200-299 | 1.99*** | 1.18** | 1.30* | 1.10 |
| Beds 300-399 | 2.10*** | 1.20** | 1.22 | 1.15 |
| Beds 400-499 | 1.92*** | 1.16** | 1.11 | 1.04 |
| Beds 500-599 | 2.05*** | 1.31*** | 1.12 | 1.13 |
| Beds 600-699 | 1.84** | 1.31*** | 1.12 | 1.24 |
| Beds >=700 | 2.51*** | 1.38*** | 1.04 | 1.20 |
| Female (ref =Male) | 0.79*** | 0.99 | 1.02 | 0.97 |
| Volume (mean) | 1.00*** | 1.00*** | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | |
| Age group 70-74 | 1.30* | 1.14*** | 1.19* | 1.03 |
| Age group 75-79 | 1.52*** | 1.24*** | 1.30** | 1.18** |
| Age group 80-84 | 2.27*** | 1.44*** | 1.23* | 1.25*** |
| Age group 85+ | 4.87*** | 1.73*** | 1.50*** | 1.51*** |
| Race (ref=white) | | | | |
| Race Black | 1.27 | 1.16* | 1.18 | 1.25** |
| Race Other | 0.92 | 0.95 | 0.72* | 0.66*** |
| CCI (ref =0) | | | | |
| CCI of 1 | 1.56*** | 1.32*** | 1.25** | 1.33*** |
| CCI of 2 or above | 6.26*** | 2.24*** | 2.04*** | 2.15*** |
| Teaching status | 1.02 | 0.94 | 1.43*** | 1.19** |
| Year (ref=2014) | | | | |
| Year 2015 | 0.91 | 0.99 | 1.01 | 1.00 |
| Year 2016 | 0.96 | 0.99 | 0.79** | 1.02 |
| Year 2017 | 1.01 | 1.00 | 0.93 | 1.07 |
| | | | | |
| Constant | 0.003*** | 0.09*** | 0.01*** | 0.03*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as odds-ratio for dichotomous safety indicators.
EOL Q, End-of-Life Inpatient Care Index Quintile; readmit, Readmission for any reasons; PE, Pulmonary embolism; DVT, Deep Vein Thrombosis; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C3. Spine-specific spending and health care utilization for Cervical spinal fusion utilization*

| Outcome Variables | Total 90-day spine-specific episode Spending | IP USER OR | OP USER OR | Part B USER OR | SNF USER OR | HHA USER OR | DME USER OR |
|---|---|---|---|---|---|---|---|
| EOL (ref =Q1) | | | | | | | |
| EOL Q2 | $441 | 0.99 | 0.94 | 0.90 | 0.94 | 1.16** | 1.04 |
| EOL Q3 | $1,393* | 1.16*** | 0.95 | 0.86 | 0.97 | 1.36*** | 1.12* |
| EOL Q4 | $5,291*** | 1.23*** | 0.83** | 0.97 | 1.16** | 1.57*** | 1.25*** |
| EOL Q5 (high) | $17,306*** | 1.29*** | 0.65*** | 1.01 | 1.44*** | 2.32*** | 1.18** |
| Beds count (ref = <100) | | | | | | | |
| Beds 100-199 | $4,182*** | 1.04 | 1.22* | 0.94*** | 1.82*** | 1.29** | 0.83 |
| Beds 200-299 | $4,873*** | 1.03 | 1.16 | 0.86 | 2.09*** | 1.52*** | 0.75** |
| Beds 300-399 | $5,667*** | 1.04 | 1.21* | 0.78 | 2.23*** | 1.79*** | 0.85 |
| Beds 400-499 | $6,431*** | 1.10* | 1.08 | 0.65 | 2.24*** | 1.38** | 0.73** |
| Beds 500-599 | $6,376*** | 1.09 | 1.03 | 1.05 | 2.24*** | 1.38** | 0.73** |
| Beds 600-699 | $7,325*** | 1.18** | 1.13 | 0.77 | 2.57*** | 1.50*** | 0.67*** |
| Beds >=700 | $7,907*** | 1.15** | 1.06 | 1.17 | 2.67*** | 1.85*** | 0.81* |
| Female (ref =Male) | -$1,710*** | 0.83*** | 1.08*** | 1.56*** | 1.25*** | 1.37*** | 1.11*** |
| Volume (mean) | -$23*** | 1.00*** | 1.00 | 1.00 | 1.00*** | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | | | | |
| Age group 70-74 | $2,109*** | 1.10*** | 1.09*** | 1.35*** | 1.43*** | 1.33*** | 1.11*** |
| Age group 75-79 | $6,380*** | 1.30*** | 1.20*** | 1.80*** | 2.42*** | 1.94*** | 1.11*** |
| Age group 80-84 | $12,202*** | 1.50*** | 1.24*** | 2.10*** | 4.65*** | 2.91*** | 0.98 |
| Age group 85+ | $21,626*** | 1.82*** | 1.10** | 2.13*** | 9.52*** | 3.44*** | 0.81*** |
| Race (ref=white) | | | | | | | |
| Race Black | $8,252*** | 1.20*** | 0.90** | 0.85 | 1.59*** | 1.65*** | 1.19*** |
| Race Other | $4,956*** | 0.92* | 0.98 | 0.72*** | 1.08 | 1.12** | 0.99 |
| CCI (ref =0) | | | | | | | |
| CCI of 1 | $3,737*** | 1.24*** | 1.17*** | 1.11* | 1.55*** | 1.38*** | 1.60*** |
| CCI of 2 or above | $18,108*** | 2.05*** | 1.40*** | 1.17** | 3.04*** | 1.95*** | 1.86*** |
| Teaching status | $10,216*** | 1.05 | 1.81*** | 0.69* | 1.45*** | 1.13 | 0.85** |
| Year (ref=2013) | | | | | | | |
| Year 2015 | $1,133*** | 1.00 | 0.99 | 0.95 | 1.09** | 1.12*** | 0.97 |
| Year 2015 | $1,978*** | 0.98 | 1.00 | 0.99 | 1.16*** | 1.18*** | 0.97 |
| Year 2016 | $2,314*** | 1.00 | 0.97 | 0.93 | 1.11*** | 1.19*** | 0.96 |
| Year 2017 | -$6,068*** | 3.24*** | 1.07* | 1.22** | 1.23** | 1.28*** | 1.06* |
| Constant | $29,230*** | 0.11*** | 2.00*** | 34.64*** | 0.02*** | 0.06*** | 0.67* |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous utilizations.
EOL Q, End-of-Life Inpatient Care Index Quintile; IP, Inpatient; OP, Outpatient; Part B, Medicare Part B (office-based and provider); SNF, Skilled Nursing Facilities; HHA, Home Health Agency; DME, Durable Medical Equipment; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C4. Variation in spine surgery safety measures for Cervical spinal fusion safety*

| Outcome Variables | Died within 90-days OR | 90-day readmit OR | PE within 90 days OR | DVT within 90 days OR |
|---|---|---|---|---|
| EOL (ref =Q1) | | | | |
| EOL Q2 | 1.04 | 0.96 | 0.88 | 0.97 |
| EOL Q3 | 1.00 | 1.05 | 1.06 | 1.13* |
| EOL Q4 | 0.98 | 1.12*** | 1.01 | 1.16* |
| EOL Q5 (high) | 0.98 | 1.12*** | 1.02 | 1.21** |
| Beds (ref = <100) | | | | |
| Beds 100-199 | 1.40** | 1.07 | 1.23* | 1.08 |
| Beds 200-299 | 1.53*** | 1.06 | 1.12 | 1.08 |
| Beds 300-399 | 1.64*** | 1.06 | 1.28* | 1.16 |
| Beds 400-499 | 2.13*** | 1.16** | 1.37** | 1.26** |
| Beds 500-599 | 2.22*** | 1.15* | 1.21 | 1.10 |
| Beds 600-699 | 2.31*** | 1.25*** | 1.39** | 1.24* |
| Beds >=700 | 2.27*** | 1.22*** | 1.28* | 1.26** |
| Female (ref =Male) | 0.60*** | 0.80*** | 0.94 | 1.01 |
| Volume (mean) | 1.00*** | 1.00*** | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | |
| Age group 70-74 | 1.19* | 1.12*** | 1.08 | 1.09* |
| Age group 75-79 | 2.03*** | 1.39*** | 1.31*** | 1.20*** |
| Age group 80-84 | 3.74*** | 1.61*** | 1.45*** | 1.54*** |
| Age group 85+ | 9.96*** | 2.03*** | 1.45*** | 1.58*** |
| Race (ref=white) | | | | |
| Race Black | 1.12 | 1.23*** | 1.18* | 1.25*** |
| Race Other | 1.11 | 0.92* | 0.58*** | 0.68*** |
| CCI (ref =0) | | | | |
| CCI of 1 | 1.77*** | 1.30*** | 1.44*** | 1.42*** |
| CCI of 2 or above | 5.63*** | 2.29*** | 2.18*** | 2.34*** |
| Teaching status | 1.10 | 1.05 | 1.32*** | 1.28*** |
| Year (ref=2013) | | | | |
| Year 2014 | 0.96 | 1.01 | 1.07 | 0.99 |
| Year 2015 | 1.06 | 0.99 | 0.98 | 0.97 |
| Year 2016 | 1.05 | 1.00 | 0.92 | 0.98 |
| Year 2017 | 1.07 | 1.03 | 0.93 | 1.01 |
| Constant | 0.004*** | 0.10*** | 0.01*** | 0.02*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as odds-ratio for dichotomous safety indicators.
EOL Q, End-of-Life Inpatient Care Index Quintile; readmit, Readmission for any reasons; PE, Pulmonary embolism; DVT, Deep Vein Thrombosis; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C5. Spine-specific spending and health care utilization for Anterior-posterior Fusion utilization*

| Outcome Variables | Total 90-day spine-specific episode Spending | IP USER OR | OP USER OR | Part B USER OR | SNF USER OR | HHA USER OR | DME USER OR |
|---|---|---|---|---|---|---|---|
| EOL (ref =Q1) | | | | | | | |
| EOL Q2 | -$5,679* | 1.13 | 0.83** | 0.72* | 0.92 | 1.12 | 0.97 |
| EOL Q3 | -$1,814 | 1.22* | 0.85 | 0.78 | 0.85* | 1.33* | 1.07 |
| EOL Q4 | $8,380* | 1.13 | 0.71** | 0.91 | 0.86 | 1.29* | 1.09 |
| EOL Q5 (high) | $31,733*** | 1.11 | 0.62*** | 1.17 | 0.94 | 2.05*** | 1.26* |
| Beds count (ref = <100) | | | | | | | |
| Beds 100-199 | $4,993 | 0.90 | 1.07 | 0.85 | 1.32* | 1.01 | 0.90 |
| Beds 200-299 | $6,587 | 1.08 | 1.11 | 0.74 | 1.55*** | 1.29 | 0.86 |
| Beds 300-399 | $11,255* | 1.06 | 0.85 | 0.87 | 1.35* | 1.61* | 0.98 |
| Beds 400-499 | $19,116** | 1.08 | 1.11 | 0.82 | 1.64*** | 1.26 | 0.86 |
| Beds 500-599 | $15,943** | 1.09 | 0.93 | 1.30 | 1.38* | 1.22 | 0.93 |
| Beds 600-699 | $11,575 | 1.06 | 1.01 | 0.55* | 1.55** | 1.33 | 0.90 |
| Beds >=700 | $17,802* | 1.11 | 1.17 | 1.41 | 1.16 | 1.69* | 1.29 |
| Female (ref =Male) | $4,808*** | 0.94* | 1.14*** | 1.47*** | 1.76*** | 1.60*** | 1.07** |
| Volume (mean) | -$28* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | | | | |
| Age group 70-74 | $3,523*** | 1.04 | 1.11*** | 1.39*** | 1.42*** | 1.21*** | 1.03 |
| Age group 75-79 | $5,223*** | 1.19*** | 1.17*** | 2.15*** | 2.09*** | 1.49*** | 0.99 |
| Age group 80-84 | $6,747*** | 1.27*** | 1.09 | 2.08*** | 3.07*** | 1.85*** | 0.82*** |
| Age group 85+ | $8,685*** | 1.19* | 1.05 | 1.86* | 4.36*** | 1.60*** | 0.69*** |
| Race (ref=white) | | | | | | | |
| Race Black | -$1,924 | 1.15* | 0.80*** | 0.66** | 1.35*** | 1.25*** | 1.09 |
| Race Other | $4,925** | 1.05 | 0.92 | 0.83 | 1.09 | 1.08 | 1.01 |
| CCI (ref =0) | | | | | | | |
| CCI of 1 | $6,847*** | 1.14*** | 1.14*** | 1.03 | 1.31*** | 1.21*** | 1.32*** |
| CCI of 2 or above | $24,610*** | 1.62*** | 1.38*** | 1.04 | 1.95*** | 1.39*** | 1.37*** |
| Teaching status | $22,478*** | 1.16* | 2.02*** | 0.57** | 1.51*** | 0.88 | 0.67*** |
| Year (ref=2013) | | | | | | | |
| Year 2015 | -$2,654* | 0.93 | 0.96 | 0.97 | 0.98 | 1.01 | 0.95 |
| Year 2015 | -$3,502* | 0.89* | 0.96 | 1.04 | 1.00 | 1.02 | 0.94 |
| Year 2016 | -$3,081* | 0.92 | 0.96 | 1.05 | 0.97 | 1.01 | 0.97 |
| Year 2017 | -$47,028*** | 5.22*** | 1.04 | 1.68*** | 0.90* | 0.95 | 1.03 |
| Constant | $101,598*** | 0.175*** | 2.02*** | 42.27*** | 0.11*** | 0.31*** | 1.03 |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous utilizations.
EOL Q, End-of-Life Inpatient Care Index Quintile; IP, Inpatient; OP, Outpatient; Part B, Medicare Part B (office-based and provider); SNF, Skilled Nursing Facilities; HHA, Home Health Agency; DME, Durable Medical Equipment; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C6. Variation in spine surgery safety measures for Anterior-posterior Fusion safety*

| Outcome Variables | Died within 90-days OR | 90-day readmit OR | PE within 90 days OR | DVT within 90 days OR |
|---|---|---|---|---|
| EOL (ref =Q1) | | | | |
| EOL Q2 | 1.05 | 0.94 | 0.80* | 0.95 |
| EOL Q3 | 0.81 | 1.03 | 0.90 | 1.10 |
| EOL Q4 | 0.97 | 1.04 | 0.83 | 1.00 |
| EOL Q5 (high) | 1.02 | 1.03 | 0.92 | 1.00 |
| Beds (ref = <100) | | | | |
| Beds 100-199 | 2.02** | 0.98 | 1.21 | 1.05 |
| Beds 200-299 | 2.49*** | 1.13 | 1.20 | 1.29* |
| Beds 300-399 | 2.17** | 1.16 | 1.35 | 1.30* |
| Beds 400-499 | 2.69*** | 1.17 | 1.09 | 1.18 |
| Beds 500-599 | 3.28*** | 1.34** | 1.40* | 1.41** |
| Beds 600-699 | 3.57*** | 1.15 | 1.46 | 1.36** |
| Beds >=700 | 3.72*** | 1.31* | 1.15 | 1.24 |
| Female (ref =Male) | 0.58*** | 0.99 | 1.00 | 1.00 |
| Volume (mean) | 1.00*** | 1.00 | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | |
| Age group 70-74 | 1.31* | 1.07* | 1.15 | 1.12* |
| Age group 75-79 | 1.77*** | 1.20*** | 1.31** | 1.29*** |
| Age group 80-84 | 2.85*** | 1.30*** | 1.32* | 1.37*** |
| Age group 85+ | 5.27*** | 1.35** | 1.14 | 1.03 |
| Race (ref=white) | | | | |
| Race Black | 1.20 | 1.17* | 1.02 | 1.10 |
| Race Other | 0.85 | 1.06 | 0.79 | 0.82 |
| CCI (ref =0) | | | | |
| CCI of 1 | 1.94*** | 1.28*** | 1.22* | 1.27*** |
| CCI of 2 or above | 6.21*** | 2.07*** | 1.75*** | 1.98*** |
| Teaching status | 1.46** | 1.07 | 1.45** | 1.43*** |
| Year (ref=2013) | | | | |
| Year 2014 | 0.96 | 0.93 | 1.08 | 0.95 |
| Year 2015 | 1.02 | 0.90* | 0.95 | 0.89 |
| Year 2016 | 0.82 | 0.94 | 0.72** | 0.91 |
| Year 2017 | 0.87 | 0.77*** | 0.74** | 0.83* |
| Constant | 0.003*** | 0.13*** | 0.02*** | 0.03*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as odds-ratio for dichotomous safety indicators.
EOL Q, End-of-Life Inpatient Care Index Quintile; readmit, Readmission for any reasons; PE, Pulmonary embolism; DVT, Deep Vein Thrombosis; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C7. Spine-specific spending and health care utilization for Complex Fusion utilization*

| Outcome Variables | Total 90-day spine-specific episode Spending | IP USER OR | OP USER OR | Part B USER OR | SNF USER OR | HHA USER OR | DME USER OR |
|---|---|---|---|---|---|---|---|
| EOL (ref =Q1) | | | | | | | |
| EOL Q2 | $1,231 | 1.04 | 0.91 | 0.58** | 0.95 | 1.00 | 0.91 |
| EOL Q3 | $2,870 | 1.16* | 0.84 | 1.11 | 0.88 | 1.17* | 0.97 |
| EOL Q4 | $10,065** | 1.17** | 0.66*** | 1.10 | 1.09 | 1.36*** | 0.98 |
| EOL Q5 (high) | $35,534*** | 1.22** | 0.67*** | 1.13 | 1.01 | 1.91*** | 1.04 |
| Beds count (ref = <100) | | | | | | | |
| Beds 100-199 | $9,844* | 1.18 | 1.17 | 0.87 | 1.22 | 1.30 | 0.97 |
| Beds 200-299 | $7,471 | 1.08 | 1.16 | 0.77 | 1.16 | 1.52** | 0.97 |
| Beds 300-399 | $11,374* | 1.16 | 1.06 | 0.85 | 1.05 | 1.61** | 0.98 |
| Beds 400-499 | $11,058 | 1.10 | 1.12 | 0.92 | 1.28 | 1.37* | 0.99 |
| Beds 500-599 | $14,210** | 1.11 | 1.08 | 1.55 | 1.01 | 1.52** | 1.07 |
| Beds 600-699 | $6,541 | 1.14 | 1.06 | 1.07 | 1.39 | 1.38* | 0.90 |
| Beds >=700 | $13,848* | 1.16 | 0.97 | 1.33 | 1.09 | 1.78*** | 1.09 |
| Female (ref =Male) | $1,225 | 0.91** | 1.05 | 1.37** | 1.53*** | 1.46*** | 1.05 |
| Volume (mean) | -$8 | 1.00** | 1.00 | 1.00 | 1.00 | 1.00* | 1.00* |
| Age group (ref=65-69) | | | | | | | |
| Age group 70-74 | $1,009 | 1.02 | 1.09 | 1.50*** | 1.33*** | 1.16*** | 0.99 |
| Age group 75-79 | $804 | 1.11* | 1.03 | 1.86*** | 1.88*** | 1.30*** | 0.93* |
| Age group 80-84 | $390 | 1.07 | 1.07 | 2.62*** | 2.68*** | 1.35*** | 0.80*** |
| Age group 85+ | $2,481 | 1.25** | 0.83* | 4.05*** | 4.32*** | 1.23** | 0.62*** |
| Race (ref=white) | | | | | | | |
| Race Black | $3,172 | 1.25** | 0.80** | 0.60** | 1.37*** | 1.09 | 1.01 |
| Race Other | $8,009*** | 1.00 | 0.92 | 0.69* | 0.94 | 0.85* | 1.04 |
| CCI (ref =0) | | | | | | | |
| CCI of 1 | $10,047*** | 1.29*** | 1.10* | 1.02 | 1.29*** | 1.15*** | 1.23*** |
| CCI of 2 or above | $20,354*** | 2.22*** | 1.23*** | 0.87 | 1.83*** | 0.98 | 1.01 |
| Teaching status | $23,138*** | 1.09 | 2.17*** | 0.52** | 1.07 | 0.84* | 0.76** |
| Year (ref=2013) | | | | | | | |
| Year 2015 | -$2,233 | 1.03 | 1.03 | 0.98 | 1.01 | 1.07 | 0.97 |
| Year 2015 | $673 | 0.99 | 1.12* | 0.85 | 1.04 | 1.10* | 0.94 |
| Year 2016 | $1,768 | 1.03 | 1.07 | 0.90 | 1.07 | 1.17** | 0.88** |
| Year 2017 | -$18,488*** | 1.90*** | 1.09 | 1.03 | 1.02 | 1.08 | 0.97 |
| Constant | $95,871*** | 0.21*** | 2.30*** | 41.63*** | 0.21*** | 0.38*** | 1.16 |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous utilizations.
EOL Q, End-of-Life Inpatient Care Index Quintile; IP, Inpatient; OP, Outpatient; Part B, Medicare Part B (office-based and provider); SNF, Skilled Nursing Facilities; HHA, Home Health Agency; DME, Durable Medical Equipment; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C8. Variation in spine surgery safety measures for Complex Fusion safety*

| Outcome Variables | Died within 90-days OR | 90-day readmit OR | PE within 90 days OR | DVT within 90 days OR |
|---|---|---|---|---|
| EOL (ref =Q1) | | | | |
| EOL Q2 | 1.08 | 1.02 | 0.82* | 1.02 |
| EOL Q3 | 1.12 | 1.11 | 0.77* | 1.08 |
| EOL Q4 | 1.21* | 1.10 | 0.90 | 1.25** |
| EOL Q5 (high) | 1.09 | 1.15* | 1.06 | 1.37*** |
| Beds (ref = <100) | | | | |
| Beds 100-199 | 1.87* | 1.19 | 1.11 | 1.29 |
| Beds 200-299 | 2.31*** | 1.09 | 1.02 | 1.14 |
| Beds 300-399 | 2.49*** | 1.19 | 1.41 | 1.36* |
| Beds 400-499 | 2.19** | 1.14 | 1.30 | 1.51** |
| Beds 500-599 | 1.96** | 1.10 | 1.24 | 1.34 |
| Beds 600-699 | 2.47*** | 1.15 | 1.38 | 1.52* |
| Beds >=700 | 2.68*** | 1.17 | 1.43 | 1.48** |
| Female (ref =Male) | 0.59*** | 0.92* | 0.96 | 0.89* |
| Volume (mean) | 1.00*** | 1.00** | 1.00* | 1.00 |
| Age group (ref=65-69) | | | | |
| Age group 70-74 | 1.05 | 1.05 | 1.06 | 1.06 |
| Age group 75-79 | 1.29** | 1.12* | 1.05 | 1.09 |
| Age group 80-84 | 1.32** | 1.07 | 0.92 | 1.18* |
| Age group 85+ | 2.40*** | 1.25** | 1.18 | 1.13 |
| Race (ref=white) | | | | |
| Race Black | 1.27* | 1.25** | 1.27 | 1.36** |
| Race Other | 1.06 | 0.99 | 0.72 | 0.82 |
| CCI (ref =0) | | | | |
| CCI of 1 | 2.73*** | 1.33*** | 1.57*** | 1.16* |
| CCI of 2 or above | 16.91*** | 2.41*** | 2.12*** | 2.03*** |
| Teaching status | 1.14 | 1.12 | 1.36** | 1.25** |
| Year (ref=2013) | | | | |
| Year 2014 | 0.95 | 1.03 | 1.04 | 1.14 |
| Year 2015 | 1.02 | 1.00 | 0.97 | 1.09 |
| Year 2016 | 0.95 | 1.02 | 0.73** | 1.13 |
| Year 2017 | 0.91 | 1.00 | 0.65*** | 1.11 |
| Constant | 0.006*** | 0.19*** | 0.03*** | 0.04*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as odds-ratio for dichotomous safety indicators.
EOL Q, End-of-Life Inpatient Care Index Quintile; readmit, Readmission for any reasons; PE, Pulmonary embolism; DVT, Deep Vein Thrombosis; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C9. Spine-specific spending and health care utilization for Spinal fusion except cervical utilization*

| Outcome Variables | Total 90-day spine-specific episode Spending | IP USER OR | OP USER OR | Part B USER OR | SNF USER OR | HHA USER OR | DME USER OR |
|---|---|---|---|---|---|---|---|
| EOL (ref =Q1) | | | | | | | |
| EOL Q2 | $537 | 1.05 | 0.89 | 0.83 | 0.84** | 1.19** | 1.05 |
| EOL Q3 | $1,778** | 1.09** | 0.87* | 0.90 | 0.91 | 1.29*** | 1.05 |
| EOL Q4 | $5,241*** | 1.16*** | 0.77*** | 1.18 | 1.02 | 1.44*** | 1.13** |
| EOL Q5 (high) | $18,801*** | 1.21*** | 0.60*** | 1.39* | 1.25*** | 2.39*** | 1.19*** |
| Beds count (ref = <100) | | | | | | | |
| Beds 100-199 | $3,172** | 1.00 | 1.21* | 0.72 | 1.25* | 1.21* | 0.97 |
| Beds 200-299 | $4,072** | 1.04 | 1.06 | 0.68* | 1.23* | 1.43** | 0.94 |
| Beds 300-399 | $3,721** | 1.01 | 1.09 | 0.58* | 1.26* | 1.48*** | 0.97 |
| Beds 400-499 | $3,408* | 1.06 | 1.08 | 0.63* | 1.24* | 1.16 | 0.98 |
| Beds 500-599 | $5,801*** | 1.11** | 0.98 | 1.13 | 1.10 | 1.15 | 0.98 |
| Beds 600-699 | $5,677** | 1.10 | 1.11 | 0.60* | 1.38** | 1.37** | 0.94 |
| Beds >=700 | $5,672*** | 1.14** | 1.02 | 1.14 | 1.16 | 1.61*** | 1.13 |
| Female (ref =Male) | $1,234*** | 0.98* | 1.14*** | 1.28*** | 1.76*** | 1.58*** | 1.02* |
| Volume (mean) | -$19*** | 1.00*** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Age group (ref=65-69) | | | | | | | |
| Age group 70-74 | $1,861*** | 1.09*** | 1.07*** | 1.26*** | 1.48*** | 1.27*** | 1.02 |
| Age group 75-79 | $4,390*** | 1.23*** | 1.14*** | 1.78*** | 2.29*** | 1.70*** | 1.01 |
| Age group 80-84 | $7,060*** | 1.41*** | 1.16*** | 1.76*** | 3.69*** | 2.21*** | 0.89*** |
| Age group 85+ | $11,592*** | 1.72*** | 1.11*** | 2.10*** | 5.95*** | 2.60*** | 0.75*** |
| Race (ref=white) | | | | | | | |
| Race Black | $4,231*** | 1.06* | 0.91** | 0.85 | 1.38*** | 1.74*** | 1.38*** |
| Race Other | $4,005*** | 0.91** | 0.92** | 0.78** | 0.97 | 1.08* | 1.14*** |
| CCI (ref =0) | | | | | | | |
| CCI of 1 | $3,737*** | 1.30*** | 1.17*** | 1.12*** | 1.41*** | 1.28*** | 1.52*** |
| CCI of 2 or above | $11,611*** | 1.85*** | 1.42*** | 1.07 | 2.12*** | 1.49*** | 1.74*** |
| Teaching status | $10,363*** | 1.01 | 1.78*** | 0.57** | 1.26** | 0.92 | 0.80*** |
| Year (ref=2013) | | | | | | | |
| Year 2015 | -$603* | 0.96* | 0.99 | 0.97 | 1.05** | 1.04* | 0.96** |
| Year 2015 | -$414 | 0.97 | 1.00 | 0.91* | 1.06** | 1.11*** | 0.94*** |
| Year 2016 | -$1,021** | 0.93*** | 1.00 | 0.87** | 1.04 | 1.09*** | 0.92*** |
| Year 2017 | -$11,794*** | 2.69*** | 1.04 | 0.94 | 0.96 | 1.04 | 0.91*** |
| Constant | $54,340*** | 0.11*** | 2.03*** | 48.80*** | 0.07*** | 0.18*** | 0.75*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as beta-coefficients for spine-specific spending and odds-ratio for dichotomous utilizations.
EOL Q, End-of-Life Inpatient Care Index Quintile; IP, Inpatient; OP, Outpatient; Part B, Medicare Part B (office-based and provider); SNF, Skilled Nursing Facilities; HHA, Home Health Agency; DME, Durable Medical Equipment; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

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*TABLE C10. Variation in spine surgery safety measures for Spinal fusion except cervical safety*

| Outcome Variables | Died within 90-days OR | 90-day readmit OR | PE within 90 days OR | DVT within 90 days OR |
|---|---|---|---|---|
| EOL (ref =Q1) | | | | |
| EOL Q2 | 1.06 | 1.02 | 0.87** | 1.04 |
| EOL Q3 | 0.99 | 1.02 | 0.93 | 1.05 |
| EOL Q4 | 1.01 | 1.07** | 0.91 | 1.01 |
| EOL Q5 (high) | 0.90 | 1.10*** | 0.94 | 1.08 |
| Beds (ref = <100) | | | | |
| Beds 100-199 | 1.44*** | 1.00 | 1.22** | 1.12 |
| Beds 200-299 | 1.34** | 1.03 | 1.31*** | 1.18** |
| Beds 300-399 | 1.59*** | 1.00 | 1.23** | 1.14* |
| Beds 400-499 | 1.70*** | 1.06 | 1.30** | 1.29*** |
| Beds 500-599 | 1.90*** | 1.11* | 1.30** | 1.20* |
| Beds 600-699 | 2.01*** | 1.11 | 1.30** | 1.22** |
| Beds >=700 | 2.03*** | 1.10* | 1.27** | 1.27** |
| Female (ref =Male) | 0.66*** | 0.98 | 0.97 | 1.00 |
| Volume (mean) | 1.00*** | 1.00*** | 1.00 | 1.00* |
| Age group (ref=65-69) | | | | |
| Age group 70-74 | 1.49*** | 1.12*** | 1.12** | 1.08** |
| Age group 75-79 | 2.15*** | 1.28*** | 1.31*** | 1.24*** |
| Age group 80-84 | 3.49*** | 1.51*** | 1.43*** | 1.42*** |
| Age group 85+ | 7.82*** | 1.87*** | 1.39*** | 1.59*** |
| Race (ref=white) | | | | |
| Race Black | 1.26** | 1.09** | 1.25*** | 1.22*** |
| Race Other | 0.92 | 0.89*** | 0.59*** | 0.68*** |
| CCI (ref =0) | | | | |
| CCI of 1 | 1.90*** | 1.38*** | 1.38*** | 1.32*** |
| CCI of 2 or above | 4.65*** | 2.06*** | 1.81*** | 1.95*** |
| Teaching status | 1.01 | 1.02 | 1.32*** | 1.32*** |
| Year (ref=2013) | | | | |
| Year 2014 | 1.07 | 0.96* | 1.11** | 0.98 |
| Year 2015 | 1.11 | 0.97* | 0.97 | 1.00 |
| Year 2016 | 1.03 | 0.92*** | 0.83*** | 1.01 |
| Year 2017 | 1.10 | 0.92*** | 0.78*** | 0.98 |
| Constant | 0.002*** | 0.10*** | 0.014*** | 0.03*** |

*p<0.05, ** p<0.01, ***p<0.001.
Estimates for the highest EOL quintile relative to the lowest EOL quintile based on regression estimates presented as odds-ratio for dichotomous safety indicators.
EOL Q, End-of-Life Inpatient Care Index Quintile; readmit, Readmission for any reasons; PE, Pulmonary embolism; DVT, Deep Vein Thrombosis; OR, Odd Ratio; CCI, Carlson Comorbidity Index.

**APPENDIX D.**

An unobserved potentially confounding factor would require an association between the independent and dependent variables above and beyond the difference in effect that we observed. To estimate the magnitude for any such hypothetical confounding factor to reach this threshold, we performed a sensitivity analysis for unmeasured factors in observational studies.[45]

In both the "Fusion, except cervical" and "Cervical fusion" cohorts we identified the minimum strength of association required that an unmeasured confounder would need to have so that is fully explained away the significant association that we observed between the 5th and 1st EOL quintile in spine-specific cost and readmission. The finding from this sensitivity analyses are described in the following paragraphs.

Spine Specific Costs: We standardized the large difference in mean spine-specific spending that we observed between the 5th and 1st EOL quintile using Cohen's D statistic,

$$= M_{Q5} - M_{Q1}\sqrt{\left[\frac{(sd_{Q1} + sd_{q5})}{2}\right]}$$

Where $M_{q\#}$ is the mean spine spending within the EOL quintiles, and $sd_{q\#}$ is the corresponding standard deviations.

Using standard mean costs, we performed a sensitivity analysis to estimate the minimum strength of association required for an unmeasured confounding factor to explain away the observed difference. While the standardized difference in mean costs between the 1st and 5th EOL quintile in our observed model was 0.75 for "Fusion, non-cervical", and 0.70 for "Cervical fusion", we found that the minimal standardized ratio for costs to remove the observed effect is much higher: 3.37 for the "Fusion, except lumbar cohort" and 3.19 for "Cervical Fusion" cohort (Figure D1).

Similarly, the observed odds ratios for readmission of 1.12 ("Fusion, except cervical") and 1.12 ("Cervical fusion") in the highest EOL quintile can only be explained away by an unmeasured confounder with odds ratios of 1.432 and 1.487 working in the opposite direction of the observed model, respectively (Figure D2). Any weaker confounding factor would be unable to offset the effect that we observed.

These results give us skepticism about the presence of an unobserved factor with sufficient magnitude on the outcome to alter our results or conclusions. The magnitude of an unobserved factors to reverse the effect of cost across EOL would need to be inordinately and unlikely large.

To further address this concern, we also point to the alternative specification that we provided in the appendix using the mixed-effects analysis. This model adds flexibility by allowing the intercept for individual hospitals to vary as a function of the influence of factors not observed in our data. The mixed effects analysis is then estimated from the inverse weighting of components to maximize the estimate of the "within" hospital variation. Essentially, this approach showed that even after ignoring the unobserved variation between-hospitals which could be a potential source of bias if the EOL measure was inadequate, the association between higher EOL quintile and higher rates of adverse safety events were generally greater than those from the primary models. For example, relative to regions in the low EOL quintile within the "fusion, except cervical" cohort, those in the high EOL quintile had significantly higher likelihood for DVT (OR 1.09; 95%CI 1.01 - 1.19; p=0.036) and readmission at 90 days (OR

1.10; 95%CI 1.04 - 1.16; $p<0.001$.) This model suggests that our findings are robust against a hypothetical unobserved confounding factor.

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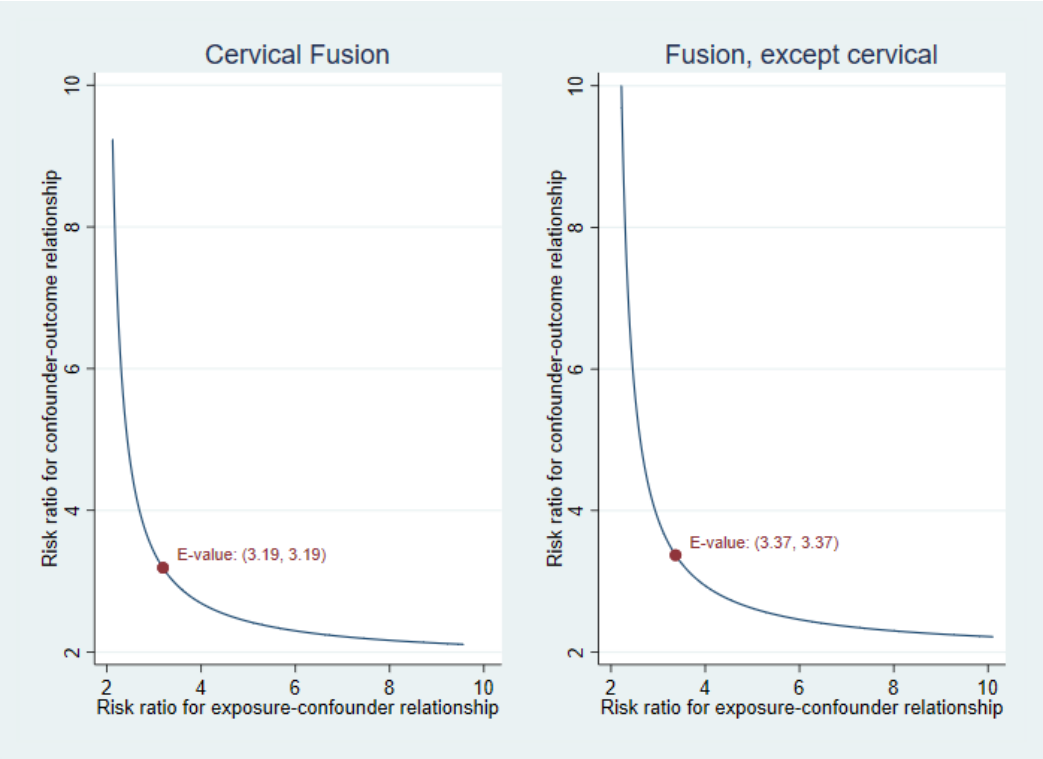
FIGURE D1: The minimal standardized ratio for costs to remove the observed effect



http://dx.doi.org/10.2106/JBJS.21.00389


FIGURE D2: The minimal standardized ratio for readmission to remove the observed effect